2) Production

Table 3.1.7 shows production records for the different producing companies by mining method. Annual Indian production during the Seventh Five Year Plan increased overall by 46.68 million tons from 154.20 million tons to 200.88 million tons. With the exception of CIL and SCCL other companies showed changes in the range of 4.5 million tons accounting for less than a 3% share of total production. The opencast mining of CIL contributed most to the increase in output achieving an increase of 45.64 million tons over this period which represents 97.8% of the overall increase. The increased output of opencast mining by NCL and SECL was particularly marked since their combined increase amounted to 28.67 million tons or more than 60% of the increase. In contrast the output of underground mining by both CIL and SCCL slightly decreased.

The share of total India production accounted for by the combined open cast mining output of CIL and SCCL rose from 49.7% in 1985-86 to 62.5% in 1989-90.

Table 3.1.8 indicates the gradewise production records for CIL. Of the total increase in production of 37.362 million tons which was achieved by CIL between 1985-86 and 1988-89 76.3% was accounted for by the increase in medium to poor quality non coking coal output of Grade C or under which recorded a growth of 28.519 million tons. A particularly large increase of 15.1 million tons was achieved for the coal Grades below E. Production of coking coal continued to increase but the overall grade structure became increasingly weighted on the inferior grades.

From the above it can be seen that the large increase in demand for non-coking coal which originated largely from the power sector was mostly met through the increased production capacity of opencast mining and of NCL and SECL in particular. It was not possible to meet the increased demand for metallurgical coal from the steel industry however and the shortage in this area continued to increase.

(3) Demand and Supply in the Eighth Five Year Plan

The attached Table 3.1.9 indicates the plan of sector-wise demand and company-wise production during the Eighth Five Year Plan(draft). The overall demands including washery middlings are projected 229.60 million tons in the initial year of 1990-91 and 286.75 million tons in the final year of 1994-95 respectively. These figures indicate the demands revised downward from original forecasts assessed by Working Group on Coal & Lignite, but show considerable increases of 32.14 million tons and 89.29 million tons respectively as compared with the actual consumption of 197.46 million tons in 1989-90 which was the final year of the Seventh Five Year Plan.

1) Demand

The demand from steel sector shown in Table 3.1.9 is indicated as of raw coal and the amount of imported coal is not included. The quantity of washed coal is calculated as 14.06 million tons in Annual Plan 1990-91, and the import of 5.2 million tons of coking coal is projected in this year in order to supplement the quantitative shortage of domestic production and to improve the ash content to 17% required. The quantities of indigenous washed coal and imported coal for 1991-92 and 1994-95 are assessed 13.81 million tons, 4.70 million tons, 16.19 tons and 5.80 million tons

respectively, so a continuing necessity of imported coal is forecasted to satisfy the quantity and quality required.
The demand from power sector which occupies the major part of demand for non-coking coal shows a sharp increase in Eighth Plan continuously, and has been assessed at 185.1 million tons (including 6.6 million tons of washery middlings) for combined utility and captive power sector in the final year of 1994-95 which represents near 65% of overall demand.

2) Production

The projected overall production of India is 215.01 million tons in the initial year of 1990-91 and is 282.41 million tons in the final year of 1994-95, and these figures represent 14.13 million tons and 81.53 million tons of increase as compared with 200.88 million tons of the actual production in 1989-90 of the final year of Seventh Five Year Plan. The major contribution for increase is projected as achieved by opencast mining of CIL's subsidiaries particularly CCL, NCL and SECL. As concerning ECL, BCCL, SECL and SCCL the considerable increases by underground mining are expected.

In Table 3.1.10 data found in the 'Coal Atlas' issued by the CMPDI relating to the already launched program for development of large scale mining to realize the increased output has been summarized. According to this, open cast mining will form the main support for increased output while the mined coal is largely of inferior quality non-coking coal variety. Since there are annual differences in the capital requirement per ton of annual production it is difficult to make any generalization but the general range projected is between 108 and 1,239 rupees with an average of 581 rupees so that there is not a great difference in this sense between open cast and underground mining.

(4) Distribution

The distribution of coking coal for use as metallurgical coke feedstock is controlled in accordance with the Collieries Control Order of 1945. The Coal Controllers designated by the CIL are responsible for carrying out these controls. The allocation to individual steel plants is determined at the Coal Allocation Meetings which are held monthly between representatives of the steel plants, coal producing companies and rail companies. Moreover regular meetings take place between the representatives of the steel plants, coal producing companies and rail companies to ensure a regular supply of coal.

There is no such control system in the case of non-coking coal but a Standing Linkage Committee has been set up in the Department of Coal which handles the most important end users such as the power and cement industries and provides preferential allocations for these sectors.

The coal controllers also carry out distribution of high grade non-coking coal with a view to the resource preservation although only 14,000 tons were concerned in this respect over the period from April to December, 1988.

For both the SRC feedstock coal and the non-coking coal to be used together with SRC, a prerequisite condition is of course that the ash content be low and it is necessary to undertake measures to ensure that the preferential allocation of such coal requirement will be assured in the event of introducing SRC technology.

(5) International Demand and Supply of Coal

Table 3.1.11 indicates the production and trades of the world's major coal producing countries. The growth in coal production in India has been marked in recent years so that India now enters into the group of countries ranking after China, the USA and the Soviet Union. In 1989 India ranked fourth worldwide in terms of production but it undertook almost no exports. It is evident from these facts that the increased production which has been achieved is almost entirely directed to meeting internal demand. In 1989 world exports amounted to 379.1 million tons of which 102 million tons originated from Australia which thus constituted the major exporter having about 27% of the total. Australia was followed in order by the USA, South Africa, the Soviet Union, Poland and Canada. As regards the importing nations Japan was most important importing 101 million tons, while Asia overall imported 158 million tons, and Europe 127 million tons.

There are many factors relating to future demand and supply which are still uncertain. Various types of forecast exist and according to Table 3.1.12 showing the OECD forecasts for coal trading it is predicted that the increase of exports from the USA will steadily continue to increase. A large increase in Australian exports is also anticipated. As for the import demand for Indian steel industry feedstock coal for the time being no important supply upsets are envisaged to occur. Nevertheless it is advisable to draw up an overall import schedule taking account of the active employment and preservation of domestic coal resources together with trade balance considerations.

3.1.4 Transport Systems and Transport Costs

(1) Coal Transport Systems

1) Main Transport Systems

Various transport systems are employed for the conveyance of produced coal to the consumers in required amounts and at the required time. The most important of these are railways, roadways, merry-go-round systems, conveyor belts and rail-cum-sea route carriers.

The railway network in India provides a comprehensive transport system and since provision of rail lines and sidings linking producing and consuming sites is undertaken the transporting capacity of the railways is considerable so that these constitute the major means of transport in the case of coal which is large bulk freight. In the case of the power stations of the south which are big consumers of coal a combination of rail and sea carriers is employed to transport coal.

As roadways are relatively close to production sites these are used to complement transport in the case of small consumers who do not have their own rail sidings.

Other transport methods besides the above two methods mentioned above are taken to be used for supplying big consumers in the immediate vicinity of production sites.

2) Actual Transport Records and Planned Schedule

The attached Table 3.1.13 indicates the actual performance of the different transport systems in the conveyance of coal and coal products over a four year period from 1985-86. Railway transport shows a steady gradual increase while the amounts transported by merry-go-round have been striking. However in the case of transport by road this has tended to remain level or to fall off. As well as reflecting the fact that the merry-go-round or belt conveyor systems have been chosen in the case of new big consumers located in the vicinity of the production sites, this is a result of restrictions on long distance transport by road imposed by the necessity to save on diesel fuel.

Table 3.1.14 indicates the planned schedule of the system-wise transport for CIL and SCCL forming the most part of total coal conveyance over a period of Eighth Five Year Plan with actual performance in the final year of Seventh Five Year Plan. The increases of 20 million tons and 80 million tons are projected for the initial year and final year respectively as compared with the final year of the Seventh Five Year Plan and about half of these increases are allocated to rail transport. The share of rail transport shows a slight decreasing trend but accounts for about 60% and continues a principal part of coal transport in Eighth Five Year Plan.
The considerable increases are planned for merry-go-round and other transport systems (viz. conveyor belts, ropeways, etc.) and the major part of these seems to be for the pit head power stations which are planned to start their operations in this period. In contrast only a small growth is projected for roadway transport.

(2) Transport Costs

Rail transport costs are determined as for every distance and item of commodity by the railway price list. In the case of truck conveyance the large number of small firms involved made it difficult to get a clear picture of the general situation. Using the data provided in the Indian reply to the JICA mission it was found that it cost 0.32 Rs/t•km to transport coal or coal products over a 250 km range by rail whereas 1.1 Rs/t•km was needed for road transport of 50 km range. The cost of merry-go-round and conveyor belt systems varies widely by individual case and figures for cost could not be obtained.

At the time of the present mission the rail transport cost for the same distance rises to 0.448 Rs/t•km by revision of the tariff.

The following records of the evolution of railway fees is included in the Economic Survey 1989-90 issued by the Ministry of Finance. As can be seen the increase has been considerable and rapid.

Year	1970-71	1980-81	1985-86	1988-89
Rs/t•km	0.0543	0.1050	0.2150	0.2787

The cost of rail transport for the candidate coals of the present report is treated in 3.2.

(3) Transport Systems for the SRC Plant

Table 3.1.15 shows amounts to be transported by coalfield and by transport system as for the plan of CIL in 1990-91.

The transport situation regarding the coalfields where the samples of the candidate coals have been collected for the present report purposes is given below:

(Units: million tons, Figures in ( ) are %.)

Sample	Coalfield	Rail	Road	Total
Assam Coal	Makum	0.73(76.8)	0.22(23.2)	0.95(100)
Samla Coal	Raniganj	17.72(82.6)	3.72(17.4)	21.44(100)
Argada-Sirka Coal	South Karanpura	5.33(71.3)	2.15(28.7)	7.48(100)
O/A Middlings	Jharia	16.37(74.7)	5.53(25.3)	21.90(100)

As shown above more than 70% of coal transport depended on rail which exceeds the average in CIL of 62%. The above table does not include figures for the Neyveli lignite (the majority of which is sent to the nearby power plant by conveyor belt).

In the event of an SRC plant being constructed it is anticipated that this will be in the vicinity of the steel plant or near to the producing mine. If Assam coal or Neyveli lignite is chosen given the large distance from the existing steel plants transport whether it be of feedstock or of SRC will take place by rail. Further, if a candidate coal is chosen which is found at relatively short distance it would be possible to undertake transport by truck. However, given the transport capacity of roads and comparative transport costs it is judged that rail transport will probably be advantaged.

3.1.5 Coal Price

The pricing policy of India's public industries involves price control via the so-called administered price. The administered price covers fees and prices of infrastructure related items and of basic capital investments of the goods and services provided by the public industries. This price is normally set at a 10 to 14% ratio of profits to net worth after tax, taking into consideration the production costs of leading firms and it is adjusted in line with fluctuations in the major cost components.

The pit head price of coal is determined by the Central Government in accordance with the Colliery Control Order of 1945.

The attached Annex 3.1.2 indicates Notification concerning current grades and pit head prices announced by Department of Coal. The prices shown in above were effective as of January 1, 1989 for CIL and as of January 24, 1989 for SCCL. In this section the price structure is considered and the individual prices of candidate varieties for SRC feedstock and coke making are treated in 3.2.

(1) Grades and Prices of Non-coking Coal

1) Grading and Pit Head Price

The non-coking coal produced in the North Eastern States is classified separately from the non-coking coal mined elsewhere. The North Eastern Coal is not divided into any grades but premiums and penalties are set according to the ash content. The non-coking coal mined elsewhere is divided into seven grades according to the UHV index which is calculated on the combined ash and moisture content reported as the manner of air dry basis (sample equilibrated at 40 °C and 60% relative humidity) in accordance with Indian Standard 1350.

SCCL coal and coal classified as long flame coal are priced higher than the other coal of the same grade. The price difference between the long flame coal and other coal of the same grade at CIL is an additional 25 Rs/t. SCCL coal is 59 to 97 rupees more expensive than CIL output in the case on non long flame varieties.

There are further differences in pit head price based on the size and size control method these differences can be found in the notes to the above mentioned Notification.

2) Consumer Price

Consumer price results from the addition of the transport costs and levies to the pit head price. The various levies which are imposed differ depending on the State where production occurs, the grade of coal involved and the end user concerned.

Coal price for Samla coal chosen as a candidate SRC feedstock is given below. This figure has been obtained at the production site and consumer price results from addition of different transport cost depending on the distance and the method employed.

(Unit: Rs/t)

Grade 'B'	Steam	Slack	ROM (-250mm)
Coal value	438.90	431.20	433.40
Royalty	6.50	6.50	6.50
R.D.E. Cess (35% on coal value)	153.615	150.92	151.69
Stowing Cess	3.50	3.50	3.50
P.E. Cess (5% on coal value)	21.945	21.56	21.67
P.W.D Cess	1.00	1.00	1.00
A.M.B.H. Cess	0.40	0.40	0.40
TOTAL	625.86	615.08	618.16
S.S.T. (4%)	25.03	24.60	24.72
Total inc. S.S.T.	650.89	639.68	642.88

Samla coal is found in the Raniganj coalfield of West Bengal and is produced by ECL so that items in Annexure-1 of the attached Annex 3.1.2 apply. The coal value is equivalent to the basic price and since this coal is Raniganj long flame coal it is 10% more expensive than ordinary long flame coal in accordance with Note 20 of the above mentioned document. Moreover in the case of the ROM since the top size is regulated by manual facilities in accordance with Note 6, (ii) as well as a surcharge of 5 Rs/t to the normal ROM price a further 10% is put on top of the price. As this example makes evident it is necessary to take into account the differences which occur in the basic price of a given grade of coal depending on the site of production.

In the example given above of Samla coal we found that the coal price becomes about 1.48 times higher even without including transport costs. This amount of increase varies depending on the producer, state location of the site, grade of coal, and consumer involved and as shown in Table 3.1.16 once sales tax and C.S.T. are added on the range of increase is between 1.07 and 1.65. The lower rate of increase is enjoyed by WCL, SECL and NCL while the higher range occurs with ECL, BCCL and CCL.

(2) Grades and Prices of Coking Coal

1) Grading and Pit Head Price

Coking coal is classified according to its coking property into either coking coal or semi-coking or weakly coking coal, the former being further divided into six grades according to the ash content, the latter into two grades according to the combined ash and moisture content. The pit head price is determined for correspondent grade.

2) Consumer Price

Consumer price of coking coal supplied as raw coal is the sum of pit head price, various levies and transport cost in the same manner of non-coking coal.
The most part of coking coal for steel sector are of after beneficiation. In this case the washery-wise contract price including various levies is negotiated annually between coal company of supplier and steel company of consumer. Consumer price at each steel plant results from the addition of the transport cost to the contract price.
Moisture and ash content are set in above contract. The adjustment of weight purchased is made for excess of moisture over the agreed limit and bonus, penalty and cut-off point are determined for ash content fluctuation.
Following examples of consumer price and contract level of ash content and moisture content are obtained during second site survey.

PRICE AT ROURKELA STEEL PLANT IN 1990-91

(Unit: Rs/t)

PRIME COKING COAL		MEDIUM COKING COAL	
WASHERY	PRICE	WASHERY	PRICE
DUGDA	1,074.00	KATHARA	977.16
BHOJUDIH	1,068.36	SAWANG	1,079.06
SUDAMDIH	975.22	RAJRAPPA	955.35
CHASNALA	1,091.84	KARGALI	974.34
PATHERDIH	1,094.00	GIDI	1,079.06

AGREEMENT FOR THE SUPPLY OF WASHED/MEDIUM COKING COAL FROM CCL WASHERIES TO THE STEEL PLANTS OF SAIL FOR THE PERIOD 1.4.1990 TO 31.3.1991

(Unit: %)

WASHERY	AVERAGE ASH	AGREED RANGE (NO BONUS NO PENALTY)	CUT-OFF POINT ASH
KARGALI	17.0	17.0±0.5	20.0
KATHARA	18.0	18.0±0.5	20.0
SAWANG	18.5	18.5±0.5	21.0
GIDI	18.0	18.0±0.5	21.0
RAJRAPPA	17.0	17.0±0.5	20.0

AGREED GROSS MOISTURE CONTENT AT THE LOADING POINT

(Unit: %)

WASHERY	AGREED GROSS MOISTURE
KARGALI	6.5
GIDI	6.5
KATHARA	9.0
SAWANG	8.5
RAJRAPPA	7.0

(3) Price Evolution and Production Costs

Table 3.1.17 shows the average pit head price and production cost of coal produced by CIL.

Pricing is adjusted in line with increases in production costs but the average pit head price is below the actual production costs and at the end of 1988 the cumulative deficit of the CIL had reached 22.6 billion rupees.

A look at the cost components for 1988 shows that largest share is taken by salaries and wages and despite the increased productivity in terms of output per manshift this accounted for 44% of costs, followed in descending order by the 14% for stores, 10% for depreciation, 8% for interest and 7% for power.

In general production costs in this sector depend on the natural conditions of the deposits and the level of technology applied to their exploitation rather than on the quality of the coal being mined.

In order to meet a considerable increase in demand for coal originating largely from the power sectors the introduction of large open cast mining equipment has been carried out. However the other side to the improved rates of mining recovery and mining capacity thus achieved has been the large scale outlay of equipment investment including that for imports which was necessitated.

A large increase in production of the poor quality coal for power generation tends to lower the overall average quality and is seen as one factor contributing to the need for price increases.

(4) Price of Imported Coal

In terms of worldwide coal trading Australia is the first exporter worldwide followed by the USA in second position as shown in Table 3.1.11. Australia is the source of almost all Indian imports at present. For imports Japan is the world's major importer and the EEC countries taken together also import considerable quantities. These countries constitute the major coal trading nations and exert considerable influence over the formation of the international price quotations.

Table 3.1.18 indicates the evolution of the export price for metallurgical coal FOB of Australia and the

USA, while the evolution of import prices for metallurgical coal CIF in Japan and the EEC are shown in Table 3.1.19.

A shift towards an upward trend in export prices began in 1989 which was slight in the case of American coal but which meant that Australian coal regained its 1985 level of an average 44.77 US$/t. The import price in Japan came close to returning to the 1985 level with an average of 58.39 US$/t while the import price in the EEC increased to 57.20 US$/t.

Concerning the import price for coal in India following evolution at Rourkela Steel Plant is shown.

	(Unit:Rs/t)
1990-91	1,648.75
1991 APRIL	1,697.00
1991 MAY	1,697.00
1991 JUNE	1,853.00
1991 JULY	2,220.00
1991 AUGUST-SEPTEMBER	2,450.00

The exchange rate was 18.10 Rs/US$ on October 9, 1990 and fell 25.71 Rs/US$ on August 16, 1991. Therefore it seems that above rise in price is caused by the fall in the exchange rate.

It is impossible to compare figures directly but since the imported amount is small compared to that imported to Japan it is supposed that this means that purchase on the spot market becomes comparatively expensive so that compared to Japan the import price is more costly in India.

3.1.6 Considerations on Reserves and Demand

The present section considers the state of India's coal deposits and the demand situation for these as evaluated on the basis of documents received during the on site inspection. The following is a summary of these aspects.

(1) Coking Coal Resources

Indian coal resources are composed of reserves of 175.49 billion tons of Gondwana type coal, 840 million tons of Tertiary period coal and 6.34 billion tons of lignite.

27.71 billion tons of the above Gondwana coal resources are classified as coking coal but the larger part of this has insufficient coking qualities and so cannot serve as the main feedstock for metallurgical coke. These resources can only be used as a component for blending at a fixed ratio.

The main constituent raw material for metallurgical coke is prime coking coal which possesses a strong coking quality. The share of this component is reflected in the Indian demand pattern for 1990-91 when domestically produced coking coal met 37.9% of demand and imported coal 17.9% accounting together for 55.8% of total demand. A shortage of output for domestic coking coal arose and the supply plan was for a domestic supply accounting for 36.7% and 27.0% imports representing 63.7% of the total coal supply. Moreover, of the above reserves of 27.71 billion tons of coking coal only 4.17 billion tons proved and 1.13 billion tons indicated giving a total of 5.3 billion tons are reserves of prime coking coal so that the make up of reserves means that there are conditions limiting the realization of a self sufficient supply for coking coal.

Table 3.1.3 shows Indian trial calculations for the life span of prime coking coal. Although these trial calculations use a figure of 4.5 billion tons for the geological reserves, the value accorded to this in other estimates to date has been 5.3 billion tons, as noted above. Further, while the trial calculation takes the annual consumption of the steel industry to be 15 million tons, a figure of 13 million tons results if one takes the ratio of domestic to imported coal to be 2.43/1.6 as indicated in the 'Annual Plan 1990-91' which envisages meeting the entire 1990-91 demand from the steel industry with domestic output. The figure of 0.5 for the ratio of consumable reserves to minable reserves used in trial calculations accords with the figures for actual yield of clean coal given in the 'Operational Statistics' and the forecast yield for clean coal in the 'Annual Plan 1990-91'. In view of the above the Indian trial calculation is seen as generally acceptable and it is therefore considered necessary to use imported coal or introduce technology permitting its substitution in order to assure the long term supply of metallurgical coke feedstock.

(2) SRC Feedstock Coal

Annex 3.2.2 indicates the qualities which are desirable for an SRC feedstock coal. A low content of insoluble components such as ash or inertinite is one such desirable quality.

Data on reserves received for the present purposes comprises the grading classification by UHV (useful heat value) calculated from the combined moisture and ash content on a air dry basis of the proved and indicated reserves of Gondwana formation non-coking coal. The Grade A or B class of these reserves can be described as relatively superior because of their low ash content. Amounts graded as A and B grade are 1.65 billion tons and 4.88 billion tons respectively. Coalfields having large deposits of these grade coals are Karanpura, Korba and Raniganj for Grade A and for Grade B the Raniganj coalfield which contains near to half of the total deposits for this grade followed by Bisrampur, Karanpura, Sohagpur and Talcher coalfields.

Further, much of the Tertiary period coal and lignite has a low ash content and low intertinite. The total reserves of Tertiary period coal amount to 840 million tons of which the Makum coalfield has large deposits of 240 million tons. The total reserves of lignite are 6.34 billion tons of which Neyveli coalfield has the largest deposits with 3.3 billion tons.

Further, in terms of coalification the range of relatively low coalified varieties from high volatile bituminous coal to lignite are easily dissolved and the long flame Grade A or B coal is therefore preferable to same graded non long flame coal.

While it is necessary to experimentally verify their suitability as SRC feedstock the reserves of the coalfields mentioned above contain relatively large deposits with comparatively desirable qualities. The candidate coals for the present report (with the exception of the oil agglomerated middlings) were all chosen from among the above deposits.

(3) Non-Coking Coal for Blending

It is desirable that the non-coking coal which is to be blended with SRC also have a low ash content but from the viewpoint of the strength of coke produced lignite is excluded.

Further as deposits of low ash content coal found in individual Indian coalfields are not very large it is preferable to choose a different coalfield to that selected to supply the raw material SRC feedstock for reasons of coalfield life span.

(4) Assuring Supplies of SRC Feedstock Coal and Blending Non-Coking Coal

With the exception of a part of coking coal, coal supplies in India are self sufficient but demand shows a trend towards continuing growth. Since a low ash content is necessary for both the SRC feedstock coal and the non-coking coal for blending use, this demand will be competing with that of other consumers. Conversely, the actual share of such deposits in total reserves is small. Therefore, it is considered necessary that measures to ensure a preferential allocation of the coal required be taken in the case of introducing SRC technology.

3.2 Evaluation of Coal for SRC Production Test

Involves an examination of the suitability of the selected coals as feedstock for SRC production based on the analysis data as well as other factors such as recoverable reserves and ease of transportation.
In addition, the related information on coking coals which are used for coke production test is described in this section.

3.2.1 The Candidate Coals for SRC Production

(1) Selection of the Candidate Coals and Sampling

Based upon the discussions on scope of work between Indian Government and JICA preliminary study team on February 5, 1990, five candidate coals for SRC production including oil agglomerated middlings were selected. Table 3.2.1 shows characteristics and reserves of candidate coals for trial SRC production, submitted by Indian side. Sampling of these coals were carried out by Indian side during the on site survey in September and October, 1990 and JICA team observed those works except oil agglomerated middlings.
Sampling place and date of those are as under:

1) Argada-Sirka Coal

200 kg sample was collected on Sep. 18-19, 1990
Argada seam, Sirka Colliery, Central Coalfields, Ltd.
Hazaribagh District, Bihar State.

2) Neyveli Lignite

200 kg sample was collected on Sep. 23, 1990
Mine-I, Neyveli Lignite Corporation.
South Arcot District, Tamil Nadu State.

3) Samla Coal

200 kg sample was collected on Oct. 6, 1990
Samla seam, Pandaveswar Colliery, Eastern Coalfields, Ltd.
Burdwan District, West Bengal State.

4) Assam Coal

200 kg sample was collected on Oct. 17, 1990
60 ft Bottom seam, Ledo/Lacht Khani Colliery, North Eastern Coalfields Division, Coal India, Limited.
Dibrugarh District, Assam State.

5) Oil Agglomerated Middlings

100 kg sample was produced by oil agglomeration testing facility of the Central Fuel Research Institute (CFRI).
Middlings for feed material of the oil agglomeration were taken from Lodna Washery of Bharat Coking Coal Ltd. located in Bihar State.

(2) Appropriateness of Candidate Coals for SRC Production

The guidelines for selection of a coal variety suited as feed material for SRC production were shown in the inception report. Annex 3.2.1 shows details of these guidelines. It was stated above all that a fuel ratio lower than 1.3, an ash content lower than 10% together with the total ash plus inert contents lower than 20% were highly desirable.

JICA team endeavoured to collect data concerning these during its observation of the sampling and collection. The data thus collected is shown in the attached in Annex 3.2.2 which was partly revised by the information collected during 2nd on site survey in September, 1991. The samples collected were analysed in Japan and results are noted in Chapter 3, section 3 concerning the SRC production test (refer to Table 3.3.1).

A consideration of the appropriateness of the above five candidate coal varieties as SRC feedstock is to be conducted in the consideration of the above guidlines and focusing on the four aspects of coal quality, availability (reserves, production situation, demand), the ease of transport (technical and cost aspects) and coal price.

1) Appropriateness of Coal Quality

According to Table 3.2.1 provided by the Indian party the analytical results for Argada-Sirka coal are having the relatively high levels of 15-22% ash content and 28-32% inertinite, while its fuel ratio of 1.5 is also high. Results of the analysis of samples received in Japan gave a fuel ratio of 1.3, ash content of 17.9% and inertinite of 30.6% showing that this is a high ash, high inert content coal. It is therefore assumed that the solubility of this coal will be poor. Result of a sink and float test suggests that coal washing would probably not serve to lower ash content.

Indian results in data provided indicate that Neyveli lignite has a moisture content of 15-22% (air dry basis), but since this is a woody lignite and the raw lignite has a moisture content above 50% it would be necessary to dehydrate the lignite before supplying this to the SRC process. Moreover as the oxygen content of 22-23% is very high it is judged that a large hydrogen consumption would be involved in dissolving this. However given its low ash content (4-6%) and low inertinite content (1-5%) this lignite is considered to have high solubility in its dry basis.

Indian results in data provided indicate that the ash content of Samla coal is 12-15% and the inertinite content 10-12% and analytical results obtained in Japan for samples also indicate a similar range. As the ash content and inertinite content are lower than those of Argada-Sirka coal it is considered to be superior to this in terms of solubility. Result of a sink and float test shows that an effective reduction of ash content can not be expected. However, for the techno-economic evaluation in this report, it was agreed between JICA and Indian side at the meeting during the 3rd visit of India in January, 1992 that an ash content of the washed Samla coal to be 9%.

Assam coal shows a caking property and is currently used for coke production. Indian results indicated an ash content less than 10% with 8.2% and also a low inertinite content of 4.5% and a fuel ratio of 1.3. Japanese results indicated 2.1% for ash of content, 3.3% for inertinite and a fuel ratio of 1.28 suggesting an extremely high solubility for this coal. Despite the fact that the sulphur content of this coal is relatively high at 1.6%, in terms of quality this is the most promising of the five candidate coals as SRC feed material. According to the Indian counterpart (CFRI), Assam coal having around 2-5% ash content is usually some handpicked coal from Upper Assam and therefore non representative coals and usually the ash content of various coals from Assam can vary from 5-20%. Keeping in view the possible quality variation, it was agreed between JICA and Indian side at the meeting during the 3rd visit of India in January, 1992 that an ash content of unwashed Assam coal should be considered as 4-6% in this study. And as this coal has very good washability and its ash may be easily brought down to lower level, it was also agreed that the ash content of washed Assam coal to be 2-3%. Figure 4 of Annex 3.2.2 shows clearly the

cleaning possibility of coal at 60 ft seam, Makum coalfield, Assam, which was tested by CFRI Coal Survey Laboratory, Jorhat.
Indian data for the oil agglomerated middlings shows high figures for ash content (22-24%), inertinite (40-48%) and also for the fuel ratio (2.3). Results of analysis in Japan were similar with an ash content of 21.0%, inertinite of 41.3% and so suggest that solubility is very poor.

The solubility of the five candidate coals indicated above was confirmed by autoclave tests carried out in Japan on the samples as mentioned later. On the basis of the above data it is assumed that Assam coal has the highest solubility, followed by lignite and Samla coal, then by the low soluble samples of Argada-Sirka and oil agglomerated middlings.

2) Appropriateness in Terms of Availability

As a capacity of 500 t/d (dry coal basis) has been set for the SRC Plant proposed as object of the report some 165,000 tons of dry coal will be needed annually in order to supply this plant given that there are 330 operating days per annum. Taking into account the moisture content and handling loss etc. of coal input to be produced it is calculated that between 200,000 and 250,000 tons of coal will be required annually. Taking the plant life to be 20 years for one plant it will be necessary to secure 4 to 5 million tons of coal. In the case of lignite the moisture content is higher so that an annual supply of 350,000 tons would be required resulting in a total of 7 million tons for a 20 years period. Further, if the capacity of a commercial plant is assumed to be 3,000 t/d then the total amount of coal for one plant would be between 24 and 30 million tons of coal, or 42 million tons for lignite. Taking these parameters into account the availability of each variety of coal has been examined.

Indian data indicates the reserves (tentative estimation) of Argada-Sirka coal to be 600 million tons. The available resources of the Argada seam of the Sirka colliery of Central Coalfields Ltd. from which the sample was collected is estimated to contain 14.56 million tons of minable coal deposits (according to a 1976 estimation), while the total reserves including the Sirka and Argada'A' seam which are similar in coal quality, are taken to be 47.32 million tons. Since the total output since 1976 is about 6 million tons if this is subtracted from the above estimate we find that somewhere in the region of 41 million tons of available deposits remain at present. Mining is done on an opencast system and the target annual production is 600,000 tons both at present and at 1990-2000. Target annual supply is 600,000 tons up to 1999-2000 and the main users are the power plants. It would seem possible to assure a supply to a SRC demonstration plant of a 500 t/d capacity but not enough to supply to a commercial plant of 3,000 t/d and it would be necessary to look for support supplies at nearby coal deposit.

The Neyveli lignite deposits consist of a single seam and the proved reserves of the area amount to 3,300 million tons while there are 2,000 million tons of minable reserves. The remaining deposits in Mine-I where sample was collected are currently estimated at 164.04 million tons or 252.04 million tons taking into account the expansion plan. The remaining minable reserves of Mine-II are estimated at 383.7 million tons. Mining at Mine-I is mechanized opencast working and the present production schedule is 6.5 million tons per year but actual performance exceeds 7 million tons per year. The Eighth Five Year Plan (draft) shows that total lignite production by NLC is expected to increase 17.50 million tons in 1994-95 from 11.24 million tons in 1989-90. The main part of the lignite supply goes to the power station located at the pithead and the production expansion plan is in line with an expansion of the power plant facility. External sales are at present very small and only account for 400,000 tons per year at present. In the event of a commercial plant to serve as source of raw materials for SRC production the available deposits are judged quite sufficient to meet needs and it is considered relatively easy to increase production.

According to Indian data the deposits of Samla coal (tentative evaluation) amount to 500 million tons. The proved reserves of the Samla seam (R-II and III seams) of the Pandaveswar Colliery of Eastern Coalfields Ltd. where the sample was collected amount to 5.4 million tons but the proved reserves of the Samla seam in the total Pandaveswar area are estimated at 97.71 million tons. Working is mostly by underground mining and the annual output for this area in 1988-89 was 1.299 million tons although this is less than usual. Production at the Samla seam accounts for about 55% of the total output of the Pandaveswar area (in Aug. 1990). 70% of the coal output goes to power plants and railway companies. Although the Eighth Five Year Plan shows a considerable decrease of coal production from Pandaveswar Area, it is considered possible to supply to a 500 t/d SRC demonstration plant. However in the case of a commercial plant of a 3,000 t/d capacity it would be necessary to consider including supplies from other coal seams of similar quality.

The total geological reserves of the Makum coalfield, Assam are 235.66 million tons of which 123.66 million tons are proved. The 60 feet seam from which sample of Assam coal was collected accounts for 84% of the total proved reserves. However, out of 123.66 million tons of proved reserves 73.30 million tons is locked up in goaf, pillars, barriers and under fire. As to 60 feet seam, the proved reserves of virgin/under development is estimated to be 37.31 million tons. If mining recovery is assumed to be 50% of geological proved reserves in case of underground mining, minable quantity of coal from 60 feet seam is estimated to be 18.655 million tons. In case of open cast mining, minable quantity is increased due to higher mining recovery of 90%. Both underground and opencast mining are practised. Production performance records over the last five years have been between 800,000 and 1 million tons annually. Of this output some 200,000 to 250,000 tons of blendable coal has been supplied to the steel plants of Durgapur, Bokaro and Rourkela. The main part of the coal is supplied to railway companies, paper mills, cement and tea manufacturers in the Assam state. The Eighth Five Year Plan is now in progress and according to this production programme of North Eastern coalfields is revised downward because of poor coal offtake and environmental preservation. In 1990-91 coal production was 0.61 million tons and production programmes for 1991-92 and 1994-95 are 0.70 million tons and 0.90 million tons respectively. It is considered possible to supply to a SRC demonstration plant of a 500 t/d capacity. However, in consideration of the unique quality of Assam coal and its necessity as a fuel source in the region a careful balancing of demand and supply is considered essential. In the event of a large commercial scale plant it would be necessary to consider a supply plan incorporating supplies from nearby coalfields.

The stage of commercial production has not yet been reached for the oil agglomerated middlings. At present, there are only trial plants of 2 t/h and 10 t/h capacity. However the trend in India is to further increase the amount of middlings from coal washeries for coking coal production. It is under planning to materialize commercialization of oil agglomeration as its countermeasure. Therefore, it is anticipated that these will be used as a source for raw materials used in SRC production. However at present the concrete details of this progression are difficult to define.

3) Appropriateness in Terms of Ease of Transport

Location of the SRC plant could be either in the proximity of the steel plant which forms the main user or near to the mining site of the raw material coal. In this study the location at the Rourkela steel plant had already been suggested as the likeliest candidate site and the participation of the steel company SAIL which is the envisaged user will be more essential than that of the mining company to the progress of project realization. In view of the above it was assumed that the SRC plant would be installed at the Rourkela steel plant which is under the control of SAIL and so the question of transport was examined on this basis.

The production sites for Argada-Sirka and Samla coal are located in the large coalfield range which spreads across the Bihar and West Bengal states and the majority of SAIL controlled steel plants are found near to these coalfields. The Rourkela Steel Plant is located within a range of some 300 km distance by rail from these coalfields. At present, coal for steel and for fuel uses is carried by rail. It is assumed possible to integrate the carriage of Argada-Sirka and Samla coal to the SRC plant into this current system of transport. As mentioned in the Minute of Meeting of 2nd site survey, calculation using up-to-date railway tariffs (1991) show that transport costs for the two coals are nearly equal with 133.0 Rs/t for Argada-Sirka coal and 137.0 Rs/t for Samla coal.

In the case of oil agglomerated middlings, the production plant for these could be located in the coalfield area of Bihar state which is the mining center for coal for coke production. Transport from there of the oil agglomerated middlings to the Rourkela steel plant could be done by rail as in the case of carriage of the coal normally employed for steel production and fuel purposes. It was provisionally assumed that the installation site of the oil agglomerated middlings plant would be the Patherdih Washery (Jharia Coalfield, Bihar State) in which case the transport cost to the Rourkela steel plant is 163.60 Rs/t.

In the case of Assam coal it is necessary to send coal over a long distance (approx. 1,700 km) from Margherita of Assam State to the Rourkela Steel Plant. Assam coal is supplied to the Rourkela Steel Plant as a blendable coal used in coke production and so there are precedents to its transport. However, the transport cost is high and calculating on a similar basis to previous cases gives a result of 643.00 Rs/t.

In the case of Neyveli lignite it must be kept in mind that since this is a woody lignite it is susceptible to spontaneous combustion. It is therefore necessary to undertake special measures and its transport over long distances is not desirable. Moreover since the moisture content exceeds 50% transport in the form of raw coal is extremely uneconomical. If lignite is to be supplied as a raw material for SRC production then rather than sending the lignite it would be advisable to install the SRC plant in Neyveli itself. Transport cost for lignite and SRC to the Rourkela Steel Plant assuming the same conditions would be 612.00 Rs/t in both cases.

4) Coal Price

The pithead price of Indian coal is decided by the Central Government as mentioned in Section 3.1.5. In the case of Argada-Sirka and Samla coals standard pithead prices are fixed according to the grade of coal. In the case of oil agglomerated middlings no price is set since this is not yet in the commercial stage of development. A system of according either premiums or penalties dependent on the ash content is employed when setting the standard price for Assam coal. Both internal and external sales prices are determined separately in the case of Neyveli lignite.

Calculating the pithead basic price in accordance with the quality of the coal samples collected we find that Argada-Sirka coal of Grade B and slack coal is priced 367.00 Rs/t. Samla coal of long flame grade B and slack coal is priced 431.20 Rs/t.

Although the ash content analysis of the Assam coal showed a result of 2.1%, as mentioned at (1) in this section, ash content shall be considered to be 4-6% in this study so the pithead price corresponding with 5% of average ash would be calculated 647.0 Rs/t.
Moreover, for a case study of the techno-economics in this study, it was agreed between JICA and Indian side during the 3rd visit of India in January, 1992 that the price of beneficiated Assam and Samla coals at the Steel Plant, at an ash level of 2-3% and 9% respectively, would be around 1550 Rs/t for Assam and 950 Rs/t for Samla.
The internal price of Neyveli lignite is set at 227 Rs/t and the external sales price at 275 Rs/t.

Table 3.2.2 summarizes the coal prices and transport costs from pithead to Rourkela Steel Plant for the four candidate coals excluding the oil agglomerated middlings.

5) Summary

The primary parameter for selection of a coal suited as a raw material for SRC production is that the coal should be one readily dissolved in the solvent and have a high finished product recovery rate. In this regard the candidate coals selected by the Indian side (leaving aside oil agglomerated middlings) are varieties which dissolve easily and have a comparatively low ash content among Indian coals. In particular Assam coal is considered most suited for SRC production. Further if dehydration of the Neyveli lignite can be effectively carried out this coal variety has excellent qualities of low ash content and high solubility. A consideration of other factors such as availability, ease of transport, pricing, etc., the Assam coal seems to be the best option among the five candidate coals. This is followed in terms of appropriateness by Neyveli lignite and Samla coals. Although the lignite has the disadvantage of a high moisture content it is the best option in terms of the quantity of resource available. Samla coal has the geographical advantage of being close to the steel plants and it is considered to be a relatively easily dissolved coal among the non-coking coals. The Argada-Sirka coal is inferior to Samla coal since it has high ash and inert contents. As the oil agglomerated middlings has the highest ash and inert content, it is considered inferior to the other four alternatives. Final selection of the candidate coal involved in the conceptual planning for the SRC plant carried out on the basis of the results of autoclave tests and coking tests in addition to a consideration of the above factors.

3.2.2 Non-Coking Coals used with SRC for Blending Coking Coal

When the Inception Report was presented it was proposed that two non-coking coals should be selected in addition to selecting five candidate coals for SRC production. And these non-coking coals (substitute coals) should be low in ash content, sulphur content, chlorine content as well as being potentially available in large quantities at a economical price. As these non-coking coals were considered as substitutes for blending with SRC in the coke production, it was suggested that samples of these should be collected and used in Japanese tests. However, during the 1st on site survey in September to October, 1990 the Indian party decided that there was not sufficient time available to the present survey and that it would be difficult to choose two specific non-coking coals. As a result of discussions it was agreed by the both parties that one of the five coals for SRC use would be selected and this employed for coke production test.

It is aimed to use the non-coking coal for the blending of coke production together with SRC in this study. In this sense Assam coal is excluded. Moreover since the source of the oil agglomerated middlings is a coking coal this is also disqualified. Further, the lignite with its high moisture and oxygen components is roughly textured when coked and makes the overall coking strength poor, so the Neyveli lignite is an inappropriate coal. The remaining possibilities are the Argada-Sirka and Samla coals. Since the candidate having the relatively lower ash content is superior Samla coal was selected and used as the substitute coal. At the discussion during the 2nd on site survey (1991), this selection was agreed upon between JICA team and Indian counterpart.

3.2.3 Coking Coals used for Coke Production Test

In this study varieties of coking coals were selected from those which are at present used in the Rourkela Steel Plant (RSP) coke oven and samples for coke production test in Japan were also collected from those coals. These are classified as prime coking coal, medium coking coal and imported coal.
Prime coking coals are three kinds of the washed coals supplied from Bhojudih, Sudamdih and Chasnala washeries. Capacity of processing raw coal in each washery is 2 MMt/y equally. In 1988-89, RSP was supplied 317,564 tons of Bhojudih washed coal, 202,087 tons of Sudamdih washed coal and 74,284 tons of Chasnala washed coal, which accounted for 16.2%, 10.3% and 3.8% of all supplied coking coals respectively. (Refer to Table 4.3.1)
Medium coking coals are three kinds of the washed coals supplied from Kargali, Swang and Rajrappa washeries. Capacity of processing raw coal in each washery is 2.72, 0.75 and 3.0 MMt/y respectively. In 1988-89, RSP was supplied 146,744 tons of Kargali washed coal, 106,616 tons of Swang washed coal and 260,457 tons of Rajrappa washed coal, which accounted for 7.5%, 5.4% and 13.3% of all supplied coking coals respectively.

Central Coal Supply Organization of SAIL manages the purchase of such prime and medium coking coals and makes a contract for purchasing coking coal with coal suppliers. As to the medium coking coal, coal price was reviewed and revised between SAIL and CCL/CIL in September, 1991 because the royalty rate went up from August, 1991. Revised basic price is 835.38 Rs/t which is applied to all medium coking coals from CCL's washeries including Kargali, Swang and Rajrappa. As to prime coking coal, renewal of purchase price has not been agreed upon between SAIL and CIL. However increase rate of basic price is expected to be 26.00 Rs/t while the present basic price being 826.00 Rs/t.

Regarding the imported coal RSP was supplied 518,108 tons of Australian coking coal in 1988-89. This figure accounts for 26.5% of all supplied coals. Import of foreign coal is managed by the Commercial Directorate of SAIL. According to them Goonyela coal, Curragh coal and Cook coal are importing from Australia for RSP at present and purchased price is 2450.00 Rs/t at RSP in Aug./Sep. 1991.

Details of each coking coal are shown in Annex 3.2.3.

And for a case study of the techno-economics in this report, it was agreed between JICA and Indian side at the meeting during the 3rd visit of India in January, 1992 that a coke blending using low volatile medium coking coal would be considered. The coal was assumed to be bituminous rank coal having 18-20% of volatile matter, 22-25% of ash and 1.1 of reflectance as well as the same price as washed prime coking coal.

3.3 SRC Production Tests

3.3.1 Aim and Procedure of Tests

The aim of the present test using an 0.5 litre autoclave is to select the coal and liquefaction conditions to be used in conceptual design of the SRC demonstration plant from among those of the five candidate varieties of Indian coal. The tests also aim to obtain basic experimental data concerning the yields of finished product and by-products given the above determined conditions. Finally the tests also aim to produce sample SRC for coke production tests.

In order to realize the above aims the tests are to proceed according to the following steps.

(1) TEST-1

In order to narrow down the selection from five varieties to two choices tetraline will be used as a solvent and the different reaction conditions such as residence time, reaction temperature, amount of catalyst added, varied in order to permit selection of a coal with high solubility. Following this two appropriate candidate coals will be selected, also taking into consideration the results of the on site survey in India.

(2) TEST-2

Tetraline and anthracene oil will be employed as solvents for the two coal varieties narrowed down through TEST-1. For each of these coal varieties tests will be conducted varying conditions of the liquefaction reaction such as residence time, initial pressure, reaction temperature, amount of catalyst added and hydrogen partial pressure. Three sets of test conditions will be selected for those aspects which have a particular influence on the finished product yield. Next, SRC for coke production tests will be produced under two candidate coals and the three sets of conditions and the coke production test using SRC be carried out as described in Chapter 4.

One suitable coal and one set of conditions will be selected from the two candidate coals and three sets of conditions on the basis of the results of the tests on SRC production and of the coke production tests using SRC.

(3) TEST-3

Using anthracene oil as the initial solvent repeated use of the solvent with the coal and test conditions selected through TEST-2 will be carried out (recirculation: four times). The finished product and by-product yields using recirculated solvent will be verified and results used as basic data in the conceptual design of the SRC Demonstration Plant.

(4) Production of SRC for Coke Production Tests

SRC for coke production tests will be produced using the two candidate coals of TEST-2 and the three sets of test conditions (giving six sample cases) and using the one coal and one set of conditions of TEST-3 (one sample case).

The SRC production test will be conducted following the above order of procedure and the test results notified accordingly.

3.3.2 Sample Materials for the Test

The present section notes the method to be used for preparing the sample materials (coal, solvent, catalyst) used in the SRC production test and the analytical data of these samples.

(1) Coal

With the exception of the oil agglomerated middlings (OA middlings), the remaining four varieties of coal of the five candidates sent from India (200 kg each) are prepared as shown in Figure 3.3.1. Firstly samples are air dried, then crushed to a maximum size of 25 mm diameter, then samples for a Sink-and-Float tests (50 kg) and SRC production test (50 kg) are reduced by the conical quartering method specified in JIS M 8811. The samples chosen for the SRC production test are further ground to a powder with less than 10 mm diameter throughout which is divided into two parts 25 kg each using a riffle sampler. These 25 kg samples are further milled to below 100 mesh and this is employed as the SRC production sample.

The SRC production test samples of OA middlings are to be prepared according to the increment reduction method specified in JIS M 8811.

The analytical data of the coal varieties prepared in accordance with the above are shown in Table 3.3.1 and the Sink-and-Float test results for the same samples are shown in Table 3.3.2.

Further, to provide reference data on OA middlings, this was washed using benzene and the de-oiled OA middlings analyzed and results presented together with the analytical data for the other OA middlings samples.

(2) Solvent

The solvent used in the tests was either marketed tetraline or anthracene oil prepared by the following method.

Blended solvent of 50 vol% creosote oil and 50 vol% anthracene oil is brought to the boiling point of 350°C and according to the method specified in the ASTM D 1160 the fraction above 350°C is distilled and removed while the fraction below 350°C is used as anthracene oil. The analytical data of this anthracene oil are shown in Table 3.3.3.

(3) Catalyst

The catalyst used in the tests is marketed iron sulphide (II) which has been milled to under 200 mesh. The analytical data of the catalyst are indicated in Table 3.3.4.

3.3.3 Test Methods

Figure 3.3.2 is a flow chart presentation of the SRC production test methods.

The SRC production test procedure is divided mainly into three phases viz 1. autoclave operations (items 1 to 6 of Figure 3.3.2), 2. filtration (items 7 to 10 of Figure 3.3.2) and 3. distillation (items 11 to 14 of Figure 3.3.2). Details of these three phases are given below:

(1) Autoclave Operations

The coal sample (under 100 mesh) prepared according to the method outlined in section 3.3.2 is placed in a vacuum drying oven and at 60°C under a 2 mmHg pressure the coal is dried to an equilibrium state (normally drying is for 24 hours, or in the case of lignite for

48 hours). 50 g of the dried coal and 100 g of solvent (tetraline or anthracene oil) and the specified amount of catalyst (1.5 g when the ratio of addition is 3%) are measured out and placed in the autoclave indicated in Figure 3.3.3.

Next, after by the nitrogen and hydrogen gases air in the autoclave have been purged, a hydrogen gas is used to compress to the specified pressure and the coal slurry is stirred while heat is applied at an incremental rate of 3°C/min up to the set temperature. The specified temperature is maintained for a set time while the reaction takes place.

Once the reaction is completed heating is immediately terminated and the autoclave is removed from the electric furnace and the autoclave cooled to room temperature while stirring continues.

After cooling, the gas content is sent through the trap and gas metre where the amount is measured and then the gas is taken out into a gas bag. The gas collected in the gas bag then undergoes a gas chromatography to analysis the gas composition.

After removing the gas the autoclave is opened and the contents are poured in a stainless steel beaker. After measurement of weights the contents are used as material for the filtration.

(2) Filtration

The products produced by the autoclave operations are heated in a water bath to a temperature of 50°C and a filtering apparatus with a 9 cm diameter filter paper (refer Figure 3.3.4) is used for filtration of the products.

After washing the residue with about 200 ml of tetrahydrofuran it is dried at 75°C under a 2 mmHg pressure for three hours. After this the weight is measured. Then the ash content of the residue is measured using the method specified in JIS M 8812.

After measurements are completed the filtrate is used for the distillation.

(3) Distillation

Specific gravity of filtrate is measured using the method specified in JIS K 2425 (hydrometer method) and then the liquid in ml units is charged in a fully automatic vacuum distillation apparatus based on the specifications of the ASTM D 1160. (refer to Figure 3.3.5)

After this the liquid in a nitrogen gas flow under a 10 mmHg pressure is distilled until the tower top temperature (T3) reaches 450°C calculated at normal pressure. Weight measurements are made of both the vat residue (SRC) and distillate (oil).

3.3.4 Methods for Calculating Individual Recovery Yields

The yields (on a daf coal base) for each of the liquefied products is calculated using the equations below:

(1) Input coal amount (daf,g)
= input coal amount (g)
- ash amount (g) in the input coal
- water amount (g) in the input coal

(2) Un-reacted coal amount (daf,g)
= residue amount (g)
- ash amount (g) in the input coal
- input catalyst amount (g)

(3) Solubility (daf,wt%)

$$= \frac{[\text{input coal amount (daf,g)}] - [\text{un-reacted coal amount(daf,g)}]}{\text{input coal amount (daf,g)}} \times 100$$

(4) SRC yield(daf,wt%)

$$= \frac{\text{recovered amount of SRC (g)}}{\text{input coal amount(daf,g)}} \times 100$$

(5) Oil and water yield (daf,wt%)

$$= \frac{[\text{recovered amount of oil and water (g)}] + \text{loss (g)}}{\text{input coal amount (daf,g)}} \times 100$$

(6) Gas yield (daf,wt%)

$$= \frac{\text{recovered amount of gas (g)}}{\text{input coal amount (daf,g)}} \times 100$$

(7) Hydrogen consumption (daf,wt%)

$$= \frac{[\text{input hydrogen amount (g)}] - [\text{recovered amount of hydrogen (g)}]}{\text{input coal amount (daf,g)}} \times 100$$

(8) Water yield (daf,wt%)

$$= \frac{[\text{recovered amount of water (g)}] - [\text{water amount (g) in the input coal}]}{\text{input coal amount (daf,g)}} \times 100$$

Further, in the case of calculating the water yield, the recovered amount of water is taken to be that obtained when moisture of the entire content inside the autoclave at the stage of item 6 of Figure 3.3.2 is measured using the method specified in JIS K 2425.

3.3.5 Analysis

Figure 3.3.6 summarizes the analytical items covered in the present tests. The analytical data for the coal, catalyst, and solvent noted in the figure have already been examined in section 3.3.2. Further, the individual analytical results obtained in stages from autoclave operations to vacuum distillation were used for calculating the individual product yields. Therefore, in this present section comments will concern the samples and analytical methods for analysis of the finished products of SRC, oil and residue.

(1) Samples for Analysis

Twenty two SRC samples were made under the conditions explained below.

1. TEST-1: five samples under one set of conditions (reaction temperature 430°C, initial pressure 100 Kg/cm^2G, residence time 60 min, catalyst added 3 wt%, hydrogen partial pressure 100%) applied to the five varieties of Indian coal.

2. TEST-2: six samples using two varieties of coal and three sets of conditions for the production of SRC for coke production test.

3. TEST-3: four samples obtained each time solvent recirculation occurs (four times) for one coal variety and one set of conditions.

4. SRC for coke production test: seven samples of SRC produced for coke production test.

Further, since the quantity of the sample materials obtained from only one run of the autoclave operation was inadequate to make analyses several runs were carried out under the same conditions. The samples were prepared after uniform mixing of the lots of materials thus obtained.

(2) Analytical Methods

The analytical methods employed in each of samples are summarized in Table 3.3.5.

3.3.6 TEST-1 : Selecting Two of the Five Candidate Coals

(1) Test Conditions

SRC production test was carried out under the conditions indicated in Table 3.3.6 and tetraline was used as solvent with an initial pressure of 100 Kg/cm^2G, and a coal-solvent ratio of 1/2 used for the five varieties of Indian coal.

(2) Test Results with a Residence Time of 60 Minutes

A constant residence time of 60 minutes was applied in each test while the reaction temperature and amount of catalyst added was varied. The solubility for each of the coal varieties was recorded and indicated in Figure 3.3.7. Further, in the case of Assam coal, at a reaction temperature of 380°C the viscosity of the coal solution is high, making filtration impossible so that the solubility for this could not be calculated.

From Figure 3.3.7 the following is concluded.

1) The solubility of each of the coal varieties increases dramatically up to a reaction temperature of 410°C, while the increase tends to slow down above that temperature.

2) For any given reaction temperature the addition of the catalyst results in a slight improvement of the solubility compared to results when no catalyst is added. However, there is no remarkable difference due to the catalyst addition.

3) In order of solubility Assam coal has the best rate followed by Neyveli lignite, Samla coal, Argada-Sirka coal and finally the OA middlings.

Figures 3.3.8 to 3.3.12 show the solubility, SRC product yield, oil and water product yield, gas product yield and hydrogen consumption. From these figures the following is concluded.

1) In the case of OA Middlings, Argada-Sirka coal and Assam coal the SRC product yield is higher than the product yield for oil and water whatever the reaction temperature.

2) The SRC product yield of Samla coal is higher than the oil and water product yield in all cases except at a reaction temperature of 430°C when catalyst is added.

3) The relative importance of the SRC product yield and that of the oil and water product yield varies in the case of Neyveli lignite depending on the reaction temperature and whether catalyst has been added or not. In particular at a reaction temperature of 430°C the relative importance of the two yields is reversed by the addition of catalyst.

4) Gas product yields are below 7% for OA middlings, Argada-Sirka coal, Assam coal and Samla coal whatever the reaction temperature. Only Neyveli lignite shows a high value of 8 to 15%.

5) The hydrogen consumption for all coals is around 1 to 2%.

(3) Test Results with a Residence Time of 90 minutes

Figure 3.3.13 shows the solubility for the individual coal varieties in tests conducted with a constant residence time of 90 minutes when the reaction temperature and amount of catalyst added is varied. The same order of solubility is found as in the case of the 60 minute residence time tests with Assam coal having the best rate followed in descending order by Neyveli lignite, Samla coal, Argada-Sirka and OA middlings.

Figures 3.3.14 to 3.3.18 indicate the solubility, SRC product yield, oil and water product yield, gas product yield and hydrogen consumption for each of the coal varieities. From these figures the following is concluded.

1) The same trends are observed in the individual product yields in relation to changes in the reaction temperature as in the tests with a 60 minute residence time.

2) There are slight increases in solubility, the product yield for water and oil and the gas product yield over the results with a 60 minute residence time but the SRC product yield is found to decline.

(4) Comments and Conclusions

TEST-1 results show that Assam coal provides a suitable feedstock candidate for SRC production since it has high solubility and SRC yield. In order to further confirm this the various product yields obtained by tests on the liquefied coal varieties under the same set of conditions (reaction temperature of 430°C, residence time of 60 minutes, catalyst addition of 3 wt%) need to be converted to a dry coal base. Results of this conversion are shown in Figure 3.3.19. This shows that the residue resulting from the un-reacted coal and ash is small in case of Assam coal. Since the oil product yield is above or superior to the residue there is no fear of a shortage of solvent. Moreover, since the SRC yield is high it is concluded that this variety is suitable as a feed coal for SRC production.

In the case of Neyveli lignite and Samla coal, as in the case of Assam coal, the oil yield is higher than the residue. Shortages of solvent for recirculation will not occur even if there is a loss of the oil coating the residue during residue washing procedures. The SRC process can therefore be adequately realized. A more detailed comparison of Neyveli lignite and Samla coal shows that Neyveli lignite has the advantage of having less amount of residue than that of Samla coal and a higher oil product yield. However, Neyveli lignite is at a disadvantage because of the large amount of carbon dioxide in its gas and the high water yield. There is a large moisture content in the raw Neyveli lignite and so increased costs involved by dehydration and waste water treatment facilities cannot be avoided, and this constitutes a definite disadvantage compared with Samla.

The oil product yield is lower than that of residue in the case of Argada-Sirka coal and OA middlings. Since part of the solvent intended for recirculation which coats the residue is eliminated from the system during residue separation there is a strong likelihood that the resulting shortage of recirculatory solvent will impair the realization of the SRC process. These candidates are therefore deemed unsatisfactory as SRC feed coals.

In view of the above Assam coal is found suitable as a SRC feed coal followed by Neyveli lignite and Samla coal. Further, the Argada-Sirka coal and OA middlings options are concluded unsatisfactory as an SRC feed coal.

The aim of the TEST-1 is to narrow down the choice to two of the five candidate coals. In view of the above conclusions alone it is difficult to select two options. A consideration of results of the on site survey in India (refer to Chapter 3, Section 2) indicate that Samla coal is being produced close to the Rourkela Steel Plant which is seen as the most suitable location for the SRC plant. Proximity to the steel plant will ensure convenient regular transport. On the other hand technical problems are envisaged to arise in the transport of Neyveli lignite, which is located at considerable distance from Rourkela, so that transport costs would be high. Moreover, in view of the fact that the Indian party has proposed Samla coal as the first candidate for SRC feed coal it is concluded that the two varieties of coal suited for selection for TEST-2 are Assam coal and Samla coal.

3.3.7 TEST-2 : Selection of One Candidate Coal and Set of Conditions from the Two Candidate Coals

(1) Test Conditions

SRC production test under the conditions shown in Table 3.3.7 using Assam coal and Samla coal, the two candidate coals, were conducted using tetraline and anthracene oil as solvent, at a reaction temperature of 430°C, for a residence time of 60 minutes at initial pressure of 100 Kg/cm^2G, with a catalyst addition of 3 wt% and a hydrogen partial pressure of 100%.

(2) Test Results for Samla Coal

1) Influence of Reaction Temperature

Figure 3.3.20 indicates the various product yields recorded when the reaction temperature was varied in a range between 360 and 450°C using tetraline and anthracene oil as solvents. As can be seen from this figure regardless of which solvent was used the solubility remains uniform above a temperature of 410°C. Moreover, there is a tendency for the SRC product yield to increase with the increase of the reaction temperature when tetraline is used as solvent but in the case of anthracene oil the maximum rate is reached with 410°C. From the above it is concluded that the reaction temperature for Samla coal must be above 410°C.

2) Influence of the Initial Pressure

Figure 3.3.21 shows the variations in the individual product yields when the initial pressure is set at 80, 100 and 120 Kg/cm^2G. Results show that there is a slight increase in the solubility with the increase in the initial pressure. Further, the maximum SRC product yield is reached at an initial pressure of 100 Kg/cm^2G and so it is concluded that this is the most suitable setting for initial pressure.

3) Influence of Residence Time

The residence time was varied in a range from 30 minutes to 120 minutes and the results for the various product yields are shown in Figure 3.3.22. There is a slight increase in the solubility as the residence time is lengthened. Further, the SRC product yield with a tetraline solvent is found to remain at almost uniform level regardless of the residence time variations. In the case of an anthracene oil solvent the SRC product yield increases up to 60 minutes and becomes uniform after this. The appropriate residence time is therefore concluded to be 60 minutes.

4) Influence of the Amount of Catalyst

The amount of catalyst added was varied at 0, 3 and 6 wt% and the individual product yields resulting are shown in Figure 3.3.23. The solubility was found to increase as the catalyst added was increased. In particular, in the case of anthracene oil there was a more marked increase in the solubility than was the case with tetraline solvent and it was proved that the effect of the catalyst addition was greater in the case of an anthracene oil solvent. Further in the tetraline case the SRC yield increased in proportion as the catalyst addition was increased but in the anthracene oil case the SRC yield reached a maximum point with a 3 wt% catalyst addition. The appropriate catalyst addition is therefore taken to be 3 wt%.

5) Influence of the Hydrogen Partial Pressure

The various product yields resulting at an initial pressure of 100 Kg/cm^2G when the hydrogen partial pressure is varied between 70% and 100% are shown in Figure 3.3.24. Further, for setting the hydrogen partial pressure hydrogen and nitrogen gases are employed and the following procedure carried out. In the case of a 70% setting once the hydrogen gas has been charged up to a pressure of 70 Kg/cm^2G into the autoclave then nitrogen gas is used to bring up the pressure inside the autoclave to a level of 100 Kg/cm^2G.

The solubility is found to increase as the hydrogen partial pressure rises. Further, while in the case of a tetraline solvent the SRC product yield is almost uniform regardless of the hydrogen partial pressure in the case of an anthracene oil solvent this increases when the partial pressure is increased from 90 to 100%. The suitable hydrogen partial pressure is therefore concluded to be 100%.

(3) Test Results for Assam Coal

1) Influence of Reaction Temperature

Figure 3.3.25 indicates the various product yields recorded when the reaction temperature was set at 410, 430 and 450°C using tetraline and anthracene oil as solvents. Assam coal was found to dissolve at a reaction temperature of 360 and 380°C using either tetraline or anthracene oil but the resulting coal solution was semi-solid at room temperature (about 25°C) making filtration impossible. Therefore the product yields for this range of reaction temperature could not be determined. As can be seen from this figure regardless of which solvent was used the influence of reaction temperature on solubility is small and there is a slight decrease at 450°C. Further, regardless of the solvent used, there is a tendency for the SRC product yield to decrease with the increase of the reaction temperature.

Moreover, conversely to the SRC product yield the product yield for oil and water increases with the increase in reaction temperature. This shows that the viscosity of the coal solution decreases as the reaction temperature is increased making filtration easier.

From the above, a reaction temperature of 410°C would seem to be the suitable temperature in the case of Assam coal in view of the SRC product yield but taking ease of filtration of coal solution into account it is concluded that the appropriate reaction temperature for Assam coal is above 430°C.

2) Influence of the Initial Pressure

Figure 3.3.26 shows the variations in the individual product yields when the initial pressure is set at 80, 100 and 120 Kg/cm^2G. Results show that there is a slight increase in the solubility with the increase in the initial pressure. In the case of an anthracene oil solvent the SRC product yield remains at a uniform level regardless of what the initial pressure is but in the case of a tetraline solvent the maximum SRC product yield is reached at an initial pressure of 100 Kg/cm^2G.

It is therefore concluded that an initial pressure of 100 Kg/cm^2G is the most suitable setting for initial pressure.

3) Influence of Residence Time

The residence time was varied in a range from 30 minutes to 120 minutes and the results for the various product yields are shown in Figure 3.3.27. The solubility remains nearly uniform regardless of the residence time. Further, the SRC product yield with an anthracene oil solvent tends to decrease up to a 90 minute residence time and after this becomes uniform. In the case of a tetraline solvent the SRC product yield tends to decrease at a residence time between 60 minutes and 90 minutes.

The appropriate residence time is therefore concluded to be 60 minutes.

4) Influence of the Amount of Catalyst

The amount of catalyst added was varied at 0, 3 and 6 wt% and the individual product yields resulting are shown in Figure 3.3.28. The solubility is unaffected by the amount of catalyst added and remains nearly uniform. In the case of an anthracene oil there was a slight decrease in the solubility as the amount of catalyst added was increased. In the case of a tetraline solvent the SRC product yield reached a maximum point with a 3 wt% catalyst addition. The appropriate catalyst addition is therefore taken to be 3 wt%.

5) Influence of the Hydrogen Partial Pressure

The various product yields resulting at an initial pressure of 100 Kg/cm^2G when the hydrogen partial pressure is varied between 70% and 100% are shown in Figure 3.3.29. The solubility remains nearly uniform regardless of the hydrogen partial pressure. Further, the SRC product yield is almost uniform regardless of the hydrogen partial pressure in the case of an anthracene oil solvent. Also in the case of a tetraline solvent the SRC product yield increases as hydrogen partial pressure is increased.

The suitable hydrogen partial pressure is therefore concluded to be 100%.

(4) Comments and Conclusions

From the above results it is concluded that the factor among liquefaction conditions having the largest influence on the finished product yield (especially SRC product yield) in the case of Samla and Assam coals within the range of the test is the reaction temperature. Therefore it was decided that the most suitable conditions for production of SRC for coal blending of coke production (for two coal varieties and with three sets of conditions) would be three settings for the reaction temperature (410, 430 and 450°C) at an initial pressure of 100 Kg/cm^2G over a residence time of 60 minutes with a catalyst addition of 3 wt% and a hydrogen partial pressure of 100%.

Under these three sets of conditions and with the two coal varieties, six lots of SRC samples of 100g each would be produced using an anthracene oil as solvent. These SRC would then be supplied for a coke production test. Results of this coke production test are given in Chapter 4. As the results of test to determine whether the SRC additive was effective in strength of coke of the blended coal based on Indian coals, it was identified which ever SRC could improve coke strength. However, regardless of the coal varieties or production conditions, the characteristics of the SRC did not showed a clear difference in strength of coke produced by blending SRC. In other words, the results of the coke production test were not enough to permit the selection of one coal variety and one set of conditions from among the two coal varieties and three sets of conditions.

The selection of one coal and one set of conditions from the six options was therefore carried out largely on the basis of the results of the SRC production test as follows:

Figure 3.3.30 indicates the various product yields of Assam and Samla coals which result using anthracene oil when the reaction temperature is varied at 410, 430 and 450°C. The product yield of the main product SRC is found to decrease for both coal varieties as the reaction temperature is increased. Further, at the same reaction temperature the solubility, SRC yield and oil and water yield of Assam coal is found to be higher than those of Samla coal. Moreover, the nearly same values for the gas product yield and hydrogen consumption are shown for the both coals at the same temperature. From the above results it is concluded that Assam coal is a better option than Samla coal for obtaining a high product yield of SRC.

However, filtration of a coal solution produced from Assam coal at a reaction temperature under 380°C is impossible. Therefore the ease of filtration of the coal solutions produced with the two coals and under the three sets of conditions was examined.

Figure 3.3.31 indicates the viscosity of the coal solutions at a temperature of 35°C. The viscosity of a coal solution produced from Assam coal at a reaction temperature of 410°C is higher than that of a coal solution from Samla coal produced under the same conditions. This means that the filtering characteristic of an Assam coal solution is poor. However, above 430°C the viscosity of an Assam coal solution is lower and so the filtering characteristic is superior.

Also, as is evident from results of the coke production test the quality of the produced SRC as a caking additive is good whichever original coal or set of production condition is chosen.

If one coal and one set of condition is therefore to be selected it is considered that the most appropriate selection is Assam coal at a reaction temperature of 430°C in view of the product yield for finished products, the filtering characteristic and quality of SRC.

Further, in the case of Samla coal since the SRC product yield is high and filtering characteristic is comparatively good, a temperature of 410°C is judged to be appropriate but in order to assure sufficient recirculation solvent, a temperature of 430°C is found to be more appropriate as a reaction condition.

In conclusion Assam coal was selected as suitable for TEST-3 with conditions of a reaction temperature of 430°C at an initial pressure of 100 Kg/cm^2G for a residence time of 60 minutes with a catalyst addition of 3 wt% and a hydrogen partial pressure of 100%.

3.3.8 TEST-3 : Tests with Recirculated Solvent

(1) Test Conditions

Using Assam coal and an initial solvent of anthracene oil in a coal-solvent ratio of 1 to 2 the coal was dissolved with liquefaction conditions set at a reaction temperature of 430°C with an initial pressure of 100 Kg/cm^2G for a residence time of 60 minutes and a catalyst addition of 3 wt% and a 100% hydrogen partial pressure of 100%. The recovered oil (boiling point range approx. 200 - 450°C) was used as solvent at the second dissolution of coal under the same liquefaction conditions noted above and such dissolution of coal using the recovered oil from the previous test as solvent for the next test was repeated three times. Namely, the test was repeated four times in total.

(2) Results

Figure 3.3.32 shows the product yields with repeated use of the same anthracene oil used as the initial solvent. For the present purposes several tests were carried out for each recirculated batch and the mean arithmetic values are marked in the figure with black dot while the range of values is indicated by the bar lines. The figure result shows that regardless of the times recirculated the solubility and gas product yields remained at the same uniform level. Further, although there is a slight increase in the SRC product yield up to the third recirculation this becomes uniform after this. Moreover, the product yields for oil and water and the hydrogen consumption show a slight reduction up to the third recirculation but are uniform in value after this. Thus with the fourth recirculation all of the product yields are seen to reach a nearly uniform level. Table 3.3.8 indicates the product yields at this time.

3.3.9 Analysis of Finished Products

Table 3.3.9 indicates the sample materials used in analysis of the finished products and those production conditions. In cases where the production conditions were the same for the various samples the same experiment number was given, samples produced for analysis purposes have an "A" indicated in front of the experiment number, while samples produced for coke production test have an "S" indicated in front of the experiment number. Also, the analytical methods used for the various kinds of samples are as indicated previously in Table 3.3.5.

(1) Analysis of Produced Oils

Table 3.3.10-11 indicate the analytical results. From these the following can be understood.

1) Comparing the use of tetraline and anthracene oil as solvents, without regard to the coal varieties adopted, in case tetraline is employed the hydrogen content and calorific value are high, while the specific gravity, viscosity, fa and 50% point of distillation temperature are low. This is seen to be due to the presence of the tetraline used as a solvent in the produced oil.

2) In contrast to the differences remarked due to the use of different solvents, almost no difference is registered in results because of the use of different coal varieties.

3) When solvent is recycled, the more times recycling takes place the higher the hydrogen content becomes while the values for specific gravity and fa decrease. This is seen to be due to the increase in the hydrogen donating capacity of the produced oil.

(2) Analysis of SRC

Tables 3.3.12-13 indicate the analytical results. From these the following can be understood.

1) Whatever the coal varieties or production conditions used, there is almost no difference observed in the SRC qualities. However, when tetraline is used as solvent the fa, toluene insoluble matter and hexane insoluble matter are slightly lower than when antheracene oil is used as solvent. This is judged due to the enriched aliphatic composition of the SRC caused by hydrogenation.

(3) Analysis of Residue

Table 3.3.14-15 indicate the analytical results. From these the following can be understood.

1) In the case of coals with a high solubility such as Neyveli lignite and Assam coal there is a large content of catalyst and coal ash remaining in the residue. This has a large influence on the sulphur and oxygen content values in the ultimate analysis.

(4) Analysis of SRC Samples for Coke Production Test

Table 3.3.16 indicates the analytical results. From this the following can be understood.

1) Comparing the SRC samples for coke production test

(Table 3.3.16) with the SRC for analysis (Table 3.3.12-13) nearly the same results are obtained under the same conditions of production.

(5) Analysis of Coal Solution and Filtrate

Table 3.3.17 indicates the analytical results. From this the following can be understood.

1) A smaller specific gravity and viscosity is obtained when tetraline is used as the solvent rather than anthracene oil. These lower values are seen to result from the solvent used.

2) The difference in results caused by the use of differing coal varieties or differing production conditions is not as marked as the difference due to the use of different solvents.

3.3.10 Summary Conclusions

Five varieties of Indian coal were used to conduct SRC production tests, which gave the following results.

(1) TEST-1 results showed that the coal variety of the candidates proposed for SRC production which gave the highest results for solubility and SRC yield was Assam coal. This was followed by Samla coal and Neyveli lignite. Further, Argada-Sirka coal and OA middlings were found to be unsuitable as SRC production materials. The objective of TEST-1 was to select two coal varieties from the five candidate varieties proposed. However, the results of the SRC production tests shown above revealed that it was difficult to make a choice of two varieties. Therefore information obtained during the on site survey in India was also referred to provide an additional yardstick and it was judged that the most appropriate coals for use in TEST-2 were Assam and Samla coals.

(2) In the TEST-2 SRC production tests were carried out under a number of different liquefaction conditions with both Assam and Samla coals. The optimum conditions for producing SRC for coke production tests were shown to be at reaction temperatures of 410, 430 and 450°C in the case of both coal varieties. Therefore using these three sets of conditions and the two coal varieties, six SRC samples were produced. The result of coke production tests using the six SRC samples revealed no significant difference in the SRC strength whichever the sample used.
The most suitable coal variety and conditions from the candidate two varieties of coal and three proposed conditions was decided to be Assam coal with a reaction temperature of 430°C, an initial pressure of 100 Kg/cm^2G, a residence time of 60 minutes, a catalyst addition of 3 wt% and a hydrogen partial pressure of 100%. These values were determined on the basis of the results of the SRC production tests.

(3) In the TEST-3 anthracene oil was initially used as the solvent and was reused a number of times by recirculation with the test conditions indicated in (2) above. The changes in the yields for each cycle were recorded and it was found that yields remained almost constant up to the fourth recirculation when individual yields were then calculated.

(4) SRC to be used for coke production tests was produced with the initial test conditions used in TEST-3 above employing anthracene oil.

(5) The analysis of the various products obtained in the TEST-1 to 3, and when producing SRC sample for coke production tests were conducted.

Annex 3.3.1 summarises the List of Experimental Data of Autoclave Test.

Annex 3.3.2 presents the List of Japanese Industrial Standards (JIS) used in the SRC production test.

3.3.11 Additional Comments on the Process

In Japan there was once a serious concern about supply of coking coal in particular of strong coking coal as progress of the steel industry. In order to solve the problem a method to add binder to coking coal was developed. The following binders were studied and some of them have been put to practical use.

(1) coal-derived pitch
(2) bojun-tan
(3) petroleum-derived pitch
(4) solvent refined coal

Mitsui SRC Development Co. performed various studies on binders. Followings are its comments on the above different binders.

(1) Coal-derived pitch

Coal-derived pitch which is produced as a by-product of coke production has been used as binder from the past time. In recent years it is used as binder for partial briquetting of coal charge but its production is limited and also its usage for production of electrodes is more important. Thus the availability is further limited as a binder for coke production.

(2) Bojun-tan

Bojun-tan developed at one of the Japanese National Laboratories is produced by coal and tar being mixed and heated, and has the same quality as coal-derived pitch. However, in this case tar is required twice as much as coal and thus it is almost impossible to secure supply of tar for industrial scale production.

Presently small amount of bojun-tan is produced only for paint manufacture. Recently the new bojun-tan process has been studied. It advances the first stage depolymerisation of coal by mixing and heating coal and hydrogenated anthracene oil. But the prospect of industrialization of this process is poor because the viscosity of coal solution gradually increases due to usage of a hydrogenated solvent and the continuous operation becomes difficult.

(3) Petroleum-derived pitch

This is a binder produced by pyrolysis of heavy oil with high aromatic fraction instead of tar. But the product contains the problem of insufficient coking property as binder due to lack of member of aromatic rings.

(4) Solvent refined coal

This originates from the German Pott-Broche method. It produces the pitch-like material from coal which is pyrolyzed and extracted with a solvent and separated from impurity. There are many similar methods headed by the SRC-I developed by US Gulf Oil Corp. SRC process is the most effective process to utilize in industrial scale. Salient features are as follows:

1) Recirculating solvent and reaction conditions

When coal is processed only by a first stage depolymerisation under the mild reaction conditions (hydrogen pressure 50-100 Kg/cm^2, temperature 400°C) with anthracene oil, the coal hydrogenation rate decreases as the time goes because the paraffinic compounds are gradually condensed in the recirculating solvent and the aromatic compounds will decrease. Consequently, if the recirculating solvent is repeatedly used, HI•QS (hexane insoluble material and quinoline soluble material: pure SRC) decreases and QI (quinoline insoluble material: unreacted material) increases. Additionally, heavy oil fraction are polymerized and the viscosity of the recirculating solvent increases, which will lead to difficulty of separation of liquid/solid. The problem can be somewhat relieved by supplementing the solvent from the outside of the process but the requirement of supplement is too great to industrialize. In order to maintain the aromatic fraction enough to process and accelerate resolution of high grade paraffinic compounds, the coal depolymerized materials must be further resolved. For that purpose the reaction temperature and pressure need to be increased and the reaction time must be extended. It is confirmed from the past experience that the reaction pressure must be 150 Kg/cm^2, hydrogen partial pressure above 90%, reaction temperature 430°C and residence time 60 minutes.

2) Ash and unreacted coal in product SRC

Below mentioned are the effects to coking property when SRC contain ash and other foreign materials. The previous test result in Japan confirms that coking strength is in proportion to the volume of HI•QS (pure SRC). The permissible HS (hexane soluble material: oil fraction) is below 10%, QI (quinoline insoluble material: unreacted material) below 10% and ash below 10%. Outside these limitations coke strength is remarkably reduced.

Table 3.1.1 QUALITY PARAMETRES OF COAL FROM DIFFERENT COALFIELDS OF INDIA (1/2)

Coalfields	Seams	air dry basis				dry mineral matter free basis				Gray king
		Moisture %	Ash %	Suphur %	Phosphorus %	Volatile matter %	Calorific value (kcal/kg)	Carbon %	Hydrogen %	(LTC) coke type
(A) LOWER GONDWANA COALS										
Damodar-Koel Valley										
1.Raniganj										
(a) Raniganj Formation	Dishergarh, Sanctoria, etc.	2.5-3.5	15-20	0.5-0.7	0.01-0.15	39-44	8110-8450	83-85	5.3-5.8	E-G1
	Samla-Jambad etc.	3.0-11.0	13-25	0.5-0.7	0.01-0.15	39-42	7610-8170	79-82	5.2-5.5	A-B
(b) Barakar Formation	Laikdih-Chanch, etc.	0.8-2.0	15-25	0.5-0.7	0.01-0.20	25-36	8440-8830	86-90	4.5-5.4	E-G
	Salanpur	0.8-2.0	25-35	0.5-0.8	0.01-0.18	25-35	8300-8800	87-90	4.5-5.2	B-D
2.Barjora	I-IX	3.0-8.0	26-36	0.4-0.9	0.01-0.36	37-43	7810-8060	81-84	4.8-5.7	A
3.Jharia										
(a) Raniganj Formation	Mohuda, Lohpiti, etc.	1.5-2.2	20-25	0.5-0.7	0.20-0.40	36-40	8440-8550	85-87	5.4-5.8	E-F
(b) Barakar Formation	I-VIII	0.6-1.5	18-35	0.5-0.8	0.05-0.30	17-28	8550-8890	90-93	4.5-4.9	C-F
	IX-XVIII	0.6-2.0	15-25	0.5-0.7	0.05-0.30	22-35	8440-8890	87-91	4.6-5.4	G-G8
4.East Bokaro										
Barakar Formation	Jarangdih to Uchitdih	0.8-2.4	15-27	0.5-0.9	0.05-0.40	28-36	8330-8670	85-90	4.5-5.4	D-G2
	Kargari Top, Karo Bottom	0.7-1.9	17-28	0.5-0.7	0.06-0.17	24-37	8440-8780	86-90	4.5-5.4	E-G4
5.West Boakro										
Barakar Formation	Kuju, Murpa, etc.	4.2-4.7	15-22	0.5-0.7	0.10-0.35	34-37	8170-8370	84-86	4.9-5.1	C-D
	V-VIII	0.5-2.5	21-35	0.5-0.6	0.03-0.35	21-36	8440-8780	86-91	4.6-5.3	D-G3
6.Ramgarh (Block I,II,IV)										
Barakar Formation	VI-VIIIA	0.5-3.0	18-30	0.6-1.0	0.01-0.25	24-38	8220-8780	85-87	4.5-5.3	E-G
7.North Karanpura										
Barakar Formation										
(a) Chano-Rikba, Badam-Isko, etc.	I-VI	0.5-3.0	20-35	0.5-1.0	0.06-0.34	30-40	8330-8780	85-91	4.9-5.3	E-G3
(b) Bachra,Churi,Manki,Pinderkom,etc.	I-VI	5-10	15-30	0.2-0.8	0.01-0.23	35-42	7400-8000	79-82	4.0-4.9	A-G
8.South Karanpura										
Barakar Formation	Argada group,Sirka,Saunda,Nakaria,etc.	2.5-8.0	15-30	0.4-0.8	0.03-0.20	37-40	7800-8100	80-84	4.7-5.2	A-C
9.Hutar										
Karharbari Formation	II	6-10	8-14	0.3-0.5	0.005-0.01	35-40	7500-7700	80-81	4.2-4.5	A
10.Daltonganj										
Karharbari Formation	Rajhara'A'	3-4	13-18	0.4-0.7	0.005-0.01	9-13	8500-8560	89-93	3.5-4.0	A
Giridih-Rajmahal Area										
1.Giridih										
(a) Karharbari Formation	Upper and Lower Karharbari, Bhadua	0.6-1.3	12-22	0.4-0.6	0.01-0.04	27-33	8725-8950	89-91	4.7-5.2	E-G6
(b) Barakar Formation	Khandiha, Balihill, etc.	0.7-1.3	20-34	0.3-0.4	0.02-0.16	27-33	8000-8850	88-90	4.6-5.1	D-E
2.Deogarh										
Barakar Formation	I-III	5-9	15-35	0.3-0.5	0.002-0.04	38-42	7300-7900	80-83	4.5-5.2	A
3.Rajmahal										
Barakar Formation	I-XII	8-10	20-45	0.3-0.7	0.005-0.01	38-40	7400-7800	78-81	4.0-5.2	A

Table 3.1.1 QUALITY PARAMETRES OF COAL FROM DIFFERENT COALFIELDS OF INDIA (2/2)

Coalfields	Seams	air dry basis				dry mineral matter free basis				Gray king
		Moisture %	Ash %	Suphur %	Phosphorus %	Volatile matter %	Calorific value (kcal/kg)	Carbon %	Hydrogen %	(LTC) coke type
4.Darjeeling										
Karharbari Formation		1-5	19-23	-	-	14-18	8450-8700	90-93	3.5-4.0	A
Sone-Mahanadi Valley										
1.Singrauli										
(a) Raniganj Formation	Jhingurda	8-9	25-35	0.4-0.6	0.01-0.04	40-42	7095-7300	76-78	4.5-4.8	A
(b) Barakar Formation	Tirra, Purewn, etc.	7-9	15-30	0.5-0.7	0.02-0.03	37-45	7640-7750	78-81	4.4-5.3	A
2.Sohagpur										
(a) Rungta, Kotma, Jhagrakhand	I-III, Kotma, etc.	5-9	15-30	0.4-0.6	0.001-0.009	34-40	7740-8465	79-84	4.8-5.2	A
(b) Churcha-Kutkona, etc.	II-V	2-4	15-25	0.3-0.6	0.002-0.005	33-40	8220-8440	85-87	4.9-5.2	C-D
3.Chirimiri	I-III	5-7	12-20	0.3-0.4	0.005-0.016	36-38	7750-8100	80-83	4.8-5.2	A
4.Bisrampur	Pasang, Patpahari, etc.	5-9	14-18	0.4-0.6	0.004-0.015	35-38	7600-8100	80-83	4.2-4.8	A
5.Korba	Jatraj, Ghordewa, etc.	6-9	15-35	0.5-0.8	0.005-0.016	32-41	7780-8170	81-84	4.2-5.3	A
6.Lakhanpur		7-10	15-20	-	-	35-38	7300-7600	78-81	4.2-4.8	A
7.Ib-River	Ib, Rampur, Lajkura, etc.	6-9	15-35	0.5-0.7	-	32-40	7400-7800	78-84	4.3-5.1	A
8.Talcher	I-IV	6-8	15-40	0.5-0.7	0.003-0.04	35-45	7830-7940	79-82	4.9-5.3	A-B
Pench-Kanhan-Tawa Valley										
1.Dalta West, Rawanwara, etc.	I-III	2-6	15-25	0.5-0.7	0.02-0.05	32-38	7650-8140	82-85	4.8-5.4	C-D
2.Damua, Rakhikole, etc.	II-III	2-5	18-24	0.6-1.0	0.05-0.06	32-38	8520-8710	86-89	5.1-5.5	D-F
3.Pathakera	I-IV	2-4	25-30	0.5-0.8	-	33-40	8500-8790	84-86	5.4-5.8	C
4.Tandsi-Nonkharak Area	I-III	2-4	20-25	-	-	33-35	8620-8730	87-89	5.3-5.4	C-D
Wardha Valley										
1.Kamptee, Umrer, Pipla, etc.	II-V	7-10	15-30	0.5-0.9	0.01-0.04	35-40	7250-7860	78-82	4.2-4.6	A
2.Mairi, Ballarpur, Ghugus, Rajur, etc.	I-IV	8-11	15-25	0.4-0.8	0.01-0.05	38-45	7220-7750	76-80	4.3-5.1	A
Godavari Valley										
1.Kothagudem, Tandur, Ramagundam, etc.	Salarjung, King, Queen, Ross, etc.	6-8	15-25	0.3-0.7	0.005-0.04	35-40	7300-7950	78-82	4.2-5.1	A
2.Gollet, Lingola, Belampalli	I-IV	5-8	15-30	0.4-0.8	0.01-0.05	35-42	7590-8000	78-83	4.5-5.4	A
(B) TERTIARY COALS										
Assam										
1.Makum, etc.		2-3	5-15	2.0-6.0	0.001-0.01	42-48	8000-8500	79-82	5.4-6.0	G-G3
2.Dilli, Jeypore, etc.		4-16	8-20	0.4-8.0	0.01-0.02	45-50	7250-8000	75-79	5.5-6.3	A-B
Jammu & Kashmir										
1.Kalakot, Jangalgali, etc.		0.5-2	10-35	0.6-7.0	0.002-0.01	13-17	8380-8730	91-93	3.9-4.2	A

Ref. : Coal resources of India : Its formation, Distribution and Utilisation - Mukherjee et al, Fuel Science and Technology Vol.1, No.1, July '82

Table 3.1.2 PETROGRAPHIC CHARACTERISTICS OF SOME INDIAN COALS

coalfield	seam	Petrographic composition (visible mineral free basis vol%) Vitrinite	Exinite	Inertinite	Average reflectance in oil (Ro %)
LOWER GONDWANA COALS					
(A) Prime coking coals					
Jharia	IX-XVIII	35-70	0-2.5	30-65	0.9-1.3
Giridih	Lower & Upper Karharbari	50-60	0-1	40-50	1.2-1.4
(B) Medium coking coals					
East Bokaro	Kargali	45-65	1-5	35-50	0.85-0.95
East Bokaro	Bermo, Karo	35-50	1-3.5	45-65	0.9-1.05
Raniganj	Laikdih, Chanch, etc.	45-65	3-7	30-50	0.85-0.95
West Bokaro	V, VI, VII	6-12	6-12	45-55	0.75-0.90
Ramgarh	VI, VII, VIII	45-60	4-12	38-50	0.7-0.9
Jharia	Mahuda Group	65-85	2.5-10	10-30	0.75-0.85
Jharia	V-VIII	25-45	0-1	55-75	1.2-1.5
Pench Kanhan Valley	Main Seam	57-60	8-10	32-34	0.93-0.96
(C) Semi coking coals					
Raniganj	Dishergarh, Sanctoria	70-85	4-10	10-20	0.75-0.85
Raniganj	Ponitati, Hatnal, Koithi, Burradhemo	70-85	5-10	10-20	0.7-0.85
Sonhat(Churcha,Kutkona)	V	40-60	5-10	30-50	0.65-0.75
(D) Non-coking coals					
South Karanpura	Argada, Sirka, Hathidari, etc.	50-70	3-10	25-40	0.6-0.8
Hutar	II	40-45	3-5	50-55	0.4-0.6
Rajmahal	Laimatia	20-25	2-3	75-80	0.45-0.5
Singrauli	Jhingurda	70-75	2-5	20-25	0.4-0.45
Singrauli	Turra, Purewa	40-50	5-12	40-50	0.45-0.5
Chirimiri	II, III	35-45	5-8	50-60	0.55-0.65
Bisrampur	Pasang, etc.	25-30	10-15	55-60	0.5-0.6
Sohagpur	Bottom Seam	50-55	7-10	35-40	0.55-0.65
Korba	Jatraj, Ghordewa, etc.	40-45	5-10	45-50	0.6-0.65
Umaria	I, II	35-45	5-10	45-55	0.5-0.55
Talcher	Bottom Seam (I)	40-45	5-10	45-50	0.5-0.55
Talcher	Jagannath (II)	60-65	5-10	25-30	0.5-0.55
Pench Kanhan Valley	III	45-55	8-12	35-45	0.5-0.6
Wardha Valley	Main Seam	25-35	15-20	50-55	0.55-0.6
Godavari Valley	King, Queen, Ross, Salarjung, etc.	35-45	5-15	40-60	0.55-0.6
TERTIARY COALS					
Assam					
Makum	60', 20' etc.	80-90	5-10	5-10	0.55-0.7
Jeypore	IV, V, VI	80-85	5-10	10-15	0.45-0.55
Arunachal Pradesh					
Namchik-Namphuk	III, IV, V	60-80	10-25	10-20	0.45-0.55
Jammu-Kashmir					
Kalalot, Jangalgali, etc.		85-90		10-15	1.75-1.85

Table 3.1.3 ESTIMATED LIFE OF INDIAN PRIME COKING COALS

Unit : Reserves million tons
Life years
Consumption MMt/Y

PROVED RESERVES	4504
MINABLE RESERVES	2700
CONSUMABLE RESERVES (FOR COKE MAKING)	1350
ESTIMATED LIFE OF RESERVES AT CURRENT CONSUMPTION RATE	63
RESERVES LIFE CONSIDERING GROWTH IN STEEL SECTOR @ 5%	30
CONSUMPTION PATTERN FOR COKE MAKING	
STEEL SECTOR	15
OTHERS	6.5

SOURCE : QUESTIONNAIRE ON SOLVENT REFINED COAL PRODUCTION PLAN IN INDIA
JULY, 1989 JAPAN INTERNATIONAL COOPERATION AGENCY

Table 3.1.4 SECTOR-WISE CONSUMPTION OF COAL IN 7TH FIVE YEAR PLAN PERIOD

Unit : million tons
INDEX : 1985-86 100
% : Total Raw Coal + Middlings 100

		1985-86 Actual			1986-87 Actual			1987-88 Actual			1988-89 Actual			1989-90 Actual		
		CONSUMPTION	INDEX	%	CONSUMPTION	INDEX	%	CONSUMPTION	INDEX	%	CONSUMPTION	INDEX	%	CONSUMPTION	INDEX	%
Power	Raw Coal	75.11	100	47.7	81.89	109	49.7	93.69	125	53.0	102.01	136	55.0	113.00	150	57.2
	Middlings	2.22	100	1.4	2.01	91	1.2	1.97	89	1.1	2.14	96	1.2	2.12	95	1.1
	Total	77.33	100	49.1	83.90	108	50.9	95.66	124	54.1	104.15	135	56.2	115.12	149	58.3
Steel		24.52	100	15.6	23.39	95	14.2	23.60	96	13.3	20.18	82	10.9	23.92	98	12.1
Loco		9.10	100	5.8	7.87	86	4.8	7.22	79	4.1	6.35	70	3.4	5.73	63	2.9
Cement		7.90	100	5.0	8.54	108	5.2	8.25	104	4.7	9.55	121	5.2	8.74	111	4.4
Fertiliser	Raw Coal	3.98	100	2.5	4.43	111	2.7	3.95	99	2.2	4.09	103	2.2	3.97	100	2.0
	Middlings	-	-	-	-	-	-	0.15	-	-	-	-	-	-	-	-
	Total	3.98	100	2.5	4.43	111	2.7	4.10	103	2.3	4.09	103	2.2	3.97	100	2.0
Core Sector	Raw Coal	120.61	100	76.7	126.12	105	76.6	136.71	113	77.3	142.18	118	76.7	155.36	129	78.7
	Middlings	2.22	100	1.4	2.01	91	1.2	2.12	95	1.2	2.14	96	1.2	2.12	95	1.1
	Total	122.83	100	78.1	128.13	104	77.8	138.83	113	78.5	144.32	117	77.9	157.48	128	79.8
Others	Raw Coal	33.63	100	21.4	36.56	109	22.2	38.04	113	21.5	41.05	122	22.1	39.98	119	20.2
	Middlings	0.89	100	0.6	-	-	-	-	-	-	-	-	-	-	-	-
	Total	34.52	100	21.9	36.56	106	22.2	38.04	110	21.5	41.05	119	22.1	39.98	116	20.2
Total	Raw Coal	154.24	100	98.0	162.68	105	98.8	174.75	113	98.8	183.23	119	98.8	195.34	127	98.9
	Middlings	3.11	100	2.0	2.01	65	1.2	2.12	68	1.2	2.14	69	1.2	2.12	68	1.1
	Total	157.35	100	100.0	164.69	105	100.0	176.87	112	100.0	185.37	118	100.0	197.46	125	100.0

NOTE : The figures of imported coal not included

SOURCE : Report 1988-89, Department of Coal
Annual Plan 1990-91, Department of Coal
Eighth Five Year Plan 1990-95 and Annual Plan 1991-92, Department of Coal

Table 3.1.5 PROGRESS OF ELECTRICITY SUPPLY AND PATTERN OF CONSUMPTION (1/2)

A: INSTALLED PLANT CAPACITY

(Unit : thousand MW)

Year	Installed Plant Capacity					
	Utilities					
	Hydel	Thermal	Nuclear	Total	Non-Utilities	Grand Total
1	2	3	4	5	6	7
1970-71	6.4	7.9	0.4	14.7	1.6	16.3
1975-76	8.5	11.0	0.6	20.1	2.1	22.2
1976-77	9.0	11.8	0.6	21.5	2.3	23.8
1977-78	10.0	13.0	0.6	23.7	2.5	26.2
1978-79	10.8	15.2	0.6	26.7	2.6	29.3
1979-80	11.4	16.4	0.6	28.4	2.9	31.3
1980-81	11.8	17.6	0.9	30.2	3.1	33.3
1981-82	12.2	19.3	0.9	32.3	3.4	35.8
1982-83	13.1	21.4	0.9	35.4	3.9	39.2
1983-84	13.9	24.4	1.1	39.3	4.4	43.7
1984-85	14.5	27.0	1.1	42.6	5.1	47.7
1985-86	15.5	30.0	1.3	46.8	5.5	52.3
1986-87	16.2	31.8	1.3	49.3	6.1	55.4
1987-88*	17.3	35.6	1.3	54.2	6.6	60.8
1988-89**	17.8	39.7	1.6	59.1	7.2	66.3

B: ENERGY GENERATED (GROSS)

(Unit : billion kwh)

Year	Energy Generated (Gross)					
	Utilities					
	Hydel	Thermal	Nuclear	Total	Non-Utilities	Grand Total
1	2	3	4	5	6	7
1970-71	25.2	28.2	2.4	55.8	5.4	61.2
1975-76	33.3	43.3	2.6	79.2	6.7	85.9
1976-77	34.8	50.2	3.3	88.3	7.3	95.6
1977-78	38.0	51.1	2.3	91.4	7.6	98.9
1978-79	47.1	52.6	2.8	102.5	7.6	110.1
1979-80	45.5	56.3	2.9	104.6	8.2	112.8
1980-81	46.5	61.3	3.0	110.8	8.4	119.3
1981-82	49.6	69.5	3.0	122.1	9.0	131.1
1982-83	48.4	79.9	2.0	130.3	10.0	140.3
1983-84	50.0	86.7	3.5	140.2	10.8	151.0
1984-85	53.9	98.8	4.1	156.9	12.3	169.2
1985-86	51.0	114.4	5.0	170.4	13.0	183.4
1986-87	53.9	128.9	5.0	187.8	14.3	202.1
1987-88*	47.4	149.5	5.0	201.9	15.3 @	217.2
1988-89**	57.8	157.5	5.8	221.1	16.3 @	237.4

* Provisional
** Tentative
@ Quick estimate
Note: Figures may not add up to the total due to rounding off.

Table 3.1.5 PROGRESS OF ELECTRICITY SUPPLY AND PATTERN OF CONSUMPTION (2/2)

C: PATTERN OF ELECTRICITY CONSUMPTION (UTILITIES ONLY)

(Unit : %)

Year	Domestic	Commercial	Industry	Railways/ Tramways (Traction)	Agriculture	Others
1	2	3	4	5	6	7
1970-71	8.8	5.9	67.6	3.2	10.2	4.3
1975-76	9.7	5.8	62.4	3.1	14.5	4.5
1976-77	9.5	6.2	62.5	3.3	14.4	4.1
1977-78	9.9	6.4	61.6	3.3	14.6	4.2
1978-79	9.8	5.6	61.8	2.8	15.6	4.4
1979-80	10.8	6.0	58.9	2.9	17.2	4.2
1980-81	11.2	5.7	58.4	2.7	17.6	4.4
1981-82	11.6	5.8	58.8	2.8	16.8	4.2
1982-83	12.7	6.1	55.4	2.8	18.6	4.4
1983-84	12.9	6.4	55.8	2.6	17.8	4.5
1984-85	13.6	6.1	55.2	2.5	18.4	4.2
1985-86	14.0	5.9	54.5	2.5	19.1	4.0
1986-87*	14.2	5.9	52.5	2.4	20.7	4.3
1987-88**	14.7	6.0	48.8	2.5	23.8	4.2

* Provisional
** Tentative

Table 3.1.6 SPECIFICATION OF COAL FOR SOME THERMAL POWER STATIONS

TPS	CAPACITY MW(e)	MOISTURE % (air-dried)	ASH %	VOLATILE MATTER %	CALORIFIC VALUE kcal/kg	ASH FUSION (MRA) °C	HARDGROVE GRINDABILITY INDEX
BONDEL	330	10	25	24	4600-5000	1450	48-55
CHANDRAPURA	660	6	40	19	4100	1310	-
OBRA	450	9-11	25-33	26-29	3800-4200	1450	59
PATRATU	620	12-13	27-30	33-43	4500-4700	1310	50
PATRATU (EXTENTION UNIT)		4-15	20-45	15-24	3600-5000	1200	45-50
INDRAPRASTHA	284	5.5-7.5	32-45	26-31	4500	1380	50

Source: Problems & Prospects of Coal Utilization in India, Paper Presented at the 37th Annual Meeting of IIChE, New Delhi, Dec 1984 Mazumdar, B.K., Chakraborty, M. & Mukherjee, D.K.

Table 3.1.7 COMPANYWISE UNDERGROUND AND OPENCAST PRODUCTION IN 7TH FIVE YEAR PLAN PERIOD

Unit : million tons
INDEX : 1985-86 100
% : All India 100

		1985-86 Actual			1986-87 Actual			1987-88 Actual			1988-89 Actual			1989-90 Actual		
		PRODUCTION	INDEX	%	PRODUCTION	INDEX	%	PRODUCTION	INDEX	%	PRODUCTION	INDEX	%	PRODUCTION	INDEX	%
ECL	Underground	16.33	100	10.6	16.40	100	9.9	15.84	97	8.8	16.40	100	8.4	14.72	90	7.3
	Opencast	7.70	100	5.0	9.22	120	5.6	12.15	158	6.8	13.73	178	7.1	9.74	126	4.8
	Total	24.03	100	15.6	25.62	107	15.5	27.99	116	15.6	30.13	125	15.5	24.46	102	12.2
BCCL	Underground	12.94	100	8.4	13.76	106	8.3	13.81	107	7.7	14.35	111	7.4	13.38	103	6.7
	Opencast	8.14	100	5.3	10.25	126	6.2	11.30	139	6.3	11.95	147	6.1	13.24	163	6.6
	Total	21.08	100	13.7	24.01	114	14.5	25.11	119	14.0	26.30	125	13.5	26.62	126	13.3
CCL	Underground	4.72	100	3.1	4.27	90	2.6	4.17	88	2.3	4.61	98	2.4	4.75	101	2.4
	Opencast	19.41	100	12.6	20.84	107	12.6	23.10	119	12.9	23.43	121	12.0	23.86	123	11.9
	Total	24.13	100	15.6	25.11	104	15.1	27.27	113	15.2	28.04	116	14.4	28.61	119	14.2
NCL	Underground	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-
	Opencast	11.61	100	7.5	13.60	117	8.2	16.50	142	9.2	19.63	169	10.1	23.27	200	11.6
	Total	11.61	100	7.5	13.60	117	8.2	16.50	142	9.2	19.63	169	10.1	23.27	200	11.6
WCL	Underground	10.43	100	6.8	10.35	99	6.2	10.09	97	5.6	10.11	97	5.2	9.94	95	4.9
	Opencast	7.74	100	5.0	8.99	116	5.4	11.11	144	6.2	11.95	154	6.1	13.07	169	6.5
	Total	18.17	100	11.8	19.34	106	11.7	21.20	117	11.8	22.06	121	11.3	23.01	127	11.5
SECL	Underground	15.13	100	9.8	14.90	98	9.0	14.77	98	8.2	15.40	102	7.9	15.65	103	7.8
	Opencast	19.12	100	12.4	21.25	111	12.8	25.18	132	14.0	29.01	152	14.9	36.13	189	18.0
	Total	34.25	100	22.2	36.15	106	21.8	39.95	117	22.2	44.41	130	22.8	51.78	151	25.8
NEC	Underground	0.40	100	0.3	0.40	100	0.2	0.36	90	0.2	0.40	100	0.2	0.35	88	0.2
	Opencast	0.44	100	0.3	0.51	116	0.3	0.64	145	0.4	0.50	114	0.3	0.49	111	0.2
	Total	0.84	100	0.5	0.91	108	0.5	1.00	119	0.6	0.90	107	0.5	0.84	100	0.4
TOTAL CIL	Underground	59.95	100	38.9	60.08	100	36.2	59.04	98	32.9	61.27	102	31.5	58.79	98	29.3
	Opencast	74.16	100	48.1	84.66	114	51.1	99.98	135	55.6	110.20	149	56.6	119.80	162	59.6
	Total	134.11	100	87.0	144.74	108	87.3	159.02	119	88.5	171.47	128	88.1	178.59	133	88.9
SCCL	Underground	13.24	100	8.6				12.56	95	7.0	13.91	105	7.1	12.03	91	6.0
	Opencast	2.42	100	1.6				3.84	159	2.1	4.69	194	2.4	5.78	239	2.9
	Total	15.66	100	10.2	16.58	106	10.0	16.40	105	9.1	18.60	119	9.6	17.81	114	8.9
CIL+SCCL	Underground	73.19	100	47.5				71.60	98	39.8	75.18	103	38.6	70.82	97	35.3
	Opencast	76.58	100	49.7				103.82	136	57.8	114.89	150	59.1	125.58	164	62.5
	Total	149.77	100	97.1	161.32	108	97.3	175.42	117	97.6	190.07	127	97.7	196.40	131	97.8
TISCO/IISCO/DVC		4.43	100	2.9	4.45	100	2.7	4.30	97	2.4	4.48	101	2.3	4.48	101	2.2
All India		154.20	100	100.0	165.77	108	100.0	179.72	117	100.0	194.55	126	100.0	200.88	130	100.0

SOURCE : OPERATIONAL STATISTICS Vol.II 1985-86 TO 1988-89, COAL INDIA LIMITED
ANNUAL REPORT (1988-89), DEPARTMENT OF COAL
ANNUAL PLAN 1990-91, DEPARTMENT OF COAL
EIGHTH FIVE YEAR PLAN 1990-95 AND ANNUAL PLAN 1991-92, DEPARTMENT OF COAL

Table 3.1.8 GRADEWISE PRODUCTION IN CIL

(Unit : million tons)

Grade	1985-86	1986-87	1987-88	1988-89
S-I	0.232	0.202	0.279	0.256
Gr.A	0.205	0.157	-	-
S-II	1.317	1.291	0.831	0.515
W-I	2.387	2.303	2.822	2.737
W-II	13.516	13.531	13.839	15.917
W-III	3.224	3.746	3.899	4.007
W-IV	4.431	5.558	5.684	5.349
SLV	0.031	0.658	0.912	0.626
Med.(Met)	0.638	0.692	0.484	0.696
Total Coking (Steel & Washery Grade)	25.981	28.138	28.750	30.103
SC-I	0.136	0.182	0.465	0.327
SC-II	0.180	0.193	0.190	0.194
WG-II	0.249	0.327	0.245	0.053
WG-III	0.138	0.150	0.297	0.525
WG-IV	-	-	0.034	0.093
Gr.A	0.304	0.365	-	-
NLW-I	0.020	0.003	-	-
NLW-II	0.018	0.057	0.070	0.097
NLW-III	0.604	0.719	0.668	0.923
NLW-IV	3.579	4.956	5.710	6.002
Med.(Non Met.)	0.104	0.092	0.343	0.094
Other Coking & NLW	5.332	7.044	8.022	8.308
Grade A	3.217	2.904	2.857	3.029
Grade B	21.276	21.935	22.473	23.149
Grade C	25.173	24.963	29.297	32.636
Assam Coal	0.840	0.905	1.000	0.900
Superior Non-Coking	50.506	50.707	55.627	59.714
Grade D	17.206	18.643	20.214	23.162
Grade E & Below	35.085	40.204	46.411	50.185
Inferior Non-Coking	52.291	58.847	66.625	73.347
Total Non-Coking	102.797	109.554	122.252	133.061
Total Coal	134.110	144.736	159.024	171.472

SOURCE : OPERATIONAL STATISTICS Vol.II 1985-86～1988-89, COAL INDIA LIMITED

Table 3.1.9 DEMAND AND PRODUCTION DURING EIGHTH FIVE YEAR PLAN PERIOD

(Unit : million tons)

YEAR		1989-90 ACTUAL	1990-91	1991-92	1992-93	1993-94	1994-95
SECTOR-WISE DEMAND							
STEEL & COKE OVENS			27.20	27.70			33.50
SPONGE IRON			0.70	0.90			2.30
POWER (UTILITIES)			128.00	132.70			163.20
			(3.00)	(2.91)			(4.50)
POWER (CAPTIVE)			13.10	14.70			15.30
			(1.20)	(2.10)			(2.10)
RAILWAYS			5.80	4.70			3.10
CEMENT			11.50	12.70			16.00
FERTILISER			4.60	4.00			4.00
OTHERS			34.40	37.00			41.80
			(0.10)	(0.23)			(0.95)
TOTAL			225.30	234.40			279.20
			(4.30)	(5.24)			(7.55)
COMPANY-WISE PRODUCTION							
ECL	OC	9.74	11.38	10.85	12.36	14.27	17.05
	UG	14.72	14.82	16.15	17.11	18.78	20.95
	TOTAL	24.46	26.20	27.00	29.47	33.05	38.00
BCCL	OC	13.24	14.09	13.49	13.13	14.15	14.77
	UG	13.38	14.51	15.51	16.26	16.74	17.23
	TOTAL	26.62	28.60	29.00	29.39	30.89	32.00
CCL	OC	23.86	24.32	26.25	28.79	32.59	38.00
	UG	4.75	4.85	5.00	5.21	5.41	5.50
	TOTAL	28.61	29.17	31.25	34.00	38.00	43.50
NCL	OC	23.27	27.20	29.50	33.45	36.00	38.00
	UG						
	TOTAL	23.27	27.20	29.50	33.45	36.00	38.00
WCL	OC	13.07	13.80	14.30	15.00	15.50	16.30
	UG	9.94	10.10	10.20	10.50	11.00	11.50
	TOTAL	23.01	23.90	24.50	25.50	26.50	27.80
SECL	OC	36.13	38.83	41.14	44.12	46.47	47.46
	UG	15.65	16.50	17.11	17.88	18.53	19.34
	TOTAL	51.78	55.33	58.25	62.00	65.00	66.80
NEC	OC	0.49	0.24	0.30	0.30	0.35	0.44
	UG	0.35	0.37	0.40	0.45	0.45	0.46
	TOTAL	0.84	0.61	0.70	0.75	0.80	0.90
OVERALL CIL	OC	119.80	129.86	135.83	147.15	159.33	172.02
	UG	58.79	61.15	64.37	67.41	70.91	74.98
	TOTAL	178.59	191.01	200.20	214.56	230.24	247.00
SCCL	OC	5.78	6.40	7.75	8.47	10.17	12.26
	UG	12.03	13.10	15.65	16.03	16.83	18.05
	TOTAL	17.81	19.50	23.40	24.50	27.00	30.31
CIL + SCCL	OC	125.58	136.26	143.58	155.62	169.50	184.28
	UG	70.82	74.25	80.02	83.44	87.74	93.03
	TOTAL	196.40	210.51	223.60	239.06	257.24	277.31
OTHERS		4.48	4.50	4.80	4.90	5.00	5.10
TOTAL COAL		200.88	215.01	228.40	243.96	262.24	282.41
LIGNITE			11.00	12.32	13.30	15.30	17.50

NOTE : 1. The figures in bracket indicate washery middlings

2. Demand for coal does not cover imported coal

SOURCE : EIGHTH FIVE YEAR PLAN 1990-95 AND ANNUAL PLAN 1991-92, DEPARTMENT OF COAL

Table 3.1.10 MINING PROJECT (UNDER CONSTRUCTION Rs. 200 MILLION & ABOVE)

COMPANY	NAME	MINING METHOD	CAPACITY million tons	GRADE	DATE OF SANCTION	COMPLETION SCHEDULED	CAPITAL million rupee	CAPITAL Rs/t
ECL	RAJMAHAL	OC	10.50	F	OCT'88	MAR'95	5627.0	536
	JHANJHRA	UG	3.50	C,D,E	DEC'82	MAR'94	1845.5	527
	SONEPUR-BAZARI	OC	3.00	C,D	JUL'85	MAR'91	1929.6	643
	SATGRAM	UG	1.20	B	MAY'79	MAR'88	263.6	220
	AMRITNAGAR	UG	1.14	D	SEP'85	MAR'94	654.5	574
	DHEMOMAIN	UG	1.42	B,SEMI-COKE II	MAR'83	MAR'90	737.6	519
	JAMBAD	UG	1.70	C,D	SEP'89	MAR'90	2105.5	1239
	KALIDASPUR	UG	0.96	NON-COKING	NOV'87	MAR'93	479.6	500
	SARPI	UG	0.90	D	SEP'87	MAR'95	530.5	589
	LAUDOHA	UG	0.68	NON-COKING	MAR'88	MAR'96	493.4	726
	KOTTADIH	OC+UG	2.48	B,D	JUN'89	MAR'98	2675.2	1079
BCCL	POOTKEE BULLIARY	UG	3.00	PRIME COKING STEEL II~W IV	DEC'83	MAR'94	1998.7	666
	BLOCK II	OC	2.50	PRIME COKING W III, W IV	JUN'82	MAR'87	1120.5	448
	BHALGORA	UG	1.20	PRIME COKING W II	OCT'80	MAR'85	462.1	385
	KATRAS	UG	0.90	PRIME COKING W IV	OCT'79	MAR'84	260.4	289
	NORTH AMLABAD	UG	0.72	PRIME COKING STEEL II	OCT'80	MAR'85	261.8	364
CCL	PIPARWAR	OC	6.50	G	SEP'89	MAR'96	5424.3	835
	NEW KALYANI	OC	2.25	F	AUG'81	MAR'90	243.8	108
	AMLO	OC	1.50	F	AUG'81	MAR'90	333.0	222
	K.D.HESALONG	OC	1.50	E	NOV'88	MAR'91	375.6	250
NCL	AMLOHRI	OC	4.00	POWER	JUN'82	MAR'90	3236.2	809
	KHADIA	OC	4.00	POWER	SEP'85	MAR'94	4000.0	1000
	DUDHICHUA	OC	5.00	POWER	FEB'84	MAR'94	2896.8	579
	KAKRI	OC	2.50	POWER	SEP'89	MAR'91	1378.0	551
	NIGAHI	OC	4.20	POWER	NOV'90	MAR'94	4628.9	1102
SECL	BHARATPUR	OC	3.50	F	NOV'83	MAR'89	614.8	176
	DIPKA	OC	2.00	F	JUN'85	MAR'89	560.4	280
	BELPAHAR	OC	2.00	E	DEC'82	MAR'89	573.8	287
	CHURCHA WEST	OC	0.60	B	MAR'85	MAR'90	326.4	544
	AMLAI	OC	0.70	D	MAR'84	MAR'89	308.1	440
	BALGI	UG	0.60	B,D	SEP'83	MAR'89	280.0	467
	BANGWAR	UG	0.65	D	MAY'85	MAR'91	251.4	387
	DHANPIRI	OC	1.25	D	SEP'79	MAR'85	240.9	193
WCL	GHUGUS	OC	1.50	E	NOV'83	MAR'90	653.8	436
	TANDSI	UG	0.90	MEDIUM COKING W IV	SEP'85	MAR'95	515.8	573
	PADAMPUR	OC	1.25	E	MAR'84	MAR'92	507.4	406
	SAONER	UG	1.50	E	AUG'83	MAR'93	469.6	313
	SASTI	OC	1.00	E	SEP'89	MAR'91	251.5	252
	SILEWARE EXPN. Ph.II	UG	1.00	E	MAR'85	MAR'92	380.6	381
	NILJAI	OC	1.90	E	APR'87	MAR'96	968.9	510
TOTAL	TOTAL	40	87.60				50865.5	581
CIL	OPENCAST	22	63.15				36199.7	573
	UNDERGROUND	18	24.45				14665.8	600
	COKING	6	9.22				4619.3	501
	SEMI+NON	1	1.42				737.6	519
	NON-COKING	33	76.96				45508.6	591

SOURCE : COAL ATLAS, AUGUST 1990, Central Mine Planning & Design Institute Limited.

Table 3.1.11 WORLD COAL PRODUCTION BY REGION WITH THEIR WORLD SHARES (%) (1/2)

	Production (million tons)					World Share (%)				
	1973	1978	1987	1988	1989	1973	1978	1987	1988	1989
United States	530.1	576.8	762.3	783.5	804.8	24.1	22.6	23.2	23.2	23.5
Canada	12.3	17.1	32.7	38.6	38.7	0.6	0.7	1.0	1.1	1.1
North America Total	542.4	593.9	795.0	822.1	843.5	24.7	23.3	24.2	24.4	24.6
Brazil	2.4	4.6	6.9	7.3	8.4	0.1	0.2	0.2	0.2	0.2
Columbia	3.0	4.0	13.5	15.3	18.9	0.1	0.2	0.4	0.5	0.6
Mexico	4.3	6.8	6.2	5.6	5.7	0.2	0.3	0.2	0.2	0.2
Others	1.9	1.7	2.1	3.3	4.0	0.1	0.1	0.1	0.1	0.1
Central and South America Total	11.6	17.1	28.7	31.5	37.0	0.5	0.7	0.9	0.9	1.1
Soviet Union	461.2	501.5	516.1	526.4	518.0	21.0	19.7	15.7	15.6	15.1
Czechoslovakia	27.8	29.2	25.6	25.5	25.3	1.3	1.1	0.8	0.8	0.7
Poland	156.6	192.6	193.0	193.0	177.0	7.1	7.6	5.9	5.7	5.2
Others	12.3	11.2	12.1	11.9	11.6	0.6	0.4	0.4	0.4	0.3
East Europe Total	196.7	233.0	230.7	230.4	213.9	8.9	9.1	7.0	6.8	6.2
West Germany	103.7	90.1	82.4	79.3	77.5	4.7	3.5	2.5	2.4	2.3
United Kingdom	132.0	123.6	104.4	103.8	101.0	6.0	4.8	3.2	3.1	2.9
France	26.4	21.2	14.7	12.9	12.3	1.2	0.8	0.4	0.4	0.4
Spain	10.0	11.4	14.1	14.3	14.5	0.5	0.4	0.4	0.4	0.4
Others	17.4	13.6	9.5	7.3	7.3	0.8	0.5	0.3	0.2	0.2
West Europe Total	289.5	259.9	225.1	217.6	212.6	13.2	10.2	6.8	6.5	6.2
Japan	25.1	18.7	13.1	11.2	10.2	1.1	0.7	0.4	0.3	0.3
China	417.0	593.0	890.8	940.5	980.0	19.0	23.2	27.1	27.9	28.6
India	77.9	101.5	179.7	188.3	194.0	3.5	4.0	5.5	5.6	5.7
DPR Korea	30.0	35.0	39.5	40.0	39.5	1.4	1.4	1.2	1.2	1.2
Rep. of Korea	13.6	18.1	24.3	24.3	22.0	0.6	0.7	0.7	0.7	0.6
Others	8.9	12.1	15.6	17.4	16.5	0.5	0.4	0.5	0.5	0.5
Asia Total	572.5	778.4	1,163.0	1,221.7	1,262.2	26.0	30.5	35.4	36.2	36.8
South Africa	62.4	90.4	172.8	178.2	180.0	2.8	3.5	5.3	5.3	5.3
Zimbabwe	2.8	2.5	4.1	4.4	5.1	0.1	0.1	0.1	0.1	0.1
Others	2.5	2.3	2.2	2.3	3.5	0.1	0.1	0.1	0.1	0.1
Africa Total	67.7	95.2	179.1	184.9	188.6	3.1	3.7	5.4	5.5	5.5
Australia	55.5	69.9	147.7	134.6	147.8	2.5	2.7	4.5	4.0	4.3
New Zealand	2.3	2.0	2.3	2.2	2.2	0.1	0.1	0.1	0.1	0.1
Oceania Total	57.8	72.0	150.0	136.8	150.0	2.6	2.8	4.6	4.1	4.4
World Total	2,199.4	2,550.9	3,287.7	3,371.4	3,425.8	100.0	100.0	100.0	100.0	100.0

Source : Coal Information 1990 (IEA/OECD)

Note : 1. Data for Hard Coal (anthracite, bituminous)

2. Estimated figures for 1989

3. Totals may not accord exactly since fractions are rounded off.

Table 3.1.11 WORLD TRADING FOR COAL (2/2)

(Unit: million tons)

	Amount Imported			Amount Exported		
	1978	1987	1988	1978	1987	1988
Canada	14.3	14.3	17.5	14.0	26.7	31.7
United States	2.7	1.6	1.9	36.9	72.2	86.1
North America Total	16.9	15.9	19.4	50.9	98.9	117.8
Brazil	3.5	9.7	9.3	-	-	-
Columbia	-	-	-	0.2	9.7	10.8
Other Central South American Countries	1.5	1.8	2.0	-	0.1	0.9
Central and South American Total	5.1	11.5	11.3	0.2	9.8	11.7
Belgium	7.0	9.1	11.1	0.2	1.0	1.0
Denmark	6.1	12.1	10.3	-	0.1	0.1
France	23.4	13.3	12.1	0.4	0.8	1.5
West Germany	6.9	8.3	7.5	18.8	6.3	5.0
Italy	12.5	21.3	19.8	-	-	-
Holland	5.0	12.2	13.8	0.5	1.7	1.8
Spain	3.4	8.9	8.8	-	-	-
Turkey	0.5	3.7	4.5	-	-	-
United Kingdom	2.4	9.8	12.0	2.3	2.3	1.7
Other West European Countries	11.1	22.5	27.0	0.2	0.5	0.8
West Europe Total	78.3	121.7	126.9	22.4	12.7	11.9
Czechoslovakia	5.6	4.2	4.7	3.8	2.0	1.9
Poland	1.1	1.1	1.1	40.1	30.2	32.3
Other East European Countries	21.4	26.4	25.2	0.3	0.7	0.5
East Europe Total	28.1	31.7	31.0	44.2	32.9	34.7
Soviet Union	9.9	9.6	11.9	27.0	35.5	39.4
Japan	52.9	90.9	101.2	-	-	-
China	2.4	1.9	2.2	3.1	13.5	16.3
Hong Kong	-	8.0	9.3	-	-	-
India	-	-	-	0.5	-	-
Korea	2.4	20.6	23.6	-	-	-
Taiwan	1.4	14.0	17.5	-	-	-
Other Asian Countries	1.2	4.5	4.5	1.5	1.9	2.1
Asia Total	60.4	139.9	158.3	5.1	15.4	18.4
Egypt	0.9	1.3	1.3	-	-	-
South Africa	-	-	-	15.3	42.3	42.6
Zimbabwe	-	-	0.1	0.2	0.1	0.1
Other African and Middle Eastern Countries	0.4	5.9	6.0	0.1	0.1	-
Africa, Middle East Total	1.3	7.2	7.4	15.6	42.5	42.6
Australia	-	-	-	36.6	95.7	102.2
New Zealand	-	-	-	-	0.3	0.4
Oceania Total	-	-	-	36.6	96.0	102.6
World Total	199.8	342.3	366.2	202.0	343.6	379.1

Notes : 1. Based on ([Coal Information 1990] IEA/OECD etc.)
2. Data is for Hard Coal (anthracite, bituminous)
3. Totals may not accord exactly as fractions are rounded off.

Table 3.1.12 FORECASTS FOR COAL TRADING OF OECD COUNTRIES

(Unit : conversion to 1 million tons of coal)

Country	Amount of Imports									Amount of Exports								
	1988			1995			2000			1988			1995			2000		
	Metal-lurgical Coal	Thermal Coal	Total	Metal-lurgical Coal	Thermal Coal	Total	Metal-lurgical Coal	Thermal Coal	Total	Metal-lurgical Coal	Thermal Coal	Total	Metal-lurgical Coal	Thermal Coal	Total	Metal-lurgical Coal	Thermal Coal	Total
Canada	5.89	10.54	16.43	6.57	2.86	9.43	6.57	5.57	12.14	24.70	3.69	28.39	23.29	5.43	28.71	23.29	8.00	31.29
United States	-	1.83	1.83	-	1.86	1.86	-	1.79	1.79	56.93	28.79	85.70	55.71	30.71	86.43	69.43	41.43	110.86
North America Total	5.89	12.37	18.26	6.57	4.71	11.29	6.57	7.36	13.93	81.63	32.47	114.09	79.00	36.14	115.14	92.71	49.43	142.14
Australia	-	-	-	-	-	-	-	-	-	53.71	40.61	94.33	60.71	58.29	119.00	67.79	73.71	141.50
Japan	73.37	25.34	98.70	78.76	27.67	106.43	92.29	32.43	124.71	-	-	-	-	-	-	-	-	-
New Zeland	-	-	-	-	0.06	0.06	-	0.06	0.06	0.40	-	0.40	0.61	-	0.61	0.61	-	0.61
Oceania Total	73.37	25.34	98.70	78.76	27.73	106.49	92.29	32.49	124.77	54.11	40.61	94.73	61.33	58.29	119.61	68.40	73.71	142.11
Belgium	6.84	3.36	10.19	7.29	6.14	13.43	7.43	6.29	13.71	0.03	0.69	0.71	-	-	-	-	-	-
Denmark	-	8.84	8.84	-	11.77	11.77	-	12.61	12.61			0.09			0.07			0.07
France	8.50	3.44	11.94	7.14	7.14	14.29	7.14	9.00	16.14	-	1.37	1.37	-	0.14	0.14	-	0.14	0.14
West Germany	0.60	6.34	6.94	0.57	9.31	9.89	0.57	13.79	14.36	3.59	1.51	5.10	1.54	1.43	2.97	1.54	1.43	2.97
Italy	9.63	9.57	19.20	10.00	20.00	30.00	10.00	28.57	38.57	-	-	-	-	-	-	-	-	-
Holland	4.00	9.74	13.74	4.71	14.14	18.86	5.29	17.86	23.14	0.01	1.76	1.77	-	1.29	1.29	-	0.71	0.71
Spain	3.74	4.47	8.21	3.57	5.14	8.71	9.71	11.57	21.29	-	-	-	-	-	-	-	-	-
Turkey	3.10	1.10	4.20	5.49	6.85	12.34	11.37	15.29	26.66	-	-	-	-	-	-	-	-	-
United Kingdom	7.59	4.20	11.77	10.14	5.43	15.57	10.86	5.86	16.71	-	1.59	1.59	-	-	-	-	-	-
Other European Countries	4.49	16.21	20.67	11.82	15.72	27.51	13.39	18.57	31.98			0.46			0.24			0.30
OECD Europe Total	48.49	67.27	115.70	60.73	101.64	162.37	75.76	139.41	215.17	3.63	7.53	11.16	1.54	3.17	4.71	1.54	2.64	4.19
OECD Total	127.74	104.99	232.66	146.06	134.09	280.14	174.61	179.25	353.87	139.37	80.61	219.97	141.87	97.60	239.47	162.66	125.79	288.44

Source : Coal Informaiton 1990 (IEA/OECD)

Notes : 1. 1988 Figures are for recorded performance.

2. Slight discrepancies may arise due to rounding off of fractions.

3. Other European Countries means Austria, Finland Greece, Iceland, Ireland, Luxembourg, Norway, Portugal, Sweden and Switzerland.

Table 3.1.13 TRANSPORT OF COAL AND COAL PRODUCTS

(Unit : million tons)

			1985-86	1986-87	1987-88	1988-89 (Apr.-Dec.)
Rail	CIL	External	85.77	89.95	94.78	72.12
		Internal	4.57	4.73	4.93	3.66
		Total	90.34	94.68	99.71	75.78
	SCCL		10.30	10.54	11.55	8.81
	TISCO/IISCO		3.14	3.45	3.64	2.95
	Others		7.90	9.45	12.95	10.93
	Total		111.68	118.12	127.85	98.47
Road	CIL	External	23.50	24.37	26.20	18.86
		Internal	13.48	13.02	13.32	9.45
		Total	36.98	37.39	39.52	28.31
	SCCL		2.94	3.26	2.65	2.21
	TISCO/IISCO/DVC		N.A.	N.A.	N.A.	N.A.
	Total CIL+SCCL		39.92	40.65	42.17	30.52
Belt	CIL		4.86	5.63	5.76	6.44
	SCCL		0.42	0.77	0.45	0.34
	Total CIL+SCCL		5.28	6.40	6.21	6.78 *
Ropeway	CIL		3.90	4.03	4.30	N.A.
	SCCL		-	-	-	-
	Total CIL+SCCL		3.90	4.03	4.30	
MGR	CIL		8.66	9.50	15.06	14.87
	SCCL		2.13	2.08	1.97	1.82
	Total CIL+SCCL		10.79	11.58	17.03	16.69

* Includes Ropeway

SOURCE : REPORT 1988-89, DEPARTMENT OF COAL

Table 3.1.14 MODE-WISE COAL MOVEMENT OF CIL AND SCCL

YEAR	COMPANY		RAIL	ROAD	MGR	OTHERS	TOTAL
1989-90 ACTUAL	CIL	million tons	107.72	26.01	26.77	10.73	171.23
		%	62.9	15.2	15.6	6.3	100.0
	SCCL	million tons	9.66	3.43	4.22	0.42	17.73
		%	54.5	19.3	23.8	2.4	100.0
	CIL+SCCL	million tons	117.38	29.44	30.99	11.15	188.96
		%	62.1	15.6	16.4	5.9	100.0
1990-91	CIL	million tons	114.49	24.63	31.56	15.42	186.10
		%	61.5	13.2	17.0	8.3	100.0
	SCCL	million tons	13.43	2.56	5.50	1.40	22.89
		%	58.7	11.2	24.0	6.1	100.0
	CIL+SCCL	million tons	127.92	27.19	37.06	16.82	208.99
		%	61.2	13.0	17.7	8.0	100.0
1991-92	CIL	million tons	118.44	26.14	32.72	17.15	194.45
		%	60.9	13.4	16.8	8.8	100.0
	SCCL	million tons	13.21	4.29	4.10	1.80	23.40
		%	56.5	18.3	17.5	7.7	100.0
	CIL+SCCL	million tons	131.65	30.43	36.82	18.95	217.85
		%	60.4	14.0	16.9	8.7	100.0
1994-95	CIL	million tons	136.17	31.87	46.63	24.18	238.85
		%	57.0	13.3	19.5	10.1	100.0
	SCCL	million tons	18.03	5.27	5.01	2.00	30.31
		%	59.5	17.4	16.5	6.6	100.0
	CIL+SCCL	million tons	154.20	37.14	51.64	26.18	269.16
		%	57.3	13.8	19.2	9.7	100.0

NOTE : INCLUDING DOUBLE MOVEMENT OF WASHED COAL AND MIDDLINGS
BUT EXCLUDING IMPORTED COAL AND REHANDLED COAL

SOURCE : EIGHTH FIVE YEAR PLAN 1990-95 AND ANNUAL PLAN 1991-92, DEPARTMENT OF COAL