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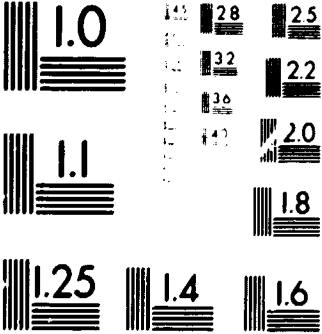

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND

THE GOVERNMENT OF THE KINGDOM OF NEPAL

PRE-FEASIBILITY STUDY FOR A SPONGE IRON PLANT IN NEPAL

PROJECT NO. XP/NEP/91/047

FINAL REPORT

WS ATKINS INTERNATIONAL

DECEMBER 1991 **F2308.001/**

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EXECUTIVE SUMMARY

1 Introduction

The United Nations Industrial Development Organisation (UNIDO) and the Government of the Kingdom of Nepal commissioned WS Atkins to undertake a study of the economic and technical feasibility of establishing a sponge iron plant in Nepal. The overall objective was to assess the feasibility of exploiting the only known substantial iron ore deposits in Nepal at Phulchoki, situated 26 kilometres south east of Kathmandu.

This Final Report follows the visit of the Consultants to Nepal in June and July 1991 and the submission of an Interim Report in August 1991.

2 Market Aspects

Sponge Iron

The rate of growth in the domestic demand for sponge iron will depend primarily on the development of a Nepalese steelmaking industry. This development is presently constrained by the power requirement for electric arc steelmaking. The next major hydropower development in Nepal is likely to be the Arun project but no early construction programme could be confirmed at the time of the Consultant's visit. Once power can be made available, this would encourage the re-rolling mills around Biratnagar and Birganj to install electric steelmaking furnaces.

The effective demand for steel billets, for the production of reinforcing bar and sections, is forecast to reach 147 000 tonnes by the year 2000. On the basis of the assumptions made in the report, this would imply a domestic demand for sponge iron of 33 350 tonnes by the year 2000.

reserves.

To date no ore from the Phulchoki deposits has been beneficiated and made into pellets or tested for reducibility. If it is decided to proceed with a full feasibility study, representative bulk samples of the iron ore should be sent to a competent research laboratory for grinding, beneficiation, pelletisation and reduction tests,

No significant natural gas or coal deposits are known to exist in Nepal, so that any iron making process would need to be based on imported non-coking coals.

Suitable deposits of limestone are available in Nepal and are currently being mined at the Jogimara quarry alongside the Prithivi Rajmarg highway.

In the early years of operation, the bulk of production would need to be exported. Thailand is considered to represent a potential opportunity and, if it could be penetrated, the Indian market could provide a more secure logistical opportunity.

Pig Iron

exported.

5 **Plant Locations**

A review of the available sites led to the following conclusions with regard to plant locations:

* the Phulchoki ore should be open-cast mined and the run-of-mine ore transferred to Godavari by aerial ropeway;

US $150 per tonne.

ows for both process options were drawn up in constant price terms,
king account of the effects of financing and inflation. The results may
narised as follows:

Year	Net After Tax Profit
1997	-170
1998	75
1999	212
2000	297
2001	390

In economic terms, the internal rate of return improves significantly to 16.2 percent. The project is also shown to yield net foreign exchange benefits to the Nepalese economy.

▼

Option	IRR	NPV @ 10% (NR million)
ACCAR	14.3%	506
COREX	8.3%	-710

to a competitive Nepalese sponge iron plant if suitable marketing agreements could be reached. It is therefore considered that the commercial risk of a Nepalese sponge iron plant investment could be minimised by reaching a marketing agreement with one of the major Indian steel producers, which might also provide some equity participation

9. Recommendations

The following sequence of immediate actions is recommended:

1) **Carry out exploratory investigations to determine the full extent of the iron ore reserves. Both surface and drilled samples should be taken and their quality assessed.**

2) **Carry out beneficiation tests on representative samples of ore.**

It is estimated that the project would create 430 permanent direct employment opportunities in Nepal. The total employment generated, including secondary and tertiary employment would amount to some 1220 new jobs.

8. <u>Conclusions</u>

logistical problems.

Due to the high level of pr
prices on the Indian market
notoriously difficult to penet
stated the objective of achiev
This would probably lead t
ultimately more competitive

3) Carry out a full feasibility study of the proposed direct reduction plant including market studies.

4) In parallel with the above, environmental impact assessments should be carried out for the mining and aerial ropeway sites and for the beneficiation site.

1. INTRODUCTION

This Final Report has been produced following the visit of the Consultants to Nepal between 26th June and 26th July 1991 and the submission of an Interim Report in August 1991. The Consultants' work programme included a programme of meetings with relevant public and private sector organisations, a series of factory visits, collection of data and reconnaissance of the potential mining and industrial development sites. Visits to the re-rolling mills' factories and head-offices were made in the Kathmandu, Biratnagar and Birganj areas. The production of the companies interviewed comprised over 80 per cent of the production of reinforcing bar and light sections in Nepal in the last financial year.

The study was primarily designed to examine the economic and technical feasibility of establishing a sponge iron plant in Nepal based on Phulchoki ores. However, the feasibility of developing the Corex process to produce pig iron was also assessed.

Section 2 of the report examines the markets for sponge iron and pig iron and Section 3 reviews the availability of raw materials for ironmaking in Nepal. Section 4 describes the pros and cons of the various direct reduction processes available and Section 5 identifies those process options considered most appropriate for Nepalese conditions. Section 6 assesses the proposed plant locations and their associated infrastructure requirements. Finally, Section 7 sets out a provisional evaluation of the identified process route options and arrives at some initial conclusions.

We would like to convey our thanks for the excellent cooperation and assistance we received from the staff of the Ministry of Industry Department of Mines and from the UNIDO representative in Kathmandu

2. MARKET ESTIMATES

2.1 Current Demand

2.1.1 Reinforcing Bars and Sections

Demand for reinforcing bar and light sections in Nepal is largely met by the production of the ten rolling mills which were operating at mid 1991. These mills generally produce mild steel reinforcing bar, plain, deformed and twisted, in the size range 8 to 32 mm diameter. Angles, channels and flats are normally produced up to a maximum dimension of 65mm. The locations of the mills, and their production for the first nine months of the Nepalese financial year, 1990/91, are set out in Table 2.1.

TABLE 2.1 - ROLLING MILL PRODUCTION IN NEPAL

Company	Location	Production (9 months) (MT.000)
Gayatri Industries	Biratnagar	721
Pasupata Iron & Steel	Biratnagar	2857
Everest Iron & Steel	Biratnagar	1950
Hetauda Iron & Steel	Biratnagar	4279
Gauri Shankar	Birganj	3682
Himal Iron & Steel	Parwanipur	4440
Ashok Steel Indust.	Birganj	6336
Navin Re-rolling	Birganj	0
Everest Rolling Mill	Bhairahawa	2174
Pancha Kanya	Bhairahawa	3889
		30328

Sources: 1) Ministry of Industry
2) The rolling mill companies

Note: The Nepalese financial year runs from July 16th to July 15th on the Gregorian calendar

At least a further six rolling mills have apparently been issued with industrial licences, namely: Annapurna Rolling Mills, Mechi Steel Industries, Nepal Steel Pvt., Bajranj Iron & Steel, Western Nepal Rolling Mills and Birendra Kumar Kanodiya. However, it is not clear that there is sufficient demand at present to support additional capacity. Most of the existing mills are only operating on one shift and production is typically between 20 and 30 percent of the three shift capacity.

No significant exports of reinforcing bar or sections have been recorded and a number of producers stressed the near impossibility of penetrating the highly protected Indian market. Imports of reinforcing bar and sections take place spasmodically and are usually related to specific project demands. They appear to arise for a number of reasons:

* a requirement for bar diameters and section dimensions outside the range of those manufactured domestically

* a requirement for high tensile steel bar

* bilateral aid donors specifying products of a specific national origin

Table 2.2 sets out the apparent consumption of reinforcing bar and light sections in Nepal for the 11 year period 1980/81 to 1990/91.

TABLE 2.2 - APPARENT CONSUMPTION OF BARS AND SECTIONS

(Tonnes)

Year	Domestic Production	Recorded Imports	Apparent Consumption
1980/81	5070	5991	11061
1981/82	7260	4959	12219
1982/83	11692	0	11692
1983/84	12394	4053	16447
1984/85	15334	10064	25398
1985/86	28380	0	28380
1986/87	34548	0	34548
1987/88	25625	5000	30625
1988/89	34834	1200	36034
1989/90	40038	0	40038
1990/91	40437	38	40475

Sources:
1) Department of Industries, Ministry of Industry.
2) National Trading Ltd.
3) Rolling Mill Companies

Notes:
1) Figures for 1990/91 are estimates based on 9 months returns
2) None of the rolling mills visited appeared to keep more than a few weeks stock of finished products.

The average compound annual rate of growth in consumption over the 11 year period, at 13.9 percent, is exceptionally high by world standards. This probably reflects the relatively higher rates of growth in steel consumption commonly observed in countries in the early stages of industrialisation and development.

Table 2.3 shows rolling mill sales by size distribution, for reinforcing bar and sections. The figures cover sales by the ten operating companies for the period March to May 1991. This period represents the first three months for which a detailed consolidated breakdown of these sales statistics has been kept in Nepal. Sales of 10mm and 12mm bar cover some 89 percent of all rebar sales, and if 8mm and 16mm bars are included almost 99 percent of sales are covered. This correlates with the views of the manufacturers and stockholders that the end uses are almost wholly in the domestic and commercial building sub-sectors, which would require rebar of these diameters.

Sales of sections are predominantly of angles and flats, which comprised some 97 percent of the total. The most important demand for sections again arises from the building sector, for their use in the fabrication of light frame structures, including agricultural buildings. Bars and flats are also used to some extent as architectural features, such as railings and grilles.

A number of manufacturers and consumers indicated that there is a marked seasonal variation in sales and the factors influencing this seasonality may be summarised as follows:

January/February/March - low rainfall, steady demand

April/May/June - low rainfall and lengthening days leads to high demand

July/August/September - low demand due to the monsoon

October/November/December - relatively large number of festivals and shortening days (labourers are paid by the day) leads to below average demand.

TABLE 2.3 - ROLLING MILL SALES BY SIZE DISTRIBUTION

Reinforcing Bar

Diameter	Tonnage	Distribution (%)
8mm	474	5.7
10mm	3388	40.7
12mm	3984	47.8
16mm	394	4.7
18mm	7	0.1
20mm	71	0.9
22mm	0	0.0
25mm	12	0.1
28mm	0	0.0
32mm	0	0.0
Total	8330	100.0

Sections

Type	Tonnage	Distribution (%)
Flats:		
20x3	451	37.3
20x5	170	14.0
25x5	51	4.2
40x5	30	2.5
50x6	9	0.7
Total Flats	711	58.8
Angles:		
25x25x3	173	14.3
40x40x3	84	6.9
40x40x5	109	9.0
50x50x5	47	3.9
65x65x6	54	4.5
Total Angles	467	38.6
Gate Channel	20	1.7
Channel	11	0.9
Square Bar	1	0.1
Total	1210	100.0

Source: Association of Rolling Mill Companies. Based on an analysis of three months sales figures for the ten companies from March to May 1991.

The principal raw material for the rolling mills, steel billets, has not been imported from India for the past five years. The companies stated that Indian billets were substantially more expensive than even alternative European sources. Current sources of billets are typically China, Poland, Austria and Germany.

Wire rod

Although most of the rolling mill companies would have the capability to roll wire rod, none of them currently do so. Several had wire drawing subsidiaries but these all import wire rod. It was stated to be unprofitable to roll wire rod in-house. There appear to be two reasons for this. Firstly, demand for wire rod is principally of the smaller diameters, 5.5 and 6mm, and rolling down to these sizes would effectively reduce plant capacity. Secondly, the level of protection for wire rod, at 5 percent, is half that for reinforcing bar.

2.1.2

The principal products manufactured by the wire drawing companies are: nails and tacks, coiled steel wire, barbed wire, chains, wire mesh and gabions. The final end uses for these products are distributed across all sectors of the economy. Gabions are in particular demand in Nepal for river training works and earth retaining structures. A substantial proportion of wire products is consumed by the agricultural sector, for such products as wire mesh fencing, baling wire and barbed wire.

The estimated consumption of wire rod for the seven year period !983/84 to 1989/90 is shown in Table 2.4.

TABLE 2.4 - ESTIMATED CONSUMPTION OF WIRE ROD

Year	Imports (MT)
1983/84	15487
1984/85	21130
1985/86	15234
1986/87	4964
1987/88	11507
1988/89	9640
1989/90	11551

Sources: Foreign Trade Statistics, Department of Customs. Department of Industries, Ministry of Industries

Note: Figures for 1987/88 and 1988/90 estimated from wire production

The above figures are "lumpy" and show no consistent trend. It is probably more realistic to take an average and state that the consumption of wire rod in Nepal lies typically between 10,000 and 15,000 tonnes per annum. It should be borne in mind that the "effective" demand for wire rod is substantially higher than this, if the imports of finished wire products are taken into account. The import statistics do not permit the precise quantification of imported steel wire by weight but imports in 1988/90 were estimated at some 3600 tonnes. A large proportion of these imports may be accounted for by orders for development projects and to some extent explain the erratic nature of domestic wire production.

2.1.3 Iron and Steel Castings

Five companies in Nepal were listed by the Ministry of Industry as having significant capacity in the production of iron castings. To these must be added the recently revived Biratnagar Workshop (Pvt) Ltd., which was originally established to serve the Biratnagar Jute Mill, but now produces castings for a variety of local industries. The companies, and their theoretical ferrous foundry capacities, are listed in Table 2.5.

TABLE 2.5 - IRON FOUNDRIES IN NEPAL

Company	Location	Capacity (Tonnes/Year)
National Casting Industries (Pvt) Ltd.	Hitaura	277
Nepal Cast Iron Industries	Hitaura	1600
Ferrocast Industries	Birganj	5000
Dhalaut Karyasala Lagankhal	Patan	500
Agricultural Tools Factory Ltd.	Birganj	450
Biratnagar Workshop (Pvt) Ltd.	Biratnagar	350
Total		8177

Sources: 1) Ministry of Industry.
2) Consultants visits.

Note: It is not clear that all foundries quote their capacities on a consistent basis eg three-shift working.

Total theoretical iron foundry capacity in Nepal is therefore around 8000 tonnes per annum. However, this assumes full production over three shifts and only a fraction of this figure has ever been achieved. The production of cast iron goods in Nepal for the past five years, as recorded by the Department of Industries, is shown in Table 2.6.

TABLE 2.6 - PRODUCTION OF CAST IRON GOODS

Year	Domestic Productn. (Tonnes)
1990/91	175
1989/90	173
1988/89	220
1987/88	179
1986/87	198

Sources:
1) "Industrial Statistics", Department of industries, Ministry of Industry.
2) "Foreign Trade Statistics", Department of Customs, Ministry of Finance
3) Foundries visited.

Notes:
1) Imports of finished castings are not included in the above estimates.
2) Figures for 1990/91 are estimates.

It became clear during the consultants' factory visits that a number of factories, mainly in the textiles sub-sector, were operating small "in-house" foundries to service their internal requirements for castings. Typically, such a workshop type foundry would be producing one-off replacement spares at an annual rate of between five and fifteen tonnes. It is difficult to estimate the aggregate production of castings by such workshops but it is probably around 200 tonnes per annum.

The total current production of iron castings in Nepal may therefore be estimated at 400 tonnes per annum, made up of 200 tonnes of direct production plus a further 200 tonnes of in-house production.

For the foundries visited, the predominant source of raw materials was domestic and imported Indian scrap, although quantities of Indian pig iron have been imported in the past. Prices paid for scrap are currently around 10 Nepal Rupees per kilogramme, depending on quality. However, it should be borne in mind that purchases are in small lots, typically not exceeding 50 tonnes each.

The foundry sub-sector in Nepal is closely linked to the other industrial sub-sectors. During the consultants' visits a wide range of castings was observed, including products for the following industries: cement,textiles, jute, sugar milling, food processing, leather tanning and brickworks. In addition, pump bodies and tube well components are manufactured, as well as the usual range of building and civil engineering items such as grills, gratings and manhole covers.

There is a single enterprise, the Kamal Iron & Steel Company, casting mild steel pencil ingots from scrap. The factory possesses a 2.5 tonne capacity induction furnace. Production in the 1989/90 financial year was estimated at around 2535 tonnes. The quality of Kamal ingots was stated by the rolling mill companies to be "variable". Clearly, the quality will depend directly on the quality of the available scrap. This company could only be a very minor consumer of pig iron, given the need to control the carbon content in steel billet production.

In addition to domestically produced castings, a wide variety of iron and steel castings are imported as spares or incorporated in imported machinery and equipment. The import statistics do not provide a sufficient level of disaggregation to enable these imports to be quantified. However, most of these may be expected to continue for the foreseeable future, increasing as the economy grows; although there should be a gradual local integration of production as domestic foundries develop the capability to produce castings of increasing complexity.

2.2 Pricing and Distribution

2.2.1 Long Products

The products of the rolling mills and the wire drawers may be purchased ex-factory by a client in his own truck or at a large number of retail hardware outlets distributed throughout Nepal. Most of the companies estimated that about 50 percent of purchases were ex-factory. No large wholesalers/stockists were identified.

The rolling mills appear to act as an unofficial cartel with regard to pricing. A number of the companies produced price lists with product prices, quantity discounts, transport charges and payment terms which were identical in every respect. An example of the latest price list current at 7th July 1991 is given in Appendix B. Prices are quoted at a Kathmandu/Pokhara/Nepalgunj datum, with progressive transport discounts for locations nearer to the factory. The quantity discount is 5 percent on the first to the fifth truckload and 6 percent thereafter.

Prior to the recent, July 1991, price increase of around 20 percent, average ex-factory prices were quoted at NR 15.75 per kilogramme for torbar and sections and NR 15.50 for plain bars and flats. To these figures is added a sales tax of 10 percent and an excise duty which works out at NR 0.33 for angles and NR 0.25 for the remaining items. Current, post increase, retail prices vary between NR 23.6 and NR 25.6 for rebar, and NR 24.5 to NR 29.1 for sections.

2.2.2 Castings

The bulk of the foundry products produced by weight are manufactured for specific clients and to the clients own specification, whether they be for in-house or external use. The channels of distribution tend therefore to be well established. Prices for castings do not depend solely on weight but vary according to complexity. Also, many foundries carry out machining operations to produce a finished product. Prices can therefore be misleading for comparative purposes. However, as a rough guide, prices for simple castings with minimal finishing operations were noted to be in the range NR 25 to NR 30 per kilogramme.

2.3 Provisional Demand Forecasts

2.3.1 Sponge iron

The future effective demand for sponge iron, assuming in the first instance that the steelmaking capacity is available, is directly related to the domestic demand for steel billets. The assumptions concerning the likely rate of build-up of domestic steelmaking capacity in Nepal, and the probable percentage of sponge iron in the electric arc furnace charge, will be addressed in the evaluation section of the report.

The current effective demand for steel billets is derived from the total consumption of long products. Although wire rod quality billets are not presently rolled in Nepal, they represent an opportunity for a steelmaking facility. It may be reasonably assumed that once a billet making plant is established that such billets would be manufactured competitively in Nepal and would supply the domestic wire drawers. The total effective 1991 demand for billets is therefore estimated to derive from some 40500 tonnes of bars and sections and, say, 12500 tonnes of wire rod, giving a total long products demand of 53,000 tonnes. This assumes that a proportion of wire products will continue to be imported in finished form.

2.3.2 International Comparisons

Table 2.7 shows apparent per capital consumption of crude steel against gross domestic product (GDP) per capita for a range of countries at different stages of industrial development. The figures illustrate the strong correlation between steel consumption and economic growth. They also demonstrate that consumption increases more rapidly in relation to GDP at lower levels of GDP per capita. It may therefore reasonably be inferred that steel consumption in Nepal will go on increasing over the next 15 to 20 years and that the rate of increase will be relatively high in comparison with the more industrialised countries.

TABLE 2.7 - STEEL CONSUMPTION AND GNP

Country	Apparent Consumption (Kg per cap)	GDP per Capital (US $)
Bangladesh	4.0	180
Nepal	12.3	180
India	24.7	340
Pakistan	17.3	340
Indonesia	13.0	520
Philipinnes	36.3	740
Syria	10.7	970
Thailand	64.0	1250
Malaysia	119.2	2210
Brazil	84.5	3030
Portugal	181.8	4325
Saudi Arabia	186.5	5750
United Kingdom	304.2	14630
Austria	392.0	16598
USA	412.2	20750

Sources: 1) International Iron and Steel Institute
2) International Financial Statistics, IMF
3) WS Atkins studies

Note: : Figures are for 1989
: Crude steel consumption only is included

2.3.3 Econometric Approach

Regression analysis was used to investigate the correlation GDP and the apparent consumption of bars and sections in Nepal. The data was fitted to a relationship of the form:

$$C_t = K I_t^a$$

Where: C_t = consumption per capita in year t.

I_t = GDP per capita in year t

K,a = constants

The constant 'a' is analogous to the income elasticity of demand and was calculated to be 3.28 for the 11 year series 1980/81 to 1990/91. A correlation coefficient of 0.96 was obtained.

The average rate of growth of GDP in Nepal in constant price terms over the last 10 years has been around 4 percent per annum. Reasonable upper and lower limits for average growth over the next 15 to 20 years would be between 6 percent and 2 percent. On the basis of the derived elasticity, this implies upper and lower limits for the growth in consumption of reinforcing bar and sections of 6.6 and 19.7 percent. By comparison, the rate of growth of the smoothed time series of apparent consumption is 13.3 percent.

2.3.4 Forcast demand for billets

The growth rate in apparent consumption of reinforcing bars and sections has fallen off in the last 5 years to around 9.9 percent on a smoothed basis. However, in the latter part of this period the Nepalese economy, and the industrial sector in particular, was generally constrained for 15 months by the trade and transit dispute with India. This dispute has now been resolved and there are signs of renewed buoyancy in the industrial sectors. Taking account of both the time series and econometric analyses, it would not appear unreasonable to take, as the central scenario, an annual growth rate in the consumption of long products of 12 percent up to the year 2000, falling to 9 percent thereafter. This is somewhat higher than for the Interim Report, where the rate of growth in consumption was assumed to fall to 7.5 percent after the year 2000.

This projection is considered to be a reasonable prima facie assumption since, as indicated above, for a country in the early stages of industrialisation and development, relatively high rates of growth in per capita steel consumption may be expected. The forecast effective demand for billets on this basis, assuming a 96 percent loss in rolling, is summarised in Table 2.8.

TABLE 2.8 - FORECAST EFFECTIVE DEMAND FOR BILLETS

Year	Effective Demand (Tonnes)
1995	83,400
2000	147,000
2005	226,136

2.3.5 Pig Iron

The demand for pig iron is directly related to the demand for cast iron products in Nepal. In the evaluation section of the report, assumptions concerning the proportion of pig iron in the foundries' raw material requirements will be made.

The industrial sector is clearly the most important for the foundries. However, there are strong linkages between the industrial sector in Nepal and the agricultural sector, for example: sugar refining, food processing, jute and leather tanning. This should provide a sound long-term basis for foundry products demand. For the purposes of this Report, the rate of growth in this report demand for iron castings has been taken to be commensurate with the rate of growth in output of the modern (ie excluding cottage industries) industrial sector. For the period 1980/81 to 1989/90 this was approximately 8.0 percent per annum in constant price terms. The forecast demand for iron castings on this basis is summarised in Table 2.9.

TABLE 2.9 - FORECAST DEMAND FOR IRON CASTINGS

Year	Demand (Tonnes)
1995	545
2000	800
2005	1175
2010	1725

2.4 International Aspects

2.4.1 Sponge Iron

The main use for sponge iron is as a substitute for scrap in steelmaking. It sells at a premium over scrap since it is less contaminated and may be used to control the quality of the steel produced. World and Indian production of directly reduced iron for the period 1982 to 1990 was as follows:

TABLE 2.10 - WORLD AND INDIAN PRODUCTION OF DR IRON

Year	Production (thousand tonnes)	
	World	India
1982	7307	30
1983	7811	54
1984	9168	80
1985	11281	102
1986	12588	170
1987	13755	190
1988	14730	190
1989	16778	400
1990	17880	750

Sources: International Iron and Steel Institute
Midrex Corporation.

World production of directly reduced iron grew at an annual average of 11.8 percent over the above 9 year period. Indian production only began in 1981 and has grown very rapidly in recent years, albeit from a small base. In 1990 India had a 4.2 percent share of world production.

It was not within the brief of this study to carry out research into the sponge iron markets in India and other neighbouring subcontinental markets. However, given India's existing and planned investments in direct reduction plants, it seems unlikely that the Indian market could be penetrated without a commercial agreement with an Indian steel producer, and possibly some equity participation by the Indian company in a future Nepalese direct reduction plant.

Thailand has an existing 1.2 million tonnes electric arc furnace capacity for long products and is aiming to double this over the next 5 years to 2.4 million tonnes. They are planning to invest in an 800,000 toone capacity direct reduction module, probably Midrex or HYL as they have natural gas resources. Hence there could be a 1.6 million tonne shortfall to be made up by sponge iron and scrap. This therefore represents a potential market for a Nepalese direct reduction plant and warrants further investigation.

2.4.2 Pig Iron

Most of the world's iron is produced by the blast furnace reduction process. Although some iron in the form of pig is used in foundries to make cast iron, most is converted into steel. World production of iron rose steadily from 341 million tonnes in 1966 to 505 million tonnes in 1974. Since then, production has fluctuated between 452 million and 528 million tonnes per year. World and Indian production for the period 1982 to 1989 was as follows:

TABLE 2.11 - WORLD AND INDIAN PRODUCTION OF IRON

Year	Production (thousand tonnes)	
	World	India
1982	452949	9460
1983	457963	9162
1984	490532	9485
1985	499357	9840
1986	495647	10514
1987	503708	10923
1988	532522	11714
1989	539608	12150

Source: International Iron and Steel Institute

World production grew at an annual average of 2.5 percent over the period 1982 to 1989, compared with a 3.4 percent growth in Indian production.

Almost all of the above iron produced is destined for steelmaking. World production of foundry pig iron is estimated to be only around 6.5 million tonnes. The amount of pig iron used in foundries has been declining in favour of remelting scrap iron and steel, and to some extent the use of sponge iron.

3. AVAILABILITY OF RAW MATERIALS

3.1 Introduction

The direct reduced iron (commonly known as sponge iron) plant uses three main raw materials, namely:

* iron oxide, either sized iron ore, iron ore fines or concentrates, or iron oxide pellets
* reductant/fuel, either gaseous (natural gas), fluid (fuel oil) or solid (bituminous coal, lignite or anthracite)
* flux, usually either limestone or dolomite

3.2 Iron Ore

The only known substantial deposits of iron ore in Nepal are located at Phulchoki, situated 26kms south east of Kathmandu, near the village of Godawari. The deposits are located at a height of between +2120 metres (western end) and +2530 metres (eastern end). The ore deposit is thickly covered by forest, and it is exposed on the steep hill slope, that is, along the hill slope in the eastern portion, and across the hill slope in the western portion.

The climate at Phulchoki is severely cold in winter with occasional snow falls, and there are heavy rains during the monsoon period.

A single lane mountain road to the summit of Phulchoki passes alongside the ore deposit. There is a scarcity of water in the area, except during the monsoon period. The nearest power transmission line is at Godawari village about 6 Kms distant.

The ore deposits are located in a forest conservation area, and there may well be questions of environmental impact to be resolved before exploitation could proceed.

The Phulchoki deposits were exploratorily surveyed by the Nepal Bureau of Mines (now the Department of Mines and Geology) during 1971 to 1973. Adits and cross cuts of both the eastern and western portions were made during this period. Drilling did not prove successful, and no cores were recovered. The survey indicated a vertical seam of haematite of between 53 to 59 percent Fe, but containing high silica of between 7 to 18 percent. The thickness varied between 5 to 36 metres, with an average thickness of 22 metres. The strike length is about 1000 metres in length, with an altitude difference of 410 metres A depth from surface of about 100 metres was indicated between bench nos. 6A and 7, with the thickness at this depth similar to the thickness at the surface. The overburden is about 2.5 metres, but varies with the terrain.

The total proven reserves were 3.877 million tonnes comprising;

* 0.153M tonnes with high sulphur
* 1.728M tonnes of high grade iron ore (eastern)
* 1.943M tonnes of medium grade iron ore (western).
* 0.053M tonnes with low Fe and high gangue

The total iron ore reserves were estimated to be;

* Proven 3.877M tonnes
* Probable 1.198M tonnes
* Possible 5.598M tonnes

10.673M tonnes

Table 3.1 shows the quantities of proven ore reserves between the benches.

TABLE 3.1 - BREAKDOWN OF PROVEN RESERVES

Bench Nos	Tonnes	Comments
B1 to B3	153,325	High Sulphur
B3 to B4	181,325	
B4 to B5	81.018	
B5 to B6	53,274	
B6 to B6A	291,080	
B6a to B7	481,388	
B7 to B8	202,920	
B8 to B9	130,714	
B9 to B10	305,946	
Eastern Section	1.727,615	High Grade
B10 to B11	107,137	
B11 to B11A	93.777	
B11A to B11B	155,178	
B11B to B11C	234,188	
B11C to B12	395,142	
B12 to B12A	273,707	
B12A to B12B	353,813	
B12B to B12C	111,629	
B12C to BB13	42,901	
B13 to B13A	51,652	
B13A to B14	36,848	
B14 to B14A	42,247	
B14A to B15	45,036	
Western Section	1,943,255	Medium Grade
B15 to B16	14,493	
B16 to B17	16,740	
B17 to B18	10,800	
B18 to B19	10,800	
B15 to B19	52,833	Low Fe/High Gangue

Due to the high sulphur content of the iron ore between bench nos. 1 and 3, and the high gangue content between bench nos. 15 and 19, these areas of the deposit would not be suitable for mining, consequently the total proven reserves would reduce to 1,727,615 + 1,943,255 = 3,670,870 tonnes.

If the total iron ore reserves are similarly distributed to the proven reserves, then the total mineable reserves would be 10.106m tonnes.

The Nepal Bureau of Mines Laboratory analyses of the iron ore at each bench along the deposit is given in Table 3.2.

The high grade iron ore in the eastern section (between bench nos. 3 to 10) comprising about 1.73 million tonnes of proven reserves (4.76 million tonnes total potential reserves) has an average Fe content of 59.16% and a combined SiO_2 and Al_2O_3 content of 12.83%.

The medium grade iron ore in the western section (between bench nos. 10 to 15), comprising about 1.94 million tonnes of proven reserves (5.35 million tonnes total potential reserves), has an average Fe content of 53.98% and a combined SiO_2 and Al_2O_3 content of 18.02%.

The combined eastern and western sections between bench nos. 3 to 15 comprise 3.67 million tonnes of proven reserves (10.11 million tonnes total potential reserves) of haematite iron ore with an average Fe content of 56.42% and a combined SiO_2 and Al_2O_3 content of 15.58%.

3.3 Beneficiation Tests

For the production of commercial grade direct reduced iron (DRI)with a degree of metallisation of at least 92 percent, and a gangue content of below 5 percent, the Phulchoki iron ore would need to be beneficiated to enrich its Fe content to at least 65 percent, and to reduce its combined silica and alumina (gangue) content to below 5 percent.

TABLE 3.2 - IRON ORE ANALYSES AT EACH BENCH

Bench No	Fe total %	Si O_2 %	Al_2O_3 %	CaO %	S %	P %	Remarks
B1	40.88	6.30	3.29	Trace	6.84	0.072	High Sulphur
B2	58.79	6.86	3.34	"	3.80	0.068	" "
B3	60.52	7.28	3.44	"	1.53	0.070	" "
B4	61.88	7.32	1.86	"	Trace	Nil	
B5	60.52	8.76	2.59	"	0.39	0.070	
B6	60.59	4.54	8.22	"	Trace	Trace	
B6A	56.68	14.56	0.81	Nil	Nil	Nil	30m from portal
B6B	62.55	6.52	1.92	"	"	"	40m " "
B6C	63.66	5.82	0.13	"	"	"	57m " "
B7	60.87	10.30	0.62	"	"	0.070	
B8	60.84	9.90	2.51	"	"	0.010	
B9	50.88	17.40	4.68	"	Trace	Trace	
B10	57.37	9.70	5.75	Trace	"	"	
B10A	55.96	7.57	2.74	"	"	"	24m " "
B10B	52.21	16.80	4.00	"	"	"	47m " "
B11	56.12	13.70	1.71	"	"	0.020	
B12	52.15	16.86	4.00	"	"	0.050	
B12A	54.00	16.32	1.64	"	"	Trace	
B12B	54.73	15.00	1.00	"	"	0.040	
B12C	55.29	14.50	2.50	"	"	0.040	
B13	49.92	19.50	5.08	"	"	Trace	
B14	54.17	14.58	2.50	"	"	"	
B15	52.49	16.70	1.30	"	"	"	
B16	48.92	21.48	4.21	"	"	"	Low Fe high SiO_2
B17	48.42	22.20	2.31	"	"	"	" " " "
B18	48.03	21.88	2.87	"	"	"	" " " "
B19	49.90	20.70	1.78	"	"	"	" " " "
Av.B4-B10	59.16	9.88	2.95	Trace	Trace	0.014	Eastern Section
Av.B10-B15	53.98	15.45	2.57	"	"	0.026	Western Section
Av.B4-B15	56.42	12.83	2.75	"	"	0.021	Combined

During the preparation of their Pre-Engineering Feasibility study for a small scale iron and steel project for the Nepal Bureau of Mines, the consulting engineers, MN Dastur, sent bulk samples of Phulchoki iron ore from the eastern and western sections to the National Metallurgical Laboratory (NML), Jamshedpur, India, for beneficiation testing to confirm its suitability for ironmaking.

The chemical analyses of these bulk samples were;

Eastern : 58% Fe, 10.0% SiO_2 and 3.6% Al_2O_3

Western : 53% Fe, 15.6% SiO_2 and 5.4% Al_2O_3

The NML beneficiation studies showed that washing of the ore at -40mm and - 20mm did not enrich the Fe content of the bulk samples.

Grinding of the eastern ore sample to -48 and -65 mesh sizes, followed by hydroclassification into coarse, fine and slime fractions, and treatment of the coarse and fine fractions in Wilfley tables, yielded a concentrate assaying 62.2% Fe and 3.8% SiO_2, with a recovery of 57.9% Fe. These test results were quoted in the Dastur Pre-Engineering Feasibility Study, Volume II of August 1975. The assumptions for the present study are discussed on page 45. Tabling of the iron ore sample from the western section produced concentrates of lower grade.

Later beneficiation tests on the Phulchoki iron ore were undertaken by Sponge Iron of India Limited (SIIL) and described in the draft final report entitled "Tests on Iron Ore Samples" received from the Government of Nepal through UNIDO, dated October 1988.

Two bulk samples of 5000 Kgs weight, in the size range of 25 to 100mm were tested.

The chemical analyses of the received samples were:

Sample 1 - Fe 52.8%, Fe_2O_3 74.55%, FeO 0.68%, SiO_2 13.8%,
Al_2O_3 3.7%

Sample 2 - Fe 48.0%, Fe_2O_3 66.3%, FeO 2.15%, SiO_2 18.8%, Al_2O_3 4.7%

The beneficiation tests were conducted by the Research and Development Laboratories of National Mineral Development Corporation (NMDC), Hyderabad. These tests were aimed solely at establishing the feasibility of producing high Fe content product in the size range of 6 to 20mm, which is the normal feed size for lump ore for DRI production in a rotary kiln. No tests involving the fine grinding of the samples, nor any washing and classification was undertaken to establish the degree of Fe enrichment, reduction in gangue content and Fe yield that could be achieved from the ore as a concentrate. **Consequently, to date, no ore from the Phulchoki deposits has been beneficiated and made into pellets and tested for reducibility.**

The NMDC pilot plant beneficiation tests gave the following results;

	Sample 1	Sample 2
Fe total received %	53.4	48.4
Size of product mm	6 to 20	6 to 20
Fe total in benificiated product %	57.5	55.7
Weight recovery %	58.9	54.8
Fe unit recovery %	63.4	63.0

The poor results obtained corroborate the findings of the tests undertaken for the Dastur Pre-Feasbility Report, which concluded that little Fe enrichment could be achieved from the -20mm fraction of their bulk samples.

Wet jigging tests were undertaken by SIIL on a composite blend of the two samples using Harz type jigs, with the following results;

Beneficiated Product

Assay %	Composite Ore Sample	-15 +10mm	-10 +3mm	10 +4.75mm	-4.75 +3.2mm	-3.2mm +0.85mm
Fe tot.	51.9	52.1	53.5	55.3	53.0	56.24
SiO_2	18.1	17.3	14.1	14.4	11.7	6.9

These results confirm the earlier tests undertaken by Dastur showing that the -3.2mm fines have experienced some enrichment of Fe, accompanied by a significant reduction in the silica content.

3.4 Reductant/Fuel

The choice of reductants/fuels for gaseous processes for DRI production is wide. Currently, natural gas is the most used, since it combines the advantages of low sulphur content with easy transportability, and can be readily converted by catalytic reforming into the reducing gases, carbon monoxide and hydrogen.

Since there are no known adequate reserves of natural gas in Nepal, at the present time, shaft type processes such as Midrex and HYL III, which use this type of reductant cannot be considered. Consequently, any DRI plant in Nepal would have to be coal based. However, coals suitable for sponge iron production are not known to exist in Nepal, and will need to be imported. These coals are readily available from many parts of the world, including India.

The reducing gas for DRI production can be generated by mixing various types of coal or lignite and feeding them with the iron oxide directly into the reduction furnace or kiln.

Coals with a high reactivity (the rate at which carbon monoxide is generated from the carbon in the coal) are preferred, as they allow the kiln to be operated at lower temperatures and high output rates. The coals should have ash contents as low as possible, since it will occupy kiln volume, reducing the effective volume available for iron bearing materials. A maximum of 25% ash content is usually applied to coals for DRI production. The volatile content of the coal should be at least 30%, since a high volatile content will ensure the iron bearing materials are rapidly heated-up to the reduction temperature.

Finally, the fixed carbon in the coal should preferably be at least 50% to ensure a low rate of consumption, whilst the sulphur content should not exceed 1%, to minimise the addition of limestone as a desulphurizer.

Most coal based DRI processes are based on rotary kilns, with the most proven process being the Lurgi SL/RN process.

3.5 Flux

A limestone containing about 45% CaO is generally used in coal based DRI production, to act as the desulphurizer of the sulphur contained in the coal.

A suitable limestone is currently being mined at the Jogimara quarry situated 95Kms south west of Kathmandu, alongside the Prithivi Rajmarg highway in the Dhading district of the Bagmati zone. This quarry is currently supplying limestone of over 53% CaO to cement plants.

The Jogimara quarry has been open cast mined by the Agricultural Lime Industry for about 16 years, during which period about 200,000 tonnes of limestone has been mined. The current annual production is 30,000 tonnes, mainly supplied to the Hitaura and Tribeni Cement companies, but a small quantity is fed into nearby shaft kilns to produce quicklime, hydrated and semi-hydrated lime.

The original limestone exploration survey, in the period between 1971 and 1973,indicated proven reserves of 0.54m tonnes and 0.41m tonnes respectively in the two deposits situated on either side of the Trisuli river. Currently, only the western part containing 0.54m tonnes of proven reserves has been mined. The eastern part would require a transport system to convey the mined limestone across the Trisuli river to the Prithivi Rajmarg highway on its left hand bank.

A recent survey in 1989 has shown a further limestone deposit of 53% CaO, to the west of the existing western quarry. The estimated recoverable reserves are 6m tonnes involving excavations of up to 15 metres.

4. REVIEW OF PROCESS OPTIONS

4.1 General

The latest published data on coal based DRI plants shown in Table 4.1 indicates that there are 24 units in operation with annual capacities ranging from 20,000 to 175,000 tonnes per unit. These plants comprise, 22 based on a rotary kiln process, and only 2 on a shaft furnace process.

Of these DRI plants, 18 are 'captive' plants, producing DRI solely for their own steel making shops. The remaining 6 DRI plants produce merchant DRI for sale. All of these merchant plants are situated in India, which is probably due to the acute shortage of domestic steel scrap within this country, and the high import duties they apply on foreign scrap imports.

4.2 Rotary Kiln Processes

The rotary kiln processes in commercial operation are;

* Lurgi SL/RN (West Germany)
* Accar Grate-CAR (Boliden Allis, USA)
* TDR (Tata, India)
* Krupp Codir (West Germany)
* DRC (Davy McKee, U.K.)

As can be seen from Table 4.1, the Lurgi SL/RN process is by far the most commercially proven with 16 rotary kilns in operation producing DRI from a variety of iron bearing materials, Krupp Codir has 2 kilns in operation, whilst the other processes each have a single kiln in operation.

TABLE 4.1 - COAL BASED DIRECT REDUCTION PLANTS FOR THE PRODUCTION OF DRI FOR STEELMAKING, AS AT JANUARY 1990

Country, Company, Location	Process	Year	No. of Units	Redt.	Nom. CapY 1000t
Brazil					
Acos Finos, Piratini, Porto Alegre	SL/RN	1973	1	Coal	65
Burma					
State owned	Kinglor-	1981	1	Coal	20
Comp. Mandalay	Metor	1984	1	Coal	20
India					
SIIL, Paloncha	SL/RN	1980/85	2	Coal	60
BSIL, Chandill	SL/RN	1987	1	Coal	150
Orissa SI					
Palasapunga	Accar	1983	1	Coal	150
Ipitata, Joda	TDR	1986	1	Coal	90
Sunflag. Bhandara	Codir	1988	1	Coal	150
New Zealand					
NZ Steel 1, Glenbrook	SL/RN	1970	1	Coal	150
NZ Steel 2, Glenbrook	SL/RN	1986	4	Coal	700
Peru					
Siderperu, Chimbote	SL/RN	1980	3	Coal	100
South Africa					
Dunswart Steel, Benoni	Codir	1973	1	Coal	150
Iscor, Vanderbijlpark	SL/RN	1984/85	4	Coal	600
Scaw Metals,					
Germistion	DRC	1983	1	Coal	75
Davsteel, Zonderwater	Rotary kiln	1985	1	Coal	35

4.2.1 SL/RN Process

The SL/RN process has been in operation for over twenty years, and has demonstrated its ability to process a large number of varying types of iron ores and coals for DRI production. The production capabilities of the SL/RN units are between 120,000 and 175,000 tonnes/annum of DRI, depending on the quality of the ores and coals employed. The SL/RN process is shown schematically in Figure 4.1. It comprises a refractory lined rotary kiln equipped with combustion air inlets along its length, and a central burner located at the discharge end. The raw materials for the process, ore and coal are proportioned and fed into the kiln, where drying and preheating occurs in the first part of the kiln. Thereafter, the iron ore is reduced to DRI by means of carbon monoxide, which is generated in the kiln from the charged coal.

The temperatures required for reduction are controlled by the injection of combustion air into the kiln along its length. The reduction temperature varies with the materials being processed, but is controlled in the range of 1000 to 1100°C. After reduction, the DRI and remaining char are cooled to ambient temperature and discharged in a stable condition which avoids reoxidation. The magnetic and non-magnetic materials are magnetically separated.

In normal operations, the hot gases flow countercurrent to the material charge and exit from the kiln feed end to the waste heat recovery and gas cleaning plants.

Lurgi's claims for the SL/RN process include;

* the direct use of non-coking coals as the process fuel and reductant
* high specific kiln throughputs and short preheating times achieved using underbed air injection
* safe operations with high plant availability
* coal requirements are minimised, by designing the separation circuit to maximise carbon recovery by the re-use of the char product.

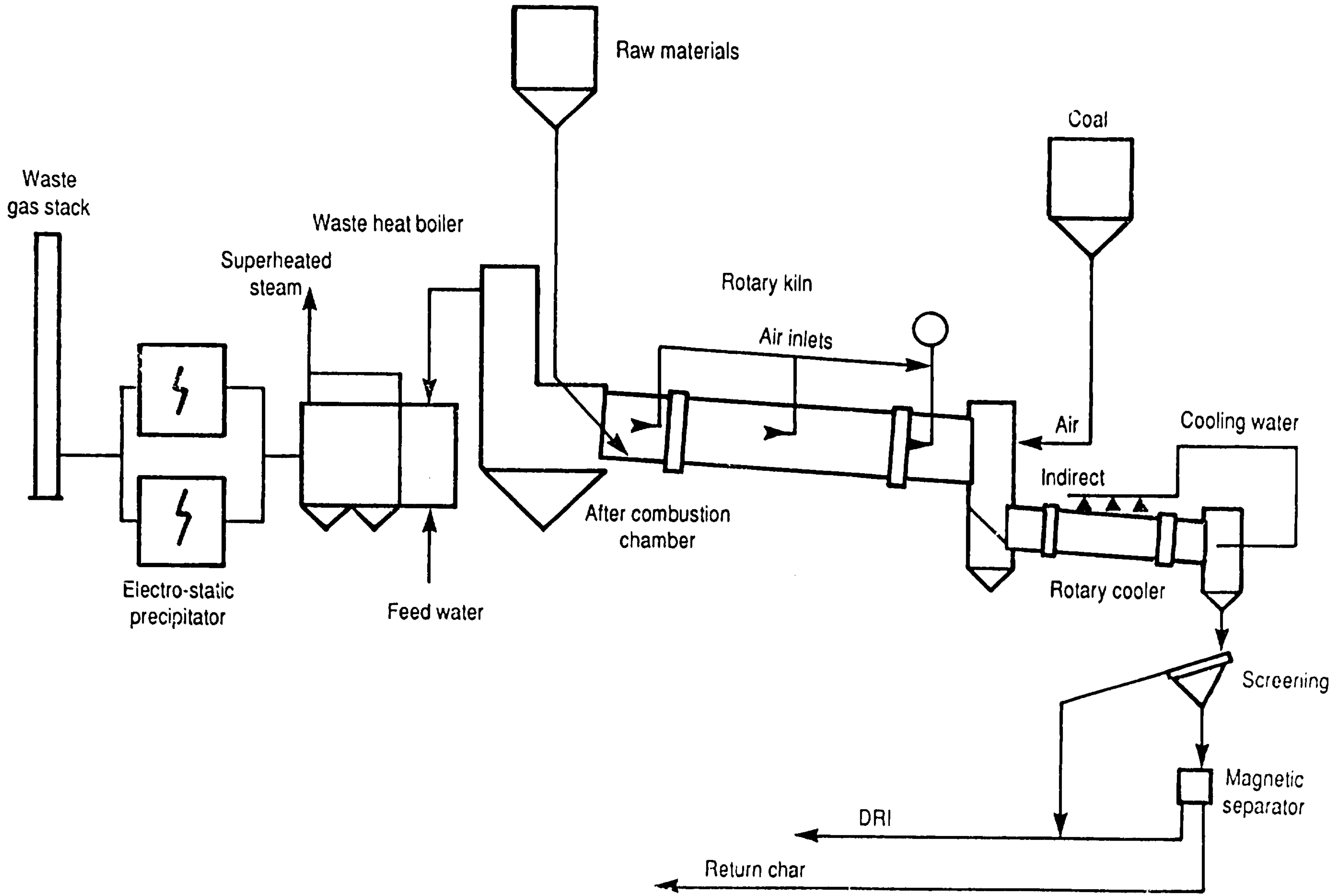


Figure 4.1 SL/RN process

* waste heat recovery plant for conversion of between 30 to 50% of the total waste gas energy into steam or electrical energy.

* close quality control of the degree of metallisation and sulphur content in the DRI

The process has successfully produced DRI from the following raw materials:

- coals ranging from high volatile lignites to bituminous coals and anthracites

- lump iron ores (5-20mm) or oxide pellets

4.2.2 The Accar Grate-CAR Process

Allis Chalmers Corporation a division of Boliden Allis, USA, have integrated their patented technologies i.e. that of the GRATE-KILN system for iron oxide pelletizing and the ACCAR system for iron ore reduction. The integration has resulted in a combined agglomeration, induration and reduction process suitable for ferrous and non ferrous concentrates.

The first production unit is currently operating in Norway at K/S Ilmenittsmeltverket A/S at Tyssedal. The unit is designed to produce 350,000 tonnes/annum of DRI pellets from local ilmenite concentrates. In this unit, coarse ore concentrates are delivered to the works and reground to 100% below 300 microns. A mix of concentrates and bentonite is fed to the balling drum for green pellet formation, with multiple passes through the drum being made for full development of suitable green pellets of correct sizing. These green pellets are transported along the travelling grate, through the drying, preheating and sealing zones. The indurated pellets exiting from the travelling grate are fed directly into the refractory lined kiln. The pellets, which have been preheated on the travelling grate are further heated in the kiln by counter-current gases to a maximum temperature of 1050°C. Air is injected into the kiln through radial ports to combust the fuel in the charge. The heat generated in the kiln also provides the heat and flow of gases for the travelling grate.

Fresh coal and char are added at the transition point between grate and the kiln. Limestone can also be added at this point for sulphur control. Fresh coal is also injected pneumatically into the kiln at the discharge end.

The reduced product discharged from the kiln is converted into HBI in a briquetting press.

Figure 4.2 shows schematically the Accar Grate-CAR process.

The Accar Grate-CAR process has the considerable benefit of combining pelletizing and the direct reduction of the pellets within a single plant, with consequent reduced capital investment costs. It can also produce hot briquetted iron (HBI), which is attractive to steelmakers as it is a low residual metallic raw material and combines all the advantage of DRI plus the physical advantages of higher density and is non-pyrophoric. These physical advantages make HBI ideal for merchant shipments, since it is easier to handle, ship and store in all types of weather.

4.2.3 Other Rotary Kiln Processes

The three remaining rotary kiln processes with commercially operating plants are the Tata Direct Reduction (TDR), the Krupp Codir and the Direct Reduction Company (DRC) processes.

All these processes can produce DRI product from either sized lump ore, or oxide pellets using a process flowsheet generally similar to the SL/RN process.

4.3 Shaft Processes

The only coal based shaft process in commercial production is the Kinglor Metor, which has two units operating in Burma, each of 20,000 tonnes per annum capacity. The process produces DRI product from a feedstock of sized lump ore or oxide pellets, and uses coal as the reductant, and either natural gas or fuel oil as the fuel for the vertical shaft furnace.

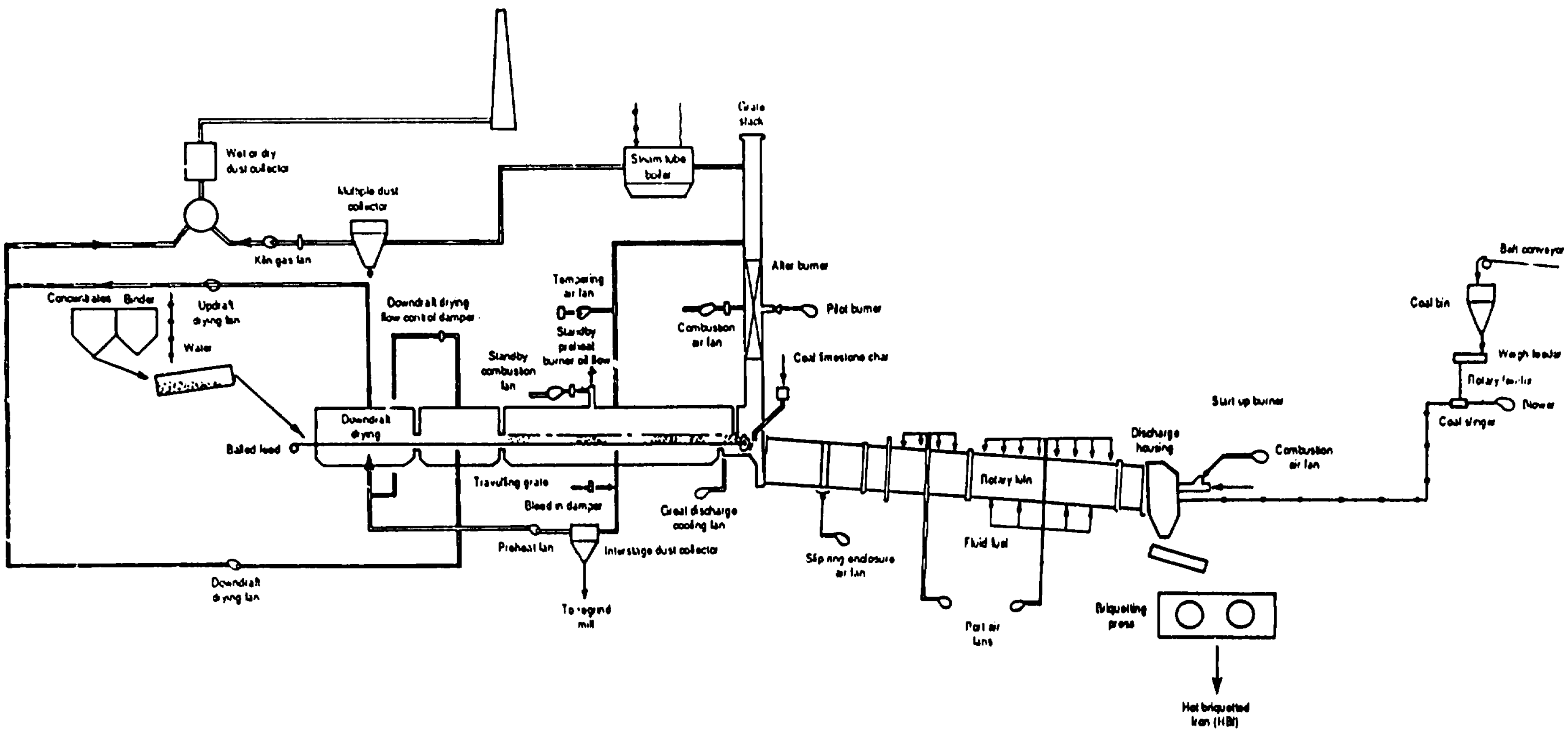


Figure 4.2 Accar Grate-Car process

Figure 4.3. shows a flowsheet for a two module Kinglor Metor plant.

This process was developed by Danieli, Italy and a two module plant was installed at Cremona. This plant ceased production during the early 1980's and Danieli have discontinued promoting the Kinglor Metor process.

4.4 Rotary Hearth Process

Midrex are currently promoting the Fastmet process which converts iron oxide fines and pulverised coal into hot DRI. Figure 4.4 shows schematically the Fastmet process. Iron ore concentrates, pulverised coal and binder are mixed together and pelletised. The resulting green pellets are fed either to a drier, or directly to a rotary hearth furnace, where the pellets are deposited in an even layer of one to three pellets deep. As the hearth rotates, the pellets are heated to 1250-1350°C and the iron oxide is reduced to metallic iron. Reduction is accomplished by the intimate contact between the carbon contained inside the pellets and the iron oxide in a high temperature environment.

Residence time is typically 10 to 30 minutes, varying according to the iron ore concentrate being reduced, the number of pellet layers, etc. During this residence time, between 90 and 95% of the iron oxide is converted into metallic iron.

The hot direct reduced iron (DRI) product can be either hot charged into a melting furnace for the production of steel or pig iron, or made into hot briquetted iron (HBI).

Midrex claim the following advantages for the Fastmet process;

* It combines conventional equipment into a workable system without requiring significant technology breakthroughs.

* it is capable of using iron ore fines and coal fines with fewer size and quality restrictions than other ironmaking processes

* it has completely independent systems for agglomeration and reduction.

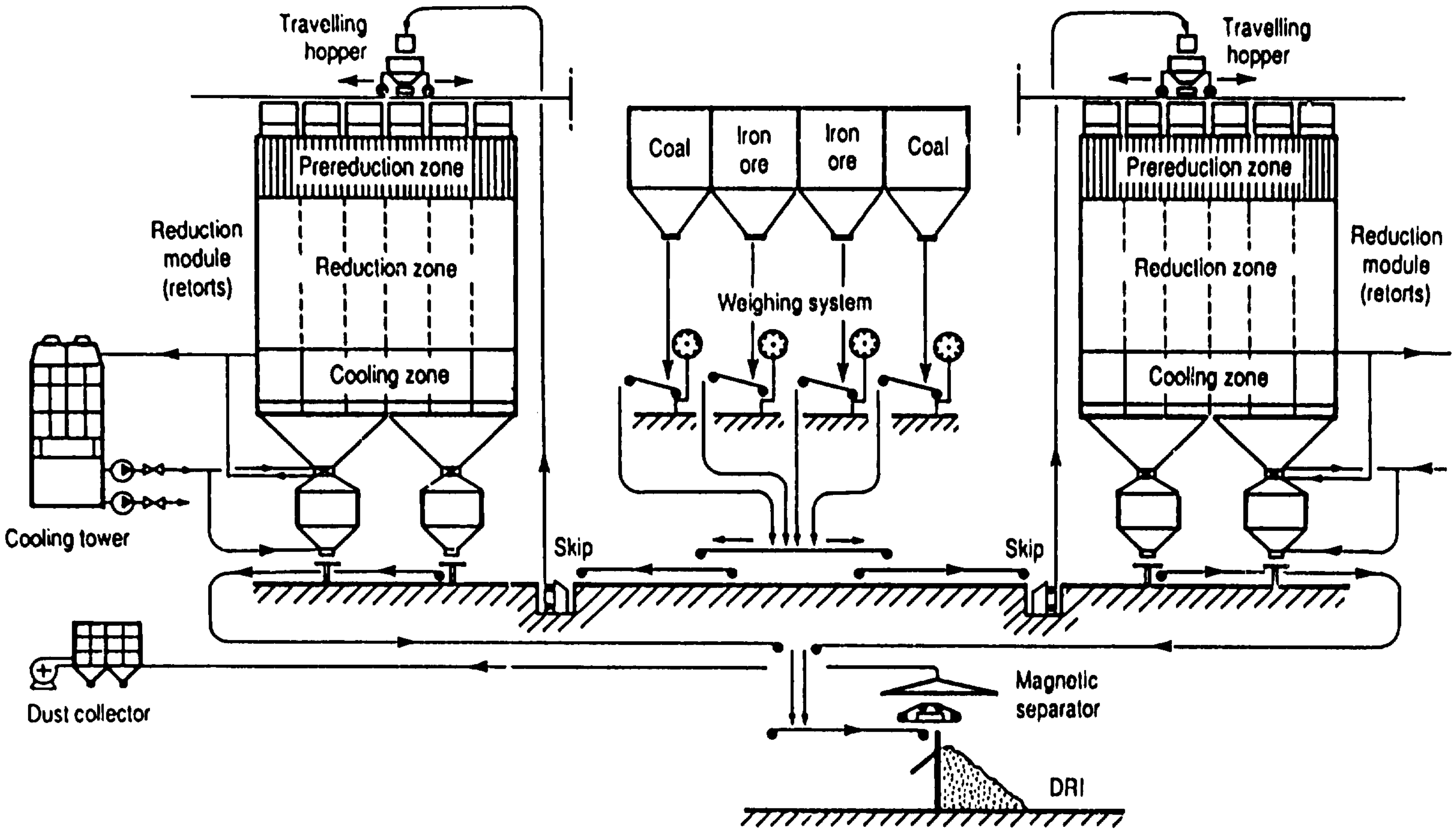


Figure 4.3 Kinglor Meteor process (two module)

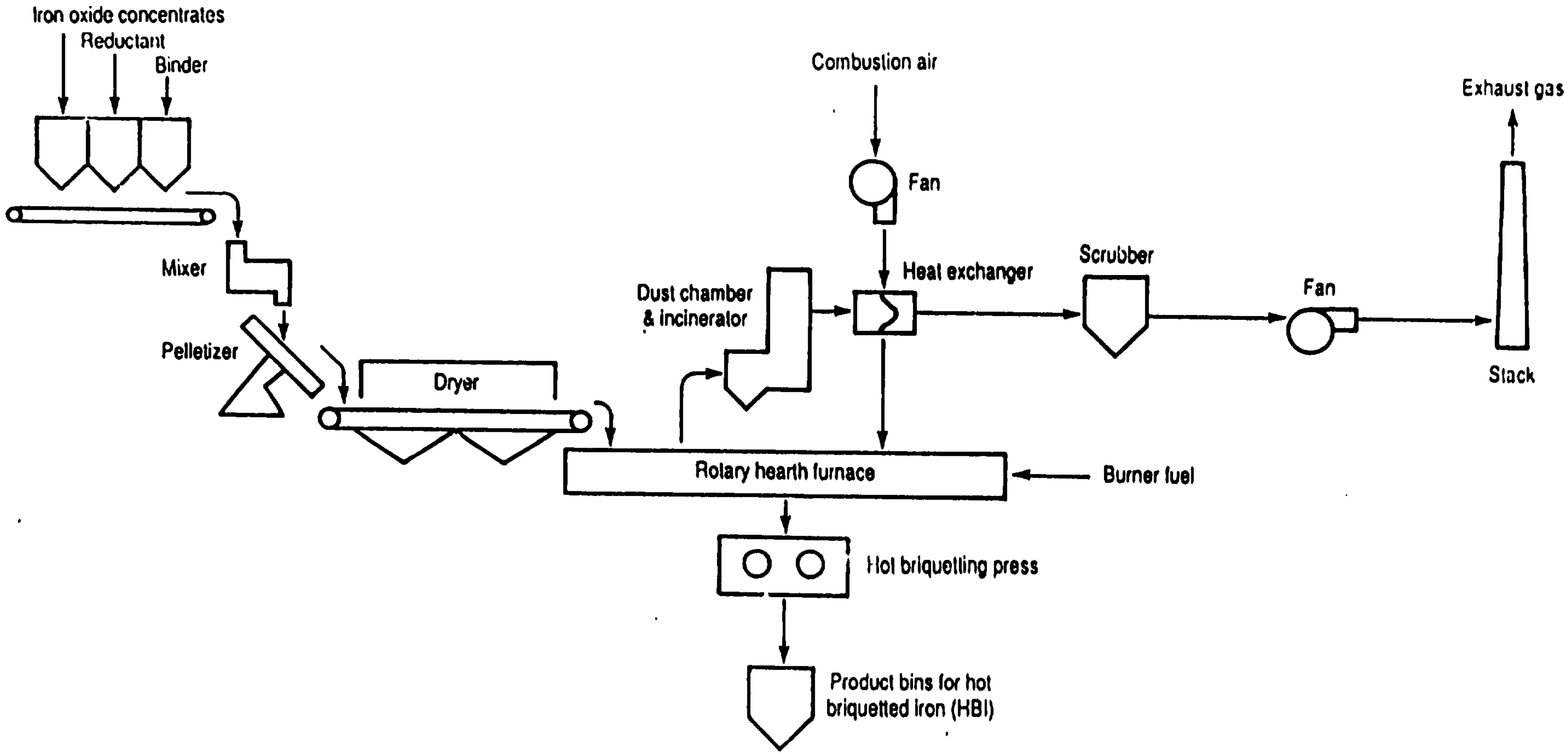


Figure 4.4 Fastmet process

* it is very flexible with respec: to the independent control of atmosphere, temperature and residence time in the rotary hearth furnace, and consequently can be adapted to suit the specific characteristics of the iron ore being reduced.

* the low residence time allows rapid adjustment of process parameters, ensuring that production losses, due to process problems, are kept to a minimum.

* the process can be designed to produce hot briquetted iron (HBI), cold pig iron, hot metal or crude steel.

* it can be built in unit capacities of 100,000 to 400,000 tonnes per annum.

* it offers competitive capital and operating costs.

Midrex have tested a wide range of specular haematites, magnetites, ilmenites, iron sands and waste oxides in their laboratory, and have found them generally suitable for reduction in the rotary hearth furnace.

The process accepts oxide fines in the size range of pellet feed (minus 0.2mm).

The reduced pellets exiting from the rotary hearth furnace can be briquetted in their hot state into hot briquetted iron (HBI).

No commercial scale Fastmet plant is currently in operation, nor is there news of one being constructed.

4.5 COREX Process

The COREX process differs from the processes already described, in that its product is not DRI or HBI, but hot metal. The process utilises non-metallurgical coals, as the reducing agent, and fuel to produce hot metal from a range of lump ores, oxide pellets and sinter.

The COREX process was develope t by Korf Engineering in association with Deutsche Voest Alpine in the early 1980's. Following several years of operation of a pilot plant at Kehl, West Germany, the first commercial scale plant of 300,000 tonnes per annum was ordered in 1985 by ISCOR (RSA) for their Pretoria works. The main function for this plant was to supplement the hot metal production from the single blast furnace at the Pretoria Steelworks to meet the requirements of their steelshop.

The process is shown schematically in Figure 4.5, which illustrates that the process comprises two main reactors:

* the melter-gasifier, where reducing gas is generated and the DRI melted (1).

* the shaft furnace, where iron ore is reduced to DRI (2).

The COREX process is designed for an operating pressure of up to 5 bars. The raw materials comprising iron ore, coal and additives are charged via lock systems. A screw conveyor feeds the coal from a storage bin (3) into the melter-gasifier. In the upper part of the melter-gasifier, the coal is completely dried and gasified as a result of its exposure to the reducing gas, which is at a temperature of around 1100°C. The reaction proceeds rapidly, thus enhancing the conversion of coal to coke which is gasified with oxygen blown into the reactor through tuyeres. The gas flow in the cylindrical part of the melter-gasifier is such as to maintain a stable fluidized bed. Upstream of the tuyeres, oxygen reacts with carbon to form CO_2 which is then converted to CO by using coke. The temperature in the fluidized bed ranges between 1600 and 1700°C. The temperature conditions of both the fluidized bed and the melter-gasifier dome guarantee the production of high-quality reducing gas containing 95% CO and hydrogen, approximately 2% CO_2 and a small portion of methane and nitrogen. After leaving the melter-gasifier, the hot raw gas is mixed with

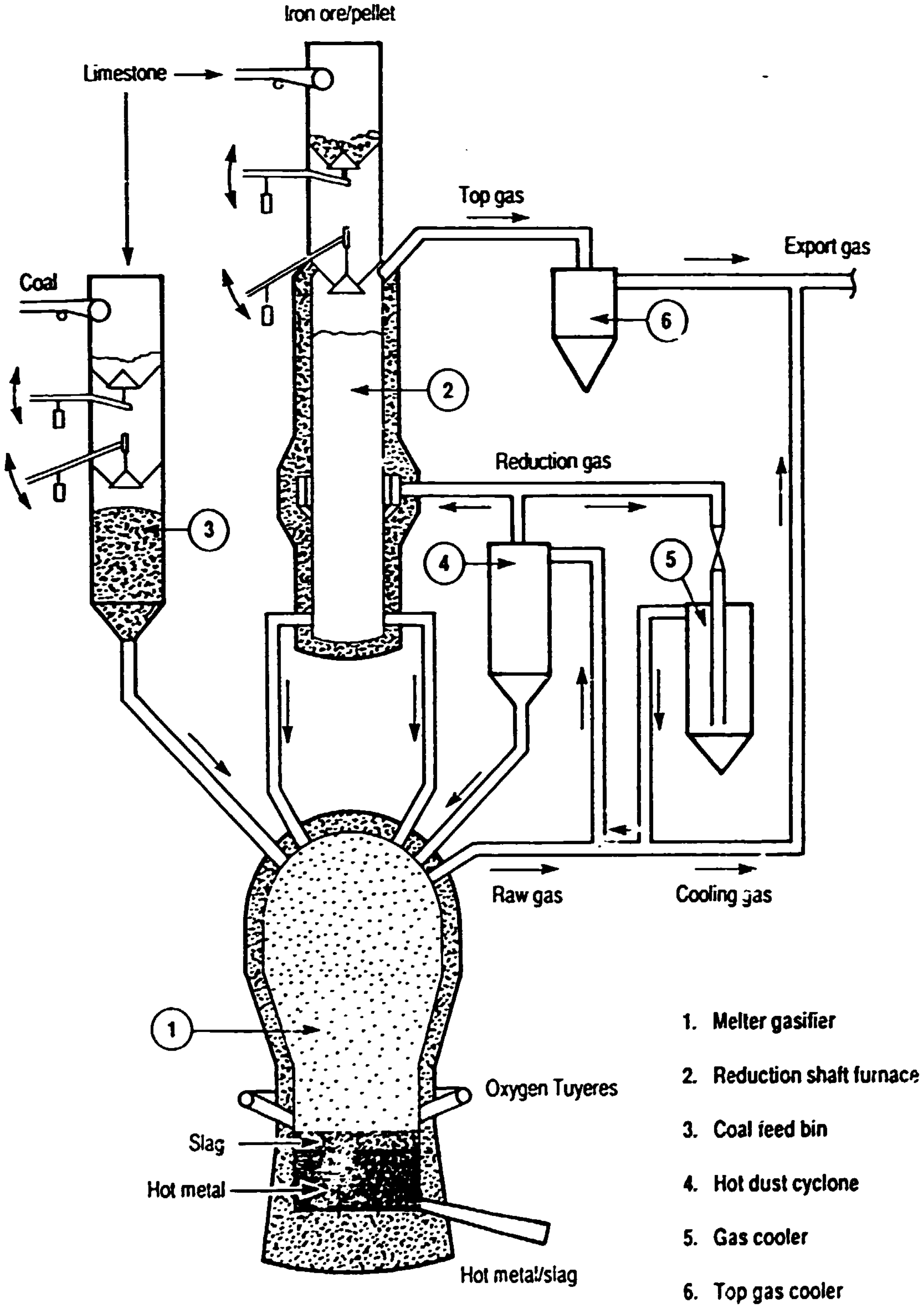


Figure 4.5 Corex process

cooling gas in order to reach a temperature of approximately 900°C. Subsequent to coarse dedusting in hot cyclones (4), the gas is introduced into the reduction shaft. Part of the pre-cleaned reduction gas is branched off upstream of the reduction furnace and treated in a Venturi scrubber (5) to obtain cooling gas. The fine particles separated in the hot cyclones are recycled into the melter-gasifier.

In the reduction shaft, the iron ore is reduced to direct reduced iron (DRI) according to the proven counterflow system. The hot DRI is then discharged from the reduction shaft via screw conveyors, and drops by gravity into the melter-gasifier. In the fluidized bed the fall of the material is strongly decelerated. In the melter-gasifier the DRI is further heated up and melted to form a hot metal and slag bath at the bottom.

Similarly to blast furnace practice, hot metal and slag are periodically tapped, approximately every three hours. The tapping temperature is between 1400 and 1500°C. The degree of metallization of the DRI produced in the reduction furnace is generally about 95%. Depending on the charging material and the mode of operation, the carbon content of the DRI will be between 2 and 5%. Because the reducing gas contains about 70% CO and 25% H_2, the reaction in the reduction furnace is exothermic.

The gas balance of the COREX process depends on the grade of coal charged, as well as its analysis. Export gas, obtained as a by-product of hot metal production, is a high-quality gas with a calorific value of approximately 2000 Kcal/Nm^3.

This gas can be used:

- for heating of furnaces within the rolling mills
- for the generation of electrical energy
- for the production of oxygen for the COREX plant.

The advantages claimed for the COREX process are;

- hot metal production using a wide range of non-coking coals as the reductant and fuel
- low capital investment cost
- economic hot metal production costs for annual productions in the range from 100,000 to 300,000 tonnes.
- utilisation of 'off-gas' for generation of electrical power or for the heating of other steelworks furnaces
- low infrastructure requirements
- high level of availability, and short start-up time
- low environmental impact

4.6 Combismelt Process

The COMBISMELT process was developed by LURGI in cooperation with MANNESMANN DEMAG. It enables the production of hot metal by the exclusive use of low-grade and noncoking coals at minimum energy consumption.

The various kinds of waste heat produced in the SL/RN rotary kiln process are recovered and consumed in a circulating fluid bed (CFB) combustion system for the generation of high-pressure steam and, subsequently, electrical power. The generated electrical power is used in a submerged arc furnace (SAF) with an open slag bath to smelt the direct reduced iron (DRI) produced in the SL/RN rotary kiln.

The COMBISMELT process comprises three main items of equipment;

- a SL/RN rotary kiln for direct reduction of the iron ore using low-grade coals
- a circulating fluid bed (CFB) energy recovery plant, and
- a submerged arc furnace (SAF) for hot metal production

The flowsheet for the COMBISMELT process is shown in Figure 4.6.

The economic advantzges of this process result from the CFB energy recovery plant, in which excess waste energies of the rotary kiln i.e. waste gases, waste coal (nonmagnetics) and in-plant dust are converted into electrical power at a high efficiency factor.

The generated electrical power is sufficient to supply a major portion of the smelting energy consumed by the SAF steelmaking furnace. Depending on the iron ore quality and the steelmaking concept, the SAF can produce high or low carbon hot metal. The required carbon is supplied by a small portion of the non-magnetics (char), the secondary product of the rotary kiln.

The high carbon hot metal can be processed into steel in a conventional electric arc furnace (EAF), or in a basic oxygen converter (BOF), or can be cast into pig iron for sale to foundries. The low carbon hot metal (semi-steel) can be finished in a ladle furnace to obtain a range of steel grades.

The process combinations for steelmaking allied to the COMBISMELT process are shown in F igure 4.7. With low grade iron ores the production of high carbon hot metal is preferred, since it will keep iron losses in the smelter slag as low as possible, whereas, high grade iron ores can be processed via DRI directly into semi-steel for final ladle furnace treatment.

The furnace burden, i.e. DRI, slag forming additives and char as reducing agent are charged preferably batchwise into the open slag of the submerged arc furnace. THis charging practice allows the utilisation of DRI fines without experiencing the difficulties that occur in electric arc furnaces with continuous charging (i.e. generation of dusts).

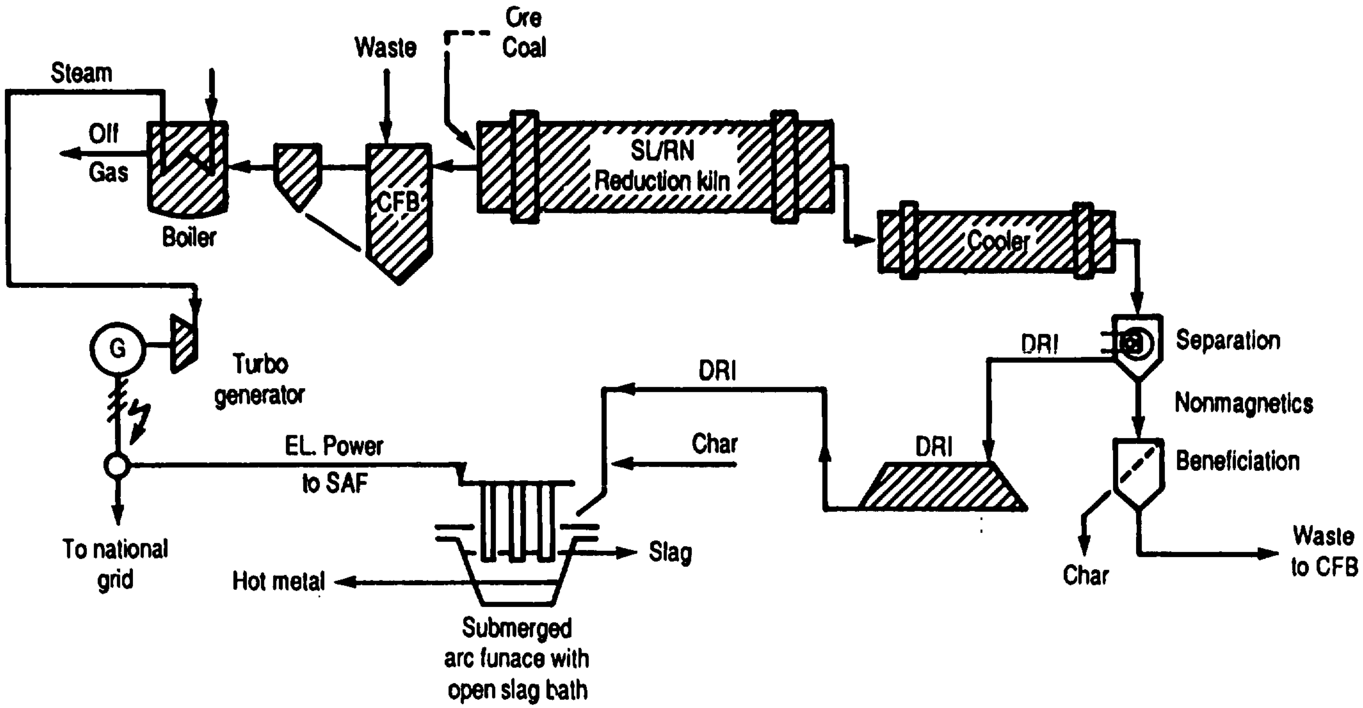


Figure 4.6 **Flowsheet for the COMBISMELT**

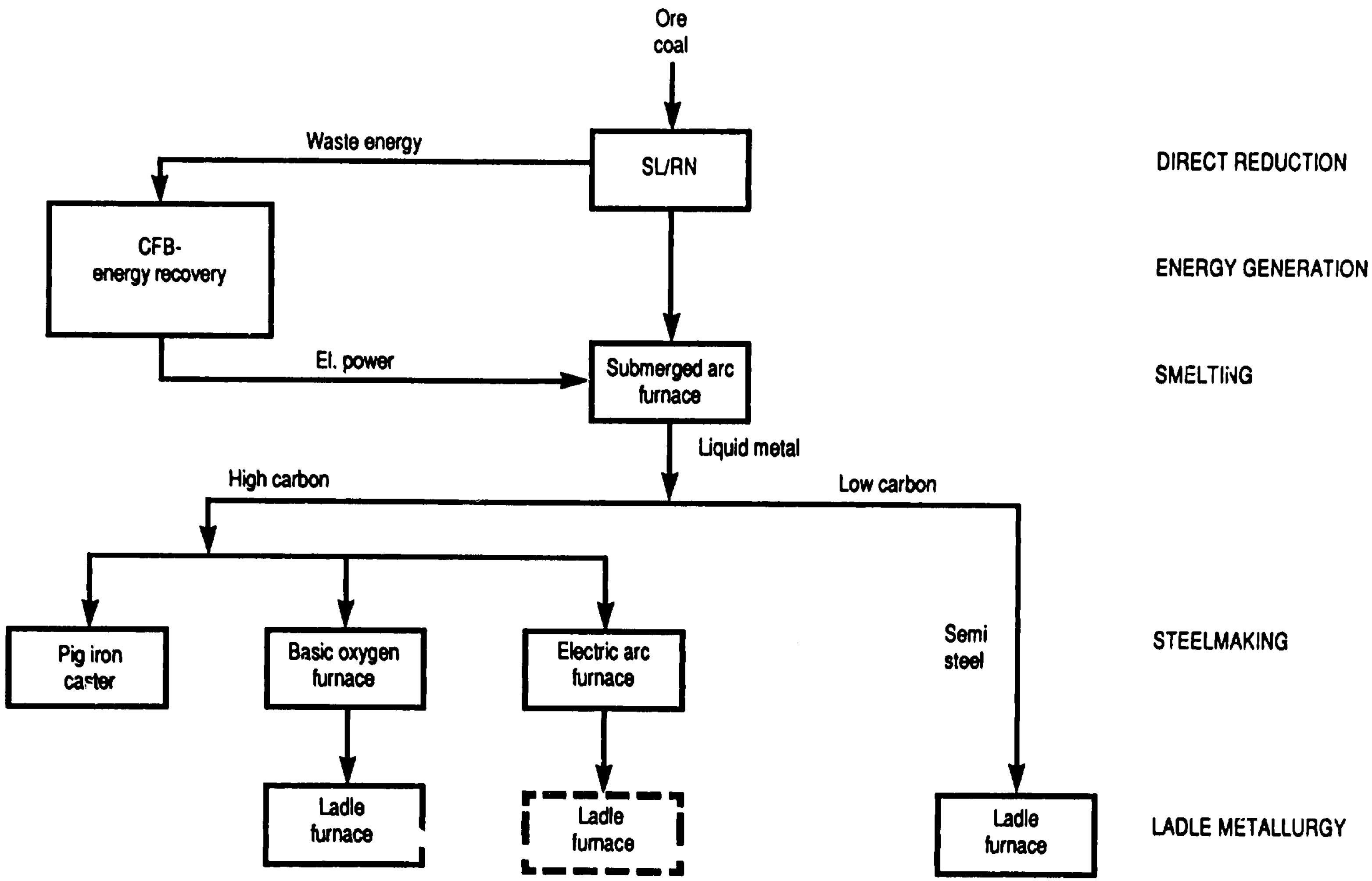


Figure 4.7 **Steelmaking process routes using COMBISMELT**

Tapping of the submerged arc furnace is made under full electrical load. Slag and hot metal tapping taking place on opposite sides of the furnace. This ensures the tapping of hot metal free from slag. The tapping temperature of the metal can be adjusted in a wide range up to 1700°C, depending on the quality of the hot metal being produced.

The advantages claimed for the COMBISMELT process are similar to those for the COREX process.

5. THE PREFERRED PROCESSES

5.1 Proposed DRI Plant

There are basically two types of DRI plant, these are:

- Merchant plants which produce DRI or HBI, and whose production is sold to external steelmakers or foundry customers. Their products have to be of a commercial grade and must meet their customers physical and chemical composition requirements. The chemical composition of the DRI or HBI is of great importance to the steelmaker, especially with regard to the amount and form of iron oxides remaining in the metallized product, and the amount and nature of the gangue.

  In most cases, the oxygen remaining in freshly metallized material is mainly in the form of FeO (Wustite). The steelmaker can either allow most of the FeO to be lost in the slag, incurring an extra Fe yield loss, or he can try to recover as much of the Fe as possible, involving extra carbon to reduce the FeO, together with the additional energy required for this reaction, thereby increasing the melting energy consumption and the melting time. Economic considerations usually dictate the latter option. Consequently, commercial grade DRI or HBI has a metallization of over 90 percent, and a gangue content of no more than 5 percent.

- Captive plants which produce DRI or HBI solely for consumption by its own steelmaking furnaces. Their steelmakers would prefer commercial grade DRI or HBI for steelmaking, although if it proves economically viable for the steelworks as a whole, lower quality DRI or HBI can be consumed.

Since the proposed DRI plant within Nepal will probably be exporting all of its production during the early years of its operation, it will by necessity be a merchant plant and must produce commercial grade product. For its production, the necessary feedstock would need to have an Fe total content of over 65%, and a gangue content of below 5%. Consequently, if the Phulchoki iron ore is to be used for DRI production it would need to be beneficiated, to enrich its Fe content, and reduce its gangue content.

5.2 Proposed Capacity of the DRI Plant

Coal based rotary kiln processes are limited by their physical dimensions to a maximum production of 170,000 tonnes per annum, subject also to the quality of the iron oxide feedstock and coal used.

A DRI plant with a rated capacity of 150,000 tonnes per annum is proposed, since such a level of production gives good 'economies of scale' and results in a lower production cost compared to that achievable from smaller capacity plants.

The iron ore requirements for this level of DRI production should be readily available from the Phulchoki iron ore deposits for a period of at least 20 years, providing the Bureau of Mines estimate of total potential mineable ore reserves of over 10 million tonnes proves to be correct.

5.3 DRI Plant Options

The SL/RN rotary kiln process produces DRI product from a feedstock of either sized lump ore, or oxide pellets, or a blend of these two raw materials. Other rotary kiln processes, such as, Krupp Codir and DRC use similar feedstock.

Only the Accar Grate CAR process and the Fastmet processes can produce DRI product using a feedstock of concentrates, due to there having in-line balling facilities before their reduction furnace. These latter two processes can, therefore, use the beneficiated Phulchoki iron ore concentrates directly, without the need for a separate pelletisation plant which the SL/RN and similar rotary kiln processes would require. Since a separate pelletisation plant to produce only about 220,000 tonnes per annum of fired oxide pellets will have a high capital cost, the overall costs of the SL/RN and similar process will be higher than either the Accar Grate-CAR or the Fastmet processes. Similarly, the production costs per tonne DRI will be higher, due to the higher capital charges.

Currently, the Accar Grate-CAR and Fastmet processes are the only coal based DRI processes which can produced hot briquetted iron (HBI), all the other processes produce direct reduced iron (DRI). Since the Fastmet process has not yet been commercially proven, it is not considered currently suitable for the proposed DRI plant. Consequently, the Accar Grate Car process has been selected as it offers the best economic option, combined with the capability to produce HBI.

5.4 Accar Grate Car DRI Plant

5.4.1 Flow Sheet

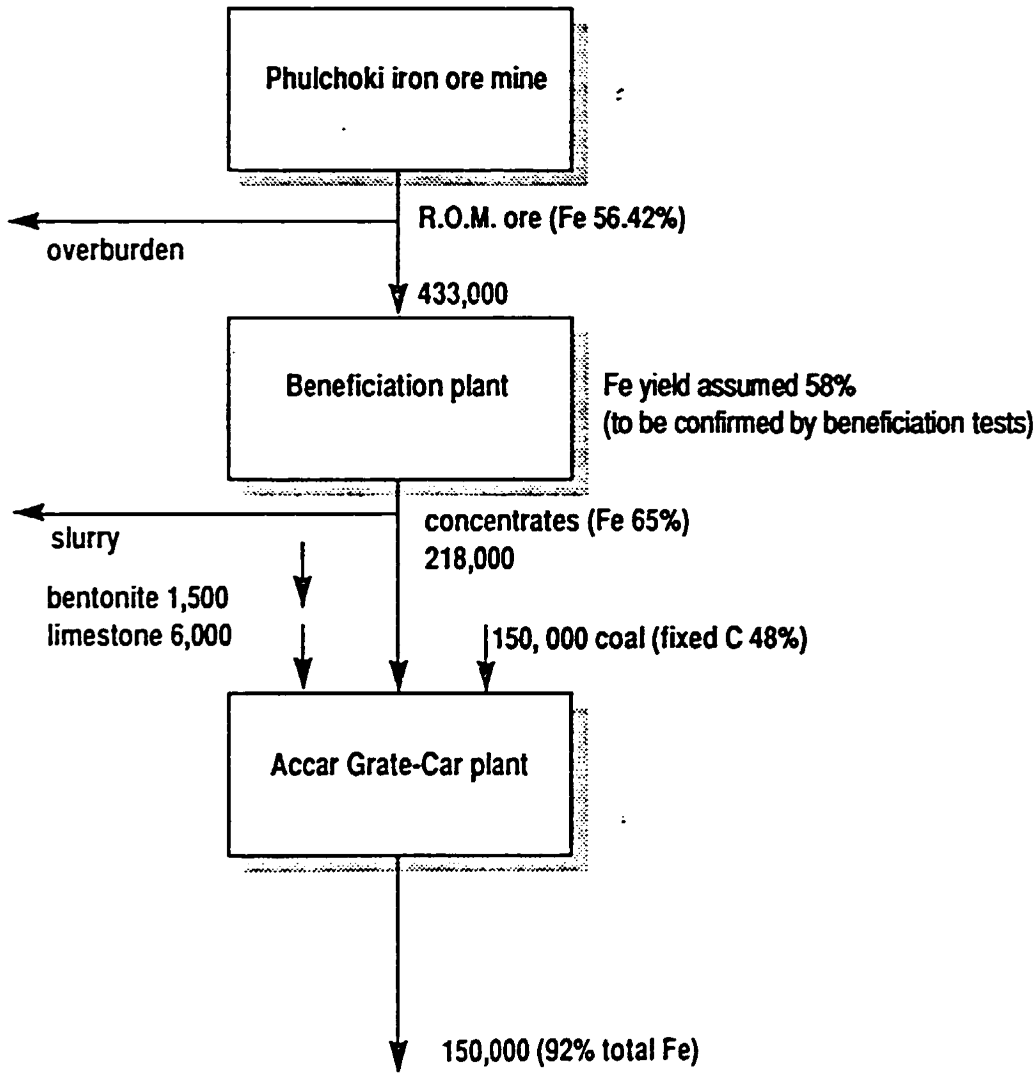
The notional flowsheet for a 150,000 tonnes per annum Accar Grate Car plant using Phulchoki beneficiated iron ore concentrates is shown in Figure 5.1.

5.4.2 Mining Scheme

For the annual production of 150,000 tonnes of HBI as proposed, the annual requirement for run-of-mine (ROM) iron ore from the Phulchoki ore deposits is 433,000 tonnes. Based on a mining operation of 300 days annually, this is equivalent to 1,450 tonnes per day. From earlier studies of the Phulchoki iron ore deposits, the ore to waste ratio has been calculated to be 1:2. Thus, the total daily quantity of ore and waste to be handled is 4,350 tonnes.

Based on the topography and physical configuration of the Phulchoki ore deposits, opencast mining would be the most economical system for mining the iron ore.

The proposed mining plan would involve commencing mining operations in the eastern section at bench no. 3, at a level of about +2.500 metres, and proceeding downwards through the 1000 metre length of strike of the deposit.



Note
All values repesent tonnes per annum

Figure 5.1 Flowsheet for Accar Grate-Car plant

Before commencement of mining operations, overburden material would be stripped in sections of about 100 metres length. The waste material would be dumped in a selected waste disposal area on the hill slope.

Access roads to the mine site and to the selected waste disposal area would need to be constructed before the start of stripping operations.

Mining would be undertaken in 10 metres high benches, using ANFO (Ammonium Nitrate-Fuel Oil) blasting.

Due to the large daily output required, excavation and disposal of waste material and iron ore will be done mechanically using front end loaders, which have greater flexibility than mobile shovels. Three front end loaders would be required for the excavation of the ore and waste.

Three 30 tonne rear-dump trucks would be used to transport the waste to the selected waste disposal area, and to transport the ROM ore (-200mm) to two loading bunkers of 2000 tonnes total capacity. These bunkers will fill the 5 tonne buckets of an aerial ropeway, which would link the mine site with the materials preparation area of the beneficiation plant.

A caterpillar mounted bulldozer, and a grader will be used for the maintenance of ramps and roads within the mine site.

Auxiliary facilities including laboratory, survey and drawing office, repair workshops, stores, welfare, garage etc would have to be provided. The most convenient site available would appear to be on the flat ground alongside the access road, close to bench no. 13.

5.4.3 Aerial Ropeway

For reasons which are explained in Section 6, the proposed site for the beneficiation plant would be Godawari, which is a horizontal distance of about 1,150 metres from the mine site. In this distance the buckets would descend about 500 metres, or a travelling distance of 1,250 metres.

Using 5 tonne buckets, there would be a daily requirement for 290 buckets, or about 40/hour. With the buckets spaced at 50 metres intervals, and a speed of 5 kms per hour, the aerial ropeway would have a capacity of 250 tonnes per hour.

5.4.4 Beneficiation Plant

The Fe yield attained by beneficiation of the Phulchoki ore can only be established by laboratory testing samples of the ore. However, from the earlier tests by Dastur, who undertook beneficiation tests at -48 and -65 mesh, improvements in quality were indicated but recovery was low. For pelletising, it will be necessary to grind to a size of 70% passing 325 mesh. Beneficiation of such a size should give an improved Fe recovery. Consequently, an estimated yield of 58% has been assumed for this study, which it is hoped could be bettered in the beneficiation tests. At this yield, the beneficiation plant would need to annually process 433,000 tonnes of ROM ore to produce the 218,000 tonnes of 65% Fe concentrates needed for direct reduction.

The beneficiation plant would include a conventional 3 stage crushing plant of 120 tonnes per hour, operating for 3,600 hours per year, of the semi mobile type, and primary ball milling to 65 mesh followed by gravity separation and regrinding to 325 mesh, high gradient magnetic separation, thickening and filtration. The concentrator would operate continuously for 350 days per year, i.e. about 7,200 hours per year.

5.4.5 Transport of Concentrates

It is proposed to transport the concentrates by road from the beneficiation plant to the direct reduction plant using 20 tonnes capacity trucks.

5.4.6 DR Plant

The DR plant would operate continuously for 350 days per annum, and with an availability of over 90%, will have an annual production capacity of 150,000 tonnes of HBI product. The raw materials stockyards would include stockpiles of about 1 months operating requirements of iron ore concentrates (20,000 tonnes) and Jogimara limestone (500 tonnes), and 2 months requirements of imported coal (25,000 tonnes).

The run-of-mine coal is crushed and screened before conveying to the coal bins which supply coal to the rotary kiln entry, and discharge end burner.

The blend of concentrates and binder (normally bentonite) is fed at a controlled rate into a balling drum for green ball formation.

Properly sized green balls are fed onto a travelling grate where they are updraught and downdraught dried and preheated. Following preheating, the pellets, together with coal, limestone and recycled char are fed into the rotary kiln and heated by counter current flowing gases to the reduction temperature of between 1000 and 1100°C.

The hot product on discharge from the kiln is converted into HBI in a briquetting press and transported to product silos of 10,000 tonnes total capacity.

5.5 Proposed Ironmaking Plant

Both the COREX and COMBISMELT processes can produce hot metal from a feedstock of unbeneficiated Phulchoki iron ore.

At all the installations where these processes are installed, i.e. COREX at ISCOR, Pretoria, and COMBISMELT at New Zealand Steel and Highveld Vanadium and Steel, the hot metal produced is converted into steel in their in-plant steelmaking furnaces. Generally, the hot metal is only cast into pig iron when there is a problem in the steelshop.

The COREX plant at Pretoria opeates with local lump iron ore of 62 or 67 percent Fe, whilst the COMBISMELT plants operate with high vanadium content ironsands at New Zealand Steel, and high vanadium content lump ore at Highveld Vanadium and Steel.

The COREX process which uses a shaft type direct reduction furnace is thermally more efficient than the COMBISMELT process which utilises a rotary kiln for direct reduction. Typically, the COREX process requires 5 G Cals/tonne hot metal of input coal, and has 3.3 G Cals/thm of surplus energy from its melter-gasifier and reduction furnace, which could be used to generate about 1150 Kwh/thm of electrical power. The COMBISMELT process requires

6.5 G Cals/thm of input coal, and has 2.65 G Cals/thm of surplus energy from its rotary kiln, which could generate about 900 Kwh/thm of electrical power.

The COREX plant is capable of supplying its power requirements for oxygen generation and ironmaking (about 500 Kwh/thm), and could have surplus power for export, depending on the capacity of the gas turbine installed. However, the COMBISMELT plant would only be capable of supplying the power requirements of its SAF (900 Kwh/thm).

5.5.1 Corex Plant

The only operating COREX plant at ISCOR's Pretoria works has a rated capacity of 300,000 tonnes per annum of hot metal. Since the process can tolerate lower quality iron ore, it could be operated to produce cold pig iron from a feedstock of unbeneficiated Phulchoki iron ore. There may therefore be sufficient ore reserves to support a plant of 300,000 tonnes per annum, which would be able to benefit from economies of scale.

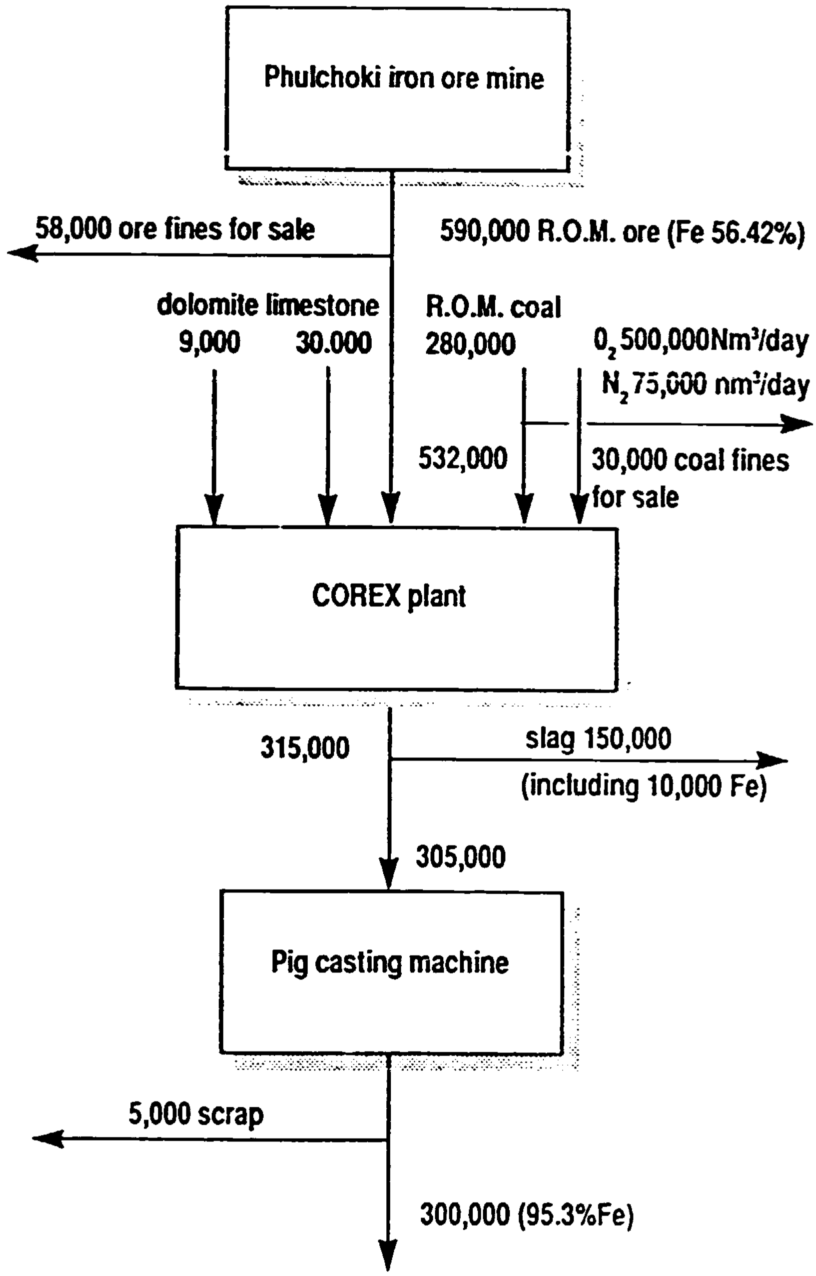
The flowsheet for a 300,000 tonnes per annum COREX plant using sized Phulchoki iron ore is shown in Figure 5.2.

Mining Scheme

The mining scheme to meet the requirements of a 300,000 tonnes per annum COREX plant would be similar to that for the Accar Grate CAR plant, although the annual quantity of iron ore to be mined increases to 532,000 tonnes. An extra front end loader, and 30 tonne rear-dump truck would be needed to handle the additional tonnages of ore and waste.

Transport of the ROM Ore

An aerial ropeway would be used to transport the ROM iron ore from the two loading bunkers to two overhead bunkers of 2,000 tonnes total capacity, situated at the base of the Phulchoki hill near Godawari. The ROM ore will



Note
All values repesent tonnes per annum, except where specified otherwise

Figure 5.2 Flowsheet for COREX plant

be discharged from these bunkers into 20 tonne capacity trucks for transport by road to the COREX plant.

Capacity of Plant

The proven COREX plant at ISCOR Pretoria works is designed for an annual production of 300,000 tonnes. To achieve the benefit of economies of scale, a similar capacity plant would be proposed for Nepal.

This plant would operate continuously for 350 days per annum, and and should achieve an availability over 90%.

The raw materials stockyards would include stockpiles of about 1 months operating requirements of ROM ore (45,000 tonnes) and limestone (3,000 tonnes), and 2 months requirements of imported coal (40,000 tonnes).

The ROM iron ore would be crushed and screened to give a sized ore of +10 to -25mm. The -10mm ore fines would be stockpiled and sold as sinter feed. The sized ore would be conveyed to burden bins adjacent to the gasifier-melter for subsequent charging via a skip hoist into the top of the shaft furnace.

The ROM coal would be crushed and screened to give a sized coal of +8 to -25mm. The -8mm coal fines would be stockpiled and sold as boiler fuel. The sized coal would be conveyed by a skip hoist to a coal bunker located above the gasifier-melter and fed by feeders through its dome.

Slag and hot metal would be tapped from a single taphole, with the hot metal poured into 60 tonne Kling type ladles, and the slag taken to slag pits or a granulation facility.

The hot metal would be transferred to a nearby 2 strand pig casting machine and cast into pigs.

The COREX process consumes 500 Nm^3 of O_2 and 75 Nm^3 of N_2, per tonne hot metal, which ISCOR purchase 'over-the-fence' from an oxygen supplier. Such a situation will not exist in Nepal, and consequently, a 700 tonnes per day oxygen plant would need to be installed on-site to provide the oxygen and nitrogen requirements of the COREX plant. The installation of such a large capacity oxygen plant has a significant effect on the overall capital cost of the project.

5.5.2 Combismelt Plant

The two combismelt plants in operation, at ISCOR, Vanderbijlpark, Republic of South Africa and New Zealand Steel, both produce sponge iron in 5 rotary kiln units, each of 150,000 and 175,000 tonnes per annum respectively. This sponge iron is subsequently smelted into hot metal in submerged arc furnaces (SAF).

Since the process, like the COREX process, can tolerate lower quality iron ore, it could also be operated to produce cold pig iron from a feedstock of unbeneficiated Phulchoki iron ore. With a single rotary kiln unit of 150,000 tonner per annum capacity, the iron ore reserves should be sufficient to support this capacity plant for over 20 years production.

The flowsheet for a COMBISMELT plant to produce 120,000 tonnes per annum of cold pig iron using sized Phulchoki iron ore is shown in Figure 5.3.

Mining Scheme

The mining scheme to meet the requirements of a 120,000 tonnes per annum COMBISMELT plant would be similar to that for the ACCAR GRATE CAR plant, although the annual quantity of iron ore to be mined would decrease to 242,000 tonnes.

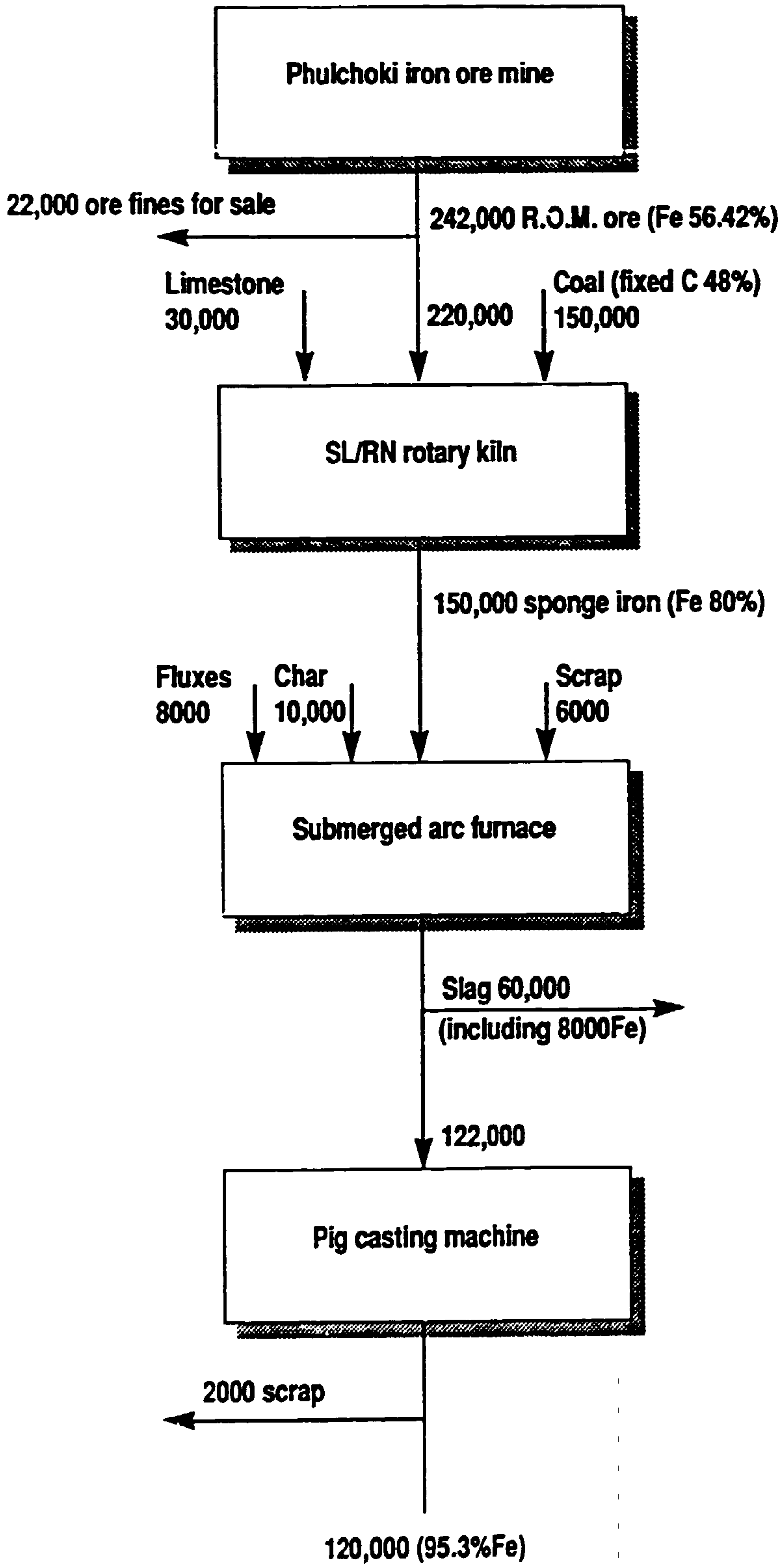


Figure 5.3 Flowsheet for Combismelt plant

Transport of the ROM Ore

The ROM iron ore would be handled and transported in a similar manner to that proposed for the COREX plant.

Capacity of Plant

The plant would operate continuously for 350 days per annum, and would be in production for at least 300 days during this period, ie an availability of 86 per cent. The raw materials stockyards would include stockpiles of about 1 months operation requirements of ROM ore and limestone and 2 months requirements of imported coal.

The ROM iron ore would be crushed and screened to give a sized ore of +10 to -25mm before conveying to the coal hopper at the rotary kiln entry. The -10mm fires would be stockpiled and sold as sinter feed. The ROM coal would be crushed and screened to give a sized coal of +8 to -25mm for charging with the iron ore. The -8mm coal fires would be used as the fuel for the discharge end burner. The sponge iron product would be hot charged into the SAF via overhead hoppers.

A single 25 tonnes rated capacity SAF equipped with a 12MW rated transformer would be used to smelt the sponge iron into hot metal for subsequent casting into cold pig iron. The SAF would be operated on average 90 minutes tap-to-tap cycle times, and based on 4800 heats per annum, would have an hourly production of 16.7 tonnes. Slag and hot metal would be tapped from separate tapholes, with hot metal poured into a 25 tonne kling type ladle and the slag taken to a slag pit. The hot metal would be transferred to a nearby single strand pig casting machine and cast into pigs.

5.6 Ironmaking Plant Options

The COREX plant has the benefit of economies of scale, since for a similar pig iron production (300,000 tonnes), the COMBISMELT plant would need at least 2 rotary kiln units to produce the sponge iron requirements of its SAF.

Also, the COREX process is thermally more efficient than the COMBISMELT process, which will result in lower operating costs.

6. PLANT LOCATIONS AND THEIR INFRASTRUCTURE FACILITIES

6.1 General

The choice of sites for the production facilities associated with a DRI plant must take into account many factors, such as: accessibility of raw materials sources and markets; cost and availability of land; infrastructure facilities including water, power, approach roads and transportation routes; existing ancillary industries; local skilled manpower and welfare facilities.

The principal site locations are indicated in Figure 6.1.

For a DRI plant, the main raw materials sources would be the Phulchoki iron ore deposits, limestone from the Jogimara quarry and imported coal, probably by rail to Raxaul on the Indian side of the frontier near Birganj, and from there by road to the plant site.

It is established that the Phulchoki iron ore would need beneficiation to allow it to be used for DRI production. The beneficiation plant could be located at the DRI plant site or at a separate site between it and the Phulchoki ore mine. The latter option would ensure that the distance the large tonnage (433,000 tpa) of R.O.M ore has to be transported is kept to a minimum, whilst only the much lower tonnage (218,000 tpa) of beneficiated ore would need to be transported to the DRI plant site.

No beneficiation plant would be needed for the COREX plant option.

Figure 6.1 Principal site locations

6.2 Beneficiation Plant

Two possible sites were considered for the beneficiation plant, these were;

- Godawari, near to the marble quarries, which are situated just over 1Km (horizontal distance) to the north of the Phulchoki iron ore deposits.

- Lele valley, near to the village of Kabre, which is situated over 2Kms (horizontal distance) to the south west of the Phulchoki iron ore deposits.

6.2.1 Godawari

There is an area of flat terrain at the base of Phulchoki hill, about 1Km south of the village of Godawari. The 20 hectares available would amply meet the land requirements of a beneficiation plant and its associated tailings ponds. The land is not cultivated, and currently has access via an unmade road to the metalled Godawari to Pathan road.

Some industry already exists in the area, including the marble quarries, brick and tile factories.

Adequate water supply for a beneficiation plant should be available from nearby rivers i.e. the Godawari, Chisapani and Dhungakhani kholas.

There is no medium tension power line into the area, and an 11KV power transmission line would need to be constructed from Pathan, about 10Kms to the north west.

A 4 metre wide metalled road exists to the tile factory, and this road would need to be extended by about 1Km to give access to the site.

6.2.2 Lele

There is an area of flat terrain to the north east of the village of Kabre. Over 50 hectares are available which would amply meet the requirements for a beneficiation plant and its associated tailings ponds. No major industries exist currently in the Lele valley, all the land being under rice cultivation. It is probable that environmental interests would raise considerable objections to any proposals for a beneficiation plant in this area.

The only access currently into the Lele valley is an unmade road from Chapagaon. A 4 metre wide metalled road from Chapagaon of about 8Kms length would need to be constructed to give access to a beneficiation plant at Kabre. The Lele khola flows through the valley and would be able to supply the water requirements of a beneficiation plant.

There is no medium tension power line into the Lele valley, and an 11KV power transmission line would need to be constructed from Pathan, about 12Kms to the north.

6.1.3 Recommended Location for the Beneficiation Plant

The costs for an aerial ropeway for the transport of the R.O.M ore from Phulchoki, and the costs of road access to the beneficiation plant will be significantly lower at Godawari. Thus, for economic reasons, plus the probable major environmental pressure against any industrial development in the Lele valley, it is recommended that the beneficiation plant be located at Godawari.

6.3 DRI Plant

For many years, the bulk of production from the DRI plant would probably be exported via Birganj/Raxaul on the southern frontier with India. Imported coal would also use this route, allowing the possibility of utilising the trucks bringing coal to the plant to depart loaded with HBI product.

Iron ore concentrates would be brought by road from Godawari, and limestone by road from the Jogimara quarry. Due to the long distances over difficult terrain from these two raw materials sources, aerial ropeways to link them with the DRI plant would be uneconomic.

The most suitable location for the DRI plant would be near an existing township, situated alongside a main highway, at the intersection of the plant's raw materials and product transport routes. Two locations in the Terai (lowlands) to the south of Kathmandu meet these conditions, these are;

* Hitaura situated about 40Kms southwest of Kathmandu, and 50Kms north of Birganj.

* Simra situated about 70Kms southwest of Kathmandu, and 20Kms north of Birganj.

Both these towns are situated on the Tribhuwan highway which links Kathmandu with Birganj on the frontier with India.

6.3.1 <u>Hitaura</u>

The industrial estate at Hitaura comprises several food factories (flour, beer and cooking oil), a large textile factory and various light industries. It has its own 11KV sub-station, and an intake pumping station supplying water from the nearby Karra khola.

Whilst the industrial estate has adequate land available for a DRI plant, the management indicates that there would be strong opposition from the on-site food factories objecting to its installation, due to possible air pollution. Consequently, a site to the south of the industrial estate would have to be used. The land in this area is flat and well drained, and should not involve high costs for site preparation.

The Nepal Electricity Authority (NEA) main sub-station for Hitaura is located about 3Kms north of the proposed plant site. This sub-station has a single 132KV incoming power transmission line connecting it to Kulekhani power stations Nos. 1 and 2 of 92MW total generating capacity. Two 66KV lines connect Hitaura with Birganj to the south. These power lines pass within 500 metres of the proposed site, and NEA confirm that a branch could be taken from one of these power lines to an incoming main sub-station at the plant.

The water supply for the plant will have to be taken from the Rapti river, since the nearer Karra khola is used to supply the Hitaura industrial estate and does not have any surplus capacity. An intake pumphouse would need to be constructed at the Rapti river, together with a supply main of about 4Kms length to the plant site.

The proposed site is situated alongside the Tribhuwan highway, ensuring good access for road vehicles into and from the site. The road distances involved for the transport of raw materials and HBI product would be 200Kms for concentrates (Godawari), 120Kms for limestone (Jogimara) and 55Kms for imported coal and HBI product (Raxaul). The latter distance being the entry/exit into Nepal, and not the source/destination for the imported coal and HBI product.

With the proposed plant site at Hitaura, and an annual HBI production of 150,000 tonnes, the movements of raw materials and HBI product within Nepal would be 104 million tonnes. Kms.

6.3.2 Simra

A small amount of industrial development exists to the south of Simra, along the Tribhuwan highway to Birganj. The land in this area is flat, and would offer a suitable location for the proposed DRI plant.

To supply power to the site would only involve the construction of a 200 metres long branch from the NEA 66KV transmission lines to Birganj, which are routed along the western side of the Tribhuwan highway.

Good quality water exists underground at Simra, and the water supply for the proposed DRI plant can be obtained by sinking tubewells to a depth of about 150 metres.

The proposed plant site is situated along the western side of the Tribhuwan highway affording good access to road vehicles.

The road distances involved for the transport of raw materials and HBI product would be 230Kms for concentrates (Godawari), 150Kms for limestone (Jogimara) and 25Kms for imported coal and HBI product (Raxaul). As mentioned previously, the latter distance is the entry/exit into Nepal, and not the source/destination for the imported coal and HBI product.

With the proposed site at Simra, and an annual HBI production of 150,000 tonnes, the movements of raw materials and HBI product within Nepal would be 108 million tonnes. Kms.

6.2.3 Recommended Location for the DRI Plant

There is little difference between the merits of Hitaura and Simra for the location of the DRI plant. Hitaura is the preferred location, as it offers better welfare and social facilities, a greater number of associated engineering companies for possible repair and maintenance support, and a large pool of available manpower from which to recruit the plants workforce. Also, transport costs for the movement of raw materials and product would be marginally lower for Hitaura.

6.4 COREX Plant

Similarly, the preferred location for the COREX plant would be Hitaura, as most of the factors which applied to its selection for the DRI plant would equally apply for the proposed COREX plant.

7. COST AND VIABILITY ESTIMATES

7.1 General

In this section, the viability of the ACCAR and COREX options is initially appraised on a cash flow basis at market prices, before taking account of the effects of inflation and financing, and sensitivity analyses are then carried out. The implications of inflation and financing for the preferred option are then examined, as are the economic internal rate of return and the foreign exchange and employment impacts.

An integrated spreadsheet computer model was developed for the process, cash flow, financial and economic evaluations. Summary results are included in the text and copies of printout tables are included in the appendices.

7.2 Capital Costs

The total capital costs of the ACCAR and COREX process options, including the associated infrastructural requirements, are summarised in Table 7.1.

Assuming that a decision whether or not to proceed with further investigations is taken by the end of 1991, at least a further two years would be required to carry out the following:

* drilling programme to establish grade and extent of the ore reserves
* ore beneficiation and reduction tests
* full feasibility study and environmental impact assessment
* preparation of specifications and enquiry documents
* tender evaluation and contract negotiations

TABLE 7.1: CAPITAL COSTS OF PROCESS OPTIONS

(NR Million at mid-1991 prices)

Item	ACCAR	COREX
Land	5.00	5.00
Mining	216.75	289.85
Benefication	277.53	-
ACCAR/COREX	1253.75	4921.50
Oxygen Plant	-	1700.00
Phulchoki Ropeway	55.25	70.55
Phulchoki Road Upgrading	21.25	21.25
Power Line to Godavari	21.25	-
Water & Power to Hetaura	8.50	4.25
Contingencies	200.03	700.74
Import Duties	26.92	46.249
Total	2086.23	7759.389

Notes:

1)

Exchange rate at July 1991 was US$ 1.0 = NR 42.5

2)

The COREX plant generates its own electric power requirement from the process off gas.

Construction on site could start in 1994 and, with approximately three years required for plant and infrastructure construction, production could begin in early 1997. The assumed project programme is set out in Figure 7.1. With a construction programme on this basis, the phasing of expenditure on capital costs would be broadly as shown in Table 7.2.

TABLE 7.2 - PHASING OF CAPITAL COST EXPENDITURE

Year	Capital Cost (NR million)	
	ACCAR	COREX
1992	12.28	27.23
1993	43.26	34.58
1994	409.69	2265.84
1995	914.75	3870.89
1996	706.25	1560.85

7.3 Operating Costs

7.3.1 Development of capacities

The HBI and pig iron production capacities, allowing for phased production and yield learning curves, are assumed to develop as follows:

Year	Production	
	ACCAR	COREX
1997	112500	225000
1998	135000	270000
1999	150000	300000
2000	150000	300000

Production is then projected to remain constant, at 150 000 tonnes per year for HBI and 300 000 tonnes per year for pig iron, over the period of evaluation of the project.

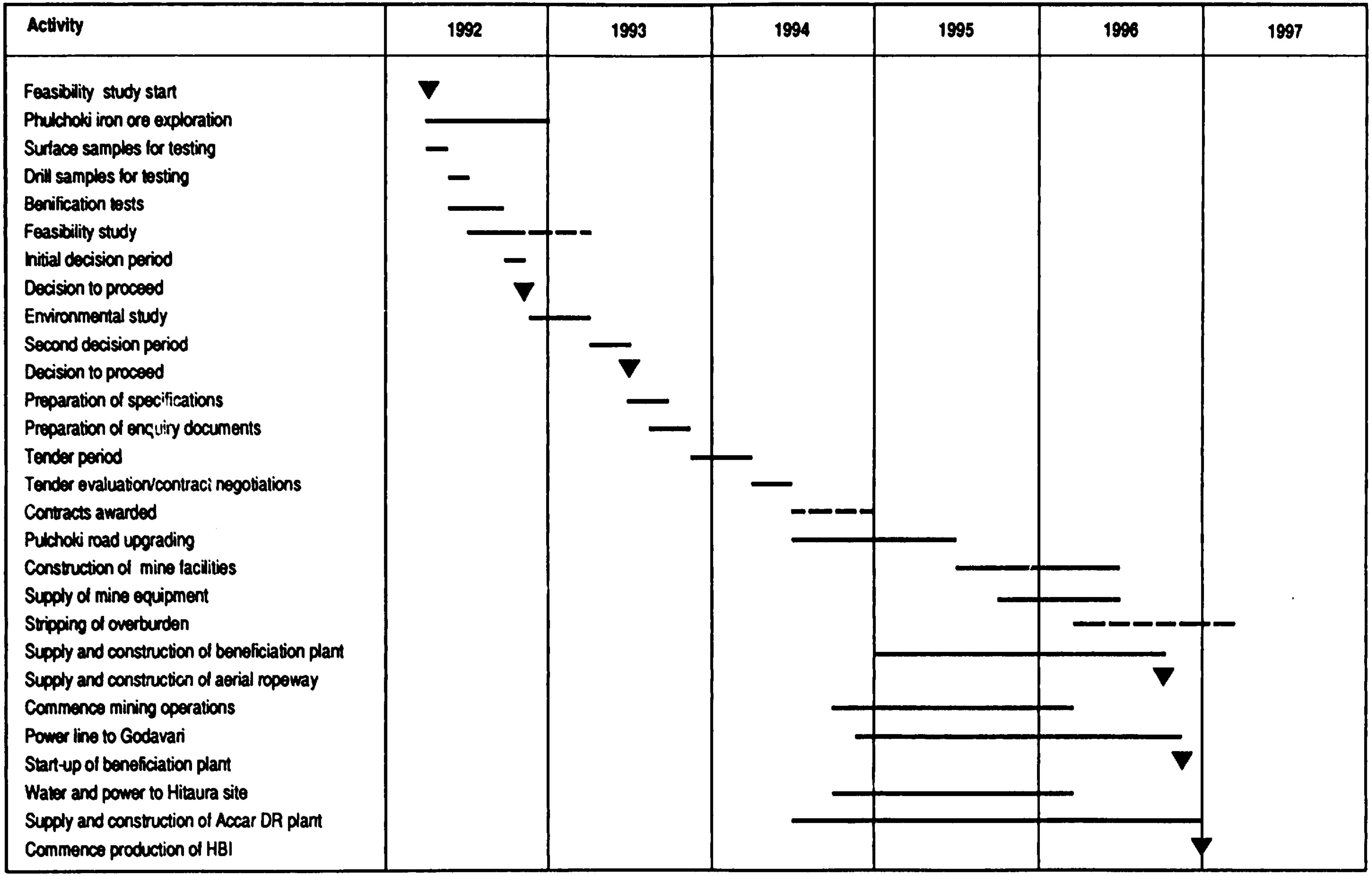


Figure 7.1 **Assumed project programme**

7.3.2 Principal input and output prices

The principal input and output prices are summarised in the following paragraphs.

Iron Ore

The mining operation is costed into total operating costs. A royalty fee of ten percent of total annual mining costs, including manpower, is assumed to be charged. This fee amounts to NR13.0 per tonne of run of mine (ROM) ore at full production for both the ACCAR and COREX processes.

Coal

Coal would need to be imported from India. Research in Nepal indicated that suitable coal could be purchased at NR 1271 per tonne c.i.f. Raxaul. No import duty is currently levied on coal. Allowing for transport and handling charges, the estimated factory gate price is NR 1331 per tonne.

Limestone

Limestone may be purchased from the Jogimara quarry at NR 225 per tonne. The factory gate price, after handling and transport charges is estimated to be NR 350 per tonne.

Electricity

The weighted average electricity tariff, including unit variable and standing charges, is calculated to be NR 1.20 per KWh.

Manpower

Manpower costs were based principally on discussion with the rolling mill companies and foundries in Nepal, since these technologies are the most comparable with the proposed plants. The average figures employed in the evaluation are summarised in Table 7.3.

TABLE 7.3 - BASIC MONTHLY RATE

Grade	Basic Monthly Rate (NR)
Unskilled/Semi Skilled	1100
Supervisory Staff	2050
Managers	6000

Salary oncost must be added to the above figures and these are made up of: two months annual bonus plus a further 20 percent oncost to cover such allowances as accident insurance and contributions to the provident fund. It should be borne in mind that these figures are based on private sector salaries.

Sponge Iron

Sponge iron from the ACCAR process is assumed to be produced in the form of hot briquetted iron (HBI), which sells at a US$10 to US$20 premium over basic DRI. No reliable time series exists for the price of DRI.The price of basic DRI is closely correlated with the price of steel scrap since it is substitutable for scrap. However, it sells at a premium over scrap since, as a purer form of iron, it may be used to control the quality of steel produced. The precise premium depends on the quality of scrap with which it is compared.

The export price of HBI was based on the estimated achievable price f.o.b Calcutta. This in turn was based on the estimated price of competing product, using Calcutta as a reference point. This was then worked back to a factory gate price after subtracting transport and handling charges and export duty. Similarly, the domestic price of HBI was based on the price of competing imports c.i.f Calcutta. This was converted to a factory gate price by adding import duty, transport and handling charges.

Scrap exports from the United States are an important determinant of world scrap prices since they traditionally account for around one third of all traded scrap. Scrap and DRI prices are volatile and it is necessary to determine a "trend" price in order to smooth out the effects of price fluctuations over time. The trend price of HBI was therefore derived, in the first instance, starting from the basis of US scrap prices. Regression analysis was used to determine the 1991 trend price for US Heavy Melting scrap, based on the time series for 1970 to 1990, as set out in Appendix C. Allowing for freight charges, the derived 1991 scrap trend price c.i.f Calcutta is approximately US$ 123 per tonne.

On the basis of steel scrap prices, the derived HBI trend price c.i.f Calcutta is as follows:

		US$/T
1991 scrap trend price	=	123
DRI premium over scrap	=	5
HBI premium over DRI	=	10 to 20
HBI trend price	=	138 to 148
Central estimate	=	143

This derived trend price of US$ 143 per tonne compares with recent spot prices f.o.b Calcutta of US$ 140 per tonne. The Midrex Corporation also quoted the current HBI price c.i.f Calcutta at between US$ 130 and US$ 150 per tonne in July 1991. For the purposes of this study therefore, a central estimate for the HBI trend price of US$ 143 per tonne would appear to be reasonable.

Allowing for an export duty of 0.5 percent and transport and handling charges, the factory gate price for exported HBI is calculated to be NR 5549 per tonne. The domestic price is similarly based on competing c.i.f. Calcutta prices but a 5 percent import duty has to be allowed for. The resulting factory gate price, after transport and handling charges, is NR 6903 per tonne.

Pig iron

Pig iron in the quantities necessary to achieve economies of scale in the COREX process would have to be almost entirely exported. The domestic foundry industry may be expected to grow rapidly with the local availability of pig iron but local demand is still likely to remain small in relation to total pig iron production. Foundry pig iron sells at a substantial premium but only limited amounts are traded and foundries are increasingly replacing pig by cheaper iron and steel scrap. Domestic prices in the heavily protected Indian iron and steel markets are high by world standards. However, indications are that imported pig iron prices c.i.f. Indian ports are in line with world prices. Small quantities may sell at a premium but current prices for significant shipments are approximately US $150 per tonne. Export prices f.o.b. Karachi have recently been recorded at US$140 per tonne.

As for DR iron, exports are subject to an export tax of 0.5 percent and imports to an import duty of 5.0 percent. Allowing for handling and transport charges, the following factory gate prices were calculated based on an f.o.b Calcutta price of US$ 150 per tonne.

Export pig iron: NR 5845 per tonne
Domestic pig iron: NR 7216 per tonne

Iron ore fines

Mining of ore for the COREX process will generate non-usable fines of -10mm size. These ore fines may be sold to sinter plants, of which a large number exist in India. Based on experience from other sinter plants, this has been priced at US $14.0 per tonne f.o.b. Raxaul. Some 58,000 tonnes of ore fines, would be produced annually.

Coal fines

Coal fines, as generated by the COREX process route, are frequently sold to a briquetting plant to be converted into briquetted coal for sale. Alternatively, they may be stockpiled and sold as fines for boiler fuel. It has been assumed for the purpose of this analysis that the briquetting option is adopted, since the demand for coal for boiler fuel in Nepal is limited. A factory gate price of NR 150 per tonne has been estimated for fines destined for briquetting for domestic use.

Slag

Some 150 000 t.p.a of slag is estimated to be generated by the COREX process. In granulated form this product is normally in some demand as a hard aggregate. A domestic price of NR 212.5 has been estimated for granulated slag.

Transport Charges

The remoteness of the ore deposits and benefication plant from Hetaura means that substantial transportation costs would be incurred with the ACCAR plant, in transporting the beneficiated ore to the DR plant. The quoted transport cost per tonne, Godavari to Hitaura, is NR 268.19, giving a cost for the 218,000 tonnes of beneficiated ore per annum of NR 58.465 million. For the Corex plant, the cost is substantially higher, at NR 142.699 million, since 532,000 tonnes of ore per annum have to be transported to Hitaura.

7.3.3 Total operating costs

The operating costs at full production for both process options are summarised in Table 7.4.

TABLE 7.4 - DR OPERATING COSTS AT FULL PRODUCTION (NR million at July 1991 prices)

Item	ACCAR	COREX
Mining	62.124	83.931
Beneficiation	48.330	-
Coal	199.650	372.680
Electricity	18.000	-
Limestone/Dolomite	2.100	12.915
Plant Spares & Consumables	69.616	118.575
Plant Manpower	3.085	4.489
Transport of Conc/Ore to Hetaura	58.465	142.677
Overheads	0.771	1.122
Total	462.141	736.389

7.4 Working Capital

In order to determine the viability of the projects the total capital needs must be assessed, including working capital to support the operations. Working capital is required to cover the establishment of stocks and the build-up of debtors (accounts payable). The working capital requirements were assessed based on normal operating parameters for a plant of this nature and taking account of the supply and distribution logistics in Nepal. The working capital requirements are expressed in days. Debtors are expressed as a function of sales and creditors as a function of purchases. The assumptions for each of the plants are shown in Table 7.5.

TABLE 7.5 - WORKING CAPITAL ASSUMPTIONS

Item	Days	
	ACCAR	COREX
HBI	30	-
Pig iron	-	30
Concentrate	30	-
Mined Ore	30	30
Limestone, etc	30	30
Coal	60	60
Ore Fines	-	15
Coal Fines	-	15
Slag	-	15
Local Debtors	30	30
Foreign Debtors	60	60
Creditors	60	60

7.5 Growth in Revenues

The projected revenues for both process routes will depend partially on the projected mix of domestic and export sales. In general, as described above, domestic prices will be higher than export prices.

The rate of growth in domestic demand for sponge iron will depend on the development of a Nepalese steelmaking industry. This development is presently constrained by the power requirement for electric arc steelmaking. The next major hydropower development in Nepal is likely to be the Arun project but no early construction programme could be confirmed during July 1991. For the purposes of this evaluation therefore, it was assumed that electric arc steelmaking capacity in Nepal would develop in 50 000 tonne capacity units at 5-year intervals starting in 1998. It was further assumed that the proportion of DR iron in the electric arc furnace charge would be close to the optimum at 50 percent. These assumptions imply the following domestic demand for sponge iron, based on the projected demand for billets given in Table 2.8.

Period	Demand (Tonnes)
1998 - 2002	33353
2003 - 2007	64706
2008 - 2012	97059

The balance of production for export therefore decreases through times as domestic demand increases. Domestic and export sales are therefore projected to develop as follows:

Period	Domestic Sales (T)	Export Sales (T)	% Export
1998 - 2002	32353	117647	78.4
2003 - 2007	64706	85294	56.9
2008 - 2012	97059	52941	35.3

The projected rate of growth in domestic demand for pig iron depends in turn on the demand for iron castings. Unless a substantial export oriented foundry industry develops in Nepal, which appears unlikely at the present time, the demand for castings is projected to follow the trend set out in Table 2.9. For the purposes of this evaluation, the domestic demand for pig iron has been based on these figures, assuming in turn an effective charge of 50 percent of pig iron. This implies the following growth in domestic demand:

Year	Pig Iron Demand (Tonnes)
1995	285
2000	421
2005	618
2010	909

The domestic demand for pig iron is therefore likely to be negligible in relation to the COREX production capacity, even if foundry production in Nepal were to grow much more rapidly than forecast.

The balances of HBI from the ACCAR process, and of pig ircn from the COREX process are assumed to be exported. The respective domestic and export prices were set out in Section 7.3. The implied projected sales revenues for each process route option are given in Table 7.6.

TABLE 7.6 - PROJECTED SALES REVENUES
(NR million at July 1991 prices)

Year	Revenue	
	ACCAR	COREX
1997	624	1366
2000	876	1821
2005	920	1822
2010	964	1822

Note: The figures for Corex include sales of ore fines, coal fines and slag.

7.6 Cash Flows and Project Viability

From the foregoing information, the cash flow statements for the ACCAR and COREX options were drawn up, as summarised in Appendix D. These tables show the gross project cash flows in constant price terms before taking account of financing and inflation. They therefore ignore cash inflows arising from the raising of loans and equity and the outflows of interest and principal repayments. They also exclude tax payments on profits. These wider aspects will be covered later in this Section.

The project life was extended to 2011, covering 15 years of production. A residual value of 10 percent of the value of the fixed assets plus recovery of the working capital was taken as a cash inflow at the end of the project life. The internal rates of return (IRR) and net present values (NPV) for each of the options were as follows:

Option	IRR	NPV (NR million)		
		Discount Rate		
		5%	10%	15%
ACCAR	14.3%	1774	506	-58
COREX	8.3%	1419	-710	-1500

7.7 Sensitivity Analyses

Sensitivity analyses were performed on capital costs and principal product prices; the results are summarised in Table 7.9.

TABLE 7.9 - RESULTS OF SENSITIVITY ANALYSES

Option and Variation Considered	IRR
ACCAR	
Central Estimate	14.3%
Capital Costs + 20%	11.7%
Capital Costs - 20%	17.7%
HBI f.o.b. Calcutta @ US $160/T	17.8%
HBI f.o.b. Calcutta @ US $130/T	11.3%
COREX	
Central Estimate	8.3%
Capital Costs + 20%	6.0%
Capital Costs - 20%	11.4%
Pig Iron f.o.b. Calcutta @ US $160/T	9.8%
Pig Iron f.o.b. Calcutta @ US $140/T	6.7%

Note: All figures are at assumed constant July 1991 prices.

The IRR for the ACCAR plant would reach 20 percent at an HBI price, c.i.f. Calcutta, of US$ 171 per tonne. The price of pig iron would need to increase to US$ 246 per tonne, c.i.f. Calcutta, to achieve an IRR of only 15 percent.

7.8 Unit Production Costs

An estimate of the break ever production costs of HBI and pig iron may be made by converting total capital costs to an annual capital charge. At a capital recovery factor of 16 percent, the costs of production at 1991 prices would be as follows:

	US $/Tonne	
	HBI	Pig Iron
Operating Costs	72.5	57.8
Capital Charges	52.4	97.3
Total Costs	124.9	155.1

7.9 Conclusions from DCF Analyses

Due principally to its relatively high capital costs in relation to revenues, the rate of return for the COREX process option route is below what is normally considered to be commercially acceptable. This result, taken together with its low interdependence within the Nepalese industrial sector, suggests that it should not be considered further for the production of pig iron.

The ACCAR process route option is on the margin of acceptability for an investment of this magnitude, which may well be required to attract private sector funds. However, the results are sufficiently encouraging at this preliminary stage to warrant more detailed financial analyses of this option.

8. FINANCIAL AND ECONOMIC ANALYSES OF PREFERRED OPTION

8.1 Inflation

In Section 7, costs and revenues were quoted at mid-1991 values and no account was taken of the method of financing the project. It is not possible to consider financing requirements without first assessing the effects which inflation will have on the final cost of the fixed assets, on the costs of operating the works and on revenues. Any forecast of future inflation is subject to some degree of error and for the project as a whole will depend partially on the sources of plant and equipment and the currencies in which product prices are denominated.

For the purposes of this study, domestic inflation in Nepal has been projected at 7.5 percent per annum. This is below the highs of recent years but reflects the longer term trend. The bulk of imported plant and equipment is likely to be sourced in the OECD countries and product prices are usually in dollar terms, or at least determined largely by the dollar price of scrap. A lower rate of inflation is therefore appropriate for the foreign currency element of costs and revenues and a figure of 4 per cent per annum has been taken.

8.2 Cash Flows in Money Values

The preferred option, the ACCAR process, was carried forward from the discounted cash flow analysis into a comprehensive financial evaluation. The capital, operating cost and revenue items were converted to estimated money values by applying the inflation rates discussed in Section 8.1 to the cash flow components in constant price terms. The effect of this escalation is to increase the total capital costs of implementing the ACCAR option from NR 2086 million to NR 2556 million, that is by a factor of 22.5 percent.

8.3 Financing Plan

To provide the basis from which a definitive financing plan could be prepared, alternative sources of funds and ways of employing them were examined. It was assumed that equity, bilateral credits and commercial bank loans would be used in accordance with accepted international practice for a project of this nature. Suppliers credits were assumed to cover 85 percent of the offshore costs of the principal plant and equipment packages. Table 8.1 sets out typical terms under which loans might be forthcoming at mid-1991 market conditions.

TABLE 8.1: ASSUMED TERMS OF CREDITS

	Domestic Bank Loan	Bilateral Credits
Interest Rate	16.0%	10.0%
Arrangement and Management Fees	1.0%	1.0%
Commitment Fee	0.5%	0.5%
Repayment Period	10 years	7 years

The terms shown are indicative only. The actual terms will depend on the specific sources used and the financial conditions current when the arrangements are negotiated. The bilateral credit terms are in line with the uniform "consensus terms" for suppliers credits agreed amongst most of the Western European countries. Interest becomes payable from the signature of the loan agreement and principal repayments normally begin around six months after the completion of commissioning. The arrangement and management fees are usually payable as downpayments at the commencement of the loan agreement, although alternative arrangements are possible. The commitment fee is levied on the undrawn balance of the loan.

It is possible that the project could attract multilateral financing on concessionary terms, for example from the Asian Development Bank. However, it was not considered prudent to make this assumption at this stage.

On the basis of the above assumptions, the financing requirements in inflated terms are summarised in Table 8.2

TABLE 8.2: FUNDS REQUIRED
(NR million)

	Amount	Distribution (%)
Sources:		
Suppliers Credit	1544	52.9
Local Bank Loans	354	12.1
Equity	1020	35.0
Total Sources	2918	100.0
Uses:		
Capital Costs	2086	71.5
Inflation During Construction	470	16.1
Financial Charges During Construction	362	12.4
Total Uses	2918	100.0

Equity therefore comprises 35 percent of total funding and this should meet the normal minimum requirement for a project of this nature.

8.4 Taxation and Depreciation

Under the current Industrial Laws and Acts for Nepal, the Direct Reduction Company could be eligible for exemption from corporate taxes on profits for a period of 8 years from the start of operations, and this was assumed for the purposes of the analysis. Thereafter the rate of corporate tax is 50 percent. Import duty is payable at a rate of 1 percent on imported machinery, equipment, tools and spare parts, and such imports are exempt from Sales Tax.

The depreciation principles applied in the evaluation may be summarised as follows:

Asset	Rate
Land	Not depreciated
Buildings	20 years
Plant and Equipment	10 years
Vehicles	5 years
Office Equipment & Fittings	6.5 years
Pre-Operating Expenses	6.5 years

8.5 Profitability

The full forecast profit and loss statement is set out in Appendix E. Net after tax profits are forecast to rise from a loss of NR 170 million in 1997, the first year of production, to a profit of NR 298 million by the year 2000. For the purposes of simulation, it was assumed that 30 percent of profits are distributed as dividends. A summary statement for the first six years of operation is shown in Table 8.3

TABLE 8.3: SUMMARY FORECAST PROFIT AND LOSS STATEMENT
Amount (NR Million)

Item	1997	1998	1999	2000	2001	2002
Revenue	797	1132	1305	1367	1426	1487
Operating Costs	525	629	715	751	785	820
Gross Profit	272	503	590	616	641	667
Depreciation	217	193	172	154	138	123
Financial Charges	226	235	206	164	113	53
Profit Before Tax	(171)	75	212	298	390	491
Tax Due	0	0	0	0	0	0
Profit After Tax	(171)	75	212	298	390	491
Dividends Due	0	23	64	89	117	147
Retained Profit	(171)	52	148	209	273	344

8.6 Cost Price of Product and Break Even Point

For comparative purposes, the cost price per tonne of HBI was calculated at 1991 prices as follows:

	US$ per tonne
Cost of Production	72.5
Depreciation	24.2
Financial Charges	25.7
Total	122.4

This figure confirms the accuracy of the preliminary comparative estimates given in Section 7.8. It also indicates that at an estimated trend price for HBI of US$ 143 per tonne, production would be profitable.

The breakeven volume of production was calculated to be at approximately 75 percent of capacity, that is at 112,500 tonnes per annum.

8.7 Economic Evaluation

An economic evaluation was carried out within the framework of the World Bank method. The numeraire in this method is uncommitted government income measured in terms of foreign exchange. This is expressed at border prices by converting into domestic currency at the official exchange rate. Domestic price distortions are adjusted for by netting out the effects of all taxes, duties, subsidies and similar types of transfers within the economy, which represent a financial cost to those paying the tax but not reflect the consumption of real resources.

Conversion factors are used, in the absence of more detailed information, to change the value of non-traded costs and benefits measured at domestic market prices into their border price values. The standard conversion factor (SCF) is a weighted average for the whole economy. From an analysis of imports, exports, import duties and export taxes, the average SCF for Nepal over the last three years was estimated to be 0.84. The commonly used factor of 0.5 was used for unskilled and semi-skilled labour.

Starting with the cash flows in constant price terms at market prices, each of the elements of the cash flows was revalued in economic terms in accordance with the foregoing principles. The results may be summarised as follows:

Economic IRR	Economic NPV (NR million)		
	@ 5%	@ 10%	@ 15%
16.2%	2012	722	93

The relative viability of the project therefore increases when evaluated in economic terms

8.8 Foreign Exchange Effects

Investment in iron ore mining operations and a beneficiation and direct reduction plant could generate significant net foreign exchange savings for the Nepalese economy. The direct benefits of the project to the balance of payments would arise principally from exports of HBI and the substitution of domestically produced for imported steel billets. These direct savings have to be offset by imports of coal, consumables, additives, spare parts, etc. In addition, to achieve these recurrent annual savings a substantial initial foreign exchange investment in plant and equipment estimated to amount to NR 1590 million would be required.

The overall estimated foreign exchange balance at full production is summarised in Table 8.4

TABLE 8.4: FOREIGN EXCHANGE SAVINGS IN THE YEAR 2000
(NR million)

Item	Annual Saving/Loss
Exported HBI	620
Imported Substitution	212
Coal and Other Imported Items	-282
Net F/E Saving	550

Over the evaluation period of the project, that is up to the year 2011, the cumulative net annual savings less the initial investment cost amount to approximately NR 3960 million, if import substitution is taken into account. The internal rate of return on the foreign exchange cash flows is 25.3 percent.

8.9 The Impact on Employment

A principal effect of the construction of the proposed plants would be the generation of a significant number of new high productivity employment opportunities. It is projected that the new plant would give rise to some 430 permanent direct jobs by 1997. Whilst the impact of the project on employment outside the works is difficult to quantify, it is nevertheless potentially very significant. Studies in a number of newly industrialising and industrialised countries have demonstrated that the iron and steel industry shows a high degree of interdependence as measured by the number of forward and backward linkages with other industries. All of the backward linkages will not be captured by the new works, since a part of the requirements for raw materials will be imported. However, industries serving the works will be stimulated as will transport and infrastructure facilities. The industries directly serving the works will include the electricity supply industries, limestone quarrying, firms supplying components and consumables and professional and other services.

Forward linkages will be generated by increasing capacity in the existing downstream industries. The predominant downstream consuming industries are the industrial, commercial and residential building sectors and civil engineering works.

The new works and the linked industries will also induce tertiary emplyment, both in the region of the factory and elsewhere in Nepal. Induced tertiary activities will include such social and commercial activities as local administration, shops, banking and financial services, educational, medical, cultural and sporting facilities.

An indication of the secondary and subsequent increased in employment in linked industries which flow from an initial direct increase in employment is given by use of the employment multiplier. Employment multipliers may be derived by operating on an extended input-output table. Two types of multiplier are generally derived. Type 1 multipliers, which give the ratio between the direct and indirect employment changes to the initial direct employment change, and Type 2 multipliers which include the expenditure induced employment in the numerator. Such data was not available in a suitable form in Nepal and has been estimated for relatively few countries. However, World Bank Staff Working Paper No. 255 "The Employment Impact of Industrial Investment" quotes Type 1 and Type 2 multipliers for South Korea. To the extent that industrial linkages in an industrialising Nepal are expected, over the next two decades, to bear some resemblance to a more industrialised economy (Korea in 1973) the comparison is relevant. The multipliers derived for the steel sector in Korea were:

Type 1 multiplier	Type 2 multiplier
(direct plus indirect employment)	(direct plus indirect plus induced employment)
1.91	2.85

Making use of these multipliers, the new permanent employment opportunities generated by the proposed investments may be estimated as:

Direct employment in the new works	430
Employment in linked industries	390
Expenditure induced employment	404
Total employment generated	1224

It should be emphasised that multiplier analysis neglects the possible existence of supply constraints, including skilled labour, foreign exchange and savings and gives no indication of the time phasing of the changes involved. Since the employment creation discussed above would necessitate some expansion in the capacity of existing steel using firms and the possible development of new enterprises, it is considered that the changes involved would not be substantially completed until at least ten years from the start up of the new direct reduction plant.

8.10 Conclusions

The foregoing evaluation demonstrates that a Nepalese DR plant could be economically and commercially viable providing suitable markets can be identified and the appropriate marketing arrangements can be made. When adequate electrical power becomes available, domestic electric arc furnace capacity is likely to develop to serve the local market. This will be a natural upstream development for some of the existing rolling mill companies. However, the initially more important export market would need to be confirmed during the course of a full feasibility study. As discussed in Section 2.4.1, the Thai market could represent an export opportunity but the Indian market would present fewer logistical problems.

Due to the high level of protection for its steel industry, domestic iron and steel product prices on the Indian market are high by world standards. The market is also notoriously difficult to penetrate. This may not last, since India has recently stated the objective of achieving full convertibility of the Indian Rupee within 5 years. This would probably lead to restructuring of the Indian steel industry and ultimately more competitive prices. Nevertheless, some residual levels of portection may well remain and India could represent the most attractive market to a competitive Nepalese sponge iron plant if suitable marketing agreements could be reached. It is therefore considered that the commercial risk of a Nepalese sponge iron plant investment could be minimised by reaching a marketing agreement with one of the major Indian steel producers, which might also be willing to provide some equity participation.

APPENDIX A

ORGANISATIONS VISITED IN NEPAL

APPENDIX A - ORGANISATIONS VISITED IN NEPAL

* United Nations Industrial Development Organisation (Nepal)
* Ministry of Industry, Department of Mines and Geology
* Himal Iron and Steel (Pvt) Ltd
* Dhalaut Karyasala Foundry
* Department of Industries, Ministry of Industry
* Nepal Industrial Development Corporation
* Pasupata Iron and Steel Company
* Gayatri Iron Industries (Pvt) Ltd
* Kamala Iron and Steel Company
* Everest Iron and Steel Company
* Hetauda Iron and Steel Company
* Ashok Textile Industries (Pvt) Ltd
* Biratnagar Jute Mill
* Biratnagar Workshop (Pvt) Ltd
* Rajeesh Hardware
* Association of Iron and Steel Manufacturers
* Ministry of Industry (Joint Secretary)
* Nepal Pipe Industry (Pvt) Ltd
* Balaju Yantra Shala (Pvt) Ltd
* Nepal Bank
* Foreign Investment Promotion Division, Ministry of Industry
* Planning and Evaluation Division, Ministry of Industry
* Ministry of Finance (Joint Secretary)
* Department of Customs, Ministry of Finance
* National Trading Limited
* National Ropeway Company
* Environment Department, Ministry of Forests and Soil Conservation
* Department of Roads, Ministry of Transport
* International Monetary Fund (Nepal)
* World Bank (Nepal)
* Industry Department, National Planning Commission
* Environment Department, National Planning Commission
* Asian Development Bank
* Nepal Electricity Authority
* Gauri Shankar Iron and Steel Company
* Ashok Steel Industries
* The Agricultural Lime Industry, Jogimara
* Nepal Coal Limited

* Hama Iron and Steel Company
* Nepal Transport Corporation
* Meteorology Department
* Hydrology Department
* Nepalconsult (Pvt) Ltd
* Economic Services Centre Ltd
* Agricultural Tool Factory
* Hitaura Main Electricity Sub-Station
* Hitaura Industrial Estate

APPENDIX B

LONG PRODUCTS PRICE LIST

PRICE OF STEEL ITEMS

EFFECTIVE FROM 2048/03/23 i.e. 7TH JULY 1991

THE PRICES FOR KATHMANDU, POKHARA & NEPALGUNJ DELIVERY ARE AS UNDER

1. COLD TWISTED DEFORM BAR

SIZE IN MM	8 MM	10 MM	12 MM	16/18/20 MM	22/25 MM	28/32 MM
RATE RS./KG	25.05	24.21	23.95	23.84	24.32	24.61

2. DEFORM BAR

SIZE IN MM	8 MM	10 MM	12 MM	16/18/20 MM	22/25 MM	28/32 MM
RATE RS./KG	24.80	23.96	23.70	23.61	24.07	24.36

3. PLAIN BAR

SIZE IN MM	8 MM	10 MM	12/16/20 MM	25/28/32 MM
RATE RS./KG	25.61	25.11	24.86	25.61

4. FLAT

SIZE IN MM	20X3, 20X5, 25X5	40X5, 50X6
RATE RS./KG	24.51	25.11

5. ANGLE

SIZE IN MM	25X25X3, 40X40X3	40X40X5, 50X50X5	65X65X6
RATE RS./KG	25.61	25.11	26.11

6.

	GATE CHANNEL	CHANNEL	SQUARE BAR
RATE RS./KG	29.11	28.86	25.86

PRICES FOR OTHER TOWNS WILL BE REDUCED PER KG AS UNDER

1. BIRATNAGAR	Less 30 Paisa/KG	2. BIRGUNJ	Less 35 Paisa/KG
3. BUTWAL	Less 16 Paisa/KG	4. BHAIRAWA	Less 20 Paisa/KG
5. HETAUDA	Less 28 Paisa/KG	6. JANAKPUR	Less 28 Paisa/KG
7. NARAYANGHAT	Less 20 Paisa/KG		

(DISCOUNTS ARE BASED ON ONE MONTH'S SALE AND WILL BE FOR ALL ITEMS)

TRUCK	DISCOUNT	PAYMENT
1st to 5th	5%	Maximum 7 days after DELIVERY
6th and above	6%	Advance minimum Rs.75,000/ Cash Discount 0.5% on Advance Cash or Full Cash Balance on Delivery

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APPENDIX C

TREND PRICE FOR SCRAP

TABLE C1: SCRAP PRICES 1970 TO 1990

Year	Scrap price (US$/Ton)
1970	41.03
1971	34.07
1972	36.77
1973	57.87
1974	109.09
1975	72.32
1976	77.98
1977	63.23
1978	75.45
1979	97.38
1980	91.32
1981	91.66
1982	63.19
1983	73.03
1984	86.28
1985	74.41
1986	73.24
1987	85.84
1988	109.33
1989	107.78
1990	107.5
Source: Metal Bulletin	

Notes: 1) Price is based on US No. 1 Heavy Melting Scrap delivered east coast USA.

2) The 1991 trend price derived from regression analysis of the time series is US$ 112.7 per tonne. Allowing US$ 10 per tonne for freight and insurance (to compare with other sources) a typical trend c.i.f price would be US$ 122.7 per tonne.

APPENDIX D

CASH FLOW STATEMENTS

ACCAR OPTION CASH FLOW

Units: NR (Million) (Constant Prices)

Item	1991	1992	1993	1994	1995	1996	1997
Revenues	0.000	0.000	0.000	0.000	0.000	0.000	624.000
Operating Costs	0.000	0.000	0.000	0.000	0.000	0.000	375.184
Investments	0.000	12.278	43.262	409.692	914.752	706.245	0.000
Increases in Working Capital	0.000	0.000	0.000	0.000	0.000	0.000	125.708
Residual Values	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Net Cash Flow	0.000	-12.278	-43.262	-409.692	-914.752	-706.245	123.108
Cumulative Net Cash Flow	0.000	-12.278	-55.540	-465.231	-1379.983	-2086.229	-1963.121

1998	1999	2000	2001	2002	2003	2004	2005	2006	200
793.000	876.000	876.000	876.000	876.000	920.000	920.000	920.000	920.000	920.00
427.358	462.140	462.140	462.140	462.140	462.140	462.140	462.140	462.140	462.14
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
19.093	17.633	0.000	0.000	0.000	-7.562	0.000	0.000	0.000	0.00
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
346.549	396.227	413.860	413.860	413.860	465.422	457.860	457.860	457.860	457.86
-1616.572	-1220.345	-806.485	-392.625	21.235	486.657	944.517	1402.377	1860.237	2318.09

COREX OPTION CASH FLOW

Units: NR (Million) (Constant Prices)

Item	1991	1992	1993	1994	1995	1996	1997	1998
Revenues	0.000	0.000	0.000	0.000	0.000	0.000	1366.114	1639.282
Operating Costs	0.000	0.000	0.000	0.000	0.000	0.000	574.678	671.705
Capital Costs	0.000	27.231	29.582	2265.835	3870.892	1560.848	0.000	0.000
Increase in Work. Cap.	0.000	0.000	0.000	0.000	0.000	0.000	213.144	42.041
Residual Values	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Net Cash Flow	0.000	-27.231	-29.582	-2265.835	-3870.892	-1560.848	578.292	925.537
Cumulative Net Cash Flow	0.000	-27.231	-56.813	-2322.648	-6193.541	-7754.389	-7176.097	-6250.560

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1821.409	1821.452	1821.498	1821.548	1821.601	1821.660	1821.722	1821.790	1821.863	1821.942	1822.020	1822.120
736.389	736.389	736.389	736.389	736.389	736.389	736.389	736.389	736.389	736.389	736.389	735.267
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27.657	0.110	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.006	0.007	0.008
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1057.363	1084.953	1085.105	1085.154	1085.208	1085.265	1085.328	1085.395	1085.468	1085.547	1085.631	1086.845
-5193.197	-4108.245	-3023.140	-1937.986	-852.778	232.487	1317.815	2403.210	3488.678	4574.225	5659.856	6746.702

APPENDIX E

FORECAST PROFIT AND LOSS STATEMENT

TABLE E.1 - FORECAST PROFIT AND LOSS ACCOUNT Units: NR million (Current Prices)

Item	1997	1998	1999	2000	2001	2002	2003
Revenues	797	1,132	1,305	1,367	1,425	1,487	1,753
Operating Costs	525	629	715	751	785	820	856
Gross Profit	272	504	590	615	641	667	901
Depreciation	217	193	172	154	138	123	0
Profit after Depreciation	56	310	418	461	503	544	901
Interest etc. on Long Term Loans	190	163	136	109	82	55	0
Interest on Short Term Loan	36	72	70	55	31	0	0
Interest Received	0	0	0	0	0	2	68
Total Interest Due	226	235	206	164	113	53	(68)
Profit before Tax	(170)	75	212	297	390	491	970
Tax due	0	0	0	0	0	0	0
Profit after Tax	(170)	75	212	297	390	491	970
Dividends due	0	23	64	89	117	147	291
Retained Profit	(170)	53	148	208	273	344	679

TABLE E.1 - continued

Units: NR million (Current Prices)

2004	2005	2006	2007	2008	2009	2010	2011
1,838	1,922	2,010	2,102	2,478	2,596	2,720	2,850
895	935	976	1,020	1,066	1,113	1,163	1,216
943	987	1,033	1,082	1,412	1,483	1,556	1,634
0	0	0	0	0	0	0	0
943	987	1,033	1,082	1,412	1,483	1,556	1,634
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
180	321	346	336	455	0	0	0
(180)	(321)	(346)	(336)	(455)	0	0	0
1,124	1,309	1,379	1,418	1,868	1,483	1,556	1,634
0	655	690	709	934	741	779	817
1,124	655	690	709	934	741	778	817

APPENDIX F

MANNING AND TRAINING REQUIREMENTS

F.1

Manning

The estimated manning requirements for the direct reduction plant project are as follows:

Mine Site	Management	Supervisors	Workers
Production	1	5	55
Maintenance Workshops	1	3	14
Administration	-	2	8
Security	-	1	10
Sub-Totals	2	11	87
Aerial Ropeway			
Operators	-	1	6
Maintenance	-	1	4
Sub-Totals	-	2	10
Beneficiation Plant			
Crushing/Grinding	-	2	6
Washing plant	1	6	36
Maintenance	1	8	20
Laboratory	1	4	12
Process Control	1	4	8
Administration	-	2	8
Security	-	1	12
Sub-Totals	4	27	102
DR Plant			
Raw Materials Storage	-	1	8
Grinding/Balling	-	4	12
Bentonite Additions	-	-	4
Rotary Kiln	1	4	16
Product Storage	-	1	8
Laboratory	1	4	12
Process Control	1	4	8
Maintenance	1	8	24
Administration	-	2	8
Security	-	1	12
Sub-Totals	4	29	112
Head Office			
Management	5	-	-
Sales	-	1	4
Purchasing	-	1	4
Accounts	-	1	6
Personnel	-	1	4
Messengers, Guards etc	-	-	12
Sub Totals	5	4	30
Total Workforce	15	73	341

F.2 **Training**

Mine Site: mobile equipment operators having driving experience would be recruited and given about 2 weeks instruction by the suppliers operational staff in the operation of dumpers, front end loaders, bulldozers etc.

The shotfirers would be familiarized with drilling and blasting methods for open cast mining for a period of about 2 weeks by an experienced mining engineer.

Mine maintenance personnel would be given about 4 weeks instruction by the equipment supplier's engineer on the assembly and maintenance of the mobile equipment. The maintenance trainees would be taught basic engineering skills using the mine site workshop equipment.

Process Plants: Both the beneficiation and direct reduction plants would be operated continuously for 350 days per year. This will necessitate 3 shift working, involving 4 teams of operational and maintenance personnel i.e. 3 working teams plus a standby team for shift changeovers, holidays, sickness and absentees.

The general practice for training personnel to operate and maintain a process plant is to recruit the plant managers, supervisors and key workers at an early stage in the project programme. This enables them to be involved in the on-site assembly and erection of equipment, ensuring they will have a fundamental knowledge of the equipment they will later be required to operate and maintain.

These personnel would form the core team who would be sent for up to 3 months for training at a similar process plant located outside Nepal, probably in India, where they would be given "on-the-job" instruction in either operation, or maintenance.

On their return to Nepal the core team would be expected to become the instructors for the training of additional operators and maintenance workers.

Technical Supervision: During the first 12 months operations of a process plant, a small team of expatriate operators and engineers is usually provided by the equipment supplier to supervise the production and product quality, and the maintenance of the plant. The duties of the expatriate supervisors would include training of counterpart Nepalese operators and engineers, to allow them to takeover production and maintenance of the plant