improvement in the environment being effected.
Nevertheless a certain number of problem points remain.

Various explanations can be given for these problems and
the main reasons are given below:

(1) Insufficiencies in Social Capital and Industrial
    Capital for Pollution Control Measures

    For example it is said that 90% of the pollution of
    water quality evident around the large metropolitan
    areas is due to domestic wastes.

    However the budgets of national government and local
    authorities allocated to strengthening sewage and
    waste water treatment facilities are not sufficient to
    enable these facilities to cope with the explosive
    increase in metropolitan populations.

    In fact, even the construction of housing is far from
    sufficient to satisfy the demand.  Moreover, not only
    is the capital insufficient to install new pollution
    control facilities in small to medium size factories
    which have superannuated but even the necessary space
    is lacking.  Of course such firms lack the means to
    effect a move to the outlying regions.

    Even in the case of large factories the capital needed
    to implement pollution control measures is
    insufficient.

(2) Underdeveloped State of Pollution Control Technology

    First, the instrumentation technology needed for
    carrying out environmental measurements is
    underdeveloped in India.

    There is a high degree of dependency on foreign
    technology in this field at present.

The under development is also a result of the fact that the domestic market for pollution control technology remains small for the time being.

Evident examples of this state of affairs can be seen in the air pollution caused by automobile exhaust which fails to improve and in the fact that the flue gas of coal fueled power plants is not desulphurized.

(3) Weakness of the Economic Foundations

In addition to the above factors the weakness of the economic foundations of India cannot be ignored either.

For example power failures are far from unusual. In such cases when the safe and regular operation of factories is disturbed it is inevitable that an increase in the discharge of pollutants results.

Moreover, it is stated that the qualities of the water and coal used industrially and domestically continues to worsen year by year. If this is true then the burden on pollution control facilities will increase.

In view of the above context the occurrence of a certain number of offenses against regulations in force is seen as socially unavoidable in the present circumstances. However, India has an immense national territory. In the larger half of India's regions it is still difficult to find any signs of environmental deterioration. Pollution problems in India are centered in the metropolitan areas where the dense population and high concentration of factories results in localized, compounded pollution, big rivers or else in the northern area where regions of intensive mining and quarrying are the principal causes.

## 5.2 Evaluation of Emission Levels of Pollutants from the Demonstration Plant

The pollutants which arise from the SRC Demonstration Plant originate from the raw material coal, catalyst or fuels used.

We shall examine the amounts of raw coal, catalyst and fuels employed and their components related to the generation of pollutants.

### 5.2.1 Raw Coal, Catalyst and Fuels

(1) Amount of Raw Coal Supplied and Origin of Pollutants

As the amount of raw coal supplied on a dry basis is taken to be 500 ton per day the amount fed into the dissolver is taken to be 21,476 kg/h.

The composition of this intake is as follows:

Dry base coal 20,833 kg/h (97.0%)
Moisture          643 kg/h  (3.0%)

Table 5.2.1 shows the analytical data of impurities which are the origin of pollutants.

(2) Catalyst

208 kg/h intake (1% of the feed coal intake) of elemental sulphur is used as a catalyst promoter for the liquification reaction.
55 kg/h of this promoter is recycled and so the fresh promoter feed intake is 153 kg/h.
It is not clear how the form of the sulphur is changed by the liquification reaction but on burning $SO_2$ will easily occur.

(3) Fuels

COG, middle and heavy distillates (byproducts of the
SRC plant), coal or C heavy oil are employed as fuel
in the SRC Demonstration Plant. Since C heavy oil is
only used at the start up this is left out of the
present considerations. The sulphur contents of the
other fuels are indicated below.

Middle and heavy            combustible sulphur 1.2 wt%
        distillate
coal for fuel               combustible sulphur 0.33 wt%
    (SAMLA, wet)
COG                         hyrogen sulfide      0.22 mol%


5.2.2  Formation of Pollutants

(1) Pollutants Arising from the Liquification Reaction

The quantities of gaseous pollutants ($H_2S$, $NH_3$)
arising during the liquification reaction are shown
below:

$H_2S$  : 0.3% of feed coal (d.a.f.)     59 kg/h
$NH_3$  : 0.1% of feed coal (d.a.f.)     20 kg/h

From the above figures it can be seen that only a very
small part of the S and N components of the feed coal
is changed into $H_2S$ or $NH_3$.
The main part of these components remains in the SRC,
liquid products or filter cake, though in exactly what
forms are not clear.

On the other hand an output of 9.8 kg/h of phenols
arises and this is moved into the waste water.

(2) Quantity of Pollutants from the Fuels

Among the output of fuel pollutants $SO_2$ calculated for each stack is shown in Table 5.2.2 (1).

Heaters and boiler are assumed to be supplied by Indian manufacturers. Expected concentrations of NOx in the flue gas is shown in Table 5.2.2 (2). With regard to S.P.M. we assume that it will be emitted from the boiler (BF 1000) only.
Concentration of carbon monoxide in the flues gas is assumed to be negligible compared with the regulation standard.

(3) Quantity of Ash

Almost all of the ash arising from the above fuels originate from the SAMLA coal (approximately 11% ash on a wet basis). The total amount of ash is estimated to be approximately 950 kg/h.

## 5.3 Pollution Control Systems to be Installed in the SRC Demonstration Plant

5.2 shows the amounts of pollutants which will arise from the SRC Demonstration Plant.

5.3 concerns the design standards for the treatment facilities to handle these pollutants, and the pollution control system thus designed.

### 5.3.1 Design Standards for the Pollution control Facilities of the SRC Demonstration Plant

Negotiations were carried out between the Indian party and the JICA mission in order to decide the design standards of pollution control facilities suited to the SRC Demonstration Plant. A thorough study was then carried out by JICA mission after return to Japan in accordance with the principles agreed to by both parties in the above negotiations. The following is an outline of this historical background.

(1) Discussions between the Indian Party and JICA Mission and Details of the Agreement Reached

The following two principles were explained and accepted during the first visit of the JICA mission to the Main Office of MECON:

1) In response to the Indian request the national Japanese emission standards for pollutants would be applied.

2) In order to reduce investment costs wherever possible existing pollution control facilities would be employed or else joint investment be undertaken.

Also MECON agreed that an environmental impact

assessment would not be carried out for the present
project.

Two visits were made to the Rourkela Steel Plant
(R.S.P.) and an inspection of the plant conducted and
negotiations held.  During the same period a visit was
made to Neyveli, and data and documents were collected
at various places.  On the basis of these collected
informations final negotiations were conducted at the
MECON main office.  The Minutes of Meetings of October
19 and 20, 1990 summarize the articles of agreement
reached.

The background to these Minutes of Meeting is as
follows:

1) The basic concept for plant design determined in
   response to the request of the R.S.P. was to
   construct the pollution control facility as an
   independent unit whichever candidate plant site
   might eventually be chosen and not to use this
   facility in common with other units.

2) MECON pointed out that there was every chance that
   the Industrial License for the SRC Demonstration
   Plant would be entrusted to the Central Government
   authorities given the nature of the project.
   It was therefore imperative that the environmental
   measures adopted met not to state standard but to
   national standards.  However, fortunately the
   contents of the two standards in the present case
   were set at the same levels.

3) In India the emission standards are set by
   individual industrial sector.  Naturally enough,
   there is no category yet applicable for SRC in
   India.  It was agreed to include the SRC
   Demonstration Plant in the category of coke ovens,
   since the nature of the pollutants and wastes is
   similar in both cases.

4) It was found as a result of the review carried out
   that national standards concerning waste water are
   stricter in India than is the case in Japan. It was
   decided to adopt the Indian standards. In the case
   of air pollutants Japanese standards were found to
   be stricter than the equivalent Indian standards
   and so the stricter Japanese standards were
   adopted.

5) Further, in response to MECON's request additional
   attention was accorded to the aspect of working
   environment standards. The standards applied were
   those of the Second Schedule of the Indian
   Factories Act and Interplant Standards on Pollution
   Control of SAIL (IPSS).

In all cases the principle was to carefully compare
national standards of India and Japan and to adopt
that which was found the stricter of the two.

(2) Design Standards Decided Upon after Return to Japan of
the JICA Mission

Design standards for the pollution control facilities
of the SRC Demonstration Plant were determined in
Japan after the return of the JICA Mission upon
consultation with plant design experts. The following
is an outline of the standards adopted and the
rationale for their adoption.

1) Waste Water Quality Standards

As waste water from R.S.P. is discharged directly
into a river, standards for effluents discharged
into inland surface water was adopted. Table 5.3.1
indicates the standards adopted together with the
national standards of India and Japan for
reference.

The following points are noted in connection with

the above standards.

(a) The largest and most important difference between the two national standards concerns $BOD_5$.

(b) The reason for the large number of regulations concerning inorganic salts in India may be the great length of Indian rivers which results in concern about damage from salty water.

(c) There are no Indian standards for items No.35 through 40. Moreover as these are not seen as possible problem sources in the vicinity of Rourkela these items are eliminated from the present considerations.

(d) In order to meet the chosen standards it is necessary to have data concerning the composition of the SRC feedstock coal and the utility water supplied by R.S.P. beforehand. Fortunately, it would seem that there are no causes for concern regarding these factors as far as can be judged from the analytical results for heavy metal contents in feedstock coal obtained in Japan (Annex 5.3.1) or the analytical data for R.S.P. supplied intake water quality (Annex 5.3.2).
In fact, with regard to test data for R.S.P. waste water quality it would seem that apart from ammoniacal nitrogen there was no mention of inorganic substances and problems were not encountered.

2) Atmospheric Emission

(a) Comparison of Standards of Ambient Air Quality

Table 5.3.2 indicates the national standards of India and Japan for ambient air quality.

The site for the SRC demonstration plant is
located in an area designated as of industrial
and mixed use. A comparison of the
environmental standards of MINAS and Japan for
such an area shows that the latter Japanese
standard is the stricter of the two in respect
of s.p.m.

(b) Emission Standards

The following is a comparative examination of
emission standards for SO2, dust and soot, and
NOx.

a) $SO_2$

The general Japanese national standard for
$SO_2$ emission is determined according to the
amount of emission in relation to stack
height using the following equation:

$$q = K \times 10^{-3} \, He^2.$$

Where,

q : the amount of $SO_2$ emitted
   ($Nm^3/h$)
K : a constant which varies according to the
   regions
   (K = 3.0 to 17.5, 16 ranks)
He : the effective stack height
   (m).

In India with the exception of thermal power
plant there are no standards for stack
height.

However the Central Board does issue the
following guidelines:

a. That the minimum stack height is 30 m.

b. Where $SO_2$ emission occurs the minimum
   height of the plant stack is to be
   calculated by the following equation:

$$H = 14(Q)^{0.3}$$

   In which equation,

   H : the stack height (m)

   Q : the amount of $SO_2$ emitted (kg/h).

   If a height greater than 30 meters
   results when the above equation is used
   then the larger height is applied.

Use of the Japanese equation noted above is
rendered difficult by the problem of the
optional choise of a K value.

In contrast the Indian method is extremely
clear in application.

Moreover, very rough calculations with the
methods show that the Indian guidelines
produce standards in the more rigorous range
of Japanese national standards.

Therefore the Indian guidelines mentioned
above were adopted for the purposes of the
SRC Demonstration Plant.

b) Dust and Soot (s.p.m.)

Table 5.3.3 shows those emission standards
for dust and soot applied in Japan which are
considered relevant to the case of the SRC
Demonstration Plant.

In India, as in the case of $SO_2$ mentioned above the Central Board has set a guideline for minimum stack height on the basis of an equation relating this to s.p.m. levels. The equation is

$$H = 74(Q)^{0.27}$$

Where,

H : the height of the stack (m)
Q : the amount of s.p.m. emitted (t/h)

As the process heaters of the SRC Demonstration Plant uses either gas, middle and heavy distillate, or bunker fuel oil it is certain that the s.p.m. concentration in the flue gases will clear both Japanese and Indian standards.

However, if coal is used as fuel for the boiler then it may be necessary to install a dust collector since compared to the Japanese case Indian coal used has an extremely high ash content.

c) NOx

NOx emissions are only regulated in the case of nitric acid plant in India. Even in this case, emission of less than 3 kg NOx per ton of dilute nitric acid is allowed.

The Japanese NOx emission standards related to the case of the SRC Demonstration Plant are shown in Table 5.3.4.

Generally in Japan, NOx removal apparatuses are not installed for small boilers or process heaters.

d) Substances which are hazardous or have offensive Odors

Substances which occur in the processes of the SRC Demonstration Plant covered by Japanese regulations concerning offensive odors are ammonia and hydrogen sulfide.

Application of the processes normally applied in Japan for treating these substances in coke oven plant is considered sufficient.

e) Modifications of the above Policies (a) (b) and (c)

During the visit to the Mecon Office at Ranchi in September 1991, the second JICA Mission received a request from its Indian counterpart to effect considerable modifications with regard to the emission standards mentioned above under sections (a) (b) and (c). The details of the requst are as follows.

a. When a plant is newly constructed or expanded in India the competent authorities require that air environmental standards be observed. It is possible to calculate the substances emitted into the air from stacks of a newly constructed plant, but in order to understand what the effect of emission from the already existing plants might be for the actual environment, measurements over a long time span are required. This inevitably involves time and expense.

b. Therefore in accordance with the
   guidelines set down by the authorities
   MECON calculates the height of a plant
   stack so as to satisfy the following
   formula in any location.

   $\Sigma$ C/Co < 1

   In the above formula Co is the maximum
   concentration tolerated by Indian
   environmental standards while C is the
   concentration in air originating from new
   plant discharges.  Since the Cco/Coco
   value of the present project are
   considered to be so small as to be
   negligible, the following formula is
   applied.

   $C_{SO2}/120 + C_{NOx}/120 + C_{S.P.M.}/500 < 1$
        (Unit of C is $\mu g/Nm_3$)

c. For calculation of the above air
   dispersion values reference is made to
   the Indian Standard-Guidelines for
   Micrometeorological Techniques in Air
   Pollution Studies (December 1978).
   (note: The method employed in India for
   calculating air dispersion is basically
   the same as that applied in Japan.
   However, the conditions set differ
   between the two countries and there are a
   greater number of case studies for
   India).
   The JICA Mission agreed to MECON's
   request to decide the stack height on the
   basis of the above calculation method.
   Our calculation methods are as shown
   below.

```
stacks concerned          five
effective chimney
height                    Bosanquet's equation
SO_2, NOx dispersion      Pasquill's equation
S.P.M. dispersion         Chamberlain's equation
```

The set conditions are recorded in 5.3.2.
(4) below.

3) Solid Wastes

The following methods of treatment can be applied
in the case of the solid wastes arising in the SRC
Demonstration Plant.

(a) SRC filter cake:
                can be used as fuel for the
                existing boilers in R.S.P.. Ash
                can be carried out together with
                the R.S.P. coal ash.

(b) Ash from boiler:
                can be carried out together with
                the R.S.P. coal ash.

(c) Activated sludge residue :
                is not hazardous and the amount
                arising is very small. It is
                blended with pulverized coal and
                burned in the boiler.

4) Noise

Ambient air quality standard in respect of noise in
India is shown in Table 5.3.5.

However Table 5.3.5 is not taken to represent noise
at the boundary line of the plant.

In Japan noise levels are regulated at the boundary lines of certain specified categories of plant (and the SRC Demonstration Plant is included in one of the relevant categories). These standards are shown in Table 5.3.6.

A direct comparison of the standards shown in Tables 5.3.5 and 5.3.6 is considered unreasonable but it is evident that Japanese standards are more rigorous.

However, if the SRC Demonstration Plant is located inside the R.S.P Plant then noise levels should be measured at the boundary line of the R.S.P. area, and it should also be taken into account that the SRC Demonstration Plant would not therefore be the only noise source.

Therefore it is considered actually difficult to determine a specific level of noise for the SRC Demonstration Plant.

5) Working Environment Standards

Tables 5.3.7 and 5.3.8 show the standards employed by the IPSS (August 1989) relating to working environment.

Although the Second Schedule of the Factories Act concerning "Permissible Levels of Certain Chemical Substances in the Work Environment" designates more than one hundred chemical substances it would be sufficient to consider measures for soot/dust and SRC volatile matter in the SRC Demonstration Plant.

For other hazardous substances since the SRC Demonstration Plant is an open type plant it is judged that high concentrations will not arise.

In any case the two standards mentioned above are

all seen to meet with the Threshold Limit Values
and Biological Exposure Indices set by the American
Conference of Governmental Hygienists (ACGIH) and
therefore are considered to be equal to Japanese
standards.
It is therefore concluded that a plant design of
the SRC Demonstration Plant in accordance with
Japanese principles and procedures will not result
in any infringement of Indian standards.

Further, as requested by MECON and as a matter of
course attention will also be given during design
to the hygienic and safety aspects of the working
environment.

## 5.3.2 Pollution Control System of SRC Demonstration Plant

The present section deals with the treatment system for dealing with pollutants in accordance with the afore-mentioned design standards.

(1) Treatment of $H_2S$

Most of the $H_2S$ which arises during the liquification reaction is found in the crude $H_2$ rich gas at the outlet of the 2nd high pressure separator while a small amount is also found in the low pressure separator off gas.

The former is caught at the DEA absorber and stripped at the DEA regenerator. The latter is caught at the acid gas absorber (Benfield process) and then stripped using an acid gas stripper. Besides the above a very small amount of $H_2S$ comes from the top of the sour water $H_2S$ stripper.

All of the stripped $H_2S$ gases are treated by the Takahax process and almost theoretically retrieved (recovery is above 99%) as elemental sulphur.

The following is an explanation of the basic principle of the Takahax process.

1) The absorption and oxidation of $H_2S$

$$H_2S \ + \ Na_2CO_3 \ \text{------------>} \ NaHS \ + \ NaHCO_3$$
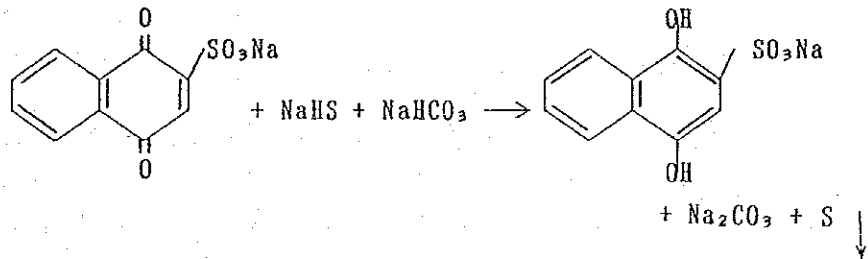
2) The oxidation of the Catalyst (regeneration)
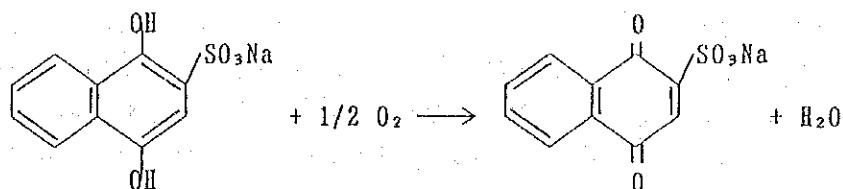


(2) Treatment of $NH_3$

The majority of the ammonia which arises during the liquification reaction is found in the OVHD gas of the 2nd high pressure separator. This gas is washed in the water wash tower and the ammonia transferred into the sour water.

(3) Treatment of Suspended Particulate Matter (S.P.M.)

As a large amount of S.P.M. is found in the boiler (BF 1000) flue gas an electric dust collector is to be installed. Accordingly, the S.P.M. concentration in the boiler flue gas is expected to decrease to $0.15g/Nm^3$.

(4) Determing Stack Height

$SO_2$, NOx and S.P.M. are emitted into the air from the stacks of process heaters and boiler. Stack heights shown in Table 5.3.9 are determined on the basis of the method outlined in 5.3.1 (2)2)e together with adequate safety factor. Evaluation as shown below is carried out using these values. In the case of the SRC Demonstration Plant a tolerable level of air pollution will satisfy equation (1).

$$\frac{C_{SO2}}{120} + \frac{C_{NOx}}{120} + \frac{C_{SPM}}{500} < 1 \qquad (1)$$

In the present project details of the stacks, the heaters which discharge the air pollutants $SO_2$, NOx

and SPM and the meteorological conditions are as
follows.

| Item No. | | BA101 | BA201 | BA401 | BA1901 | BF1000 |
|---|---|---|---|---|---|---|
| Service | | Coal | Dissolver | Fractionator | Hot Oil | Boiler |
| | | Heater | Heater | Heater | Heater | |
| Location | | | | | | |
| X axis | (m) | 315 | 215 | 175 | 0 | 70 |
| Y axis | (m) | 1485 | 1485 | 1450 | 1540 | 1550 |
| Stack Height | (m) | 40 | 60 | 60 | 50 | 80 |
| Stack Diameter | (m) | 0.70 | 1.42 | 1.29 | 1.01 | 2.18 |
| Flue Gas Temperature | (°C) | 80 | 180 | 250 | 250 | 180 |
| Flue Gas Generation | (Nm$^3$/s) | 1.493 | 6.637 | 4.070 | 2.506 | 18.549 |
| SO$_2$ Concentration | (V%) | 0.0296 | 0.0527 | 0.0540 | 0.0543 | 0.0287 |
| NOX Concentration | (V%) | 0.0070 | 0.0250 | 0.0250 | 0.0250 | 0.0750 |
| SPM Concentration | (g/Nm$^3$) | 0.0 | 0.0 | 0.0 | 0.0 | 0.15 |
| Ambient Temperature | (°C) | 15 | 15 | 15 | 15 | 15 |
| Atms. Temp. Gradient | (°C/m) | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Stability Class | | A | A | A | A | A |
| N | | | | | | 0.200 |
| Cy | | | | | | 0.12 |
| Cz | | | | | | 0.12 |
| Wind Direction | | West | West | West | West | West |
| Wind Velocity | (m/s) | | | | | |
| Case - 1 | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Case - 2 | | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Case - 3 | | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Case - 4 | | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |

As an example of the calculation results Figure 5.3
shows a concentration contour map calculated for SO$_2$
1.5 m above ground when wind velocity is 3.0 m/s using
Bosanquet's and Pasquill's equations.

The maximum concentrations above ground and locations
for the individual pollutants at the different wind
velocities are calculated below.

| Wind Velocity | (m/s) | 1.0 | 1.5 | 2.0 | 3.0 |
|---|---|---|---|---|---|
| **Max. $SO_2$ Concentration** | | | | | |
| 3 minutes figure | (Vppm) | 0.0429 | 0.0535 | 0.0608 | 0.0661 |
| 8 hours figure | (Vppm) | 0.00563 | 0.00702 | 0.00798 | 0.00868 |
| 8 hours figure | (micro g/Nm$^3$) | 16.1 | 20.1 | 22.8 | 24.8 |
| Location at Max. Conc. | (m) | 840 | 750 | 660 | 600 |
| **Max. NOx Concentration** | | | | | |
| 3 minutes figure | (Vppm) | 0.0386 | 0.0478 | 0.0559 | 0.0627 |
| 8 hours figure | (Vppm) | 0.00507 | 0.00628 | 0.00734 | 0.00823 |
| 8 hours figure | (micro g/m$^3$) | 7.1 | 8.8 | 10.3 | 11.6 |
| Location at Max. Conc. | (m) | 900 | 750 | 690 | 600 |
| **Max. SPM Concentration** | | | | | |
| 3 minutes figure | (mg/Nm$^3$) | 0.0000 | 0.0004 | 0.0018 | 0.0040 |
| 8 hours figure | (mg/Nm$^3$) | 0.0000 | 0.0001 | 0.0002 | 0.0005 |
| 8 hours figure | (micro g/Nm$^3$) | 0.0 | 0.1 | 0.2 | 0.5 |
| Location at Max. Conc. | | 3000 | 3000 | 3000 | 2760 |
| **SPM Concentration at Max. $SO_2$ & NOx** | | | | | |
| Location | (m) | 840 | 750 | 660 | 600 |
| 3 minutes figure | (mg/Nm$^3$) | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8 hours figure | (mg/Nm$^3$) | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8 hours figure | (micro g/Nm$^3$) | 0.0 | 0.0 | 0.0 | 0.0 |

By substituting as shown below the above data for the maximum concentration of the pollutants in equation (1) above, it can be proved that the MECON standards are satisfactorily met.

$$\frac{C_{so2}}{120} + \frac{C_{NOX}}{120} + \frac{C_{SPM}}{500} = \frac{24.8}{120} + \frac{11.6}{120} + \frac{0.00}{500} = 0.3 < 1$$

(5) Treatment of Waste Water

It is necessary to account for treatment of both process waste water and plant oily water. The main process waste water is the sour water which is separated out in the 2nd high pressure separator, water wash tower and 2nd low pressure separator.

The process waste water is collected and steam stripping carried out, so that $H_2S$ and $NH_3$ are

stripped in that order. The stripped $H_2S$ is sent to
the Takahax facility and the stripped $NH_3$ is burned in
the flare stack.

Cooling water blow down (CWBD) is added to the above
stripped process waste water and plant oily water so
as to adjust concentrations then the adjusted water is
sent into a dissolved air floatation unit and after
the remaining oil and suspended solids are removed it
is sent to an activated sludge treatment facility.

Table 5.3.10 shows the material balance of the
activated sludge treatment facility.

The composition of the finally discharged waste water
resulting as shown in Table 5.3.10 sufficiently
satisfies the design standards.

(6) Output of Solid Wastes

The following solid wastes are discharged from the SRC
Demonstration Plant.

1) Ash (approx. 950 kg/h) arising from the boiler and
   heaters
2) activated sludge cake (approx. 50 kg/h, wet)
3) SRC filter cake (1,806 kg/h) (sulfur content 10.4%
                                  of which about 94%
                                  comes from catalyst
                                  promotor.)

There is no problem envisaged with the burying of the
ash in 1) above. The activated sludge cake of 2) is to
be mixed with coal and burned in the boiler. The SRC
filter cake 3) is to be used as fuel in the R.S.P.
boiler plant but as this contains sulfur care is
required.

(7) Noise

Figure 5.3.2 is a contour map of the noise which is
produced by the SRC Demonstration Plant.  This contour
map was drawn up by computer analysis of the noise
from the 176 devices producing noise inside the plant
during normal operations.  The noise levels at battery
limit and noise levels inside the plant are found to
satisfy the regulation standards.

(8) Other Operating Environments

The following measures are also to be taken in
relation to the operating environment inside the SRC
Demonstration Plant.

1) Coal dust:  coal handling is to be carried out as
              far as possible in a closed system.
              Further, water sprinklers are to be
              installed in the coal yard to prevent
              the dispersal of coal dust.

2) SRC fumes :  The SRC solidification facilities are
              to be established on a closed system
              basis as far as possible and fans used
              for removal of fumes.

Table 5.2.1　ANALYSIS OF RAW MATERIAL COAL (ASSAM COAL)
AS THE ORIGIN OF POLLUTANTS

(1)　Elemental Analysis of Assam Coal as the Origin of Pollutants

|  | Dry basis | d.a.f. basis |
|---|---|---|
| ash (%) | 5.0 | – |
| nitrogen (%) | 1.1 | 1.2 |
| total sulfur (%) | 1.6 | 1.7 |
| combustible sulfur (%) | 1.5 | 1.6 |
| Cl (mg/kg) | 370 | 370 |

(2)　Classification of Sulfur (Dry Basis)

| Item | Content |
|---|---|
| sulfur as sulphate (%) | 0.0 |
| sulfur as pyrite (%) | 0.2 |
| organic sulfur (%) | 1.4 |

Table 5.2.2 (1)　QUANTITIES OF GENERATED SO$_2$ FROM EACH STACK

CALCULATED FROM SULFUR CONTENT OF FUELS

| Item No. | Service | Fuel Consumption | | Quantity of SO$_2$(kg/h) |
| | | Names of Fuel | Quantitiy(kg/h) | |
|---|---|---|---|---|
| BA101 | coal heater | COG | 750(Nm$^3$/h) | 4.7 |
| BA201 | dissolver heater | byproduct distillate | 1,510 | 36.2 |
| BA401 | fractionator heater | byproduct distillate | 940 | 22.6 |
| BA1901 | hot oil heater | byproduct distillate | 580 | 13.9 |
| BF1000 | boiler | coal (SAMLA) | 8,300 | 54.8 |

Table 5.2.2 (2)　EXPECTED NOx CONCENTRATION IN THE FLUE GAS

(unit:ppm)

| Item No. | Service | Expected NOx Concentration |
|---|---|---|
| BA101 | coal heater | 70 |
| BA202 | dissolver heater | 250 |
| BA401 | fractionator heater | 250 |
| BA1901 | hot oil heater | 250 |
| BF1000 | boiler | 750 |

## Table 5.3.1 STANDARDS FOR EFFLUENTS DISCHARGED INTO INLAND SURFACE WATER FROM SRC DEMONSTRATION PLANT – TOLERABLE LIMITS (1/3)

(generally expressed in mg/l)

| No | Item | Standards to be applied to SRC demonstration plant | Reference | | |
|----|------|------|------|------|------|
| | | | Indian national standards* | | Japanese national standards |
| | | | general | coke ovens | |
| 1 | color and ordour | note 1 | note 1 | | |
| 2 | suspended solids (S.S.) | 100 | 100 | 100 | (daily avg.150) 200 |
| 3 | particle size of S.S. | shall pass 850μ IS sieve | shall pass 850μ IS sieve | | |
| 4 | dissolved solids (inorg.) | 2,100 | 2,100 | | |
| 5 | PH | 5.5~9.0 | 5.5~9.0 | 5.5~9.0 | 5.8~8.6 |
| 6 | temperature ℃ | note 2 | note 2 | | |
| 7 | oil and grease | 10 | 10 | 10 | 35 in total |
| 8 | total residual chlorine | 1.0 | 1.0 | | |
| 9 | ammoniacal nitrogen (as N) | 50 | 50 | 50 | |
| 10 | total Kjeldahl nitrogen (as N) | 100 | 100 | | (daily avg.60) 120 |
| 11 | free ammonia (as $NH_3$) | 5.0 | 5.0 | | |
| 12 | $BOD_5$ | 30 | 30 | 30 | (daily avg.120) 160 |
| 13 | COD | 250 | 250 | | 220~270 (for coke ovens) |
| 14 | As | 0.2 | 0.2 | | 0.5 |
| 15 | Hg | 0.005 | 0.01 | | 0.005 |

Table 5.3.1   STANDARDS FOR EFFLUENTS DISCHARGED INTO INLAND
SURFACE WATER FROM SRC DEMONSTRATION PLANT
- TOLERABLE LIMITS (2/3)

(generally expressed in mg/l)

| No | Item | Standards to be applied to SRC demonstration plant | Reference | | Japanese national standards |
|----|------|------|------|------|------|
| | | | Indian national standards* | | |
| | | | general | coke ovens | |
| 16 | Pb | 0.1 | 0.1 | | 1 |
| 17 | Cd | 0.1 | 2.0 | | 0.1 |
| 18 | $Cr^{+6}$ | 0.1 | 0.1 | | 0.5 |
| 19 | total Cr | 2.0 | 2.0 | | 2 |
| 20 | Cu | 3.0 | 3.0 | | 3 |
| 21 | Zn | 5.0 | 5.0 | | 5 |
| 22 | Se | 0.05 | 0.05 | | |
| 23 | Ni | 3.0 | 3.0 | | |
| 24 | B | 2.0 | 2.0 | | |
| 25 | cyanide (as CN) | 0.2 | 0.2 | 0.2 | 1 |
| 26 | chloride (as Cl) | 1,000 | 1,000 | | |
| 27 | fluoride (as F) | 2.0 | 2.0 | | 15 |
| 28 | dissolved phosphates (as P) | 5.0 | 5.0 | | (daily avg.8) 16 |
| 29 | sulfate (as $SO_4$) | 1,000 | 1,000 | | |
| 30 | sulfide (as S) | 2.0 | 2.0 | | |
| 31 | pesticides | absent | absent | | |
| 32 | phenolic compds. (as $C_6H_5OH$) | 5 | 1.0 | 5 | 5 |
| 33 | $\alpha$-emmitters ($\mu$c/ml) | $10^{-7}$ | $10^{-7}$ | | |
| 34 | $\beta$-emmitters ($\mu$c/ml) | $10^{-6}$ | $10^{-6}$ | | |
| 35 | dissolved F | – | | | 10 |
| 36 | dissolved Mn | – | | | 10 |

Table 5.3.1  STANDARDS FOR EFFLUENTS DISCHARGED INTO INLAND
SURFACE WATER FROM SRC DEMONSTRATION PLANT
- TOLERABLE LIMITS (3/3)

(generally expressed in mg/l)

| No | Item | Standards to be applied to SRC demonstration plant | Reference | | |
|----|------|------|------|------|------|
| | | | Indian national standards* | | Japanese national standards |
| | | | general | coke ovens | |
| 37 | No. of coliform groups (/ml) | - | | | (daily avg.) 3,000 |
| 38 | org. phosphorus | - | | | 1 |
| 39 | alkyl Hg compds. | - | | | not detectable |
| 40 | PCB | - | | | 0.003 |

Note 1   All efforts should be made to remove colour and unpleasant odour as
far as practicable.

Note 2   Shall not exceed 40℃ in any section of the stream within 15 meters
downstream from the effluent outlet.

remark:* Indian national standards is the synonym of MINAS.
Notification of Ministry of Environment & Forests, Government of India,
Schedule II, Sept. 12, 1988 and IS2490 Part VII (1981) for effluents
from coke ovens.

Table 5.3.2    NATIONAL STANDARDS OF AMBIENT AIR QUALITIES
IN INDIA AND JAPAN

(unit:ppm, Figures in parentheses show values in $\mu g/M^3$.)[*]

| Nation | India[**] | | | Japan |
|---|---|---|---|---|
| Area | industrial & mixed use | residential & rural | sensitive | |
| S.P.M.[***] | 0.50 (500) | 0.20 (200) | 0.10 (100) | daily 0.10 hourly 0.20 |
| SO₂ | 0.04 (120) | 0.03 (80) | 0.01 (30) | daily 0.04 hourly 0.1 |
| CO | 4 (5,000) | 2 (2,000) | 0.9 (1,000) | daily 10 hourly 20 |
| NOx | 0.06 (120) | 0.04 (80) | 0.02 (30) | daily 0.04～0.06 |
| Photochemical oxidants | − | − | − | hourly 0.06 |

Remarks:*    Figures in parentheses are the formal values in MINNAS.
         **    The above limits should not be exceeded in 95% of the time.
        ***    S.P.M. means suspended particulate matters.

Table 5.3.3  JAPANESE NATIONAL GENERAL EMISSION STANDARDS FOR SOOT AND DUST*1

| Type of Facility | Type of Fuel | Volume of Flue Gas ($10^4 Nm^3/h$) | General Emission Standard ($mg/Nm^3$) | *2 On (%) |
|---|---|---|---|---|
| Boiler | Gas | Less than 4 | 100 | 5 |
| | Liquid or liquid-gas mixture | Less than 1<br>$1\sim4$<br>$4\sim20$ | 300<br>250<br>150 | 4 |
| | Coal | Less than 4<br>$4\sim20$ | 300<br>200 | 6 |
| Process heaters for the production of coal tar products, etc. | | Less than 4<br>More than 4 | 150<br>100 | 6 |

Remarks:

*1  abstracted data which are deemed to be useful in the designing of SRC
    Demonstration Plant.

*2  specified oxygen concentration in flue gas to be used in the following
    equation.

$$C = \frac{21 - On}{21 - Os} \times Cs$$

where

C  : soot and dust emission concentration

Cs: actually observed soot and dust emission
    concentration

Os: actual oxygen concentration in flue gas

Table 5.3.4   JAPANESE NATIONAL EMISSION STANDARDS FOR NOx[*1]

| Type of Facility | Type of Fuel | Volume of Flue Gas ($10^4 Nm^3/h$) | General Emission Standard [*2] ($mg/Nm^3$) | On (%) |
|---|---|---|---|---|
| Boiler | Gas | Less than 1<br>1~4 | 150<br>130 | 5 |
| | Solid fuel (including coal) | Less than 4<br>4~70 | 350<br>250 | 6 |
| | Liquid | Less than 1<br>1~50 | 180<br>150 | 4 |
| Process heaters for the production of coal tar products, etc. | | 0.5~1<br>1~4 | 150<br>130 | 6 |

Remarks:

*1   abstracted data which are deemed to be useful in the designing of SRC Demonstration Plant.

*2   to be applied to newly built facilities.

Table 5.3.5    AMBIENT AIR QUALITY STANDARDS IN RESPECT OF NOISE
IN INDIA (1989)

| Category of Area<br><br>Area Code | Noise Limits in dB(A) | |
| --- | --- | --- |
| | Day Time | Night Time |
| (A) Industrial area | 75 | 70 |
| (B) Commercial area | 65 | 55 |
| (C) Residential area | 55 | 45 |
| (D) Silence Zone | 50 | 40 |

Note-1    Day time is reckoned in between 6 a.m., and 9 p.m.

Note-2    Night time is reckoned in between 9 p.m., and 6 a.m.

Note-3    Silence zone is defined as areas upto 100 meters
around such premises as hospitals, educational
institutions and courts.   The Silence zones are to be
declared by the Competent Authority.
Use of vehicular horns, loudspeakers and bursting of
crackers shal be banned in these zones.

Note-4    Mixed categories of areas should be declared as one
of the four above mentioned categories by the
Competent Authority and the corresponding standards
shall apply.

Table 5.3.6 REGULATORY STANDARDS FOR NOISE EMITTED FROM SPECIFIED
FACTORIES (SUMMARY) IN JAPAN (AMENDED IN 1986)

| Time<br>Area | Daytime | Morning<br>Evening | Nighttime | Applicable Areas |
|---|---|---|---|---|
| I | 45dB(A)-<br>50dB(A) | 40dB(A)-<br>45dB(A) | 40dB(A)-<br>45dB(A) | Areas where maintenance of quiet is particulaly needed to preseve a good living environment. |
| II | 50dB(A)-<br>60dB(A) | 45dB(A)-<br>50dB(A) | 40dB(A)-<br>50dB(A) | Areas where quiet is needed for as they are used for residential purposes. |
| III | 60dB(A)-<br>65dB(A) | 55dB(A)-<br>65dB(A) | 50dB(A)-<br>55dB(A) | Areas used for commercial and industrial as well as residential purposes where there is a need to preserve the living environment of local residents. |
| IV | 65dB(A)-<br>70dB(A) | 60dB(A)-<br>70dB(A) | 55dB(A)-<br>65dB(A) | Areas mainly serving industrial purposes which are in need of measures to prevent the living environment of local residents from deteriorating. |

Note: Noise level shall be measured at the boundary line of the
specified factory.

Table 5.3.7 THRESHOLD LIMIT VALUE(TLV) FOR 8 HOURS WORKING BY IPSS
*(TIME WEIGHED AVERAGE CONCENTRATION (T.W.A.))

| Item / TLV/8 hours | T.W.A.* $(mg/Nm^3)$ | T.W.A.* (ppm) |
|---|---|---|
| S.P.M. (<10$\mu$) | 5 | |
| S.P.M. (total) | 10 | |
| SO$_2$ | 13.6 | 5 |
| NOx | 6 | 3 |

Table 5.3.8    PERMISSIBLE EXPOSURE IN AREAS OF CONTINUOUS NOISE
BY IPSS

| Total time exposure (Continuous or a No. of short exposures per day) | Sound pressure levels |
|---|---|
| Hours | dB(A) |
| 8 | 90 |
| 6 | 92 |
| 4 | 95 |
| 3 | 97 |
| 2 | 100 |
| 1 1/2 | 102 |
| 1 | 105 |
| 3/4 | 107 |
| 1/2 | 110 |
| 1/4 | 115 |

Other recommendations:

   100    impulses per day for 140 dB(A)

   1,000 impulses per day for 120 dB(A)

Table 5.3.9  HEIGHT OF STACKS

| No. | Service | Quantity of SO₂ (kg/h) | NOx Concentration in flue gas(ppm) | S.P.M.Concentration in flue gas (g/Nm³) | Designed stack height (m) |
|---|---|---|---|---|---|
| BA101 | coal heater | 4.7 | 70 | 0.0 | 40 |
| BA201 | dissolver heater | 36.2 | 250 | 0.0 | 60 |
| BA401 | fractionator heater | 22.6 | 250 | 0.0 | 60 |
| BA1901 | hot oil heater | 13.9 | 250 | 0.0 | 50 |
| BF1000 | boiler | 54.8 | 750 | 0.15 | 80 |

Table 5.3.10   MATERIAL BALANCE OF WASTE WATER AT ACTIVATED SLUDGE TREATMENT

| Stream<br>Component | Stripped sour water (total) | CWBD | Treated plant oily water | Total feed to AS | AS treated water | Additional CWBD | Finally discharged water |
|---|---|---|---|---|---|---|---|
| $H_2O$ (kg/h) | 1,915 | 4,600 | 200 | 6,715 | 6,715 | 45,400 | 52,115 |
| Phenols (mg/ℓ) | 5,000 | - | - | 1,450 | 5 | - | 1 |
| $NH_3$ (mg/ℓ) | 50 | - | - | 15 | 5 | - | 1 |
| $H_2S$ (mg/ℓ) | 5 | - | - | 2 | - | - | - |
| $BOD_5$ (mg/ℓ) | 5,000 | - | 700 | 1,500 | 25 | - | 3 |
| COD (mg/ℓ) | 10,000 | - | 3,500 | 3,000 | 230 | - | 30 |
| S.S. (mg/ℓ) | - | - | 70 | - | 30 | - | 4 |

Remarks: 1. Contaminations by CWBD itself are disregarded.
2. Sludge cake production is estimated to be about 50kg/h (wet base).

INPUT DATA

ITEM NO: BA-101,-201,-401,-1901,BF-1000

| METEOROLOGICAL DATA | T1 | = | 15.000 | (.C) | AMBIENT TEMPRATURE. |
| | U | = | 3.000 | (M/SEC) | MEAN WIND SPEED. |
| | THEATA | = | 0.0 | (DEGREE) | MEAN WIND DIRECTION. |
| | DTHDZ | = | 0.010 | (.C/M) | GRADIENT OF POTENTIAL ATMOSPHERIC TEMPRATURE. |

STACK DATA

| NO | NAME | EFFLUENT | HO(M) | HE(M) | D(M) | TE(.C) | VG(M/S) | QV1(NM3/S) | CONC(%) | XO(M) | YO(M) |
|----|------|----------|-------|-------|------|--------|---------|------------|---------|-------|-------|
| 1 | BA101 | | 40.0 | 45.8 | 0.700 | 80.0 | 5.018 | 1.493 | 0.029590 | 315.0 | 1485.0 |
| 2 | BA201 | | 60.0 | 95.7 | 1.420 | 180.0 | 6.956 | 6.637 | 0.052740 | 215.0 | 1485.0 |
| 3 | BA401 | | 60.0 | 93.4 | 1.290 | 250.0 | 6.967 | 4.070 | 0.054030 | 125.0 | 1450.0 |
| 4 | BA1901 | | 50.0 | 72.8 | 1.010 | 250.0 | 5.994 | 2.506 | 0.054320 | 0.0 | -1540.0 |
| 5 | BF1000 | | 80.0 | 147.8 | 2.180 | 180.0 | 6.957 | 15.644 | 0.028710 | 70.0 | 1550.0 |
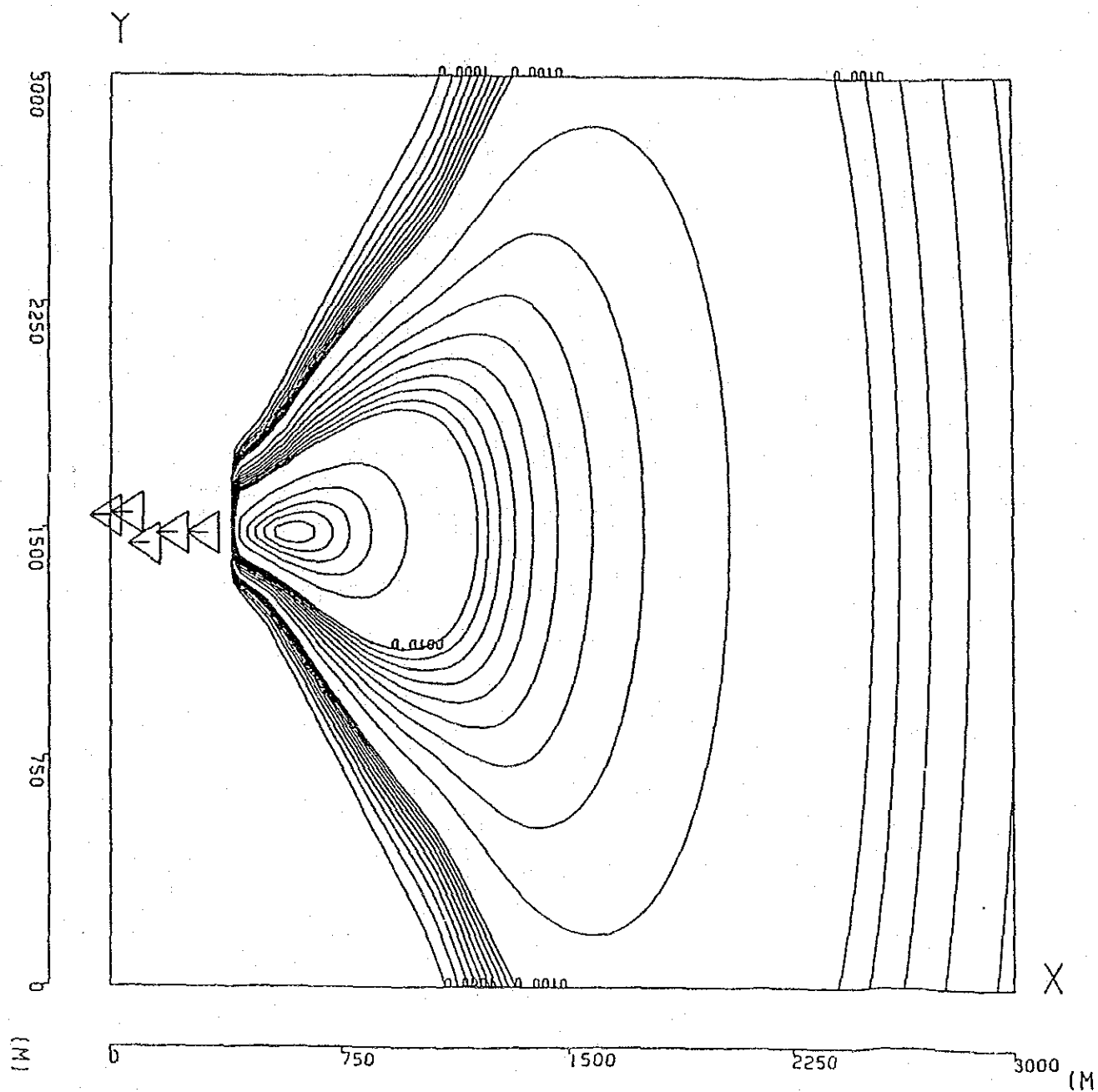
OUTPUT DATA

CMAX= 0.661139E-01 (PPM)

MAXIMUM CONCENTRATION AT THE POINT X= 600.0M, Y= 1500.0M

Figure 5.3.2
NOISE LEVEL CONTOUR MAP

Note;
" ........ Noise source
Unit ...... dB A

THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

DWG. NO.                    JICA

**Chapter 6  SELECTION OF CANDIDATE COAL VARIETIES AND
SELECTION OF SRC DEMONSTRATION PLANT SITE**

# Chapter 6   SELECTION OF CANDIDATE COAL VARIETIES AND SELECTION OF SRC DEMONSTRATION PLANT SITE

## 6.1   Selection of Candidate Coal Varieties

It is necessary to select two types of coal in this study.

One of these will be employed as SRC feedstock.   The design of plant will then be made on the assumption of use of the coal which is selected from the five candidate coals proposed as SRC feedstock.   Secondly, a non-coking coal variety is to be selected for blending with SRC for coke production.

The following is a summary of the selection methods, procedures and conclusions.

### 6.1.1   SRC Feedstock Coal

As shown in the Chapter 3, Section 2, selection of SRC feed coal will be made on the basis of evaluation of the product yields obtained in autoclave tests and of evaluation of the SRC performance obtained in a coke production test.   In addition to the above criteria, factors such as construction conditions of the demonstration plant, economic conditions, the management capability of the demonstration plant, etc. need to be considered for the selection.

The five candidate coals have been selected by the Indian party giving consideration to the quantity of the reserves as shown in section 3.2 already.   Further, it is judged from data received during the on site survey that there are sufficient quantities of each to meet the requirements of the service life of a 500 t/d demonstration plant.

In order to select one coal variety and one set of reaction conditions from the five candidate coal varieties autoclave tests were conducted in two phases being TEST-1

and TEST-2 as described in section 3.3.

The following details the procedure followed:

(1) Selection of Two Varieties from the Five Candidate
    Coals

    TEST-1 is designed to select two varieties from the
    five candidate coals. As detailed in section 3.3.6,
    under TEST-1 conditions using tetralin as solvent
    Assam coal has the highest solubility followed by
    Neyveli lignite and Samla coal, though it is difficult
    to establish relative superiority between these latter
    two varieties. The ash content and insoluble matter
    found in Argada-Sirka coal and oil agglomerated
    middlings is large and consequently the product oil
    yield is low so that it is anticipated that in actual
    operations a shortage of recirculating solvent would
    arise thus hindering the establishment of the process.
    The above two candidates are therefore eliminated from
    selection. Results of TEST-1 show that Assam coal is
    the best option of the five. To select the second
    coal a comparison of Neyveli lignite and Samla coal is
    necessary. A critical problem with both of these
    candidates is the location of the SRC plant. The
    study team judges that promotion of the SRC project
    should be carried out by SAIL and not by a coal
    company (refer to section 6.2) and therefore concludes
    that the most appropriate construction site for the
    demonstration plant is within the Rourkela Steel
    Plant. Lignite has a 50% moisture content and is
    susceptible to spontaneous combustion so that problems
    are envisaged in its transport. As the lignite mine
    is found some 1,700 km away from the RSP, high
    transport costs are unavoidable. Samla coal, on the
    other hand, is mined close to the RSP and so is
    advantaged in terms of transport cost and convenience.
    These advantages probably explain why the Indian party
    choose Samla coal as their first candidate coal. It
    is therefore concluded in view of these advantages

that the selection of Samla coal is more justified
than that of Neyveli lignite. Assam and Samla coal
were therefore the coal varieties selected for TEST-2.

(2) Selection of One Coal from the Two Candidate Varieties

TEST-2 consisted of autoclave tests using tetralin and
anthracene oil as solvent conducted to compare the
solubility, product yields and optimum reaction
conditions of Samla and Assam coals. Three different
levels were chosen for the reaction temperature since
this was found to be the test condition which had most
influence on the SRC product yield. Six test cases
resulted from the two sample coal varieties and three
sets of condition selected. Using SRC samples
produced in the six test cases the coke production
test was carried out to evaluate SRC performance in
terms of coke production. Selection of the coal
variety best suited as SRC feedstock and of the
optimum reaction conditions was done on the basis of
these test results.

Results showed that in terms of product yield Assam
coal is superior to Samla coal (refer to 3.3.7 for
details). On the other hand as mentioned in 4.4.3
results of the production test of SRC blended coke
showed that no clear difference in SRC performance was
found to result from the use of different feed coals
or differing reaction conditions.

Therefore in terms of SRC production Assam coal is at
an advantage because of its high product yield.
However, Samla coal has advantages in terms of its
supply position since it is mined in the main
coalfields of Eastern India and is located near to the
steel plants. It is therefore judged acceptable to
choose Samla coal as the base case for this pre-
feasibility study if this is shown to generate income.
Trial calculations of coke production costs for Assam
and Samla coal were therefore carried out as a

preliminary measure. Tables 6.1.1 and 6.1.2 show
calculations of production costs of SRC based on Assam
coal and Samla coal respectively. Table 6.1.3
indicates the current coke production costs at the
Rourkela Steel Plant compared to the cost of coke
produced using SRC from Assam and Samla feedstocks.
The cost of SRC plant facilities was estimated at
US$264 million in the case of Assam and at US$308
million in the case of Samla. Calculations were made
on the basis of a blending ratio in coke production of
5% SRC with 10% for non-coking coal. In the case of
Assam SRC the coke production cost is close to present
level, but in the case of Samla SRC the cost is much
higher than existing level. It is therefore concluded
that Samla SRC is not expected to prove profitable.

It was therefore concluded as a result of the above
that Assam coal was the most suitable choice for use
as the base case of the present pre-feasibility study.
For reference, consideration was also given to the
alternative case in which the second candidate Samla
coal is used.

Furthermore, JICA team was requested by Indian party
to consider a case of 50:50 ratio of Assam coal and
Samla coal as a SRC feed stock during 3rd visit of
India. Although a test of such mixed coal was not
conducted, an assumed estimation would be carried out
on this case.


6.1.2 Non-coking Coal as Blending Coal for Coke Production

As stated in 3.2.2, in case of the present study Samla has
been chosen from among the five SRC candidate coals as the
non-coking coal for blending in coke production. The
choice is justified since Assam is excluded as it is
already used for metallurgical coke as a blendable coal
because of its coking quality. Neyveli lignite is
inappropriate as a coke feed because of its lignite

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nature. Oil agglomerated middlings are the de-ashed
washed middlings of coking coal but retain a high ash
content and so are unsuitable. The only remaining possi-
bilities are Samla and Argada-Sirka coals, and a
comparison of their ash content shows that Samla, with the
lower level, is more suited. However, since Samla was
initially chosen as a candidate for SRC feedstock it has a
higher volatile matter and a lower coalification. It is
apparent from 4.3.2 indicating the coal blend of India
that the charge coals used have much higher fluidity than
those used in Japan. A marked effect from the SRC blend
cannot be obtained in the case of the addition of high
fluidity SRC to a high fluidity Indian blending coal when
the non-coking coal blended is a coal with low
coalification properties as in the case of Samla coal.

Therefore, it is considered that selection of a proper
non-coking coal for blending with coking coal is necessary
in future.

## 6.2 Selection of SRC Demonstration Plant Site

The Rourkela Steel Plant has been selected by the preliminary study team as the first candidate site for construction of the SRC demonstration plant. It was decided to investigate other possible sites where SRC feed coal was available. Only the availability of site conditions was investigated regarding feed coal oriented sites by their low imperativeness.

The following is a summary of the results of the preliminary study.

### 6.2.1 Conditions of the Rourkela Steel Plant Site

#### (1) Location

Rourkela is a town centreing around the steel plant located in Orissa State in the Eastern part of India, about 350 km to west of Calcutta. (distance by rail: 415 km)

The candidate site proposed for consideration is found inside the Rourkela Steel Plant (RSP) premises.

The surrounding area is mostly flat with slight hilly undulations in some places. Industrial water is taken from the River Sankh which is a branch of the river Brahmani.

Figures 6.2.1 and 6.2.2 are maps of the area around the RSP. RSP is an integrated steel plant with four blast furnace faces and it produces various steel products with a main production of approximately 1.3 million tons of hot metal. Operations started in 1959.

Further, it possesses five coke oven batteries with by-product refining facilities for these and produces various types of tar product and benzol product. In addition there is a fertilizer plant and thermal power station. The fertilizer plant produces Calcium Ammonium Nitrate and the thermal power station generates about 130 MW of electricity which meets about 90% of the power requirements of the plant complex.

Details of the coke oven equipment relating to the SRC demonstration plant are given in the following section (2). Further, the details of the proposed demonstration plant site and plant equipment available for use are given in the Chapter 7.

(2) Operations and Present Situation of Blast Furnace, Coke Oven and Production Facilities for Coke By-products

1) Outline

In 1989-90 the Rourkela Steel Plant produced 1,261,011 tons of hot metal, 1,318,503 tons of dry coke, 476,556,000 $m^3$ of coke oven gas, 51,504 tons of crude tar, 5,527 kl of crude benzol and 12,030 tons of ammonium sulphate.

Figure 6.2.3 shows the production flow of coke and coke by-products (both primary and secondary by-products) for 1989-90.

A comparison of production achievement with the production schedule for 1989-90 shown in The 'Corporate Plan up to 2000 AD, May 1987' reveals that the production record for hot metal output achieves 93.4% of the output scheduled , the consumption record for coke feedstock coal is 82.7% of that scheduled, and the consumption record for coke feedstock is 90.3% of that scheduled. In each

case the achievement is below the scheduled levels.

Table 6.2.1 shows a comparison of the actual performance in 1989-90 and the production schedules for that year for hot metal, coke and coke by-products in the Rourkela Steel Plant.

In 1990-91 the Rourkela Steel Plant produced 1,326,000 tons of hot metal, 1,218,802 tons of dry coke, 46,263 tons of crude tar, 4,763 kl of crude benzol and 11,060 tons of ammonium sulphate.

Figure 6.2.4 shows the production flow of coke and coke by-product (both primary and secondary by-products) for 1990-91.

2) Furnace Operations

Table 6.2.2 indicates the Blast Furnace operations in the Rourkela Steel Plant in 1989-90. According to this the Face I Blast Furnace of the Rourkela Steel Plant began operations in January, 1959. The Face II Blast furnace began operations in January, 1960, the Face III Blast furnace in January, 1962 and the Blast Furnace IV began in July, 1962.

The effective (useful) capacity in 1989-90 was 1,139 $m^3$ for Blast Furnaces I, II and III and 1,658 $m^3$ for Blast Furnace IV giving a total for all four together of 5,075 $m^3$.

The productive capacity of the blast furnaces in 1989-90 is indicated as 1,000 t/d in the case of Faces I, II and III and 1,500 t/d for Blast furnace IV giving a total of 4,500 t/d for the combined capacity but the actual average production is about 3,660 t/d, with a maximum production of 5,152 tons recorded.

Hot metal production in 1989-90 was 339,491 tons for Face I, 335,601 tons for Face II, 327,405 tons for Face III and 258,514 tons for Face IV giving a total of 1,261,011 tons for combined output. Hot metal total production in 1990-91 was 1,326,000 tons.

1,178,345 tons of hot metal representing 93.4% of the total output was sent to the Steel Melting Shop (S.M.S) in 1989-90 and the remaining 82,666 tons was sent to the Pig Casting Machine (P.C.M).

The coke ratio for 1989-90 (coke in kg per ton of hot metal) was 733 for Face I, 727 for Face II, 710 for Face III and 733 for Face IV, with an average of 725 for the four.

3) Operations of Coke Ovens

There are five batteries of coke ovens at the Rourkela Steel Plant, three of the batteries (composed of Batteries I, II and III with 70 ovens each) were constructed to meet the needs of a one million ton unit (one million ton crude steel facility) and the remaining two batteries (composed of Battery IV with 80 ovens and Battery V with 80 ovens) were constructed to meet a 0.8 million ton unit (800,000 ton crude steel facility).

The individual batteries are composed of Sub-batteries (a) and (b) organized as shown in the table below:

## Coke Ovens of the Rourkela Steel Plant

| ITEM | | BATTERY I | BAT. II | BAT. III | BAT. IV | BAT. V | TOTAL |
|---|---|---|---|---|---|---|---|
| Commissioned | (a) | 22.3.60 | 3.12.58 | 7.11.62 | 30.12.66 | 21. 9.74 | |
| | (b) | 5.4.60 | 5. 1.59 | 21.11.62 | 6. 2.69 | 27.12.83 | |
| Oven Installed | (a) | 35 | 35 | 35 | 40 | 40 | |
| | (b) | 35 | 35 | 35 | 40 | 40 | |
| | (a+b) | 70 | 70 | 70 | 80 | 80 | 370 |

Operation Records for 1989-90

| | BATTERY I | BAT. II | BAT. III | BAT. IV | BAT. V | TOTAL |
|---|---|---|---|---|---|---|
| Ovens operated | 68 | 56 | – | 80 | 39 | 243 |
| Ovens pushed (Nos.) | 28,950 | 22,622 | – | 34,562 | 17,492 | 103,626 |
| Coking times (h-m) | 20-35 | 21-41 | – | 20-17 | 19-32 | 20-33 |

Source: Annual Statistics 1989-90, Rourkela Steel Plant.

In 1989-90 repairs were being made on (a) and (b) ovens of battery III and on (b) ovens of Battery V so that of the total 370 ovens operations were limited to 243 ovens. In 1990-91 238 ovens were operated.

All of the coke ovens of Rourkela Steel Plant are of an underjet compound regenerative type having a single collecting main. The effective capacity is 21.6 m$^3$, dimensions are 4,500 mm high by 13,590 mm long by 400 mm wide, and a coal charge of 18 tons is possible.

The design data for the coke ovens of the Rourkela Steel Plant are as follows:

a) Dry coal charge per oven      17.28 t
b) Oven Dimensions
   * Height                        4,500 mm
   * Width                          400 mm
                (R/S 370 mm, C/S 430 mm)

```
* Length                        13,590 mm
* Oven centre to centre          1,100 mm
* Burner height                    625 mm
                                  (big)
* Burner height                    250 mm
                                  (small)
```

Source: Preliminary Survey Report for the Pre-
feasibility Study on the Solvent Refined
Coal Development Project in India.

Table 6.2.3 indicates the operational situation of
the coke ovens in 1989-90.  According to this data
the operational situation can be summarized as
follows.

The coal charge to coke ovens in 1989-90 was
1,736,104 tons on a dry basis, and 707,940 tons of
washed Prime Coking Coal (P.C.C.) on a wet basis,
483,480 tons of coal was imported, and an input of
647,120 tons of washed Medium Coking Coal (M.C.C.)
and of 24,450 tons of High Volatile Coal (H.V.)
recorded giving a total charge of wet coal of
1,862,990 tons.  The blending ratio of wet charge
coal was 38% washed P.C.C., 26% imported coal,
34.7% M.C.C. and 1.3% H.V. Coal.  The average coal
charge per oven was 16.75 tons.

The coal charge to coke ovens in 1990-91 was
1,606,132 tons on dry basis.  On a wet basis,
637,525 tons of P.C.C., 533,933 tons of imported
coal, 548,027 tons of M.C.C. and 6,476 tons of H.V.
Coal were charged to coke ovens giving a total of
1,725,961 tons.

The blending ratio of wet charge coal was 36.9%
P.C.C., 30.9% imported coal, 31.8% M.C.C. and 0.4%
H.V. Coal.

The dry basis production of the Rourkela Steel
Plant in 1989-90 was 1,098,314 tons of dry basis
Hard Coke, 78,710 tons of Nut Coke and 141,479 tons
of Mixed Coke giving a total of 1,318,503 tons.
The coke (dry basis) yield for 1989-90 at Rourkela
Steel Plant was 63.26% for Hard Coke, 4.54% for Nut
Coke, 8.15% for Mixed Coke with a total coke yield
(dry basis) of 75.95%.

The dry basis production of the Rourkela Steel
Plant in 1990-91 was 1,015,263 tons of dry basis
Hard Coke, 67,502 tons of Nut Coke and 136,037 tons
of Mixed Coke giving a total of 1,218,802 tons.
The coke (dry basis) yield for 1990-91 at Rourkela
Steel Plant was 63.21% for Hard Coke, 4.20% for Nut
Coke, 8.47% for Mixed Coke with a total coke yield
(dry basis) of 75.88%.

4) Operations of By-product Production Facilities

The facilities for production of coke by-products
in operation at the Rourkela Steel Plant include
the crude tar distillation equipment, the crude
benzol refining and distillation facilities, and
the ammonium sulphate production facilities.

The by-products of coke are roughly divided into
the categories of primary and secondary by-
products. Primary by-products include coke oven
gas, crude tar, crude benzol and ammonium sulphate.
Secondary by-products are tar products produced by
processing of the crude tar, and benzol products
refined from the crude benzol. Table 6.2.4 shows
the production records for by-products at the
Rourkela Steel Plant.

The capacity of the crude tar distillation
facilities is 300 t/d (100,000 t/y) and the
capacity of the benzol refining facilities is 50
t/d (16,670 t/y). In 1989-90 52,530 tons of crude

tar was distilled and 5,462 tons (6,305 kl) of crude benzol was refined so that the operating rate of the crude tar distillation facilities is calculated at 51.5% while the operating rate of the benzol refining facilities was very low achieving only 32.8%.

Output of primary coke by-products at the Rourkela Steel Plant in 1989-90 was 476,556,000 $Nm^3$ of Coke Oven Gas, 51,504 tons of crude tar, 5,527 kl (4,786 tons) of crude benzol and 12,030 tons of ammonium sulphate.

For tar products 52,530 tons of crude tar was distilled and a total of 51,102 tons of tar processed products produced from this consisting of 25,600 tons of extra hard pitch, 9,722 tons of coal tar heavy oil, 5,444 tons of wash oil, 3,391 tons of crude naphthalene oil, 171 tons of light oil, 1,537 tons of ammonia liquor and 1,557 tons of crude carbolic oil.

Crude naphthalene was processed and 1,058 tons of pressed naphthalene oil and 2,027 tons of hot pressed naphthalene separated out and prodced.

Crude carbolic acid was also processed and 1,469 tons of sodium phenolate was produced which was in turn processed to produce 64 tons of pure phenol, 1,166 tons of neutral oil and 127 tons of M.P. Cresol/Cresylic acid.

5,342 kl of raffinate was produced by compressed hydrogenation to the crude benzol. Stock raffinate was added to this raffinate output and 5,362 kl was refined to produce a variety of benzol products. The total output of benzol products in 1989-90 was 4,991 kl consisting of 3,011 kl of benzol, 1,088 kl of toluene, 381 kl of solvent naphtha, 449 kl of fore runnings and 62 kl of industrial benzol.

Output of primary coke by-product at the Rourkela
Steel Plant in 1990-91 was 46,263 tons of crude
tar, 4,763 kl of crude benzol and 11,060 tons of
ammonium sulphate.

Figure 6.2.4 shows the output of tar products and
benzol products by product in 1990-91.

(3) Future Operation Schedule for Blast Furnaces, Coke
Ovens and Coke By-product Production Facilities

1) Outline

The production schedule for hot metal, coke and
coke by-products in 1995 (after modernisation) and
in 1999-2000 at the Rourkela Steel Plant is shown
in Figures 6.2.5 and 6.2.6.

In 1995 2 million tons of hot metal, 1,490,000 tons
of metallurgical coke, 85,700 tons of crude tar,
11,200 tons of crude benzol, 20,200 tons of
ammonium sulphate and 616,700,000 $m^3$ of COG are
scheduled to be produced at the Rourkela Steel
Plant.

In 1999-2000 3.18 million tons of hot metal,
2,093,000 tons of metallurgical coke, 94,700 tons
of crude tar, 15,000 tons of crude benzol, 26,900
tons of ammonium sulphate and 822,000,000 $m^3$ of COG
are scheduled to be produced at the Rourkela Steel
Plant.

2) Blast Furnace Operations

The annual productive capacity of blast furnaces at
the Rourkela Steel Plant is scheduled to be 2.04
million tons in 1994-95 and to reach 3.271 million
tons in 1999-2000.

This increased productive capacity will be realized
by improvements in furnace productivity in 1994-95
and in 1999-2000 and by the installation of a new
blast furnace in 1999-2000.

The productivity (measured as hot metal tons per
day per blast furnace volume) of blast furnaces of
the Rourkela Steel Plant was recorded at 0.703
$t/d/m^3$ in 1989-90. The target levels for scheduled
improvements is to reach 1.130 $t/d/m^3$ in 1994-95
and 1.300 $t/d/m^3$ in 1999-2000. The effective
(useful) volume of a blast furnace in 1989-90 was
5,075 $m^3$ and it is scheduled to increase this to
7,075 $m^3$ in 1999-2000.

The coke ratio (kg of metallurgical coke per ton of
hot metal) recorded for the Rourkela Steel Plant in
1989-90 was 725.4 but improvement targets are fixed
for 700 in 1995 and 600 in 1999-2000. The hot
metal production schedule for 1995 is 2 million
tons which is to be expanded to 3.18 million tons
in 1999-2000. Consequently, the consumption of
metallurgical coke is forecast to be 1.40 million
tons for 1995 and 1.908 million tons in 1999-2000.

3) Coke Oven Operations

It is anticipated that the coke ovens of Rourkela
Steel Plant now undergoing repairs will all be in
working order by 1994-95 so that it is forecast
that in 1994-95 five oven batteries will be
operating and a total of 370 ovens be in use.

Construction of a new battery of ovens is scheduled
to be effected by 1999-2000 so that it is
anticipated that there will six oven batteries in
operation with 450 ovens in 1999-2000.

Coke production is scheduled to reach 1.768 million
tons in 1995 and 2.272 million tons in 1999-2000,

of which output 1.49 million tons is scheduled to
be metallurgical coke in 1995 and 2.093 million
tons in 1999-2000.

The yield of dry metallurgical coke for each ton of
coal charge was recorded at 677.9 kg in 1989-90,
674.1 kg in 1990-91, and it is forecast to increase
this yield to 700 kg in 1999-2000.

4) Operations of Coke By-product Production Facilities

The schedules for the production outputs and yields
in relation to coal charge of coke by-products at
the Rourkela Steel Plant in 1995 and 1999-2000 are
shown below:

| Product | 1994-95 | | 1999-2000 | |
|---|---|---|---|---|
| | Output | Yield | Output | Yield |
| Crude Tar | 85,700 t | 3.80% | 94,700 t | 3.17% |
| Crude Benzol | 11,200 t | 0.50% | 15,000 t | 0.50% |
| Ammonium Sulphate | 20,200 t | 0.90% | 26,900 t | 0.90% |
| COG | 616,700,000 $Nm^3$ | 273.3 $Nm^3/t$ | 822,000,000 $Nm^3$ | 274.9 $Nm^3/t$ |

Source: Corporate Plan upto 2000 AD (May, 1987)

The present coke by-product facilities of the
Rourkela Steel Plant have enough capacity to meet
the production schedules of 1994-95 and 1999-2000.

| Product | Processing | Processing Capacity | Output for Processing in Production Schedules | |
|---------|-----------|---------------------|----------------------------------------------|--|
| | | 1990 (t/y) | 1994-95 (t/y) | 1999-2000 (t/y) |
| Crude Tar | Distillation | 100,000 | 85,700 | 94,700 |
| Crude Benzol | Compressed Hydrogenation | 16,670 | 11,200 | 15,000 |

Source: Rourkela Steel Plant Annual Statistics and Corporate
Plan upto 2000 AD (May 1987)

The production forecasts for secondary coke by-products in 1995 and 1999-2000 at the Rourkela Steel Plant are as shown in the Corporate Plan upto 2000 AD (May 1987) and are as follows:

(Unit: tons)

| Product | 1995 | 1999-2000 |
|---------|------|-----------|
| H.P Naphthalene | 2,520 | 3,360 |
| Pitch | 33,230 | 44,360 |
| Tar oils | 21,350 | 28,520 |
| Sodium phenolate | 370 | 500 |
| Benzene | 6,720 | 9,030 |
| Toluene | 1,120 | 1,500 |
| Solvents | 450 | 600 |

In addition to the production forecasts for the above secondary coke by-products, forecasts have been made for Hard Pitch, Fuel Tar, Special Tar, Wash Oil, Heavy Oil, C. Carbolic Oil, Crude Naphthalene, Ammonia Liquor, Light Solvent Naphtha, Heavy Solvent Naphtha and Fore-Runnings.

Figures 6.2.5 and 6.2.6 show the production forecasts for these products in 1995 and 1999-2000.

6.2.2  Neyveli Site Conditions

(1) Location

Neyveli is located in the State of Tamil Nadu in the
south of India some 180 km south southwest of Madras
(about 197 km distance by road).

The candidate site is on the premises of Neyveli
Lignite Corp. which carries out quarrying and power
station activities here.

Figure 6.2.7 is a map of the Neyveli Lignite Corp. and
the surrounding area.

(2) Details of Neyveli Lignite Corp.

The Neyveli Lignite Corp. (NLC) was founded in
November, 1956 and possesses a site approximately 300
$km^2$ large on the lignite coalfield.  There are two
mines currently mined on an opencast method which
produce a total of 11.2 million t/y (being 6.5 million
t/y for Mine 1 and 4.7 million t/y for Mine 2).

The main user of the mined lignite are the two thermal
power stations also located inside the company
premises which have a combined generating output of
1,230 MW (the output of Power Station 1 is 600 MW and
of Power Station 2 630 MW).  Besides these a 152,000
t/y Urea Plant and a Briquetting and Carbonization
Plant (selling coke externally) with an annual
capacity of 436,000 tons.

Initially the Urea Plant used a synthesis gas process
to carry out direct solid fuel gasification of the
lignite but technical problems were encountered and in
1979 the plant switched from lignite to petroleum
naphtha as raw material.

The initial aim of the Briquetting and Carbonization
Plant was to supply a substitute for domestic use
charcoal and in addition to this the products of this
plant are used widely as fuel in electrical metallurgy
and electro-chemical workshops, cement plants and
paper mills. The plant uses a low temperature
distillation process and by-products include carbolic
acid, ortho-cresol, para-cresol, xylenol, phenol, etc.

There is also a Centre for Applied Research and
Development (CARD) which is engaged in research and
development activities.

The expansion plans currently under construction are
as follows:

1. expansion of Mine 2 facilities to increase annual
   output from 4.7 million tons to 10.5 million tons

2. expansion of the Power Station 2 to increase
   capacity from 630 MW to 1,470 MW.

3. transmission facilities

(3) Location of Proposed Plant Site

The candidate site proposed by the NLC is a flat area
1,700 m by 1,700 m (2,890,000 m$^2$) next to the
Briquetting and Carbonisation Plant. As this area has
been rendered even using quarried earth from the mines
to fill in any unevenness, the approaches to other
production facilities are good. The location and area
proposed are considered suitable.

(4) Available Facilities and Utilities

1) Electricity

As two large thermal power stations (of 600 MW and 630 MW output) using lignite are located within the NLC site no problems are envisaged to securing a reliable supply of electricity.

2) Steam

As process steam of 20 $kg/cm^2G$ pressure is supplied to the Fertilizer Plant and the Briquetting Plant from the boilers of the power stations it is considered possible to make use of this source.

3) Industrial Water

There are plentiful supplies of underground water which are pumped up from the lignite mines and the water quality is good. At present, excess water amounting to about 50,000 GPM (660 t/h) is supplied for irrigation water to the surrounding farm land.

4) Hydrogen

Since the Urea Plant has currently switched over to use of petroleum naphtha a supply of hydrogen is beyond its capacity. Therefore unless separate equipment is installed a supply of hydrogen gas or hydrogen content gas can not be expected available.

5) Fuel Gas

A supply of fuel gas can not be expected to be available.

6) Fuel Oils (Petrol based)

A large scale refinery, the Madras Refineries Ltd.,

operates at Madras. A supply can be secured from
this Refinery.

Also use of the low temperature distilled tar of
the Briquetting and Carbonisation Plant may also be
possible.

(5) Reception of Raw Materials

Lignite is currently supplied to the Power Station and
Coke Plant by conveyor belt. Lignite could be
received by extending this conveyor belt.

(6) Dispatch of Produced SRC

The product SRC is to be transported to surrounding
Steel Plants. It is considered best to use a rail
siding and transport the product directly by rail.
Transport distances would be about 200 km to Madras
and about 1,700 km to Rourkela.

(7) Personnel

The personnel details for NLC are as follows:

Total                    24,000
Engineers, managers       3,000
Middle rank personnel     7,500
Non-skilled              13,500

A high level of personnel training is realized at NLC
and a reliable workforce of superior quality can be
secured.

(8) Construction Work and Equipment Maintenance

No problem is envisaged in implementation of these
activities since the facilities and workforce of the
NLC can be employed.

(9) Approach Routes

    1) Road

        The site is connected to Madras by Highway No. 45.
        Distance to Madras is 197 km and no problems are
        envisaged for the delivery of materials and
        equipment.

    2) Rail

        There is a rail siding on the site.  The closest
        station is located at 6 km distance.  The line to
        Madras is metre gauge.  This can be used for the
        transport of product SRC.

## 6.2.3 Margherita Site Conditions

(1) Location

    Margherita is located at the north-eastern extremity
    of Assam state located in the north-east of India.
    The office of the North Eastern Coalfields Division of
    Coal India Ltd. is located here.  The Makum coalfield
    and other coalfields of Assam coal are distributed
    around this area.

    Two candidate sites have been proposed by the North
    Eastern Coalfields Division of Coal India Ltd. and
    both are found on the premises of the North Eastern
    Coalfields near to the Ledo colliery which has a large
    coal output.

    Figure 6.2.8 is a map of the eastern region of Assam
    State and Figure 6.2.9 is a map of the proposed
    candidate sites.

(2) Details of North Eastern Coalfields Division of Coal
    India Ltd.

North Eastern Coalfields Division of Coal India Ltd. has an annual output of about 800,000 tons of low ash, low moisture, high volatile coal. About 30% of this output is for metallurgical use. Personnel total about 5,500.

(3) Proposed Plant Site

Two candidate sites on the premises of the North Eastern Coalfields Division of Coal India Ltd. have been indicated for the proposed plant site.

1) SITE-1

This is a site adjoining a river and facing highway 38 and the railway. The plot has been prepared using mined earth from the coalfield and the site has been raised to an even height 15 m above the adjoining small river. There are about 20 residences illegally occupying the site.

2) SITE-2

This is located on the mountain side diagonally opposite Site 1 and faces highway 38 and the railway as with the former site. The site is a relatively flat area surrounded by hilly land. There are no residences or farms located either in the site area or surrounding area.

The North Eastern Coalfields Division of Coal India Ltd. has recommended this second site because it is removed from residential areas.

6.2.4 Selection of the Demonstration Plant Site

As the above evaluation demonstrates the sites of Rourkela, Neyveli and Margherita present no problems in

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terms of space or access for the demonstration plant. However, the conclusion of the present report is to select the Rourkela Steel Plant as the site on the basis of the following reasons:

(1) In the demonstration plant stage it is difficult to envisage the realization of a project which will necessarily prove profitable and generate sufficient profit. It is unlikely that the demonstration plant will generate profit through the production and external sale of SRC. It is therefore necessary that SAIL assume control at least in the demonstration plant stage.

(2) COG is available as a hydrogen supply in the case of the Rourkela Steel Plant and the distillate oil produced in conjunction with SRC production can be processed.

(3) In order to make the most effective use of the SRC produced it is desirable that this be integrated with coke production.

(4) There is plentiful expertise concerning SRC production in the Rourkela Steel Plant and the machine workshop attached to the plant can be used for repairs.

Table 6.1.1   PRODUCTION COST OF SRC BASED ON ASSAM COAL

| Inputs | Unit | | Per SRC | |
|---|---|---|---|---|
| | Unit | Cost | Consumption | Cost |
| | | Rs/Unit | Unit/Unit | Rs/Unit |
| Raw Material | | | | |
| - Feedstock Coal (Purchase) | ton | 1440.3 | 1.63 | 2348.4 |
| - Coke Oven Gas | ton | 1681.9 | 0.93 | 1569.1 |
| Utilities | | | | |
| - Fuel Coal | ton | 776.7 | 0.59 | 455.6 |
| - Electricity | kWh | 1.0 | 95.4 | 95.4 |
| - Steam(57Kg/cm² G) | ton | 251.3 | 0.71 | 177.7 |
| - Make-up Water | m³ | 0.8 | 13.9 | 11.1 |
| - Nitrogen | Nm³ | 0.7 | 37.4 | 26.2 |
| - Catalyst(Iron Ore) | ton | 918.1 | 0.05 | 41.7 |
| - Catalyst (Sulfur) | ton | 3500.0 | 0.01 | 38.1 |
| - Chem.(Filter Aid) | ton | 6427.5 | 0.02 | 105.9 |
| - Chemicals, etc. | ton | – | – | 9.8 |
| (1) Variable Cost | – | – | – | 4878.7 |
| Operating Labor | M-Y | 57230 | | 68.4 |
| Overhead | Ope. | Labor x 50% | | 34.2 |
| Maintenance(Materials) | E&M, | CIF x 1.5% | | 719.1 |
| (Labor) | M-Y | 57256 | | 27.0 |
| Administration (Supplies) | Admi. Staff x 100% | | | 11.6 |
| (Staff) | M-Y | 60327.3 | | 11.6 |
| Tax & Insurance | Book Value x 0.5% | | | 151.4 |
| (2) Direct Fixed Cost | – | – | – | 1023.3 |
| Credits | | | | |
| - Return Gas | ton | 1618.0 | 0.95 | 1531.3 |
| - Light Distillate | ton | 4015.8 | 0.05 | 212.4 |
| - Middle Distillate | ton | 3795.4 | 0.008 | 32.1 |
| - Residue | ton | 135.4 | 0.127 | 17.2 |
| (3) Total Credits | – | – | – | 1793.0 |
| (4) Production Cost = (1)+(2)-(3) | | | | 4109.0 |
| (5) Depreciation & Interest (D & I) | 20 years. 6% interest | | | 4600.8 |
| (6) Total Production Cost inc. D&I = (4)+(5) | | | | 8709.8 |

Price : Aug., 1991
COG Price : 0.96 Rs/Nm³ x 1752 Nm³/t = 1681.92 Rs/t
Plant Cost: US$ 255 million in 1991
Exchange Rate : 25.71 Rs/US$

SRC yield/coal(dry) = 67.92%

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Table 6.1.2    PRODUCTION COST OF SRC BASED ON SAMLA COAL

| Inputs | Unit | | Per SRC | |
|---|---|---|---|---|
| | Unit | Cost | Consumption | Cost |
| | | Rs/Unit | Unit/Unit | Rs/Unit |
| Raw Material | | | | |
| – Feedstock Coal (Purchase) | ton | 776.7 | 2.48 | 1923.4 |
| – Coke Oven Gas | ton | 1681.9 | 1.17 | 1970.9 |
| Utilities | | | | |
| – Fuel Coal | ton | 776.7 | 0.81 | 633.0 |
| – Electricity | kWh | 1.0 | 132.7 | 132.7 |
| – Steam(57Kg/cm$^2$ G) | ton | 251.3 | 0.98 | 246.6 |
| – Make-up Water | m$^3$ | 0.8 | 19.3 | 15.4 |
| – Nitrogen | Nm$^3$ | 0.7 | 51.86 | 36.3 |
| – Catalyst(Iron Ore) | ton | 918.1 | 0.06 | 58.1 |
| – Catalyst (Sulfur) | ton | 3500.0 | 0.02 | 52.7 |
| – Chem.(Filter Aid) | ton | 6427.5 | 0.13 | 810.1 |
| – Chemicals, etc. | ton | – | – | 13.6 |
| (1) Variable Cost | – | – | – | 5892.7 |
| Operating Labor | M-Y | 57230 | | 94.9 |
| Overhead | Ope. | Labor x 50% | | 47.6 |
| Maintenance(Materials) | E&M, | CIF x 1.5% | | 1225.1 |
| (Labor) | M-Y | 57256 | | 37.5 |
| Administration (Supplies) | Admi. Staff x 100% | | | 15.9 |
| (Staff) | M-Y | 67694 | | 15.9 |
| Tax & Insurance | Book Value x 0.5% | | | 253.8 |
| (2) Direct Fixed Cost | – | – | – | 1690.7 |
| Credits | | | | |
| – Return Gas | ton | 1618.0 | 1.197 | 1936.5 |
| – Light Distillate | ton | 4015.8 | 0 | 0 |
| – Middle Distillate | ton | 3795.4 | 0 | 0 |
| – Residue | ton | 215.1 | 0.398 | 85.6 |
| (3) Total Credits | – | – | – | 2022.1 |
| (4) Production Cost = (1)+(2)−(3) | | | | 5561.3 |
| (5) Depreciation & Interest (D&I) | 20 years. 6% interest | | | 7688.1 |
| (6) Total Production Cost inc. D&I = (4)+(5) | | | | 13249.4 |

Price : Aug., 1991
COG Price : 0.96 Rs/Nm$^3$ x 1752 Nm$^3$/t = 1681.92 Rs/t
Plant Cost : US$ 307 million in 1991
Exchange Rate : 25.71 Rs/US$

SRC yield/coal(dry) = 48.89%

Table 6.1.3 COKE/PRODUCTION COST INCLUDING D&I OF
SRC PLANT (1/2)

| Feedstock Coal | Samla | Assam | No-SRC |
|---|---|---|---|
| **1. Coal Price [Rs/t, Dry], in 1991** | | | |
| P.C.C (Washed) | 1074.4 | 1074.4 | 1074.4 |
| M.C.C (Washed) | 1073.1 | 1073.1 | 1073.1 |
| Imported Coal | 2663.0 | 2663.0 | 2663.0 |
| Non-coking Coal (Samla) | 940.3 | 940.3 | – |
| SRC including D&I | 13249.4 | 8709.8 | – |
| **2. Blend Ratio, Dry (%)** | | | |
| P.C.C | 30.0 | 30.0 | 30.0 |
| M.C.C | 40.0 | 40.0 | 40.0 |
| Imported Coal | 15.0 | 15.0 | 30.0 |
| Non-coking Coal | 10.0 | 10.0 | – |
| SRC | 5.0 | 5.0 | – |
| Total | 100.0 | 100.0 | 100.0 |
| **3. Ave. Coal Price [Rs/t, Dry], in 1991** | | | |
| P.C.C | 322.3 | 322.3 | 322.3 |
| M.C.C | 429.3 | 429.3 | 429.2 |
| Imported Coal | 399.5 | 399.5 | 798.9 |
| Non-coking Coal | 94.0 | 94.0 | – |
| SRC | 662.5 | 435.5 | – |
| Total | 1907.6 | 1680.6 | 1550.4 |
| **4. Coke Production Cost* [Rs/t of coke], in 1991** | | | |
| Raw Materials (Inc. handling loss) | 2821.6 | 2485.9 | 2254.7 |
| Others (Inc. credits) | –18.8 | –18.8 | 22.2 |
| Total | 2802.8 | 2467.1 | 2276.9 |

* Not adjusted by ash content

Table 6.1.3   COKE/PRODUCTION COST EXCLUDING D&I OF
SRC PLANT (2/2)

| Feedstock Coal | Samla | Assam | No-SRC |
|---|---|---|---|
| 1. Coal Price [Rs/t, Dry], in 1991 | | | |
| P.C.C (Washed ) | 1074.4 | 1074.4 | 1074.4 |
| M.C.C (Washed) | 1073.1 | 1073.1 | 1073.1 |
| Imported Coal | 2663.0 | 2663.0 | 2663.0 |
| Non-coking Coal (Samla) | 940.3 | 940.3 | – |
| SRC excluding D&I | 5561.3 | 4109.0 | – |
| 2. Blend Ratio, Dry (%) | | | |
| P.C.C | 30.0 | 30.0 | 30.0 |
| M.C.C | 40.0 | 40.0 | 40.0 |
| Imported Coal | 15.0 | 15.0 | 30.0 |
| Non-coking Coal | 10.0 | 10.0 | – |
| SRC | 5.0 | 5.0 | – |
| Total | 100.0 | 100.0 | 100.0 |
| 3. Ave. Coal Price [Rs/t, Dry], in 1991 | | | |
| P.C.C | 322.3 | 322.3 | 322.3 |
| M.C.C | 429.3 | 429.3 | 429.2 |
| Imported Coal | 399.5 | 399.5 | 798.9 |
| Non-coking Coal | 94.0 | 94.0 | – |
| SRC | 278.1 | 205.4 | – |
| Total | 1523.2 | 1450.5 | 1550.4 |
| 4. Coke Production Cost* [Rs/t of coke], in 1991 | | | |
| Raw Materials (Inc. handling loss) | 2253.0 | 2145.6 | 2254.7 |
| Others (Inc. credits) | -18.8 | -18.8 | 22.2 |
| Total | 2234.2 | 2126.8 | 2276.9 |

* Not adjusted by ash content

## Table 6.2.1 PRODUCTION OF HOT METAL, COKE AND BY-PRODUCTS IN ROURKELA STEEL PLANT IN 1989-90

| Paticulars | | Unit | Corporate Plan upto 2000 AD (1) | Actual (2) | Ratio (%) (2)/(1) |
|---|---|---|---|---|---|
| Hot Metal Production | A | t | 1,350,000 | 1,261,011 | 93.41 |
| Coking Coal required | B | t | 2,430,000 | – | – |
| Coal carbonised | C | t | 2,100,000 | 1,736,104 | 82.67 |
| Coal Iron Ratio | D | | 1.80 | – | – |
| Coke Produced | E | t | – | 1,318,503 | – |
| BF Coke Consumed | F | t | 1,012,500 | 914,695 | 90.34 |
| Coke Rate | G | Kg/1,000 T | 750 | 725 | 96.72 |
| **Primary By-products** | | | | | |
| Coke Oven Gas | H | 1,000 Nm3 | 578,000 | 476,556 | 82.45 |
| Crude Tar | I | t | 59,000 | 51,504 | 87.29 |
| Ammonium Sulphate | J | t | 18,900 | 12,030 | 63.65 |
| Crude Benzol | K | t | 10,500 | 4,786 | 45.58 |
| | | kl | 12,125 | 5,527 | 45.58 |
| **Secondary By-products** | | | | | |
| **Tar Products** | | | | | |
| H.P.Naphthalene | L | t | 2,360 | 2,027 | 85.89 |
| Pitch | N | t | 31,160 | 25,600 | 82.16 |
| Tar Oils | M | t | 600 | – | – |
| Sodium Phenolate | O | t | 250 | 1,469 | 587.60 |
| **Benzol Products** | | | | | |
| Benzene | P | t | 6,300 | 2,629 | 41.72 |
| | Q | kl | 7,216 | 3,011 | 41.72 |
| Toluene | R | t | 1,050 | 932 | 88.75 |
| | S | kl | 1,226 | 1,088 | 88.75 |
| Solvents | T | t | 420 | – | – |
| **YIELD** | | | | | |
| **Primary By-products** | | | | | |
| Coke Oven Gas | H/C | Nm3/t | 275 | 274 | 99.73 |
| Crude Tar | I/C | % | 2.81 | 2.97 | 105.59 |
| Ammonium Sulphate | J/C | % | 0.90 | 0.69 | 76.99 |
| Crude Benzol | K/C | % | 0.50 | 0.28 | 55.14 |
| **Secondary By-products** | | | | | |
| **Tar Products** | | | | | |
| H.P.Naphthalene | L/I | % | 4.00 | 3.94 | 98.39 |
| Pitch | M/I | % | 52.81 | 49.70 | 94.11 |
| Tar Oils | N/I | % | 1.02 | – | – |
| Sodium Phenolate | O/I | % | 0.42 | 2.85 | 673.12 |
| **Benzol Products** | | | | | |
| Benzene | P/K | % | 60.00 | 54.92 | 91.53 |
| Toluene | R/K | % | 10.00 | 19.47 | 194.69 |
| Solvents | T/K | % | 4.00 | – | – |

Source : SAIL;Corporate Plan upto 2000 AD,May 1987
SAIL ; Annual Statistics 1989-90, Rourkela Steel Plant.

Table 6.2.2    BLAST FURNACES OPERATION IN ROURKELA STEEL PLANT

[1989-90]

| Particulars | Unit | Face I | Face II | Face III | Face IV | Total |
|---|---|---|---|---|---|---|
| 1 Useful Volume | m3 | 1,139 | 1,139 | 1,139 | 1,658 | 5,075 |
| 2 Capacity | H.M.t/d | 1,000 | 1,000 | 1,000 | 1,500 | 4,500 |
| 3 Productivity | t/d/m3 | 0.817 | 0.807 | 0.788 | 0.551 | 0.721 |
| 4 Commisioned | d-m-y | 27-01-59 | 12-01-60 | 08-01-62 | 03-07-67 | |
| 5 HOT METAL | | | | | | |
| Total Production | t | 339,491 | 335,601 | 327,405 | 258,514 | 1,261,011 |
| Average Production per Calender day | t/d | 930 | 919 | 897 | 913 | 3,660 |
| Max.Production in a Day | t/d | 1,335 | 1,248 | 1,217 | 1,616 | 5,152 |
| 6 No.of Casts | | 2,096 | 2,095 | 2,038 | 1,363 | 7,592 |
| 7 Distribution | | | | | | |
| To S.M.S | t | 313,299 | 317,587 | 311,896 | 235,563 | 1,178,345 |
| To P.C.M. | t | 26,192 | 18,014 | 15,509 | 22,951 | 82,666 |
| % Sent to P.C.M. | % | 92.3 | 94.6 | 95.3 | 91.1 | 93.4 |
| 8 Operational Details | | | | | | |
| (a) Availability | h-min | 8686-55 | 8679-40 | 8663-05 | 5701-45 | 31731-25 |
| (b) Delays | h-min | 673-58 | 642-26 | 823-33 | 949-46 | 3089-43 |
| (c) % of Delays over (a) | | 7.8 | 7.4 | 9.5 | 16.7 | 9.7 |
| (d) Utilization | h-min | 8012-57 | 8037-14 | 7839-32 | 4751-59 | 28641-42 |
| (f) Scheduled shut down | h-min | 73-05 | 80-20 | 96-55 | 3058-15 | 3308-35 |
| 9 Consumption Rates | | | | | | |
| Coke | kg/t | 733 | 727 | 710 | 733 | 725 |
| Iron Ore | kg/t | 1,006 | 956 | 1,023 | 954 | 987 |
| Sinter | kg/t | 869 | 914 | 851 | 914 | 886 |
| 10 Cold Pig | t | 22,918 | 15,762 | 13,571 | 20,083 | 72,334 |

Source : Annual Statistics 1989-90, Rourkela Steel Plant.

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Table 6.2.3    OPERATION OF COKE OVENS IN ROURKELA STEEL PLANT
[1989-90]

| Particulars | Units | M.T.P. | Expn. | Total |
|---|---|---|---|---|
| **PRODUCTION** | | | | |
| Ovens Pushed | Nos. | 51,572 | 52,054 | 103,626 |
| Avg./Calender day | Nos. | 141 | 143 | 284 |
| Gross Coke (dry) | t | | | 1,318,503 |
| Avg./day | t | | | 3,612 |
| Hard Coke (dry) | t | | | 1,098,314 |
| Avg./day | t | | | 3,009 |
| Nut Coke (dry) | t | | | 78,710 |
| Avg./day | t | | | 216 |
| Mixed Coke (dry) | t | | | 141,479 |
| Avg./day | t | | | 387 |
| **COAL CHARGED (wet)** | | | | |
| P.C.C.(washed) | t | | | 707,940 |
| Imported | t | | | 483,480 |
| M.C.C (washed) | t | | | 647,120 |
| H.V.Coal | t | | | 24,450 |
| Total wet charge | t | | | 1,862,990 |
| Tons/Oven | t | | | 17.98 |
| **BLEND RATIO OF COAL CHARGED (wet)** | | | | |
| P.C.C.(washed) | % | | | 38.0 |
| Imported | % | | | 26.0 |
| M.C.C (washed) | % | | | 34.7 |
| H.V.Coal | % | | | 1.3 |
| Total wet charge | % | | | 100.0 |
| **COAL CHARGED (dry)** | | | | |
| Total | t | | | 1,736,104 |
| Tons/Oven | t | | | 16.75 |

| YIELD RATES : | | Total Tons/Oven | Yield % |
|---|---|---|---|
| Gross coke | (dry) | 12.72 | 75.95 |
| Hard coke | (dry) | 10.60 | 63.26 |
| Nut Coke | (dry) | 0.76 | 4.54 |
| Mixed Coke | (dry) | 1.36 | 8.15 |
| AVERAGE COKING TIME (h-min.) | | 20-33 | |

| ANALYSIS (%) | MOISTURE | ASH | V.M. | F.C. |
|---|---|---|---|---|
| Incomming Coal | | | | |
| At Destination : | | | | |
| M.V. washed | 5.3 | | | |
| M.V. imported | 5.2 | | | |
| H.V. Coal | 5.0 | | | |
| At loading point: | | | | |
| (indegenous) | 7.4 | | | |
| Charging Coal | 6.46 | 17.01 | 25.05 | 57.94 |
| COKE | | | | |
| Hard coke | 5.46 | 22.68 | 0.76 | 76.56 |
| Nut Coke | 11.36 | | | |
| Mixed Pearl Coke | 15.68 | | | |
| Breeze Coke | 20.54 | | | |

| MICUM TEST (%) | +40mm | -10mm |
|---|---|---|
| | 80.64 | 11.19 |

Source : Annual Statistics 1989-90, Rourkela Steel Plant.

## Table 6.2.4 PRODUCTION, PROCESSING AND LOADING OF COKE BY-PRODUCTS IN ROURKELA STEEL PLANT [1989-90]

| Products | Item | Quantity | Units | Loadings |
|---|---|---|---|---|
| COAL (dry) | Carbonised | 1,318,503 | t | |
| COKE (dry) | Production | 1,318,503 | t | |
| COKE OVEN GAS | Production | 476,556,000 | Nm3 | |
| CRUDE TAR | Production | 51,504 | t | |
| CRUDE TAR | Distilled | 52,530 | t | |
| Extra Hard Pitch | Production | 25,600 | t | 24,978 t |
| Coal Tar Fuel | Production | 2,840 | t | |
| Coal Tar Fuel transfer to | Production | 10,876 | t | |
| Special Tar | Production | 840 | t | |
| Road Tar transfer to | Production | 30 | t | |
| Wash Oil | Production | 5,444 | t | 923 t |
| Coal Tar Heavy Oil | Production | 9,722 | t — | 3,434 t |
| Crude Naphthalene Oil | Production | 3,391 | t | |
| Light Oil | Production | 171 | t | |
| Ammonia Liquor | Production | 1,537 | t | |
| —Crude Carbolic Oil | Production | 1,557 | t | |
| TAR PROCESSED PRODUCTS TOTAL | Production | 51,102 | t | |
| —Crude Carbolic Oil | Processed | 1,469 | t | |
| Sodium Phenolate | Production | 1,469 | t | |
| Neutral Oil | Production | 1,166 | t | 1,167 t |
| Pure Phenol | Production | 64 | t | 49 t |
| M.P.Cresol/Cresylic Acid | Production | 127 | t | 146 t |
| Carbolic Oil Products Total | Production | 1,357 | t | |
| Dolomite Tar | Production | 700 | t | |
| Pressed Naphthalene Oil | Production | 1,058 | t — | |
| Hot Pressed Naphthalene | Production | 2,027 | t — | 1,889 t |
| CRUDE BENZOL | Production | 5,527 | kl | |
| CRUDE BENZOL | Refined | 6,305 | kl | |
| Raffinate | Production | 5,342 | kl | 2,794 kl |
| Raffinate | Refined | 5,362 | kl | 1,022 kl |
| Benzene (N.G.) | Production | 3,011 | kl | 300 kl |
| Toluene | Production | 1,088 | kl | 60 kl |
| Light Solvent Naphtha | Production | 315 | kl | |
| Heavy Solvent Naphtha | Production | 66 | kl | 84 kl |
| Fore Runnings | Production | 449 | kl | |
| Ind.Grade Benzol | Production | 62 | kl | |
| BENZOL PRODUCTS TOTAL | Production | 4,991 | kl | 4,260 kl |
| AMMONIUM SULPHATE | Production | 12,030 | t | |
| Sulphuric Acid transfer to AS | Production | 10,002 | t | |
| Sulphuric Acid | Production | 17,986 | t | |

Source : Annual Statistics 1989-90, Rourkela Steel Plant.
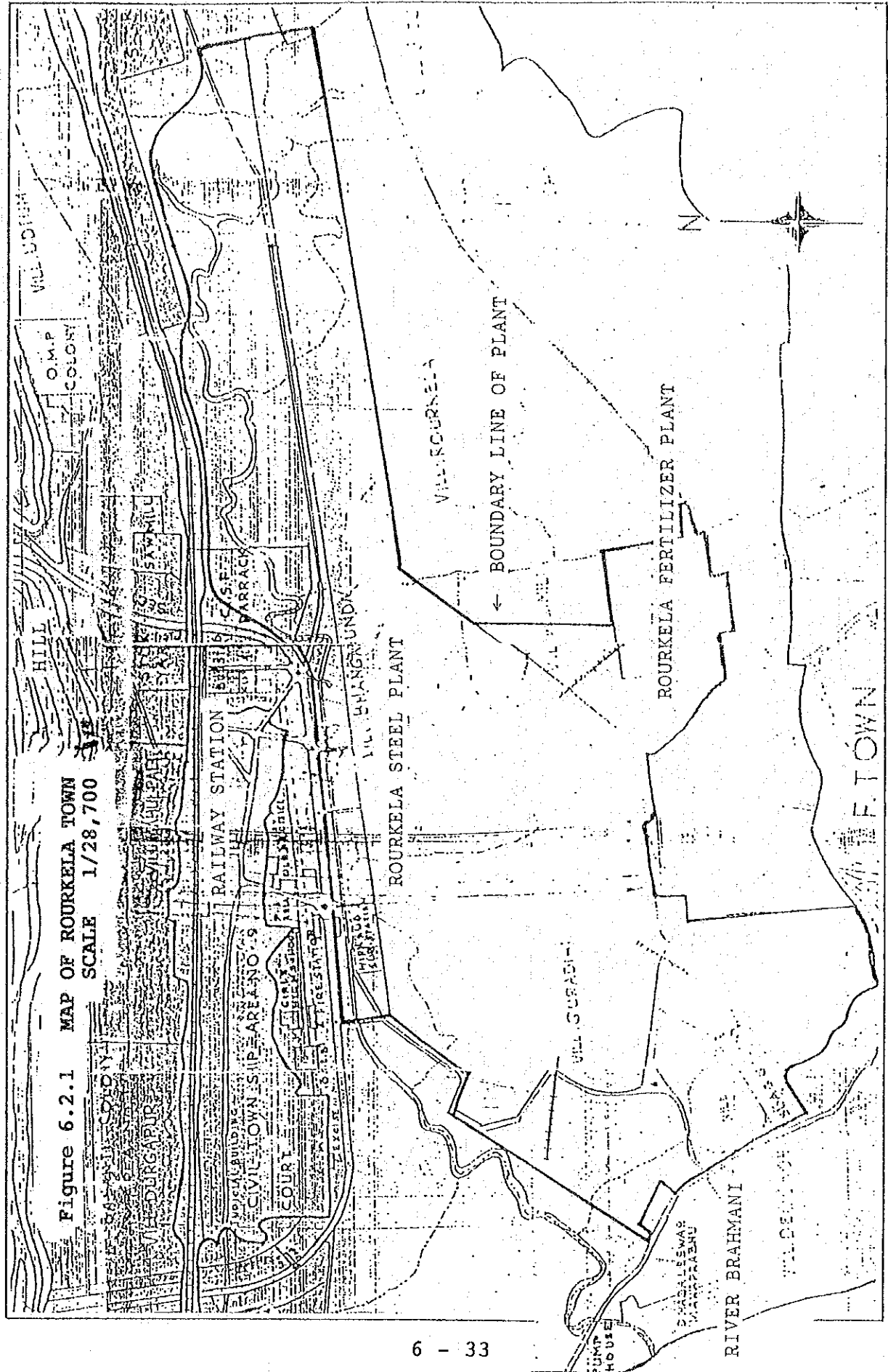
Figure 6.2.1 MAP OF ROURKELA TOWN
SCALE 1/28,700

Figure 6.2.2  MAP OF ROURKELA STEEL PLANT
SCALE 1/11,400

COKE BY-PRODUCT PLANT

[LOCATION-1]

[LOCATION-2]

[LOCATION-3]

[LOCATION-4]

[LOCATION-2, ANNEX AREA]

ROURKELA FERTILIZER PLANT

COKE OVEN

BLAST FURNACES

POWER PLANT-2

N

Figure 6.2.3 PRODUCTION OF COKE AND BY-PRODUCT IN ROURKELA STEEL PLANT (1989-90)

**Coal carbonised**

1,736,104 t (dry)
864,183 t (dry)
871,921 t (dry)

**Total**

| | | | |
|---|---|---|---|
| Total | 1,862,990 t | (100.0 )% | |
| Prime Coking Coal (Washed) | 707,940 t | ( 38.0 )% | |
| Imported Coal (Australia) | 483,480 t | ( 26.0 )% | |
| Medium Coking Coal (Washed) | 647,120 t | ( 34.7 )% | |
| Total M.V. | 1,838,540 t | (98.7 )% | |
| H.V. | 24,450 t | ( 1.3 )% | |

**Coal carbonised (dry)**

| | |
|---|---|
| Moisture | 6.29 % |
| Ash | 17.01 % |
| V.M. | 25.05 % |
| F.C. | 57.94 % |

**COKE OVENS**

| Total Coke Ovens (Nos) | [1] | [2] |
|---|---|---|
| M.T.P | 370 | 243 |
| Battery I | 70 | 68 |
| Battery II | 70 | 56 |
| Battery III | 70 | Stand by |
| Expansion Battery IV | 80 | 80 |
| Battery V | 80 | 39 |
| Ovens Pushed (Nos) | 103,626 | |
| Coal charged(dry t/oven) | 16.75 | |
| Coal charged(wet t/oven) | 17.98 | |

[1] Installed capacity
[2] under operation

**COKE (dry)**

| | Yield | Production |
|---|---|---|
| Hard Coke | 63.26 | 1,098,314 t |
| Nut Coke | 4.53 | 78,710 t |
| Mixed Coke | 8.15 | 141,479 t |
| COKE TOTAL (dry) | 75.95 | 1,318,503 t |
| COKE (wet) | Yield | Production |
| Hard Coke | 66.93 | 1,161,933 t |
| Nut Coke | 5.11 | 88,749 t |
| Mixed Coke | 9.93 | 172,460 t |
| COKE TOTAL (wet) | 81.97 | 1,423,142 t |

**Coke consumed in BF**

| | |
|---|---|
| Hard Coke | 909,328 t |
| Nut Coke | 5,367 t |
| Total | 914,695 t |
| Ratio of Coke consumed in B.F. to Total Coke | 52.69 % |

Foundry 262,299 t

Sintering Plant

**BLAST FURNACES**

| | |
|---|---|
| Hot Metal Production | 1,261,011 t |
| Coke Rate | 725.4 kg |
| Coal to Iron Ratio dry | 1.37676 t |
| wet | 1.47738 t |

**Hot Metal Distribution**

| | |
|---|---|
| S.M.S. | 1,178,345 t |
| P.C.M. | 82,666 t |
| Total | 1,261,011 t |

**TAR PRODUCTS**

| | Production | Yield |
|---|---|---|
| Hard pitch | 25,600 t | 48.73 % |
| Fuel tar | 2,840 t | 5.41 % |
| Special tar | 840 t | 1.60 % |
| Wash oil | 5,444 t | 10.36 % |
| Heavy Oil | 9,722 t | 18.51 % |
| C.Carbolic oil | 1,557 t | 2.96 % |
| C.Naphthalene | 3,391 t | 6.46 % |
| Light oil | 171 t | 0.33 % |
| Ammonia Liquor | 1,537 t | 2.93 % |
| Total | 51,102 t | 97.28 % |

**BENZOL PRODUCTS**

| Product | Production | Yield |
|---|---|---|
| Benzene | 3,011 kl | 47.76 % |
| Toluene | 1,088 kl | 17.26 % |
| L.S.Naphtha | 315 kl | 5.00 % |
| H.S.Naphtha | 66 kl | 1.05 % |
| Fore runnings | 449 kl | 7.12 % |
| Benzene I.G. | 62 kl | 0.98 % |
| Total | 4,991 kl | 79.16 % |

**Distillation**

Distillation 52,530 t
Operation time 5,979 h

**Crude Tar**

Production 51,504 t
Yield 2.97 %

**Refining** 6,305 kl

**Crude Benzol**

Production 5,527 kl
Yield (kl/t) 0.003184

**Raffinate** 5,342 kl

**Rectification**

Rectification 5,382 kl
Operation time 3,724 h

**Sulphuric Acid**

Produced (t) 17,986 t
Operation Time 7,759 h
Sulphuric Acid 6,681 t
Sulphuric Acid 10,092 t

To CRM 6,014 t
Others 657 t

**Ammonium Sulphate**

Production 12,030 t
Yield 0.69 %

**Coke Oven Gas**

Produced (1,000Nm3) 476,556
Yield (Nm3/t of Coal) t 274
C.V. (Kcal/Nm3) % 4,311

**Constituents %**

| | CO2 | O2 | CnHm | CO | CH4 | H2 | N2 | Density | Kcal/Nm3 |
|---|---|---|---|---|---|---|---|---|---|
| Bat.I,II | 3.4 | 0.3 | 2.6 | 8.8 | 22.9 | 51.3 | 10.7 | 0.5613 | 4,292 |
| Bat.IV,V | 3.0 | 0.3 | 2.8 | 8.3 | 24.4 | 53.7 | 7.5 | 0.5234 | 4,410 |

Source : Annual Statistics 1989-90, Rourkela Steel Plant

**Coal carbonised**

1,606,132 t (dry)

| Total | 1,725,961 t | (100.0 )% |
|---|---|---|
| Prime Coking Coal (Washed) | 637,525 t | (36.9 )% |
| Imported Coal (Australia) | 533,933 t | (30.9 )% |
| Medium Coking Coal (Washed) | 548,027 t | (31.8 )% |
| Total M.V. | 1,719,485 t | (99.6 )% |
| H.V. | 6,476 t | (0.4 )% |

| Coal carbonised (dry) | |
|---|---|
| Moisture | 6.56 % |
| Ash | 17.15 % |
| V.M. | 25.17 % |
| F.C. | 57.69 % |

| COKE OVENS | | [1] | [2] |
|---|---|---|---|
| Total Coke Ovens (Nos) | | 370 | 238 |
| M.T.P | Battery I | 70 | 53 |
| | Battery II | 70 | 47 |
| | Battery III | 70 | Stand by |
| Expansion | Battery IV | 80 | 79 |
| | Battery V | 80 | 59 |
| Coal charged(dry t/oven) | | 15.50 | |
| Coal charged(wet t/oven) | | 16.66 | |

[1] Installed capacity
[2] under operation

| COKE (dry) | Yield | Production |
|---|---|---|
| Hard Coke | 63.21 | 1,015,263 t |
| Nut Coke | 4.20 | 67,502 t |
| Mixed Coke | 8.47 | 136,037 t |
| COKE TOTAL (dry) | 75.88 | 1,218,802 t |
| COKE (wet) | Yield | Production |
| Hard Coke | 62.61 | 1,080,661 t |
| Nut Coke | 4.40 | 76,015 t |
| Mixed Coke | 9.62 | 166,004 t |
| COKE TOTAL (wet) | 76.63 | 1,322,680 t |

| Hard Coke consumed in BF | |
|---|---|
| Dry | 944,387 t |
| Wet | 1,005,220 t |

| BLAST FURNACES | |
|---|---|
| Hot Metal Production | 1,326,000 t |
| Coke Rate | 712.2 kg |
| Coal to Iron Ratio | dry 1.21126 t |
| | wet 1.30163 t |

| TAR PRODUCTS | Production | Yield |
|---|---|---|
| Extra Hard Pitch | 23,417 t | 47.79 % |
| Coal Tar Fuel | 2,600 t | 5.31 % |
| Special Tar | 760 t | 1.55 % |
| Wash Oil | 5,123 t | 10.45 % |
| Coal Tar Heavy Oil | 8,976 t | 18.32 % |
| C.Naphthalene | 1,382 t | 2.82 % |
| C.Carbolic oil | 2,866 t | 5.85 % |
| Light oil | 422 t | 0.86 % |
| Ammonia Liquor | 1,607 t | 3.28 % |
| Total | 47,153 t | 96.23 % |

| BENZOL PRODUCTS Product | Production | Yield |
|---|---|---|
| Benzene | 2,273 kl | 42.82 % |
| Toluene | 900 kl | 16.96 % |
| L.S.Naphtha | 371 kl | 6.99 % |
| H.S.Naphtha | 52 kl | 0.98 % |
| Fore Runnings | 245 kl | 4.62 % |
| I.G.Benzol | 118 kl | 2.22 % |
| Total | 3,841 kl | 72.36 % |

| Crude Tar | |
|---|---|
| Production | 46,263 t |
| Yield | 2.88 % |

| Distillation | 49,001 t |
|---|---|
| Operation time | 6,022 h |

| Crude Benzol | |
|---|---|
| Production | 4,763 kl |
| Yield (KL/T) | 0.26 |

| Refining | 5,308 kl |
|---|---|

| Raffinate | 4,343 kl |
|---|---|

| Sulphuric Acid | |
|---|---|
| Produced (T) | 15,861 t |
| Operation Time | 7,486 h |

| Rectification | 4,343 kl |
|---|---|
| Operation time | 3,484 h |

| Sulphuric Acid | 6,870 t |
|---|---|
| Sulphuric Acid | 9,193 t |

| To CRM | 6,156 t |
|---|---|
| Others | 714 t |

| Ammonium Sulphate | |
|---|---|
| Production | 11,060 t |
| Yield | 0.69 % |

Source : Annual Statistics 1990-91, Rourkela Steel Plant

Figure 6.2.4  PRODUCTION OF COKE AND BY-PRODUCT IN ROURKELA STEEL PLANT (1990-91)

**Coal carbonised #1**

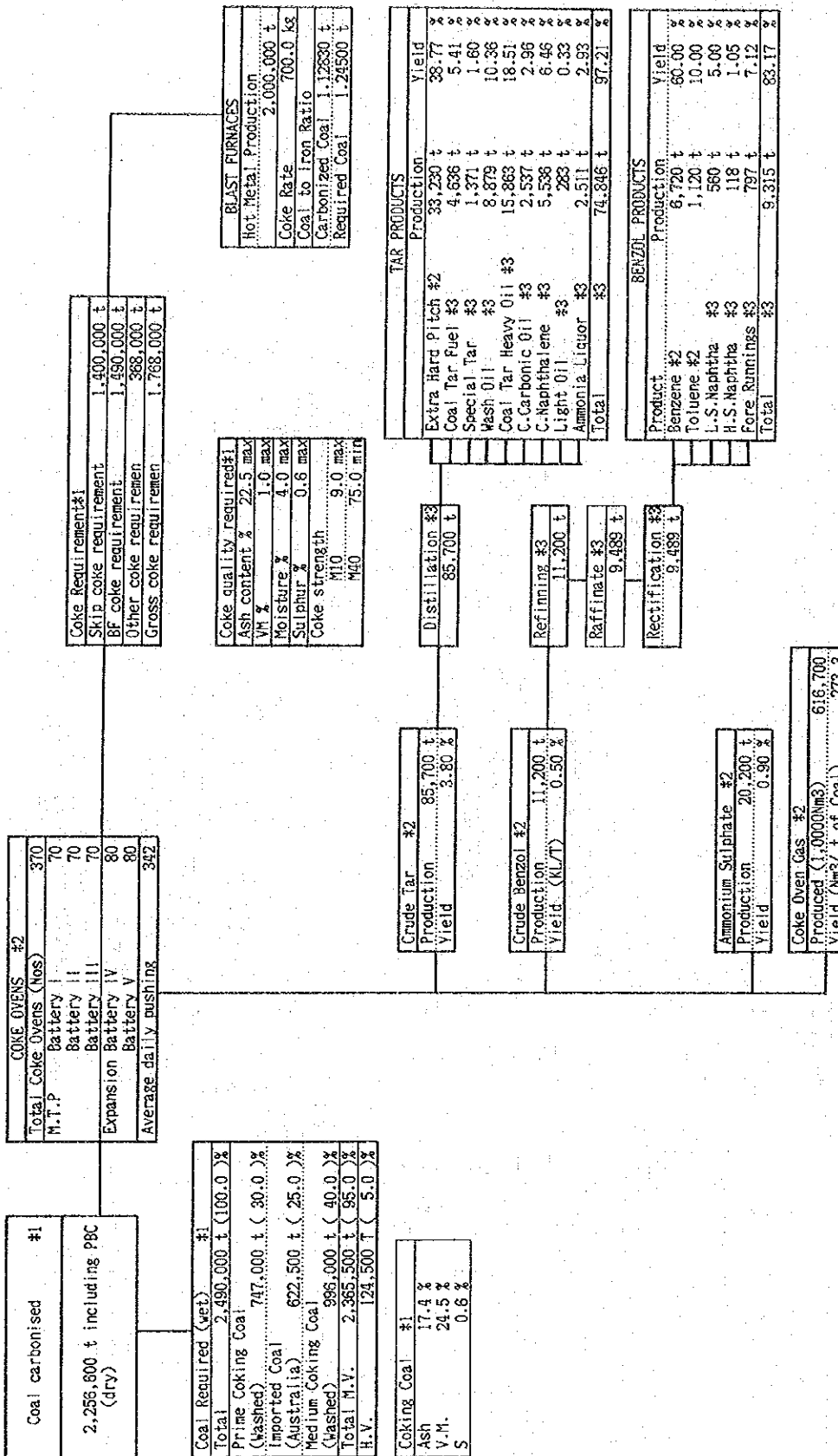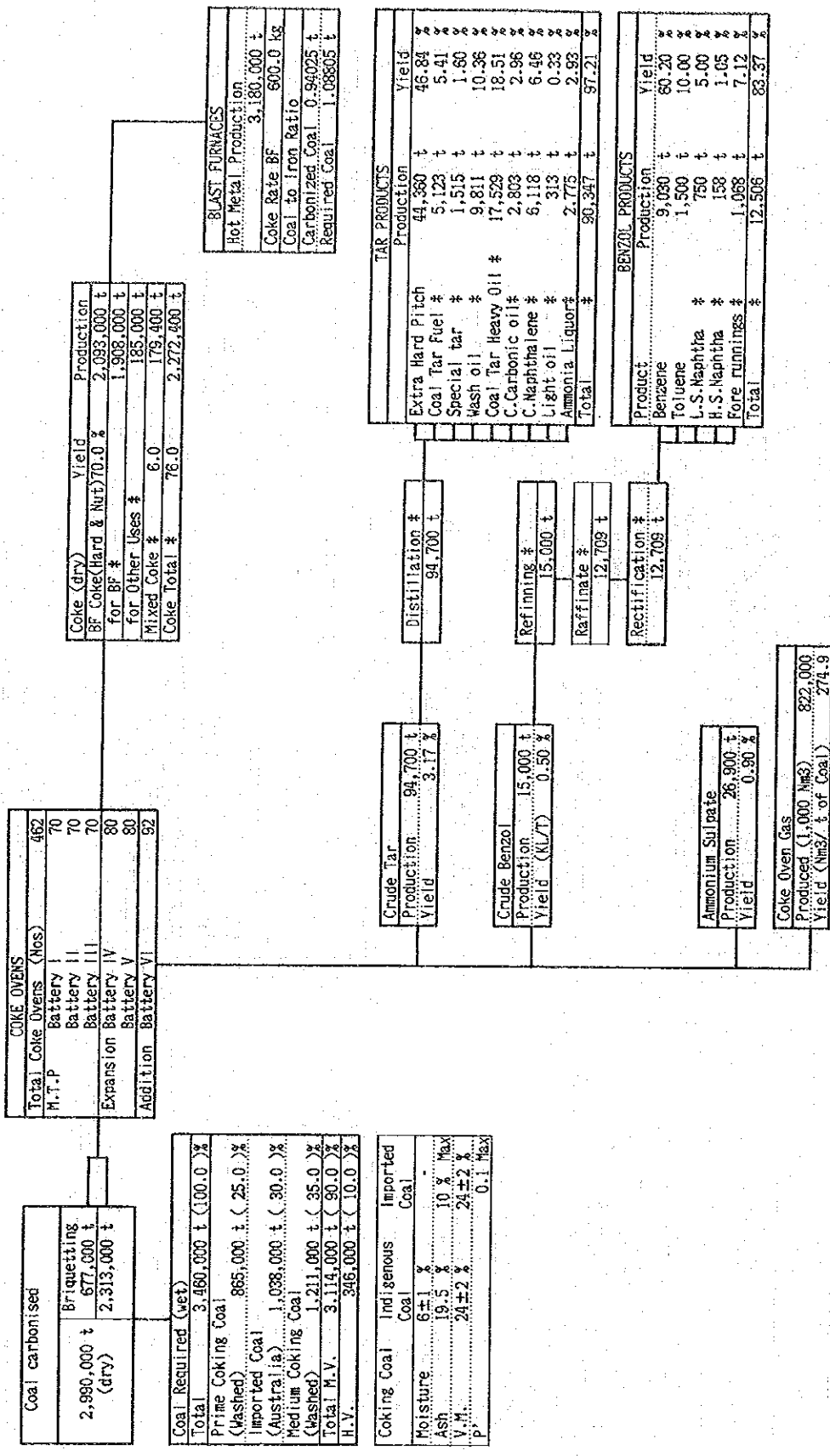2,256,800 t including PBC (dry)

**Coal Required (wet) #1**

| | | |
|---|---|---|
| Total | 2,490,000 t | (100.0)% |
| Prime Coking Coal (Washed) | 747,000 t | ( 30.0)% |
| Imported Coal (Australia) | 622,500 t | ( 25.0)% |
| Medium Coking Coal (Washed) | 996,000 t | ( 40.0)% |
| Total M.V. | 2,365,500 T | ( 95.0)% |
| H.V. | 124,500 T | ( 5.0)% |

**Coking Coal #1**

| | |
|---|---|
| Ash | 17.4 % |
| V.M. | 24.5 % |
| S | 0.6 % |

**COKE OVENS #2**

| Total Coke Ovens (Nos) | | 370 |
|---|---|---|
| M.T.P. | Battery I | 70 |
| | Battery II | 70 |
| | Battery III | 70 |
| Expansion | Battery IV | 80 |
| | Battery V | 80 |
| Average daily pushing | | 342 |

**Coke Requirement #1**

| | |
|---|---|
| Skip coke requirement | 1,400,000 t |
| BF coke requirement | 1,490,000 t |
| Other coke requiremen | 368,000 t |
| Gross coke requiremen | 1,768,000 t |

**Coke quality required #1**

| | |
|---|---|
| Ash content % | 22.5 max |
| VM % | 1.0 max |
| Moisture % | 4.0 max |
| Sulphur % | 0.6 max |
| Coke strength M10 | 9.0 max |
| M40 | 75.0 min |

**BLAST FURNACES**

| | |
|---|---|
| Hot Metal Production | 2,000,000 t |
| Coke Rate | 700.0 kg |
| Coal to Iron Ratio | |
| Carbonized Coal | 1.12830 |
| Required Coal | 1.24500 t |

**Crude Tar #2**

| | |
|---|---|
| Production | 85,700 t |
| Yield | 3.80 % |

**Distillation #3** 85,700 t

**Crude Benzol #2**

| | |
|---|---|
| Production | 11,200 t |
| Yield (KL/T) | 0.50 % |

**Refining #3** 11,200 t

**Raffinate #3** 9,489 t

**Rectification #3** 9,489 t

**Ammonium Sulphate #2**

| | |
|---|---|
| Production | 20,200 t |
| Yield | 0.90 % |

**Coke Oven Gas #2**

| | |
|---|---|
| Produced (1,0000Nm3) | 616,700 |
| Yield (Nm3/ t of Coal) | 273.3 |

**TAR PRODUCTS**

| | Production | | Yield | |
|---|---|---|---|---|
| Extra Hard Pitch #2 | 33,230 | t | 38.77 | % |
| Coal Tar Fuel #3 | 4,636 | t | 5.41 | % |
| Special Tar #3 | 1,371 | t | 1.60 | % |
| Wash Oil #3 | 8,879 | t | 10.36 | % |
| Coal Tar Heavy Oil #3 | 15,863 | t | 18.51 | % |
| C.Carbonic Oil #3 | 2,537 | t | 2.96 | % |
| C.Naphthalene #3 | 5,536 | t | 6.46 | % |
| Light Oil #3 | 283 | t | 0.33 | % |
| Ammonia Liquor #3 | 2,511 | t | 2.93 | % |
| Total | 74,846 | t | 97.21 | % |

**BENZOL PRODUCTS**

| Product | Production | | Yield | |
|---|---|---|---|---|
| Benzene #2 | 6,720 | t | 60.00 | % |
| Toluene #2 | 1,120 | t | 10.00 | % |
| L.S.Naphtha #3 | 560 | t | 5.00 | % |
| H.S.Naphtha #3 | 118 | t | 1.05 | % |
| Fore Runnings #3 | 797 | t | 7.12 | % |
| Total | 9,315 | t | 83.17 | % |

Figure 6.2.5 PRODUCTION OF COKE AND BY-PRODUCT IN ROURKELA STEEL PLANT
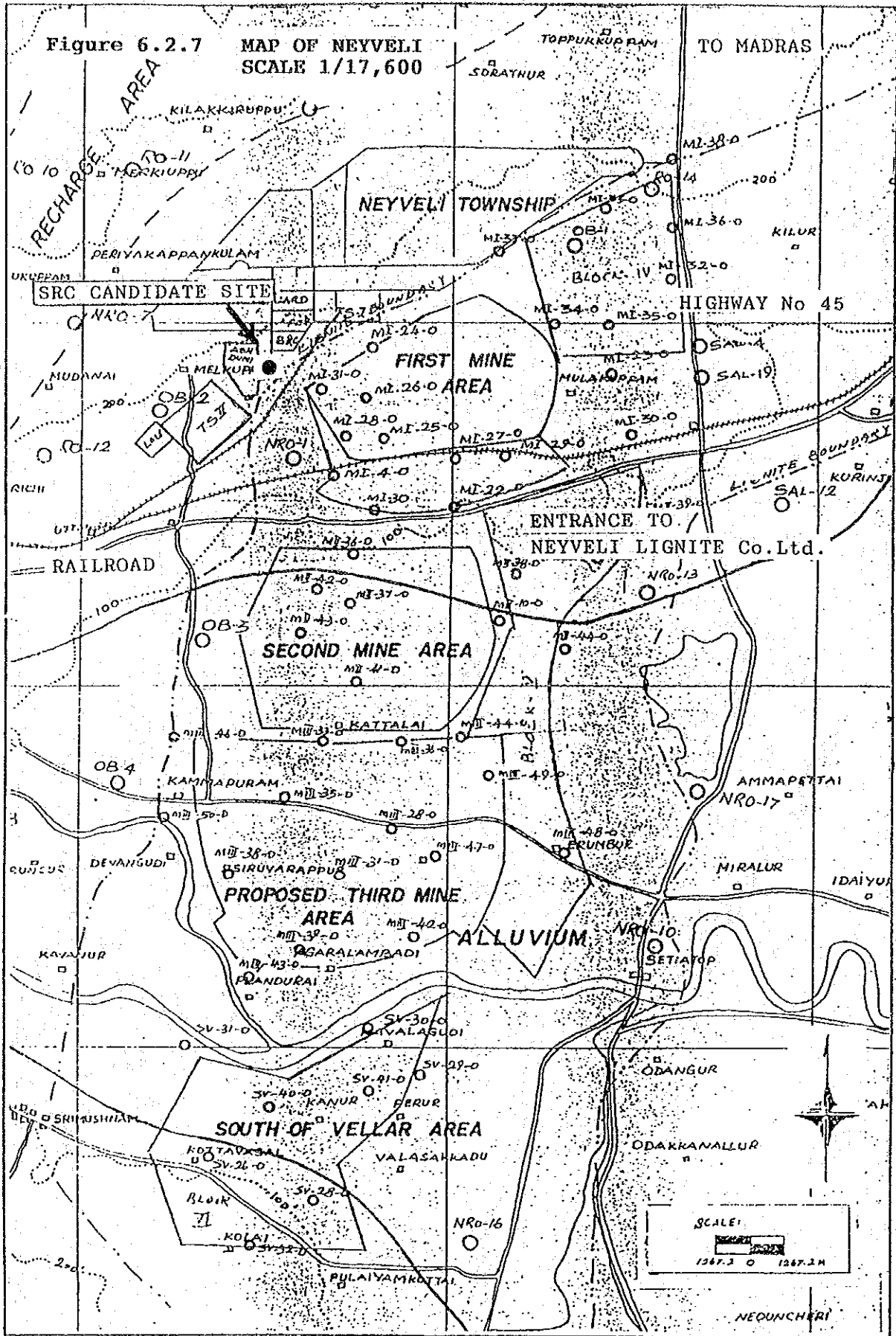[ Phase-II: after modernisation ]

Source : #1 ; SAIL's Information, 1991.
#2 ; Corporate Plan upto 2000 AD, May 1987.
#3 ; Estimated by JICA Team.

Figure 6.2.6 PRODUCTION OF COKE AND BY-PRODUCT IN ROURKELA STEEL PLANT (1999-2000)
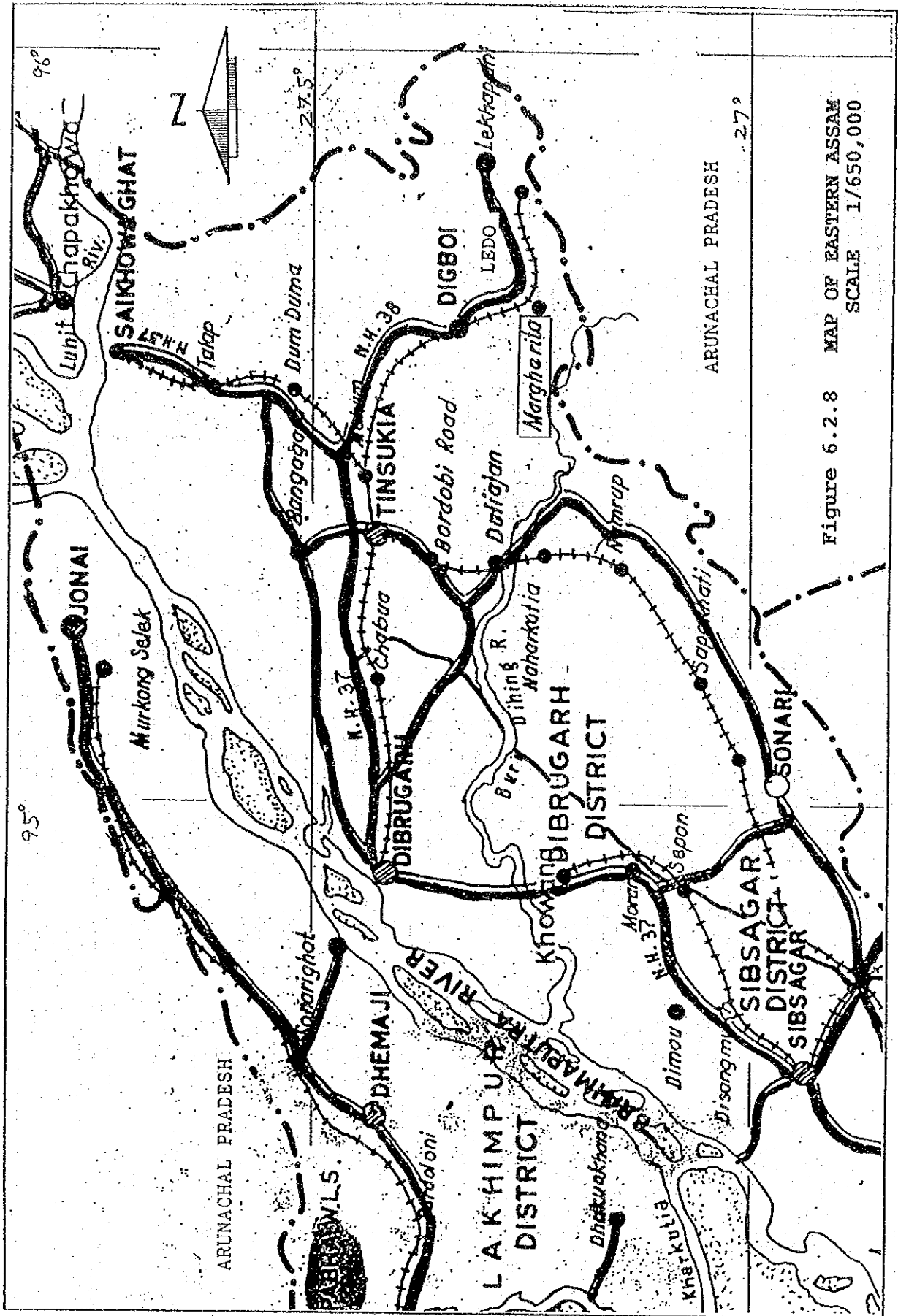[ Phase-II: after modernisation ]

**Coal carbonised**

| | |
|---|---|
| 2,990,000 t (dry) | Briquetting |
| | 677,000 t |
| | 2,313,000 t |

**COKE OVENS**

| Total Coke Ovens (Nos) | 462 |
|---|---|
| M.T.P Battery I | 70 |
| Battery II | 70 |
| Battery III | 70 |
| Expansion Battery IV | 80 |
| Battery V | 80 |
| Addition Battery VI | 92 |

**Coke (dry)**

| | Yield | Production |
|---|---|---|
| BF Coke(Hard & Nut) | 70.0 % | 2,093,000 t |
| for BF * | | 1,908,000 t |
| for Other Uses * | | 185,000 t |
| Mixed Coke * | 6.0 | 179,400 t |
| Coke Total * | 76.0 | 2,272,400 t |

**Coal Required (wet)**

| | | |
|---|---|---|
| Total | 3,460,000 t | (100.0)% |
| Prime Coking Coal (Washed) | 865,000 t | (25.0)% |
| Imported Coal (Australia) | 1,038,000 t | (30.0)% |
| Medium Coking Coal (Washed) | 1,211,000 t | (35.0)% |
| Total M.V. | 3,114,000 t | (90.0)% |
| H.V. | 346,000 t | (10.0)% |

**Coking Coal**

| | Indigenous Coal | Imported Coal |
|---|---|---|
| Moisture | 6±1 % | 10 % Max |
| Ash | 19.5 % | 24±2 % |
| V.M. | 24±2 % | |
| P. | | 0.1 Max |

**BLAST FURNACES**

| Hot Metal Production | 3,180,000 t |
|---|---|
| Coke Rate BF | 600.0 kg |
| Coal to iron Ratio | |
| Carbonized Coal | 0.94025 t |
| Required Coal | 1.08805 t |

**TAR PRODUCTS**

| | Production | Yield |
|---|---|---|
| Extra Hard Pitch | 44,360 t | 46.84 % |
| Coal Tar Fuel * | 5,123 t | 5.41 % |
| Special tar | 1,515 t | 1.60 % |
| Wash oil | 9,811 t | 10.36 % |
| Coal Tar Heavy Oil * | 17,529 t | 18.51 % |
| C.Carbonic oil* | 2,803 t | 2.96 % |
| C.Naphthalene * | 6,118 t | 6.46 % |
| Light oil | 313 t | 0.33 % |
| Ammonia Liquor* | 2,775 t | 2.93 % |
| Total | 90,347 t | 97.21 % |

**BENZOL PRODUCTS**

| Product | Production | Yield |
|---|---|---|
| Benzene | 9,030 t | 60.20 % |
| Toluene | 1,500 t | 10.00 % |
| L.S.Naphtha | 750 t | 5.00 % |
| H.S.Naphtha | 158 t | 1.05 % |
| Fore runnings * | 1,068 t | 7.12 % |
| Total | 12,506 t | 83.37 % |

**Distillation *** 94,700 t

**Refinning *** 15,000 t

**Raffinate *** 12,709 t

**Rectification *** 12,709 t

**Crude Tar**

| Production | 94,700 t |
|---|---|
| Yield | 3.17 % |

**Crude Benzol**

| Production | 15,000 t |
|---|---|
| Yield (KL/T) | 0.50 % |

**Ammonium Sulpate**

| Production | 26,900 t |
|---|---|
| Yield | 0.90 % |

**Coke Oven Gas**

| Produced (1,000 Nm3) | 822,000 |
|---|---|
| Yield (Nm3/ t of Coal) | 274.9 |

Source : Corporate Plan upto 2000 AD , May, 1987.
Note : * ; Estimated by JICA Team

Figure 6.2.7 MAP OF NEYVELI
SCALE 1/17,600

Figure 6.2.8   MAP OF EASTERN ASSAM
SCALE   1/650,000
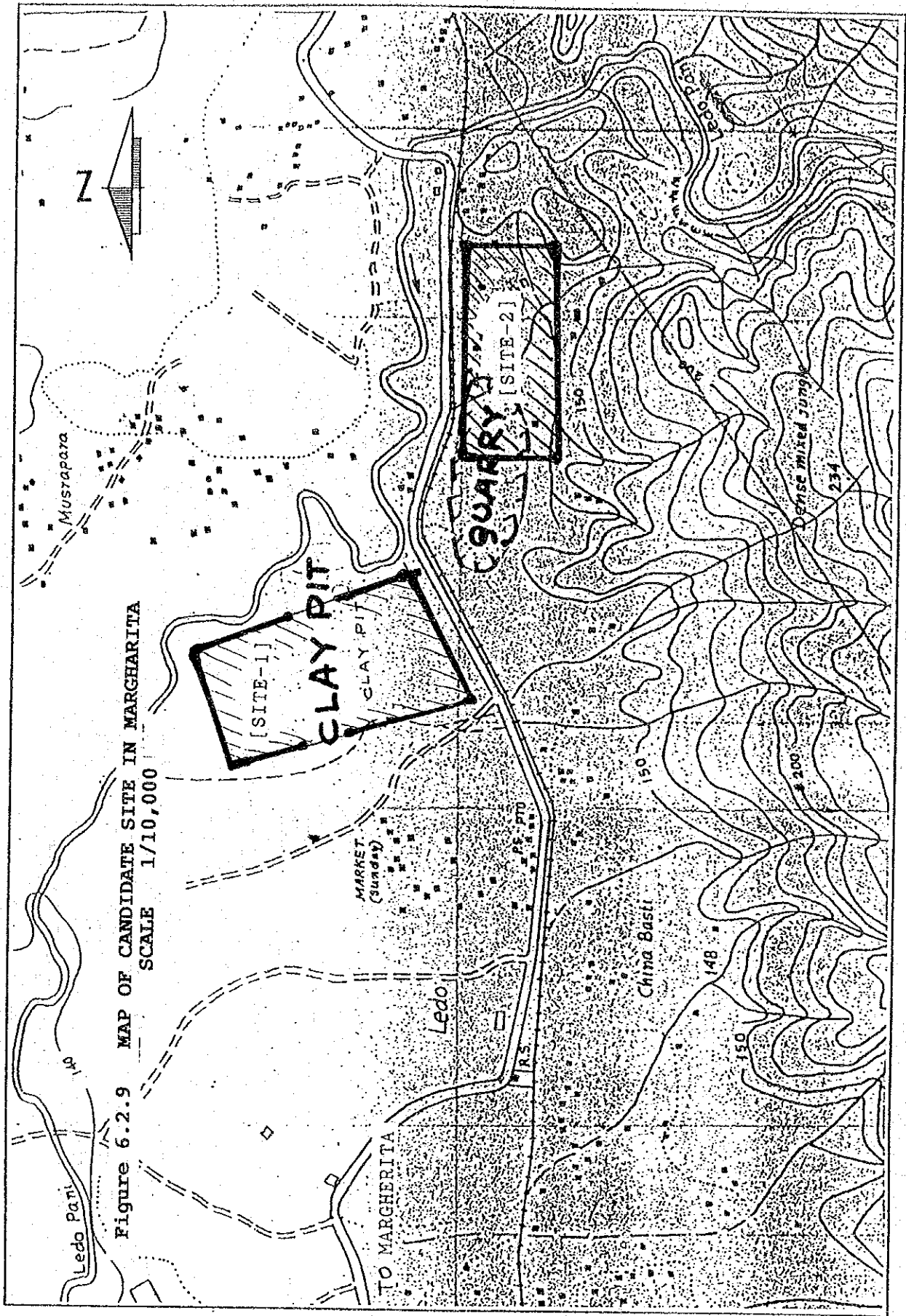
Figure 6.2.9    MAP OF CANDIDATE SITE IN MARGHARITA
SCALE   1/10,000

# Chapter 7  SURVEY OF OUTLINE OF SRC PLANT

# Chapter 7 SURVEY OF OUTLINE OF SRC PLANT

## 7.1 Review of Acts and Standards relating to Design and Construction of SRC Plant

The following is a list of the rules and standards, etc. relating to the design and construction of an SRC Plant.

### 7.1.1 Rules and Acts

Indian Petroleum Rules
Indian Factories Act
Environment Act
Notification of Central Pollution Control Board
Pollution Control Board
Indian Electricity Act
Indian Explosive Act
Indian Boiler Regulations

### 7.1.2 Codes and Standards

In principle, standards authorized in India and materials domestically manufactured are employed but in addition to these the following international standards are also applicable.

(1) General

National Fire Protection Association (NFPA)
American Occupational Health and Safety (AOHS)
Occupational Safety and Health Administration

(2) Fired Process Heater

American Society of Mechanical Engineers (ASME)
American Petroleum Institute (API)
Japanese Industrial Standards (JIS)

American National Standard Institute (ASME)

(3) Pressure Vessel

American Society of Mechanical Engineers (ASME)
American National Standard Institute (ANSI)
American Society for Testing and Materials (ASTM)
Japanese Industrial Standards (JIS)
American Petroleum Institute (API)
Japan Petroleum Institute (JPI)

(4) Tanks

American Petroleum Institute (API)
Japan Petroleum Institute (JPI)
Japanese Industrial Standards (JIS)

(5) Shell and Tube Type Heat Exchangers and Air-fin
Coolers

American Society of Mechanical Engineers (ASME)
Tubular Exchanger Manufactures Association (TEMA)
American National Standard Institute (ANSI)
American Society for Testing and Materials (ASTM)
Japanese Industrial Standards (JIS)
American Petroleum Institute (API)
Japan Petroleum Institute (JPI)

(6) Pumps and Compressors

American Petroleum Institute (API)
Japanese Industrial Standards (JIS)
American National Standard Institute (ANSI)
Manufacture's Standards

(7) Other Equipment

Japan Petroleum Institute (JPI)
Japanese Industrial Standards (JIS)
Manufacture's Standards

Contractor's Standards

(8) Pipes

American Petroleum Institute (API)
Japan Petroleum Institute (JPI)
Japanese Industrial Standards (JIS)

(9) Electrics

National Electrical Manufacture's Association (NEMA)
International Electro Technical Commission (IEC)
National Electrical Code (NEC)
Japan Electrical Manufacture's Association (JEM)
Japan Electro Technical Committee (JEC)
Institute of Electrical & Electronic Engineers (IEEE)
American Petroleum Institute (API)
Japanese Industrial Standards (JIS)

(10) Instruments

International Electro Technical Commission (IEC)
Japan Electro Technical Committee (JEC)
Institute of Electrical & Electronic Engineers (IEEE)
American Petroleum Institute (API)
Japanese Industrial Standards (JIS)

(11) Civil Engineering and Buildings

American Institute of Steel Construction, Manual of
Steels Structure (AISC)
American Society of Heating, Refrigerating and Air
Conditioning Engineer (ASHRAE)
American Occupational Health and Safety (AOHS)
Japanese Industrial Standards (JIS)

## 7.2 Collection of Data and Information Related to Design of the Demonstration SRC Plant

The following is an outline of main considerations for establishing the design basis of the demonstration plant.

### 7.2.1 Selection of a Plant Site (within the Rourkela Steel Plant)

Location-II and south annex area were selected as the plant site, since the required area can be secured here, the site is close to the tar distillation plant, allows for easy receiving of coal and permits the relatively convenient dispatch of product. The selected site is located in the south part of the Rourkela steel plant.

### 7.2.2 Intake of Feedstock Coal

The Assam coal which is the feedstock coal will be transported by freight car from Assam and in order to assure a reliable supply, coal storage bins of a 14 day storage capacity (or 7,990 ton) will be installed on the plant site. The storage bins are to be located in the north east of the plant site.

### 7.2.3 Hydrogen Production

Hydrogen is an essential auxiliary material to SRC production. Methods of hydrogen production include coal gasification, steam reforming of naphtha or hydrocarbon gas, gas separation, etc. Although the cost of the feedstock coal for coal gasification is relatively low, the construction costs for a gasification plant are high and so this method is not considered appropriate to the present plan. Construction of the hydrogen production plant used for the steam reforming method is relatively cheap but the required raw materials are difficult to

obtain and costly so that this method is also judged
inappropriate to the present plan.

With regard to the steam reforming of the product gases
which arise in the SRC plant itself, the amount is
considered too small to produce the required quantity of
hydrogen.  As to gas separation since COG (Coke Oven Gas)
is produced in the Rourkela Steel Plant in sufficient
quantities with a relatively high hydrogen content, this
option is considered the most appropriate for the present
project.

Approximately 23,100 $Nm^3$/h of COG gas is required for the
separation of the quantity of hydrogen needed to operation
of the SRC Plant.  This is a large amount in relative
terms and the calorific value is also large (about 92.3
MMkcal/h).  A considerable quantity of purge gas will be
released in the hydrogen separation which can be sent back
to the Rourkela Steel Plant together with the gas produced
in the SRC plant to serve as fuel gas.  It is estimated
that the calorific value of the fuel gas thus returned
will be about 90.1 MMkcal/h equaling about 97.6% of the
received calorific value so that this is not anticipated
to have a considerable effect on the fuel balance of the
Rourkela Steel Plant.

In view of the above it was decided to carry out hydrogen
production for the present project by feeding in the COG
gas produced in the Rourkela Steel Plant and using the gas
separation method to produce the hydrogen requirement.


7.2.4  Fuel

Fuel gas or fuel oil is necessary to the process heaters
of the SRC Plant.  Varieties of such fuels which can be
obtained outside the plant site are COG and bunker C fuel
oil.  As the COG is to be used as feedstock for hydrogen
production as explained in the previous section, there
will not be any excess supply available.  It is possible

to obtain bunker C fuel oil but the cost is comparatively
high.  Since it is desirable to keep fuel costs down in
order to enhance the economic viability of the present
project, the middle and heavy distillate of the liquefied
oil produced in the SRC Plant except the light distillate
is to be used as fuel oil for the SRC plant.  By this
method it will be possible to keep the quantity of bunker
C fuel oil to be purchased from external sources to a
minimum level.  Depending on the fuel oil balance slightly
more middle and heavy distillate may be produced than is
necessary to fuel oil consumption so that a slight excess
of middle distillate will arise and bunker C oil may not
be required except special cases such as start-up
operation.

Fuel gas is required for the coal dryer in the coal
handling area and for the pilot burners of the process
heaters in the SRC plant.  A mixture of the purge gas
produced in the hydrogen separation area and of the SRC
product gases is to be supplied to these fuel gas use
points.


7.2.5  Electric Power

It was proposed that the supply of electric power to the
Rourkela Steel Plant be kept under a level of 1,500 kW.
Such an electric supply was found insufficient to meet
the motor power needs of the SRC plant.  In response an
intake of externally supplied steam of 10 t/h was
postulated but this was also found to be inadequate to
meet the power shortage.  In order to assure that the
motive power requirement of the SRC plant is met and to
keep the intakes of externally provided electric power and
steam within the acceptable tolerance levels, it was
decided to install a boiler unit producing high pressure
steam ($57 \ Kg/cm^2 G$).  The high pressure steam produced will
be used by drivers above 150 kW.  Samla steam coal of low
price to be pulverized to fine powder was selected as the
fuel for the boiler.

## 7.2.6 Steam

10 t/h of high pressure steam (57.0 Kg/cm$^2$G) is assumed to be received from the Rourkela steel plant during normal operation.

It is also supposed that the same limit is acceptable in the case of steam of 8.0 Kg/cm$^2$G. However, this intake is unnecessary during normal operations, and will be received only temporarily on special occasions such as start up operations. For other steam requirements besides the above, steam generated inside the plant itself is employed.

## 7.2.7 Water

The intake capacity is for about 200 m$^3$/hr of treated river water for use as general use water. Uses of the above treated river water are as process water, cooling water make up, fire fighting water, etc. It is assumed that drinking water will be supplied from the Rourkela steel plant. External supply of boiler feed water will not be needed since this can be provided during normal operations by condensing the high pressure steam to be received from the outside of the battery limit. However, external supplies will be required at times when the steam system of the plant is unstable such as during start up operations, etc.

## 7.2.8 Applications of the Liquefied Oil

The middle distillate and heavy distillate portions of the liquefied oils produced inside the plant can be used inside the plant, as already mentioned in section 7.2.4 on fuel, in order to reduce the expenses made for purchase of external fuel oil. Since the light distillate-1 and light

distillate-2 contain relatively high concentrations of
useful components such as benzene, toluene, xylene and
phenol, etc., it is desirable to separate useful
components from these fractions. Therefore, these
fractions are to be dispatched to component-separating
units such as a coal tar distillation plant, located out
of the plant.


7.2.9  SRC

SRC is to be solidified in water inside the plant and
formed to pencil shape. It is to be taken up at a
moisture content of about 5% and sent by conveyor to the
SRC storage yard. After temporary storage it is to be
transported by truck to the Rourkela Steel Plant.


7.2.10 Filter Cake

Filter cake is discharged from the solid-liquid separation
area. The filter cake is a powder waste mainly composed
of coal ash, waste catalyst, insoluble organic solids with
some amount of oil and SRC. Since it contains some
quantity of oil and SRC, the cake has a low calorific
value of about 2,190 kcal/kg. As it is relatively
difficult to treat this cake inside the SRC plant the best
overall solution is to transport this by truck to the
Rourkela Steel Plant where it will be mixed with a large
quantity of coal inside the large coal boiler, etc. for
combustion.

## 7.3 Optimum Capacity of the Demonstration Plant

To determine the capacity of the demonstration plant, it will be necessary to collect and evaluate data concerning the SRC output of the plant, the coke production possible using the SRC thus produced, the coke production scale of the coke ovens, the process performance of the plant and demonstration of equipment and units, as well as acquisition of scale-up data for the future SRC commercial plant.

7.3.1 The plant can process 500 t/d of feed coal to produce about 340 t/d of SRC (in the base case) so that the annual output is 112,000 ton. The present records of Rourkela steel plant for coke production show that in 1989-90 the coal feed for production of coke was 1,736,104 ton on a dry basis, from which four coke oven batteries (with a total of 243 ovens) produced 1,318,503 ton of dry basis coke. Assuming that SRC is mixed at a ratio of 10% of the coal feed for coking then given the SRC output indicated above 1,120,000 ton of coal feed complement will be required. The recorded feed intake capacity of one coke oven is 16.75 ton. Dividing the total intake by all coke ovens by the input of one coke oven load reveals that charging and discharging are carried out 66,866 times annually. The average number of charge-discharging operations for one coke oven is 430 times a year so that 156 coke oven will be involved by the SRC blending operations. This represents 64% of the total 243 coke ovens. In view of the above results a plant with a 500 t/d scale is considered sufficient to contribute to the actual operations of the Rourkela Steel Plant.

7.3.2 An evaluation of the equipment performance of the SRC demonstration plant is possible by the verification of the performance of the critical equipment and units of the plant. The critical equipment of the plant are the dissolver preheater, the dissolver, the filter, the dissolver charge pump, the let down valve, etc. It is

necessary for the capacity of these to be above certain
levels to assure the performance of a commercial scale of
plant.

The current scale of the dissolver preheater is for a
maximum capacity of about 700 t/d for one train.   The
demonstration of the dissolver preheater in the 500 t/d
could adequately provide the engineering data for design
of the same kind of heater to be used in the future
commercial plant.   (For a capacity above 700 t/d, parallel
trains of the preheaters would be installed.)

It is supposed that the maximum size of the dissolver to
be used in a commercial plant will be of the order of 4
metre for inner diameter and 40 metre for height.   On the
other hand, the scale of dissolver necessary for a 500 t/d
plant would be 2 metre for inner diameter and 20 metre in
height.   With this difference in size it would be
perfectly possible to accurately predict the fluid
dynamics inside the postulated commercial plant dissolver
on the basis of the fluid dynamics inside the actual
dissolver of the 500 t/d plant.   It would be possible to
predict the gas hold up ratio inside the dissolver which
is an important factor in a dissolver design.   From this
an accurate forecast of the slurry residence time would
also be possible.   Therefore it would be possible to
accurately predict the reaction results of a commercial
plant (SRC yield, SRC properties, etc.) on the basis of
the reaction data gathered from the SRC Demonstration
Plant.

It is possible to use filtration data for purposes of the
commercial plant scaling up in the case of any plant with
over about 100 t/d output, so that no problem is envisaged
in scaling up filter data.   (For a capacity above 100 t/d,
the equipment would be installed in parallel trains.)

As for the dissolver charge pump and the centrifuge,
equipment of which capacity is maximum in the present
market is to be used in the 500 t/d plant.   Equipment of

almost same capacity as that of the 500 t/d plant will be used in the commercial plant with increasing the number in use so that testing of the actual equipment envisaged is possible in the demonstration plant.

The let down valve of a 500 t/d plant will be 6 inch in size which is sufficient for estimating the fluid dynamics of the 10 to 14 inch valve to be used in a commercial plant, and so design to prevent damage through abrasion will be possible.