7.4 Review of Process Configuration of Base Case

7.4.1 Plant Capacity (Feed rate to the plant)

500 ton of per day of feedstock coal (on a dry basis).

7.4.2 Annual Stream Days

330 days per year.

7.4.3 Feedstock Coal

The analytical values for the unwashed Assam coal on which design is based are given below:

(1) Proximate Analysis

Total Moisture	12.4 wt%	(raw coal basis)
Surface Moisture	10.0 wt%	(raw coal basis)
Inherent Moisture	2.4 wt%	(raw coal basis)
Volatile Matter	41.7 wt%	(dry coal basis)
Fixed Carbon	53.3 wt%	(dry coal basis)
Ash	5.0 wt%	(dry coal basis)

7.4.4 Reaction

(1) Operating Conditions at the Dissolver Outlet

Temperature	430 °C
Pressure	150 Kg/cm^2G
Residence Time	60 min

(2) Catalyst and Promoter

Catalyst	
Type	Iron Ore
Adding Rate	3.0 wt% of feed coal (dry coal basis)
Promoter	Sulfur
Adding Rate	1.0 wt% of feed coal (dry coal basis)

(3) Chemical Hydrogen Consumption

2.7 wt% of feed coal (d.a.f. basis)

(4) Yield Configuration

	wt% on Coal (d.a.f. basis)
Methane	2.9
Ethane	1.4
Propane	1.0
Butane	0.4
Carbon Monooxide	0.6
Carbon Dioxide	1.2
Ammonia	0.1
Hydrogen Sulfide	0.3
Water	3.4
Light Distillate-1	2.1
Light Distillate-2	1.7
Middle Distillate	6.9
Heavy Distillate	11.6
SRC	68.2
IOM	0.9
Total	102.7

7.4.5 Product

(1) Product Slate (dry basis)

Light Distillate-1 (C_5-180°C)	412 kg/h
Light Distillate-2 (180-200°C)	337 kg/h
Middle Distillate (200-250°C)	1,170 kg/h
Heavy Distillate (250-450°C)	2,114 kg/h
SRC (450°C+)	14,149 kg/h

(2) Product Specifications

1) Light Distillate-1

Boiling Point Range	C_5-180°C
Specific Gravity (at 30°C)	0.77
Viscosity (at 30°C)	0.6 cP

2) Light Distillate-2

Boiling Point Range	180-200°C
Specific Gravity (at 30°C)	0.92
Viscosity (at 30°C)	2.6 cP

3) Middle Distillate

Boiling Point Range	200-250°C
Specific Gravity (at 30°C)	0.96
Viscosity (at 30°C)	4.5 cP

4) Heavy Distillate

Boiling Point Range	250-450°C
Specific Gravity (at 30°C)	1.06
Viscosity (at 30°C)	80 cP

5) SRC

a) Composition of Whole SRC

Component	wt%
Net SRC (excluding solids)	95.2
Total Solids	4.8
Ash	(3.6)
Catalyst	(0.7)
IOM	(0.5)

b) Whole SRC

Softening Point	160°C

c) Net SRC (components other than solids)

Boiling Point Range	450°C+
Ultimate Analysis (wt%)	
Carbon	87.9
Hydrogen	5.9
Nitrogen	1.6
Sulfur	1.5
Oxygen	3.1
Proximate Analysis (wt%)	
Volatile Matter	35.2
Fixed Carbon	64.8
Specific Gravity (at 20°C)	1.28

(3) By-products Specifications

1) Filter Cake

Form	Powder
Compositions (wt%)	
Solids	77.0
Oil	21.5
SRC	1.5

7.4.6 Auxiliary Raw Material

(1) COG (Coke Oven Gas)

1) Main Components

Component	vol%
Hydrogen	49.9
Methane	24.2
Ethane	2.6
Carbon Monooxide	8.2
Carbon Dioxide	3.4
Nitrogen	11.4
Oxygen	0.3

2) Impurities

Component	Content
H_2S	2 - 3 g/Nm^3
NH_3	4 - 6 $g/100Nm^3$
Naphthalene	(20 - 30 $g/100Nm^3$) Note 1
Benzene	(10 - 15 g/Nm^3) Note 1
Tar Fog	(0.1 g/Nm^3 max.) Note 1

Note 1
The numerical values in parentheses have been given as contents of COG impurities for design basis of the plant by RSP. These contents of COG impurities is expected to be able to reduced to a satisfactorily low level by improving gas-liquid contact function of the existing COG wash oil scrubbing tower in RSP. It is estimated that an expense for improving the gas-liquid contact function is not large. Of course, it is possible to reduce contents of COG impurities by scrubbing COG in a COG wash oil scrubbing tower to be newly installed in the plant, however the construction costs and the operating costs of the plant will

increase considerably. From the point of view of total costs, the way to install a COG wash oil scrubbing tower in the plant is not recommendable. Therefore, on the assumption that the improvement on the gas-liquid contact function of the existing COG wash oil scrubbing tower in RSP be carried out in the future, the design basis of the plant is set based on of low level of COG impurities for this study. If the present production rate of COG in RSP is assumed to be 50,000 Nm^3/h, amounts of benzene contained in this COG is 12,000-18,000 kg/d, that is fairly large quantity of benzene. It is recommended that this benzene should be recovered by improving gas liquid contact efficiency (for example, exchange of column packing etc.). The sale of recovered benzene will yield farely profit at a low expenses.

7.4.7 Plant Configuration

(1) Main Services

Area No.	Service
100	Coal Preparation Area
200	Coal Dissolving Area
300	Hydrogen Recovery and Purification Area
400	Fractionation Area
500	Solid/Liquid Separation Area
600	SRC Solidification Area
700	Hydrogen Separation Area
800	Sulfur Recovery Area

(2) Utilities and Supporting Facilities

System No.	Service
1000	Steam and Condensate System
1100	Water System

1200	Waste Water Treatment System
1300	Cooling Water System
1400	Fire Fighting System
1500	Fuel System
1600	Air and Nitrogen System
1700	Flare System
1800	Hot Oil System
1900	Flushing Oil System
1980	Interconnecting Piping System
2000	Electric System

7.4.8 Location of Plant

(Refer to Figure 6.2.2)
The site chosen for the plant is at Location-II and south annex area (total area is about 110,000 m^2) in the south section of the Rourkela Steel Plant of Rourkela City in the state of Orissa. (Refer to Figure 6.2.2)

Note : The area of the plant site tentatively selected by RSP on September, 1990, is 80,000 m^2. However, after plot plan study it has been revealed that the plant site area is required to be 110,000 m^2 minimum for the plant.

7.4.9 Outline of Main Processes

Feed Coal is fed into the coal preparation area where feed coal is crushed and dried. Then, the slurry made up of the dried coal, solvent, catalyst and promoter is sent to the coal dissolving area, where it is converted into gas, liquid oil and SRC under hydrogen atmosphere at 430°C, and 150 Kg/cm^2G.

The heavy distillate containing solid materials is sent to the solid/liquid separation area, where part of solids such as ash, catalyst, filter aid, and insoluble organic matters (IOM) are removed from the liquid oil and SRC.

The liquid products are separated into light distillate-1, light distillate-2, middle distillate, heavy distillate, and SRC by distillation and vacuum flashing, and SRC containing a small amount of solids is solidified in the solidification area.

The gaseous products are fed into the gas/liquid separation unit and subsequently to the cryogenic unit for hydrogen recovery for re-use. The remaining gas is sent to the fuel gas system.

The make-up hydrogen gas is separated from COG in the hydrogen separation area, and fed to the coal dissolving area.

7.4.10 Process Descriptions

(1) Coal Preparation Area

This area is composed of a coal storage section, crushing and drying section, catalyst pulverizing section and promoter section.

1) Coal Storage Section

(Refer to Figure 7.4.1)

Coal is conveyed to the coal receiving yard and fed into a coal receiving hopper. From there it is transported to the coal storage facilities by rotary discharge machine (JF101) and belt conveyor. The storage facility is a rectangular concrete structure which has a coal feed conveyor installed running along the longer width of the roof. Underneath a coal discharge machine (JF102) and coal discharge conveyor are installed. The coal discharge machine is mobile along the longer axis of the structure and so the coal stored in the structure can be discharged uniformly. The storage capacity of the facility is 7,990 ton which equals a fourteen days supply of raw coal to the plant.

2) Coal Crushing and Drying Section

(Refer to Figure 7.4.1)

The raw coal feed stored in the coal storage facilities is taken uniformly from each section and continuously using a coal discharge machine. The discharged feed coal is sent by conveyor to a hammer crusher (FH101A,B). After crushing by the hammer crusher the coal is sent to a ball mill (HF1021A,B) for pulverizing. Hot flue gases generated by the hot flue gas generator (BA101) are blown into the ball mill so that drying occurs together with pulverizing.

The dried pulverized coal is collected from the gas stream using a multi cyclone (FE101) and bag filter (FD102) to be sent to the coal silo (FE101) for temporary storage.

The stored pulverized dry coal is sent to the coal dissolving area in set quantities by batch to undergo slurry preparation.

3) Catalyst Pulverizing Section

(Refer to Figure 7.4.2)

The catalyst brought to the raw catalyst receiving yard by freight car is transferred to a hopper and sent by conveyor from there to the catalyst silo (FE162) for storage. The stored catalyst is then sent by feeder and conveyor to the catalyst surge bin and from there the catalyst is sent in specified rate to the catalyst pulverizer (FH161) for pulverizing.

The pulverized catalyst is collected from the gas streams using a multi cyclone (FD161) and bag filter (FD162) and then sent to the catalyst bin (FE164) for temporary storage.
The stored pulverized catalyst is sent in set quantities by batch to the coal dissolving area to undergo slurry preparation.

4) Promoter Section

(Refer to Figure 7.4.3)

The sulphur produced from the acid gases in the sulphur recovery area of the plant are in the form of moist small flakes. The sulphur in this form is taken by truck to the promoter section and transferred to a conveyor. It is sent by conveyors to the roll foaming machine (KD171) to undergo cutting and forming. The formed sulphur is supplied into a band dryer where it is dried using nitrogen gas at high temperature.

The dried sulphur is discharged to a hammer mill where sulphur is pulverized. Then, sulphur is sent by flow conveyor to the promoter silo (FE171) for temporary storage.

Since the sulphur delivered from outside the plant is already in a dry pulverized form, this is brought by truck and loaded directly in the promoter silo by conveyor joining the above dry pulverized sulphur for storage.

The stored pulverized promoter is sent by batch in specified quantities to the coal dissolving area to undergo slurry preparation.

(2) Coal Dissolving Area

(Refer to Figures 7.4.4 and 7.4.5)

The dissolving area is composed of two sections, namely the reaction and separation sections.

1) Reaction Section

Dried coal, catalyst and promoter from the coal preparation area are received in the slurry preparation tank (FA201) and are mixed with a recycle solvent to be made into coal slurry. This coal slurry is then transferred to the slurry charge tank (FA202) after preparation. The coal slurry is fed to dissolver (DC201) by dissolver charge pumps (GA201A,B) through the dissolver charge heater (BA201). To prevent coking inside tubes of the charge heater, hydrogen gas is supplied to the slurry pipe near the heater inlet.

Coal is dissolved in the solvent by heating, and hydrogenation of the dissolved coal is performed inside the dissolver. This reaction is exothermic, and the temperature at the dissolver outlet is controlled at 430°C.

The residence time in the dissolver is approximately one hour. The reaction products containing excess hydrogen and solvents are first separated into heavy effluents containing solids and light effluents by the dissolver effluent separator (FA203). The reaction products are cooled by circulating cooling oil in order to prevent coking in this separator.

The flashing gases from this separator is cooled and separated into condensates and gases in the first high pressure separator (FA204). Part of the condensate is cooled and returned to the dissolver effluent separator as part of cooling oil, while the remainder is fed to the low pressure separation section.

The gases are further cooled down and separated into gases, water, and oil by the second high pressure separator (FA205). The entire quantity of oil is returned to the dissolver effluent separator (FA203) as cooling oil, while water is sent to the waste water treatment system. Gases are cooled and fed to the water wash tower (DA201) where ammonia and salts contained in gases are water-washed.

The primary purpose of this washing is to prevent deposition of salts in the line of the next process and to remove corrosive inorganic compounds from this stream. After cleaning by water, the gases are fed to the hydrogen recovery and purification area. Water and oil condensates from the lower section of the water washing tower are fed to the water wash tower bottom decanter (FA207) in which they are separated into water and oil condensates. Water is sent to the waste water treatment system, and oils fed to the fractionation area.

2) Separating Unit

Heavy liquefied products from the dissolver effluent separator (FA203) are fed to a pressure reducing system to have their pressure lowered. The depressurized slurry is fed to the solid/liquid separation area. Gases from the letdown vessel (FA208) are fed to the first low pressure separator (FA209) after being cooled together with the first high pressure separator bottom in the reaction section. Part of the condensate is cooled to be made into cooling oil for filter feed slurry and is sent to the solid/liquid separation area, while the remainder is supplied to the fractionation area.

The gases are supplied to the acidic gas absorber (DA202) together with off-gases that are generated in the reaction section and gas washing section.

The purified gases from the acid gas absorber are supplied to the fuel gas system, and acidic gases from the acidic gas stripper (DA203) are fed to the sulfur recovery area.

(3) Hydrogen Recovery and Purification Area

(Refer to Figures 7.4.6 and 7.4.7)

The gases from the water washing tower (DA201) contain a small amount of oil which may freeze in the H.P.U. (Hydrogen Purification Unit, CA301) and which has to be removed. A butane scrubber (DA301) is installed for this purpose. The gases are supplied to a DEA absorber (DA303) after oil has been removed from them, and acidic gases (H_2S and CO_2) are removed by diethanol amin (DEA). The treated gases are supplied to the H.P.U. to have their hydrogen recovered. Recovered hydrogen is circulated to the coal dissolving area. The separated off-gases, whose contents are primarily methane, are delivered to the fuel gas system.

The bottom oil from the butane scrubber (DA301) is fed to the butane recovery column (DA302) for recovering butane. Recovered butane is recycled to the butane scrubber. The recovered oil from the bottom of the butane scrubber is supplied to the debutanizer (DA403) in the fractionation area.

(4) Fractionation Area

(Refer to Figures 7.4.8 and 7.4.9)

This process receives liquid streams from several process areas and fractionates these streams into butane, light distillates-1 (boiling point C_5-180°C), light distillates-2 (180-200°C), middle distillates (200-250°C), heavy distillates (250-450°C) and SRC (450°C and above).

Separated oil from the water wash tower bottom decanter (FA207), light oil from the 1st and 2nd low pressure separators (FA209 AND FA210), condensed oil from the vacuum flash No.2 condensate drum (FA407), and oil recovered from the solid/liquid separation area are all sent to the light end column (DA401) for fractionation.

The net distillates from the overhead stream of the light end column are sent to the debutanizer (DA403) to be separated into butane and mixed light distillates. Butane is returned to the butane recovery column reflux drum (FA302) as make-up butane scrubber. The mixed light distillates from the debutanizer bottom are fed to the light distillate column (DA-404) and are separated into light distillate-1 and light distillate-2. Net products of light distillate-1 from the overhead of the light distillate column are sent to a storage tank. The light distillate-2 from the light distillate column bottom are cooled and sent to a storage tank.

Distillates from the bottom of light-end column are supplied to the wash solvent column (DA402) and are separated into middle and heavy distillates. The large part of the middle distillates is sent to the solids/liquid separation area where these distillates are used as make-up of washing solvent for centrifuge sludge and filter aid solvent. Net products of middle distillate are supplied to the fuel oil system to be used as plant fuel.

The large part of heavy distillates from the bottom of the wash solvent column is returned to the coal dissolving area as part of the recycle solvent. Net products of heavy distillates are supplied to the fuel oil system to be used as plant fuel.

The centrifuge effluents from the solids/liquid separation area are supplied to a pump where the pressure is boosted up and are fed to a vacuum charge heater. The high temperature of the effluents from the heater are flashed in the vacuum flash drum (FA405), and SRC is separated on the bottom of the vacuum flash drum in a liquid state. The molten SRC is supplied to the SRC solidification area. Flash vapors are condensed and are used as part of recycle solvents.

(5) Solid/Liquid Separation Area

(Refer to Figure 7.4.10)

This process removes a large part of solids such as ashes, catalysts, and IOMs (insoluble organic materials) contained in the slurry which has been discharged from the coal dissolving area. A special type of centrifuges which are able to operate under a condition of high temperature and high pressure are used for solid separation. Also pressurised horizontal leaf filters (Funda filter) are to be used for recovering oils and SRC contained in the sludge discharged from centrifuges and for making semi-dried residual solids.

1) Centrifuge Unit

The slurry from the coal dissolving area is mixed with cooling oil from the coal dissolving area, in the centrifuge feed tank and the temperature of the slurry is decreased. Then, the slurry is fed into the bowl of the centrifuge. The bowl is roted in a high speed. Solids in the slurry has a higher density than oils, therefore precipitate on the inner surface of the bowl and make sludge according to centrifuge force in the bowl. Sludge is discharged from the bowls to the casing of centrifuge by a conveyor of which rotation speed is a little different from that of the bowl. Degree of separation of solids in the centrifuge is effected by density, particle size, shape of solids. The slurry from the coal dissolving area contains very fine particles which are difficult to precipitate, all of solids can not be separated in the centrifuge. Consequently, effluents of the centrifuge contain small amount of solids. Effluents from each centrifuge are collected to the centrifuge effluents tank from which effluents are sent to the fractionation area. The sludge is discharged from the bowl with containing approximately 50% of oils. The sludge is added with wash oil in each casing of centrifuge and this sludge/wash solvent mixture flows from each centrifuge casing to the slurry tank by gravity.

2) Filter Unit

Diatomaceous earth, which is a filtering assistant, is mixed with wash solvent in a filter aid tank (FA502) to make filter aid slurry. The filter aid slurry is sent to a filter aid charge tank (FA503) where the filter aid slurry is heated up to a predetermined temperature. Then, this filter aid slurry is added to the sludge/wash solvent mixture (sludge slurry) in the slurry tank. This sludge slurry with filter aid is fed to the filters by slurry pumps. First, solids are removed in the sequence of slurry tank —> slurry pumps (GA504A-C) —> Funda filter (FD502A-C) —> wash solvent tank (FA505). Solids are collected on the filter leaves to make filter cake. Filtrate from the filters are collected to the wash solvent tank, and is re-used as wash solvent. Part of the washing solvent is blowed down after repeated use, and make-up washing solvent is supplied from the fractionation area.

After filtration (solid removal), the residual solvent in the filter is returned to the slurry tank by pressurized N_2 gas. Then, blowing with N_2 gas is performed in the sequence of N_2 gas holder ---> N_2 gas compressor ---> N_2 gas heater (EA501) ---> Funda filter ---> condenser (EA502) ---> cyclone ---> N_2 gas holder. In this operation, the residual solvent in the filter cake is separated. However, vacuum drying is followed in order to further dry filter cakes. After N_2 blowing and vacuum drying, the residual cake is discharged by the rotation of the filter leaves. The discharged residual cake is transferred by trucks to the outside of the plant to be incinerated.

(6) SRC Solidification Area

(Refer to Figure 7.4.11)

In this area, molten SRC obtained in the fractionation area is solidified and made into solid pencil-type SRC.

The molten SRC fed from the fractionation area is temporarily stored in the storage tank (FA601) and is supplied to the solidifier (KA601) by the SRC feed pumps (GA601A,B) through SRC coolers (EA601).

The SRC cooler adjusts the SRC to an optimal temperature, and hot oil for cooling is circulated. After heat-exchanging, the hot oil is cooled by the hot oil coolers which generate low pressure steam.

The SRC that is fed to the solidifier is flowed into water through a small nozzle to be cooled and solidified as solid SRC in pencil form. Cooling water is circulated in order to maintain the optimum temperature for solidification.

The solidifier SRC is raked out by the conveyor inside the solidifier, and the water contained is separated off by the screen conveyor (JD601).

The SRC is then carried to a product storage yard by conveyors. The small quantity of broken, small-sized SRC generated in the solidifier is recovered by the thickener (FD 601) and centrifuge (FD602) after part of the circulating water is extracted. The recovered SRC is added to the product SRC, and water is returned as circulating water.

The sump pit (AD601) will be installed to extract circulating water temporarily during maintenance work.

(7) Hydrogen Preparation Area

(Refer to Figure 7.4.12)

Hydrogen required by the liquefaction reaction is produced here from the COG (Coke oven gas) supplied from outside the plant. The hydrogen is produced using pressure swing adsorption (PSA) facilities.

The PSA facility is composed of a COG Compressor (GB701) for compressing the COG, four adsorbers (DA701) installed in parallel position, a retainer, a buffer tank and a make up hydrogen compressor for compressing the produced hydrogen.

After the COG supplied from outside the plant has been compressed using the COG compressor to about 10 Kg/cm^2G it is supplied to the adsorbers. Inside these the non hydrogen components in the COG are removed by the adsorbent filling the adsorbers and hydrogen to 99% purity is produced. The change in adsorption capacity for gases due to partial pressure occurring to the gas portion adsorbed by the adsorbent of gases is employed. The high purity of hydrogen gas is compressed using the make up hydrogen compressor and sent to the coal dissolving area.

The four adsorbers are set in the following operational configuration during normal operations with a specified cycle according to an automatic valve sequence controlling the changes from one state to the next for each adsorber.

A adsorber : adsorption operation
B adsorber : depressuring operation
C adsorber : purge and regeneration operations
D adsorber : pressure operation

The adsorber having completed adsorption operations undergoes first pressure equalizing operations with the regenerated adsorber of low pressure. Next pressure equalization with the retainer is carried out and pressure is partly reduced. After depressurizing, most of the gas inside the adsorber is discharged to the buffer tank. Purge and regeneration operations are then commenced and the impure gases remaining inside the adsorber are purged using highly pure gases recovered in the retainer, and the adsorber is regenerated. The regenerated adsorber is pressurized using highly pure hydrogen gas and takes COG stand by position. The gases arising during purging operations are collected in the buffer tank and are sent together with the gases arising during depressurizing operations to the fuel gas system.

Facility operations are carried out as fully automatic control operations governed by computer.

(8) Sulphur Recovery Area

(Refer to Figure 7.4.13)

The Takahaks process is applied for sulfur recovery in the plant. Acidic gases from the coal dissolving area and the hydrogen recovery and purification area are supplied to the H_2S adsorber (DA801) and contacts the adsorbent by countercurrent, and the H_2S content in the gases drops below 50 ppm. The adsorbent is supplied to an oxidation column (DA802) by pumps (GA801A,B), is regenerated by air in the co-current in the column, and is returned from the oxidation column to the adsorber.

Absorbed H_2S is oxidized to elemental sulfur and is separated in fine particles. The elemental sulfur particles dispersed in the solution in the fine particle shape are dewatered in a filter press (FD801) after being removed from the oxidation column and are discharged as sulfur cake.

7.4.11 Utilities and Supporting Facilities

(1) Steam and Condensate System

(Refer to Figure 7.4.14)

The steam and condensate system is composed of a steam system with four pressure levels and a condensate recovery system.

The principle pressure levels and the main equipment employing these are given below:

Pressure Level	Principal Using
57 Kg/cm^2G	turbines
17 Kg/cm^2G	turbines, ejectors
5 Kg/cm^2G	reboilers, preheaters
3 Kg/cm^2G	reboilers, preheaters, tank heating, steam tracing

As mentioned in 7.2.5 already, there is not sufficient excess in the supply of electricity to the plant. Further, the maximum availability of supply for steam at 57 Kg/cm^2G is assumed to be 10 t/h. Therefore, in order to assure a supply of the required driving power for the plant, a boiler producing steam at 57 Kg/cm^2G is to be installed. The boiler will burn steam coal and its design steam generation capacity is to be for 70 t/h. All the compressors, blowers and pumps above 150 kW in the plant are to be driven by steam turbines.

The 17 Kg/cm^2G steam is to be produced by heat recovery of the process streams and exhaust steam from the 57 Kg/cm^2G steam turbines. The 5 Kg/cm^2G and 3 Kg/cm^2G steams are in turn to be produced by the heat recovery of the process streams and exhaust steam of the 17 Kg/cm^2G steam turbines.

It is assumed that in normal operation a 10 t/h supply of 57 Kg/cm^2G steam will be received from outside the plant and used. Also a 8 Kg/cm^2G steam will be received in case of special operations such as start up operations, etc.

Also, a fuel coal storage bin, a fuel coal pulverizer, an electric precipitator to collect and eliminate the dust contained in combustion flue gases, will be installed as supplementary equipment required to boiler operations.

Also, a condensate recovery system, a deaerator and boiler feed water charge pumps will be installed to permit recovery and recycling of the condensate.

(2) Water System

(Refer to Figure 7.4.15)

The water system is for the distribution of the treated river water, boiler feed water and drinking water received from outside the plant to the points inside the plant where these are required for use.

The treated river water will be used as cooling water system make up, fire fighting water, process water, etc. The intake of treated river water is to be 200 t/h.

(3) Waste Water Treatment System

This system will receive the process waste water discharged from the process areas of the plant, the plant oily drawing water, and the blowdown water from the cooling water system. This system will treat the received waste water to ensure that the solids, BOD, COD, etc. contained in the waste water after processing are below the each level specified for each components.

This system consists of the gas stripping section, the dissolved air flotation unit, the biological treatment unit, the clarifier separation unit and the sludge treatment unit.

1) Gas Stripping Section

Sour water from the various process areas is supplied to a degasser to remove a small quantity of gaseous substances contained. The degassed water is supplied to an H_2S stripper to remove H_2S. The overhead vapor containing H_2S from the H_2S stripper is supplied to the sulfur recovery area. The ammonia-rich bottom from the H_2S stripper is fed to the NH_3 stripper. The overhead vapor containing NH_3 from the NH_3 stripper is supplied to the flare system to be incinerated.

The stripped water from the bottom of the NH_3 stripper is cooled and is sent to the dissolved air flotation unit.

2) Dissolved Air Flotation Unit

(Refer to Figure 7.4.16)

This unit receives the process waste water after removal of the H_2S and NH_3 in the gas stripping section, and the oily water discharged in the plant. The system is used to eliminate the suspended materials contained in particle form in the above intake waste water. First, the concentration of the constituent substances (phenols, etc.) is adjusted to make these suitable to the next process stage of biological treatment by dilution using part of the blowdown water from the cooling water system. The waste water of adjusted concentration is then supplied to the aeration basin where water to which air is dissolved, are added to the waste water, and the dissolved air then undergoes gasification and during air flotation the suspended materials are collected and separated.

3) Biological Treatment Unit

(Refer to Figure 7.4.16)

This unit receives waste water which the concentration of the constituent substances (phenols, etc.) has been adjusted to a suitable level and has been treated in the dissolved air floatation unit. In this unit, the phenols, NH_3, H_2S, BOD, COD, etc. are eliminated from the intake waste water by the action of aerobic and anaerobic microbes and the water quality thus improved. During this stage K_2HPO_4 and $FeSO_4$ are added as nutrients.

4) Clarifier Separation Process

(Refer to Figure 7.4.16)

The dissolved organic substances contained in the waste water are changed to suspended substances by treatment in the biological treatment unit. This unit receives the waste water treated in the biological treatment unit and through the addition of flocculent the formation of flock realized. After the suspended substance has been absorbed by the flock the waste water is sent to a clarifier where the flock containing the absorbed suspended substance is separated and removed to produce treated water.

5) Sludge Treatment Unit

(Refer to Figure 7.4.16)

The sludge discharged from the above treatment units is condensed using a thickener and then the water separated off using a dehydrator. The dehydrated sludge is added to the pulverized coal used as boiler fuel and is burned in the boiler of the plant.

The water removed by the dehydrator is sent back to the biological treatment unit for retreating.

(4) Cooling Water System

In this system, cooling water needed for the plant is cooled by the cooling tower for re-circulation.

Make-up water is supplied from the water system to supplement evaporation loss, mist loss, and blow down in the circulation cooling tower. Make-up water is treated river water.

This system consists of a cooling tower, pumps, a corrosion inhibitor injection facilities, and a scale dispersant injection facilities.

Principal configuration of the system is shown below:

- Cooling water circulating flow rate 5,500 t/h
- Cooling water temperature at the inlet of cooling tower 45°C
- Cooling water temperature at the outlet of cooling tower 35°C

(5) Fire Fighting System

The system consists of a fire-fighting water tank which receives water from the water system, chemical tanks, fire fighting pumps, pipes, etc.
The fire fighting pumps are driven by motor or by diesel engine. The fire fighting pumps automatically start when the water pressure in the pipes lowers due to use of water in fire fighting.

The hydraulic pressure in the fire-fighting water pipes is maintained at a fixed level by a jack pump. In a fire, fire fighting is carried out using water and chemical fire extinguisher agent supplied by this system.

(6) Fuel System

(Refer to Figure 7.4.17)

This system consists of a fuel oil system and a fuel gas system. The fuel oil system supplies fuel oil to the process heaters of the plant. After the middle distillates and heavy distillates produced in the plant are received to the distillate fuel oil tank, they are used as a main fuel oil source. During start up operations when these distillates have not yet been obtained, bunker C fuel oil is received from outside of the plant into the bunker C fuel oil tank and used as an auxiliary fuel.

The fuel gas system supplies the fuel gas required to produce the hot flue gases used in coal drying and the fuel gas required by the pilot burners of each process heater and flare stack. The purge gases produced during the separation of hydrogen from the COG in the hydrogen separation area and the product gases arising in the plant are received in the fuel gas system and used as fuel. Excess fuel gas is sent back to the Rourkela Steel Plant outside the plant as fuel gases (COG return).

Facilities for fuel coal receiving, pulverizing, and also fine coal supplying are to be installed as part of the boiler facility located in the steam and condensate system.

(7) Air and Nitrogen System

(Refer to 7.4.18)

Compressed air and nitrogen gas needed inside the plant are to be received from outside the plant. Instrument air is to be prepared in the plant and an instrument air holder is to be installed in order to hold a specified amount of instrument air and to assure to supply instrument air for emergency operations. A nitrogen gas holder and nitrogen gas compressor are to be installed in the plant so that the nitrogen gas is used after being compressed. After compression of the nitrogen gas to 5 Kg/cm^2G it is to be used for the following purposes in the plant.

1) To drain filtrates from the filter and to dry filter cake in the solid/liquid separation area.
2) To blanket the oil tanks
3) To purge during start up and shutdown for safety

(8) Flare System

(Refer to Figure 7.4.19)

This system receives the gases, vapors, liquids, slurry, etc. discharged from the plant during emergency operation and treats these in safety.

The system consists of a light gas pressure relief system, heavy gas relief system and a flare stack which receives the gases and vapors from the knock out drums of the above relief systems for combustion.

Oil, etc. separated out in the knock out drums are taken out by the flare knock-out drum pumps and sent to the slop oil tank for subsequent treatment inside the plant.

(9) Hot Oil System

Hot oil is used to heat and cool high temperature fluids and as traces the process lines of high-softening point fluids such as SRC.

The system is mainly consists of a hot oil heater, a hot oil circulation pump, a hot oil tank, a hot oil expansion drum.

The use of hot oil is shown below:

Area	Use
Dissolver Area	Cooling in heat exchanger
Fractionation Area	Heating in heat exchanger and tracing for pipe
Solid/Liquid Separation Area	Heating in heat exchanger and tank
SRC Solidification Area	Heating in tank and tracing for pipe

(10) Flushing Oil System

For flushing oil, a recycle solvent which has a relatively high boiling point and is clean, is used. The flushing oil is flushing in the pump seal sections, junction sections of meters and in other sections, to protect them.

The flushing oil is supplied by a flushing oil recycle pump.

(11) Interconnecting Pipes

(Refer to Figure 7.4.20)

The pipings required for receiving COG and utilities, for returning streams and transferring byproducts are to be installed between the plant and existing facilities.

(12) Electric Power Facilities

(Refer to Figure 7.4.21)

The electric power of 6.6 kV, 50 Hz for use inside the plant is to be received by two electric power feeders.

The receiving limit of electric power to the plant is assumed to be 1,500 kW as stated in 7.2.5. In order to reduce the electric consumption inside the plant the drivers of the rotating machine exceeding 150 kW are to use steam turbines. Since the use of electric motors exceeding a 150 kW level will thus be avoided, there will be no areas using an electric energy of 6.6 kV. The main electricity supplies used inside the plant are 415 V and 240 V and transformers will be used to step down the voltage of the 6.6 kV current. The required electric power of this voltages will be distributed to the electric motors, feeders, lighting devices and other points of use by a power distribution system.

In cases of the power failure of the normal power supply, emergency power distribution supply will ensure that an emergency power generator of 300 kVA starts immediately and automatically, and supplys the electricity essential to a safe shutdown of the plant. The emergency power generated will be used to supply instrumentation electric power (AC 110 V and DC 110 V), to operate the electric control panel (DC 110 V), to run the drivers for machinery which must be kept in operation and for lighting.

The single line diagram for the feeding of the electric power is as shown in Figure 7.4.21.

7.4.12 Accessory Facilities

(1) Buildings

The following plan has been made for various facilities from the standpoint of the plant scale and personnel organization.

1) Administration Building

The administration building will house the following departments:

- Director's Office
- Administration Department
- Production Management Department
- Production Department

The administration building will also house a telephone switchboard room, meeting rooms, and others. The building will have a reinforced concrete structure with two floors with air conditioning system .

The floor area are given bellows:

1st floor	300 m^2
2nd floor	300 m^2
Total	600 m^2

2) Change House Facilities

The building will be of steel frame construction, single story, of area 200 m^2.

3) Warehouse (Ordinary Warehouse and Chemical Store)

This warehouse building will be used to store and disburse spare parts and chemicals to be used in the plant and will comprise ordinary warehouse, and chemical store. The ordinary warehouse and chemical warehouse will be of steel flame construction and single story. Their areas are shown below:

Ordinary warehouse	430 m^2
Chemical Store	300 m^2

4) Laboratory

The laboratory contains a variety of analytic, testing, and measuring equipment needed for plant operation control and product control.

The building will be of reinforced concrete structure with single story and 200 m^2 in area with air conditioning system.

5) Control Room

Centralized monitoring of the plant operation will be made from the control room. The control room is planned to be a single-story reinforced concrete construction, measuring approximately 300 m^2 with air conditioning system.

7.5 Material Balance and Heat Balance of Base Case

7.5.1 Material Balance

The overall material balance of the plant is as shown in Figure 7.5.1.

The following summarizes details for the raw materials, secondary raw materials (COG), product SRC, by-product liquefied oils (light distillate-1, light distillate-2, middle distillate, heavy distillate oil), produced gases and purge gases from the hydrogen separation. Two cases of material balance of the base case are shown below. One case is in the unit of ton per year and the another case is in the unit of kg/h.

(1) Unit: t/y

	Intake t/y	Output t/y	Consumption in Plant t/y	Output Dispatch out of Plant t/y
Raw Coal	188,353	0	188,353	0
COG	104,544	0	104,544	0
SRC	0	112,063	0	112,063
Lt. Distillate-1	0	3,262	0	3,262
Lt. Distillate-2	0	2,669	0	2,669
Md. Distillate	0	9,266	8,316	950
Hy. Distillate	0	16,740	16,740	0
Produced Gases (including butane)	0	13,290	515	12,775
Purge Gases	0	97,060	3,786	93,274

(2) Unit: kg/h

	Intake kg/h	Output kg/h	Consumption in Plant kg/h	Output dispatch out of Plant kg/h
Raw Coal	23,782	0	23,782	0
COG	13,200	0	13,200	0
SRC	0	14,149	0	14,149
Lt. Distillate-1	0	412	0	412
Lt. Distillate-2	0	337	0	337
Md. Distillate	0	1,170	1,050	120
Hy. Distillate	0	2,114	2,114	0
Produced Gases (including butane)	0	1,678	65	1,613
Purge Gases	0	12,255	478	11,777

The larger part of the middle distillate and all of the heavy distillate are consumed as fuel oil. Further, a part of the produced gases and purge gases are consumed inside the plant as fuel gas.

7.5.2 Heat Balance

The overall heat balance of the plant is as shown in Figure 7.5.2.

7.6 Consumption Rate of Secondary Raw Materials, Utilities and Chemicals of Base Case

Amounts of secondary raw material, utilities and chemicals required for the operation of the plant are estimated as shown below:

7.6.1 Secondary Raw Material Consumption

COG 23,120 Nm^3/h

7.6.2 Utility Consumption

The consumption of utilities during normal and start up operations are shown in Table 7.6.1.

7.6.3 Chemicals Consumption

The consumption of chemicals in the plant is shown in Table 7.6.2.

7.7 Availability of Feedstocks, Utilities and Auxiliary Facilities at the Scheduled Plant Site

The following was decided in discussion with the RSP.

7.7.1 Selection of Site

The following four sites located in Rourkela Steel Plant areas were designated as candidate sites for the SRC Demonstration Plant by MECON and RSP in the first field surveys (1990).

Location-I :	Close to B site of the by product treatment plant
Location-II:	Close to the rich gas holder
Location-III:	Near to the site of the fertilizer plant proposed in the modernization plan
Location-IV:	The raw materials yard close to the by product treatment plant

However, the plant design was undertaken on the basis of the selection of Location-II adding up the south annex area (total area is about 800,000 m^2) according to the result of the meeting held during the second field survey in 1991.
For details refer to Figure 6.2.2 of Chapter 6.

7.7.2 Reception of Coal, Pulverization, Transport Facilities

The use of existing facilities is only possible in the case of Location-I above.

7.7.3 Hydrogen

Hydrogen used for production of ammonia in the fertilizer plant can not be used.

COG of 15,000 Nm^3/h at a pressure of 300 mm WC can be used as a hydrogen carrying gas. However, to keep the energy loss within a 5% margin the gas must be returned at 300 mm WC pressure.

Note: Results of substance yield show that 23,120 Nm^3/h is required and that the return of the purge gas issued from the hydrogen separation area and the produced gas from the SRC plant would involve a 2.4% calorie loss.

7.7.4 Treatment of By Product Oil

Part of the by product oil, light distillate-1, light distillate-2 and middle distillate can be treated in RSP By-product Oil Treatment Plant. It is not possible to treat the total outputs.

Note: Most of the middle and heavy distillate oil is used as fuel oil. It is scheduled to treat the light distillate-1 and light distillate-2 in the Coal Tar Distillation Plant and other facilities of RSP.

7.7.5 Residue Treatment

The combustion of SRC residue in the RSP power plant is to be considered.

Note: The filter cake has a low calorific value of approximately 2,190 kcal/kg and there are 43 ton available daily.

7.7.6 Waste Water Treatment

The SRC Plant is to be equipped with independent waste water treatment facilities.

7.7.7 Steam

A supply of steam at a pressure of 57 Kg/cm^2G to a maximum of 10 t/h is received from RSP.

7.7.8 Electricity

Electricity as required is supplied from RSP at a voltage of 6.6 kV and 440 V.

7.7.9 Water

200 t/h of treated river water which has undergone primary treatment is to supplied from RSP.

7.7.10 Other Auxiliary Facilities

As far as possible RSP facilities and services for analysis, security, public welfare, etc. are to employed.

7.8 Equipment List of Base Case

------ List will be attached herein ------

Area 100(Coal Preparation Area-Coal Storage Crushing & Drying Section)

Item No.	Service	Req'd No.	Remarks
BA101	Air Heater	1	

Item No.	Service	Req'd No.	Remarks
EA101	Gas Cooler	1	

Item No.	Service	Req'd No.	Remarks
FD101	Coal Cyclone	1	
FD102	Coal Filter	1	

Item No.	Service	Req'd No.	Remarks
FE101	Coal Silo	1	
FE102AB	Coal Surge Bin	1+1	

Item No.	Service	Req'd No.	Remarks
FH101AB	Raw Coal Crusher	1+1	
FH102AB	Coal Mill	1+1	

Item No.	Service	Req'd No.	Remarks
GB101	Gas Rycycle Fan	1	
GB102	Combustion Air Fan	1	
GB103	Fuel Gas Booster	1	

Item No.	Service	Req'd No.	Remarks
JD101	No.1 Belt Conveyor	1	
JD102	No.2 Belt Conveyor	1	
JD103	No.3 Belt Conveyor	1	
JD104	No.4 Belt Conveyor	1	
JD105	No.5 Belt Conveyor	1	
JD106	No.6 Belt Conveyor	1	
JD107	No.7 Belt Conveyor	1	
JD108	No.8 Belt Conveyor	1	
JD109	Backet Conveyor	1	
JD110	No.9 Belt Conveyor	1	
JD111	Flow Conveyor	1	
JD112	No.10 Belt Conveyor	1	

Item No.	Service	Req'd No.	Remarks
JF101	No.1 Coal Feeder	1	
JF102	No.2 Coal Feeder	1	
JF103AB	No.3 Coal Feeder	1+1	
JF104	No.4 Coal Feeder	1	
JF105	No.5 Coal Feeder	1	
JF106	No.6 Coal Feeder	1	

Item No.	Service	Req'd No.	Remarks
MG101	Magnet Separator	1	

Area 100(Coal Preparation Area-Catalyst Pulverizing Section)

Item No.	Service	Req'd No.	Remarks
FD161	Catalyst Cyclone	1	
FD162	Catalyst Filter	1	

Item No.	Service	Req'd No.	Remarks
FE161	Catalyst Hopper	1	
FE162	Catalyst Silo	1	
FE163	Catalyst Surge Bin	1	
FE164	Catalyst Bin	1	

Item No.	Service	Req'd No.	Remarks
FH161AB	Catalyst Pulverizer	1+1	

Item No.	Service	Req'd No.	Remarks
GB161	Induced Fan	1	

Item No.	Service	Req'd No.	Remarks
JD161	Belt Conveyor	1	
JD162	Flow Conveyor	1	
JD163	Belt Conveyor	1	
JD164	Belt Conveyor	1	

Item No.	Service	Req'd No.	Remarks
JF161	Vibration Feeder	1	
JF162	Vibration Feeder	1	
JF163	Rotary Feeder	1	
JF164	Screw Coal Feeder	1	

Area 100(Coal Preparation Area-Promoter Section)

Item No.	Service	Req'd No.	Remarks
EA171	Gas Heater	1	
EA172	Gas Cooler	1	

Item No.	Service	Req'd No.	Remarks
FD171	Promotor Filter	1	

Item No.	Service	Req'd No.	Remarks
FE171	Promotor Silo	1	

Item No.	Service	Req'd No.	Remarks
FF171	Dryer	1	

Item No.	Service	Req'd No.	Remarks
FH171	Atomizer	1	

Item No.	Service	Req'd No.	Remarks
JD171	Belt Conveyor	1	
JD172	Flow Conveyor	1	
JD173	Belt Conveyor	1	
JD174	Belt Conveyor	1	
JD175	Flow Conveyor	1	
JD176	Belt Conveyor	1	
JD177	Screw Conveyor	1	

Item No.	Service	Req'd No.	Remarks
GB171	Drying Air Fan	1	
GB172	Induced Fan	1	

Item No.	Service	Req'd No.	Remarks
JF171	Table Feeder	1	

Item No.	Service	Req'd No.	Remarks
KD171	Sulfur Crusher	1	

Area 200(Coal Dissolving Area)

Item No.	Service	Req'd No.	Remarks
BA201	Dissolver Charge Heater	1	

Item No.	Service	Req'd No.	Remarks
DA201	Water Wash Tower	1	
DA202	Acid Gas Absorber	1	
DA203	Acid Gas Stripper	1	
DC201	Dissolver	1	

Item No.	Service	Req'd No.	Remarks
EA201	Hydrogen Preheater	1	
EA202	Dissolver Effluent Separator OVHD Condenser	1	
EA203	1st HP Separator OVHD Condenser No.1	1	
EA204	2nd HP Separator OVHD Condenser	1	
EA205	Quench Oil Cooler No.2	1	
EA206	Letdown Vessel OVHD Cooler	1	
EA207	1st Low Pressure Separator OVHD Cooler No.2	1	
EA208	Off Gas Compressor Discharge Cooler	1	
EA209	Acid Gas Absorber Circulation Cooler	1	
EA210	Acid Gas Stripper Reboiler	1	
EA211	Acid Gas Stripper OVHD Condenser	1	
EA212	Filter Feed Slurry Cooling Oil Cooler No.2	1	

EC201	1st HP Separator OVHD Condenser No.2	1	
EC203	Quench Oil Cooler No.1	1	
EC204	1st Low Pressure Separator OVHD Cooler No.1	1	
EC205	Filter Feed Slurry Cooling Oil Cooler No.1	1	

Item No.	Service	Req'd No.	Remarks
FA201	Slurry Preparation Tank	1	
FA202	Slurry Charge Tank	1	
FA203	Dissolver Effluent Separator	1	
FA204	1st HP Separator	1	
FA205	2nd HP Separator	1	
FA206	2nd HP Separator Bottom Flush Drum	1	
FA207	Water Wash Tower Bottom Decanter	1	
FA208	Letdown Vessel	1	
FA209	1st LP Separator	1	
FA210	2nd LP Separator	1	
FA211	LP Off Gas Compressor Suction Drum	1	
FA212	LP Off Gas Compressor Surge Drum	1	
FA213	Acid Gas Stripper Reflux Drum	1	

Item No.	Service	Req'd No.	Remarks
GA201AB	Slurry Circulation Pump	1+1	
GA202AB	Slurry Feed Pump	1+1	
GA203A-C	Dissolver Charge Pump	2+1	
GA204AB	Dissolver Effluent Quench Oil No.1 Circulation Pump	1+1	

GA205AB	Dissolver Effluent Quench Oil No.2 Circulation Pump	1+1	
GA206AB	Water Wash Tower Circulation Pump	1+1	
GA207AB	Acid Gas Absorber Lean Solution Pump	1+1	
GA208AB	Acid Gas Stripper Reflux Pump	1+1	

Item No.	Service	Req'd No.	Remarks
GB201AB	Low Pressure Off Gas Compressor	1+1	

Item No.	Service	Req'd No.	Remarks
GD201	Slurry Preparation Tank Mixer	1	
GD202	Slurry Charge Tank Mixer	1	

Area 300(Hydrogen Recovery and Purification Area)

Item No.	Service	Req'd No.	Remarks
CA301	Hydrogen Purification Unit	1	

Item No.	Service	Req'd No.	Remarks
DA301	Butane Scrubber	1	
DA302	Butane Recovery Column	1	
DA303	DEA Absorber	1	
DA304	DEA Regenerator	1	

Item No.	Service	Req'd No.	Remarks
EA301	Butane Scrubber Feed Precooler	1	
EA302	Butane Recovery Column Feed/ Draw Off Heat Exchanger	1	
EA303	Butane Recovery Column Condenser	1	
EA304	Butane Recovery Column Reboiler	1	
EA305	Butane Scrubber Feed/Effluent Heat Exchanger	1	
EA306	DEA Absorber Lean Solution Cooler	1	
EA307	DEA Regenerator Reboiler	1	
EA308	DEA Regenerator OVHD Condenser	1	
EA309	DEA Regenerator Feed/Bottom Heat Exchanger	1	

Item No.	Service	Req'd No.	Remarks
FA301	Butane Scrubber Bottom Flash Drum	1	
FA302	Butane Recovery Column Reflux Drum	1	
FA303	DEA Absorber Bottom Flash Drum	1	

FA304	DEA regenerator OVHD Accumlator	1	
FB301	DEA Solution Tank	1	

Item No.	Service	Req'd No.	Remarks
GA301AB	Butane Circulation Pump	1+1	
GA302AB	High Pressure DEA Pump	1+1	
GB301AB	Recycle Hydrogen Compressor	1+1	

Area 400(Fractionation Area)

Item No.	Service	Req'd No.	Remarks
BA401	Vacuum Charge Heater	1	

Item No.	Service	Req'd No.	Remarks
CF401	Vacuum Unit No.1	1	
CF402	Vacuum Unit No.2	1	

Item No.	Service	Req'd No.	Remarks
DA401	Light End Column	1	
DA402	Wash Solvent Column	1	
DA403	Debutanizer	1	
DA404	Light Distillate Column	1	

Item No.	Service	Req'd No.	Remarks
EA401	Light End Column Condenser No.2	1	
EA402	Light End Column Reboiler	1	
EA403	Wash Solvent Column Reboiler	1	
EA404	Wash Solvent Feed Heater	1	
EA406	Debutanizer Condenser	1	
EA407	Debutanizer Reboiler	1	
EA409	Recycle Solvent Cooler No.2	1	
EA410	Vacuum Flash Drum OVHD Condenser	1	
EA411	Middle Distillate Product Cooler	1	
EA412	Butane Vaporizer	1	
EA413	Light Distillate Column Condenser	1	
EA414	Light Distillate Column Reboiler	1	
EA415	Light Distillate-2 Product Cooler	1	

Item No.	Service	Req'd No.	Remarks
EC401	Light End Column Condenser No.1	1	
EC402	Wash Solvent Column Condenser	1	
EC403	Recycle Solvent Cooler No.1	1	
EC404	Vacuum Flash Condensate Cooler	1	
EC405	Recycle Solvent Dump Cooler	1	

Item No.	Service	Req'd No.	Remarks
FA402	Light End Column Reflux Drum	1	
FA403	Wash Solvent Column Reflux Drum	1	
FA404	Debutanizer OVHD Drum	1	
FA405	Vacuum Flash Drum	1	
FA406	Vacuum Flash No.1 Condensate Drum	1	
FA407	Vacuum Flash No.2 Condensate Drum	1	
FA408	Recycle Solvent Surge Drum	1	
FA409	Light Distillate Column OVHD Drum	1	

Item No.	Service	Req'd No.	Remarks
FB401	Recycle Solvent Dump Tank	1	
FB402	Butane Tank	1	

Item No.	Service	Req'd No.	Remarks
GA401AB	Light End Column Bottom Circulation Pump	1+1	
GA402AB	Light End Column Reflux Pump	1+1	
GA403AB	Wash Solvent Column Bottom Circulation Pump	1+1	
GA404AB	Wash Solvent Pump	1+1	
GA405AB	Debutanizer Distillate Pump	1+1	
GA406AB	Vacuum Flash Charge Pump	1+1	
GA407AB	Vacuum Flash No.1 Condensate Pump	1+1	
GA408AB	Vacuum Flash No.2 Condensate Pump	1+1	

GA409AB	Recycle Solvent Pump	1+1
GA410AB	Butane Make-up Pump	1+1
GA411AB	SRC Circulation Pump	1+1
GA412AB	Light Distillate Column Bottom Pump	1+1
GA413AB	Light Distillate Column Reflux Pump	1+1

Area 500(Solid/Liquid Separation Area)

Item No.	Service	Req'd No.	Remarks
CF501	Vacuum Unit	1	

Item No.	Service	Req'd No.	Remarks
EA501	N_2 Gas Heater	1	
EA502	Recovered Oil Condenser	1	

Item No.	Service	Req'd No.	Remarks
FA501	Centrifuge Feed Tank	1	
FA502	Filter Aid Tank	1	
FA503	Filter Aid Charge Tank	1	
FA504	Slurry Tank	1	
FA505	Wash Solvent Tank	1	
FA506	Centrifuge Effluent Tank	1	
FA507	Oil Separator	1	
FA508	Recovered Oil Tank	1	
FA509	Water Surge Tank	1	

Item No.	Service	Req'd No.	Remarks
FD502A-C	Funda Filter	3	

Item No.	Service	Req'd No.	Remarks
GA501A-F	Centrifuge Feed Pump	5+1	
GA502AB	Filter Aid Pump	1+1	
GA503AB	Filter Aid Charge Pummp	1+1	
GA504A-C	Slurry Pump	3	
GA505AB	Wash Solvent Pump	1+1	
GA506AB	Recovered Oil Pump	1+1	

Item No.	Service	Req'd No.	Remarks
GD501	Centrifuge Feed Tank Agitator	1	
GD502	Filter Aid Tank Mixer	1	
GD503	Filter Aid Charge Tank Mixer	1	
GD504	Slurry Tank Agitator	1	
GD505	Wash Solvent Tank Agitator	1	
GD506	Centrifuge Effluent Tank Agitator	1	

Item No.	Service	Req'd No.	Remarks
GE501A-F	Centrifuge	5+1	

Area 600(SRC Solidification Area)

Item No.	Service	Req'd No.	Remarks
AD601	Sump Pit	1	

Item No.	Service	Req'd No.	Remarks
EA601	SRC Cooler	1	
EA602	Hot Oil Cooler	1	
EA603	Water Cooler	1	

Item No.	Service	Req'd No.	Remarks
FA601	SRC Storage Tank	1	
FA602	Hot Oil Tank	1	
FA603	Solidification Water Tank	1	
FA604	Lower Bath	1	

Item No.	Service	Req'd No.	Remarks
FD601	Thickener	1	
FD602	Centrifuge	1	

Item No.	Service	Req'd No.	Remarks
GA601AB	SRC Feed Pump	1+1	
GA602AB	Hot Oil Circulation Pump	1+1	
GA603AB	Recycle Water Pump	1+1	
GA604	Sludge Pump	1	
GA605	Pit Pump	1	
GA606	Recovery Water Pump	1	

Item No.	Service	Req'd No.	Remarks
JD601	Screw Conveyor	1	
JD602	Relay Conveyor	1	
JD603	Overhead Conveyor	1	

Item No.	Service	Req'd No.	Remarks
KA601	Solidifier	1	

Area 700(Hydrogen Separation Unit)

Item No.	Service	Req'd No.	Remarks
DA701A-D	PSA Adsorber Unit	4	

Item No.	Service	Req'd No.	Remarks
GB701	COG Compressor	1	
GB702AB	Make-up Hydrogen Cmpressor	1+1	

Item No.	Service	Req'd No.	Remarks
EA701	COG Compressor After Cooler	1	
EA702	Make-up Hydrogen After Cooler	1	
EA703	Surface Condenser	1	

Area 800(Sulfur Recovery Unit)

Item No.	Service	Req'd No.	Remarks
DA801	H_2S Absorber	1	
DA802	Oxidation Column	1	

Item No.	Service	Req'd No.	Remarks
EA801	Oxidation Column Feed Heater	1	

Item No.	Service	Req'd No.	Remarks
FA801	Gathering Tank	1	
FA802	NaOH Tank	1	

Item No.	Service	Req'd No.	Remarks
FB801	Catalyst Tank		
FB802	NaOH Tank		

Item No.	Service	Req'd No.	Remarks
FD801	Filter Press	1	

Item No.	Service	Req'd No.	Remarks
GA801AB	H_2S Absorber Bottom Pump	1+1	
GA802AB	Filter Press Feed Pump	1+1	
GA803AB	Catalyst Pump	1+1	
GA804AB	NaOH Pump	1+1	

7.9 Preliminary Plot Plan of the Plant

Figure 7.9.1 is the preliminary plot plan for the base case. The required plot area for the plant is estimated to be approximately 110,000 m^2.

7.10 Cost Data involved in Design and Construction of the Plant

The prices of the main construction materials and wages of construction personnel to be provided domestically in India during the design and construction of the SRC demonstration plant are indicated in Tables 7.10.1 and 7.10.2 as provided by MECON at hearings during the first on site visit of the Japanese mission.

Construction materials is taken to include cement and gravel for civil engineering work, iron piping, angles and iron sheets for structures, steel materials to support equipment, scaffold materials, construction fuel, welding gas, etc. The prices are given for purchase from public enterprises in the third quarter of 1990.

The construction personnel are classified into four categories according to skills and wages vary accordingly.

Documents at hand were used for the estimation of the cost of materials relating to local construction work which were not included in the above tables.

7.11 Construction of the Plant

This section explains the organizational and works program to implement design, delivery and construction of the plant.

7.11.1 Basic Policy of Plant Construction

It is important to the present demonstration plant project to keep down the total investment cost, reduce the hard currency portion to the minimum possible, and make the local currency portion as large as possible. The basic policy of the present construction plan is to keep the duties of the Japanese contractor and delivery of equipment and materials from outside India to a minimum while enlarging the duties met inside India and increasing the delivery of Indian equipment and materials through the activities of an Indian engineering company. Further, it is assumed that the construction of the present plant is conducted on a lump sum basis by the prime contractor.

7.11.2 Project Organization for Plant Construction

The following project organization for plant construction has been designed in accordance with the basic policy for plant construction. Figure 7.11.1 shows the Overall Project Organization, Figure 7.11.2 shows the Client Side Organization, Figure 7.11.3 the prime contractor side organization and Figure 7.11.4 the Indian Contractor Organization.

The general manager of the plant ordering body will supervise the overall project. A contractor general manager is to supervise the works to be undertaken by the prime contractor taking on construction work. The prime contractor is to implement front end engineering in Japan and create a basic engineering design package on the basis design data prepared by the SRC Process Licenser. This design package is to include the material balance for all equipment in the plant, the heat balance, conceptual system design and the basic engineering products. The design package is to be passed to a local contractor scheduled by the Indian engineering industry. The local contractor is to carry out the detailed engineering, procurement of Indian materials and equipment and construction work in line with the basic engineering design package. If there are any materials or pieces of equipment which cannot be supplied in India then the prime contractor will arrange for their supply and delivery from Japan or other foreign sources.

7.11.3 Personnel Requirements for Plant Construction

The personnel required for construction work is shown in Figure 7.11.5. The cumulative total amounts to about 718,700 man days.

7.12 Operation of the Plant

7.12.1 Organization and Requirements Personnel for Plant Operation

Organization and personnel required for operation of the entire plant are shown in Table 7.12.1.

7.12.2 Commissioning and Startup

(1) Preparation for Initial Startup

The following preparation must be ready for operation. This means that all the individual units are in time for initial startup.

1) All the areas and the system must be ready for operation.

2) The personnel required for normal operation are deployed at the respective station.

3) Specialists from the makers of the devices and units are present, as far as necessary.

(2) Commissioning and Startup

First the utilities and the supporting facilities are started, and then, individual processes are started for preparatory operation for warming up with oil (solvent). When all the processes and system are definitely found to be running at the specified temperature and pressure without trouble, the supply of coal slurry is started, and the individual processes are set for normal operating conditions in sequence.

This same start-up procedure is used also when the plant is to be restarted after a total plant shutdown.

(3) Normal Operation

To keep the plant operating in stable normal operating conditions continuously is very important to secure stable quality and yield of the products and to improve the productivity of the plant. Therefore, important requirements during normal operation are to have a full knowledge of the range of normal operating conditions for individual processes and systems, to make quick decisions as to the presence of abnormal states when operation conditions fluctuate, to discover faults at early stages, to eliminate the discovered abnormal states and faults efficiently, and to prevent the occurrence of accidents and shutdown.

For these purposes, the following are required.

1) Continual monitoring of processes and facilities.

2) Long-term plotting of the main operating conditions (temperature, pressure, compositions, flow rate, yield, etc.)

Comprehensive knowledge and analyses of long-term data on normal steady operation and fluctuating operation will enable early detection of abnormal states, and the execution of preventive and corrective measures against accidents and shutdown.

(4) Normal Shutdown

Safety is a major consideration in shutting down the plant operation. Inadvertent shutting down will harm personnel and damage equipment. The shutdown procedure and shutdown sequence must be carefully observed.

Another important consideration is the coking of equipment and piping at restart that may result when slurry is not fully removed from the system, as the slurry in the form of solid-liquid mixture are subject to early solidification or sticking when they are left in the units and piping and when temperature and other conditions change. Therefore, the flushing processes specified in the shutdown sequence must be executed without fail.

The procedure for normal shutdown is as follows.

1) Stop the coal supply, and as the liquid level in the slurry preparation tank sinks, supply only the recycle solvent. This will serve as a flushing process for the coal dissolving area and other areas. Temperature adjustment of the slurry preheater has to be done.

2) Discharge solid in the coal dissolving area and the fractionation area to the outside of the systems as far as possible. For this, keep supplying hydrogen and keep the system running for a while after the flow is changed from slurry to solvent. Temperature adjustment of heaters in the coal dissolving area and the fractionation area are required.

3) When solid has been removed from the coal dissolving area and the solid/liquid separation area, switch over the flow from the dissolver effluent separator (FA203) to the letdown vessel (FA208) into the slop tank. Then, lower the heater temperature, stop the hydrogen supply, and gradually lower the system pressure.

4) Introduce nitrogen into the system to purge it of hydrogen, conducting the system gas towards the flare.

5) Wash the piping from the coal dissolving area to other areas completely. When maintenance is required, drain the piping of the solvent after washing, and clean the piping with steam.

6) Stop the operation of other areas and systems in accordance with the specified shutdown procedure.

7.13 Overall Schedule for Construction and Operation of the Plant

The overall schedule for plant construction and operation assuming that works proceed along the lines of the construction plan indicated in section 7.11 and the operation plan indicated in 7.12 is taken to be as shown in Figure 7.13.1.

The main activities are assumed to require the period of time indicated below:

Licenser's work	4 months
Basic engineering (Front-end engineering)	11 months
Detailed engineering	19 months
Piping work	10 months
Mechanical Completion	39 months after the contract effective date
Commissioning	2 months
Test run	2 months
Start of commercial operation	43 months after the contract effective date

7.14 Total Construction Costs of Base Case

The total construction costs of the plant as defined in 7.4 were estimated on the basis of the construction plan shown in 7.11 and 7.13.

7.14.1 Estimate Guidelines

The estimate of plant construction costs was carried out on the basis of the following factors.

- Estimation date: June 19, 1991.

- Escalation : not considered

- Delivery source: in principle the following equipment is assumed to be by overseas procurement.

  - High pressure vessels
  - High pressure heat exchangers
  - Stainless steel and alloy vessels
  - Stainless steel and alloy heat exchangers
  - Stainless steel and alloy piping materials
  - Air fin coolers
  - Steam turbines
  - Process compressors
  - Slurry pumps
  - Chemical pumps (Special type)
  - Centrifuge system of the solid/liquid separation area
  - Filter system of the solid/liquid separation area
  - PSA unit
  - Takahax unit
  - Flare stack burner

- Taxes: not considered

- Assignment of works: assumed to be as follows:

(1) licenser: basic design, training relating to process equipment, supervisory activities for plant initial start up

(2) prime contractor: project management, front-end engineering, overseas procurement, training relating to equipment procured from overseas, support for initial start up.

(3) Local contractor: project management of works in India, detailed design, support to clients for acquisition of import permits, domestic transport of equipment procured from overseas, domestic delivery, construction, training for equipment supplied domestically and support for initial start up.

7.14.2 Estimate of Plant Construction Cost

Current construction costs at the present date of June 19, 1991 for a SRC Plant utilizing a 500 t/d input of Assam coal on a dry basis are as shown in Table 7.14.1 (Total Plant Cost Estimation Summary), Table 7.14.2 (Equipment and Materials Cost of Process Areas) and Table 7.14.3 (Equipment and Materials Cost of Utility and Supporting Facilities). The following is a summary of the individual item headings covered in these tables.

(1) Equipment and Materials

These refer to the costs of equipment and materials needed for the main equipment, utility equipment and supporting equipment. This heading does not include the costs of materials used in civil engineering and construction work.

The foreign currency prices indicated as prices for some of the equipment and materials, are for imported items and the prices earmarked represent the FOB price at export harbours of the supplying country. Prices earmarked in Indian currency for domestically supplied items represent the prices on arrival at the steel plant of Rourkela. The domestic currency costs do not include commodity tax or sales tax.

Costs indicated for spare parts are calculated on the basis of a list of spare parts which indicates the reserve of spare parts considered necessary once construction work is completed to ensure commercial operations are smooth for the first two years.

Conditions for determining the prices of supply parts were the same as in the case of equipment and materials, with the FOB price being cited for imported goods and the price on arrival at Rourkela steel plant being cited for domestically supplied goods.

Results of the above calculation for supply parts reveal that these are equal to 7% of the costs for equipment and materials.

(2) Assembly and Installation Costs

Costs involved in work for assembly, installation, piping , electric, measurement devices, insulation, painting are estimated as part of the construction costs billed by the domestic contractor, and so the entire cost is entered under the domestic currency costs.

The construction costs include labour costs for the local workforce carrying out construction works, and all costs necessary in relation to construction equipment costs, local insurance fees, the fees of domestic contractors and any other construction work costs.

It is estimated that about 338,700 man days will be necessary (refer to Figure 7.11.5).

(3) Civil Engineering and Construction Works

The cost of civil engineering and construction works are earmarked under the part of expenses billed for the contract work of the domestic contractor.

Further, since it is judged possible to supply all of the building materials needed for construction work from domestic sources, the overall cost for this item including other related expenses has been earmarked to be met with domestic capital.

The construction costs include labour costs for the local workforce carrying out construction works, and all costs necessary in relation to construction equipment costs, local insurance fees, the fees of domestic contractors and all other construction work costs.

It is estimated that about 380,000 man days will be necessary (refer to Figure 7.11.5).

Civil engineering and construction works are as follows:

1) works to prepare the entire site for the SRC Plant

2) works for roads, waste water drains, side ditches, and other facilities

3) construction work for steel frame constructions for equipment

4) work to lay reinforced concrete foundations for equipment

5) construction of auxiliary facilities (one building each for administration buildings, changing rooms, laboratories, and control rooms, with a total floor space of 2030 m^2 (refer to 7.4.12).

(4) Cost of Overseas Transport and Insurance

This item includes costs involved in the overseas transport, marine insurance and Contractor's all risk insurance fees.

It is anticipated that the foreign countries supplying equipment and material to be imported will include Japan, the USA or European countries. For the purposes of the present estimates it has been assumed that all asuch imports are supplied by Japan and the cost of sea transport and marine insurance has been estimated on this basis. The articles taken to be imported from Japan are assumed to be unloaded at Calcutta port.

The Contractor's All Risk insurance is assumed to cover the period from delivery at the Plant site of equipment and materials up to hand over. The details of the sums to be insured in relation to design defects, defective assembly operations, and other accidents will be determined on the basis of the consultant's experience and a fee for the Contractor's all risk insurance will be set.

(5) Costs of Local Unloading and Transport

The expenses incurred in the unloading of imported equipment and materials at Calcutta Port, that is the local unloading fees, harbour port facility fees, customs clearance fees, drinking water fees, handling charges (for unloading equipment and materials, and for side expenses) together with temporary storage fees.

The local transport costs are earmarked for expenses incurred in transport from Calcutta Harbour to the Rourkela Steel Plant. The distance by rail from Calcutta Harbour to the Rourkela Steel Plant is 415 km. Imported equipment and materials is to be transported using lorries and trailer trucks.

The total costs for local unloading and local transport are earmarked under domestic currency costs.

(6) Indirect Local Costs

Indirect local costs include the following items,

1) construction costs for the temporary buildings needed including a site office, temporary workshop (for welding and piping), temporary warehouse, and workers' camp.

2) furniture and accessories for these temporary buildings

3) cost of installing electricity, water and other utilities in the temporary buildings

4) wages for the office workers and typists employed in the site office, site office expenses including cost of consumables, etc.

5) cost of fuel for construction machinery

6) expenses incurred during the local stay of the administrators, supervisors and engineers dispatched from the prime contractor (to cover accommodation costs, local allowances, and local traveling expenses, etc.).

7) miscellaneous costs including communication expenses

The indirect local expenses incurred are to be earmarked under the total portion of local currency costs.

Further, the site needed for the temporary buildings is to be lent free of charge, and the electricity, water and other utilities to be used in the site office, temporary workshop and workers's camp is to be supplied free of charge from the Rourkela Steel Plant, so that these costs will not need to appear in the construction budget.

(7) Royalties

Royalties are to be paid with regard to licensing of the SRC process. The total amount for such royalties is to be earmarked under the foreign currency portion.

(8) Basic Design Fee

In payment for the basic design work carried out by the Licenser. The total amount for this item are to be earmarked under the foreign currency portion. The fee for training given relating to the process equipment and supervision accorded during the trial run of the plant carried out by Licenser, are also for convenience including in the basic design fee.

(9) Engineering Service Fee

Service fees to be paid for technical services provided by the Prime Contractor or Local Contractor include the following items.

1) Design fee and engineering fee

2) cost of supplying the equipment and materials

3) cost of on-the-spot inspections of facilities of the manufacturers for the main devices and equipment

4) drawing up of documentation such as operational manuals for machinery and equipment

Since most of the technical services to be provided by the Prime Contractor will be carried out in Japan these costs are to be earmarked as part of the foreign currency portion. Further, the costs of technical services provided by the local contractor will be earmarked as part of the local currency portion.

(10) Project Management

Costs required by administration, supervision , technical guidance, and other activities involved in Project Management undertaken by the Prime Contractor and Local Contractor include the following expenses.

1) Fees for personnel in Administration, Supervision and Technical Guidance carried out by the Prime Contractor and Local Contractor.
Figure 7.11.3 shows the personnel organization of the Prime Contractor. Figure 7.11.4 shows the personnel organization of the Local Contractor.

2) Fees for the dispatch of experts (specialist engineers of the manufacturers) by the Prime and Local Contractors to give guidance in the installation and trial run of major equipment.

3) Fares for international flights of the managers, supervisors and engineers sent to India from overseas.

The Prime Contractor plans to use Japanese personnel when dispatching experts to the local site.

The fees for Japanese personnel and the international air fares incurred as part of Project Management will be earmarked under the foreign currency portion, while fees for national personnel will be earmarked under the local currency portion.

The overseas and national experts dispatched by the Prime Contractor and Local Contractor will be responsible for construction work, administration and guidance of trial runs, as well as for technical training and guidance of the operators in the SRC Plant.

(11) Physical Contingency

Since the present outline report does not allow us to carry out rigorously strict design calculations the following physical contingency margins have been assumed as a margin of error.

cost of equipment and materials	: 10%
cost of assembly and installation	: 10%
cost of civil engineering and construction work	: 15%
others	: 0%

The above overall physical contingencies is 9.2% of the total plant cost.

7.15 Study of Alternative Case

7.15.1 Explanation of Alternative Case

The process study for this alternative case was carried out in the following pages.

JICA team was requested by Indian side to consider the mixture of washed Assam coal and washed Samla coal as a SRC feed stock during 3rd visit to India.

7.15.2 Process Configuration of Alternative Case

The main figures of the process configuration of the alternative case are as follows. Figures on items not shown below are the same as figures shown in chapter 7.4.

(1) Feed Rate

Mixed coal of 250 t/d of washed Assam coal (dry basis) and 250 t/d of washed Samla coal (dry basis).

(2) Annual Stream Days

330 days per year (same as the base case).

(3) Feedstock Coal

The analytical values for the washed Assam coal and the washed Samla coal on which design is based are given below:

	Washed Assam Coal	Washed Samla Coal
Total moisture on raw coal basis, wt%	8.3	16.1
Surface moisture on raw coal basis, wt%	6.0	6.0
Inherent moisture on raw coal basis, wt%	2.3	10.1

Volatile Matter on dry coal basis, wt%	42.8	39.5
Fixed Carbon on dry coal basis, wt%	54.7	51.5
Ash on dry coal basis, wt%	2.5	9.0

(4) Reaction

1) Operating Conditions at the Dissolver Outlet

same as the base case

2) Catalyst and Promoter

same as the base case

3) Chemical Hydrogen Consumption

Assam Coal: 2.7 wt% of feed coal (d.a.f.basis)
Samla Coal: 3.0 wt% of feed coal (d.a.f.basis)

4) Yield Configuration

	wt% on coal (d.a.f.basis)	
	Washed Assam Coal	Washed Samla Coal
Methane	2.9	2.5
Ethane	1.4	1.5
Propane	1.0	0.7
Butane	0.4	0.3
Carbon Monoxide	0.6	0.5
Carbon Dioxide	1.2	1.7
Ammonia	0.1	0.0
Hydrogen Sulfide	0.3	0.1
Water	3.4	5.5
Light Distillate-1	2.1	1.4
Light Distillate-2	1.7	1.2
Middle Distillate	6.9	4.7
Heavy Distillate	11.6	7.9

SRC	68.2	55.9
IOM	0.9	19.1
Total	102.7	103.0

(5) Product

1) Product Slate (dry basis)

Light Distillate-1 (C5-180°C)	347 kg/h
Light Distillate-2 (180-200°C)	286 kg/h
Middle Distillate (200-250°C)	760 kg/h
Heavy Distillate (250-450°C)	1,566 kg/h
SRC (450°C+)	13,610 kg/h

2) Product Specifications

Product specifications of the light distillate-1, the light distillate-2, the middle distillate and the heavy distillate of the alternative case are the same with figure of the base case.

Specifications of SRC of the alternative case are as follows:

a) Composition of Whole SRC

Component	wt%
Net SRC (excluding solids)	89.3
Total Solids	10.7
Ash	(4.4)
Catalyst	(0.7)
IOM	(5.6)

b) Whole SRC
Softening Point 160°C

c) Not SRC (components other than solids)

Boiling Point Range	450°C+
Ultimate Analysis (wt%)	
Carbon	88.1
Hydrogen	5.7
Nitrogen	2.2
Sulfur	0.9
Oxygen	3.0
Proximate Analysis (wt%)	
Volatile Matter	34.7
Fixed Carbon	65.3
Specific Gravity (at 20°C)	1.27

3) By-products Slate

Filter Cake

Form	Powder
Composition	wt%
Solids	77.0
Oil	21.1
SRC	1.9

7.15.3 Material Balance of Alternative Case

The following summarizes details for the raw materials, secondary raw material (COG), product SRC, by-product liquefied oils (light distillate-1, light distillate-2, middle distillate, heavy distillate), produced gases and purge gases from the hydrogen separation in the alternative case. Two cases of material balance are shown below. One case is in the unit of ton per year and the another case is in the unit of kg/h.

(1) Unit: t/y

	Intake t/y	Production in Plant t/y	Consumption in Plant t/y	Output Out of Plant t/y
Wa. Assam Raw Coal	89,970	0	89,970	0
Wa. Samla Raw Coal	98,330	0	98,330	0
COG	109,280	0	109,280	0
SRC	0	107,800	0	107,800
Lt. distillate-1	0	2,740	0	2,740
Lt. distillate-2	0	2,270	0	2,270
Md. distillate	0	6,020	6,020	0
Hy. distillate	0	12,400	12,400	0
Produced gases (including butane)	0	12,600	480	12,120
Purge gases	0	101,450	3,860	97,590

(2) Unit: kg/h

	Intake kg/h	Production in Plant kg/h	Consumption in Plant kg/h	Output Out of Plant kg/h
Wa. Assam Raw Coal	11,380	0	11,360	0
Wa. Samla Raw Coal	12,420	0	12,420	0
COG	13,800	0	13,800	0
SRC	0	13,610	0	13,610
Lt. distillate-1	0	346	0	346
Lt. distillate-2	0	286	0	286
Md. distillate	0	760	760	0
Hy. distillate	0	1,566	1,566	0
Produced gases (including butane)	0	1,591	61	1,530
Purge gases	0	12,810	490	12,320

7.15.4 Consumption Rate of Secondary Raw Material, Utilities and Chemicals of Alternative Case

(1) Secondary Raw Material Consumption

COG	24,170 Nm^3/h

(2) Utility Consumption

The consumption of utilities during normal and start-up operations of the alternative case are as follows:

Bunker C Fuel Oil	
Normal Operation	756 kg/h
Start-up Operation	3,700 kg/h

The consumption of utilities other than bunker C fuel oil are to be the same with figures of each item of the base case, which are shown in Table 7.6.1.

(3) Chemicals Consumption

The consumption of chemicals in the plant of the alternative case are as follows:

Liquefaction Promotor	171 kg/h
Filter Aid	10.9 t/d

The consumption of chemicals other than liquefaction promotor and filter aid are to be the same with figures of each item of the base case, which are shown in Table 7.6.2.

7.15.5 Discharge Rate of Residue

Approximately 85 t/d of filter cake is discharged from the solid/liquid separation area.

Note: A net heating value of filter cake is approximately 3,790 kcal/kg.

7.15.6 Total Construction Costs of Alternative Case

The total construction costs of the plant of the alternative case are estimated as follows:

Plant Construction Cost Case-H (Assam+Samla)

	Foreign C. (million yen)	Local C. (100 thousand Rs)
Plant area #100	0	2,136
Plant area #200	2,568	1,391
Plant area #300	668	774
Plant area #400	190	1,053
Plant area #500	2,726	1,510
Plant area #600	29	334
Plant area #700	1,338	570
Plant area #800	139	0
Process plant total	7,658	7,768
Plant area #1000	43	3,888
Plant area #1100	0	25
Plant area #1200	55	148
Plant area #1300	21	202
Plant area #1400	0	205
Plant area #1500	0	56
Plant area #1600	19	145
Plant area #1700	52	80
Plant area #1900	0	211
Plant area #1950	0	13
Plant area #1980	0	421
Plant area #1990	31	123
Utility plant total	221	5,517
Plant total	7,879	13,285
-- Additional facilities		
Railway siding	0	34
Coal washing unit	0	150
Grand total	7,879	13,469

7.16 Study of Samla Case

As described in Chapter 6, in terms of SRC production Samla coal is at a disadvantage because of its low product yield. However, Samla coal has advantages in terms of its supply position since it is mined in the main coal fields of Eastern India and is located near to Rourkela steel plant.

The case of using unwashed Samla coal as a SRC feed stock was studied. Only the major process data for financial analysis carring out as on reference was estimated in the following.

7.16.1 Major Process Data

(1) Feed Rate and Annual Stream Days

Feed rate is 500 t/d of dry coal, and annual stream days are 330 per year, which are the same as the base case.

(2) Feed Stock Coal

The analytical values for unwashed Samla coal on which design is based are given below:

Total Moisture	17.4 wt%	(raw coal basis)
Surface Moisture	7.5 wt%	(raw coal basis)
Inherent Moisture	9.9 wt%	(raw coal basis)
Volatile Matter	34.6 wt%	(dry coal basis)
Fixed Carbon	51.6 wt%	(dry coal basis)
Ash	13.8 wt%	(dry coal basis)

(3) Product Slate (dry base)

Light Distillate-1 (C_5-180°C)	98 kg/h
Light Distillate-2 (180-200°C)	81 kg/h
Middle Distillate (200-250°C)	293 kg/h
Heavy Distillate (250-450°C)	529 kg/h

SRC (450°C+) 10,185 kg/h

(4) Material Balance

Item	Intake t/y	Production in Plant t/y	Consumption in Plant t/y	Output Out of Plant t/y
Raw coal	199,758	0	199,758	0
SRC	0	80,669	0	80,669
Light distillate (1 and 2)	0	1,484	1,484	0
Middle distillate	0	2,318	2,318	0
Heavy distillate	0	4,189	4,189	0
COG	94,530	0	94,530	0
Produced gases	0	13,087	515	12,572
Purge gases	0	87,763	3,786	84,977
Residue (Filter cake)	0	78,701	46,533	32,168

(5) Utility Consumption

The consumption of all utilities are estimated to be the same as that of the base case.

(6) Chemicals Consumption

The consumption of chemicals except filter aid are estimated to be the same as that of the base case.

Filter aid 30.8 t/d

(7) Fuel Balance

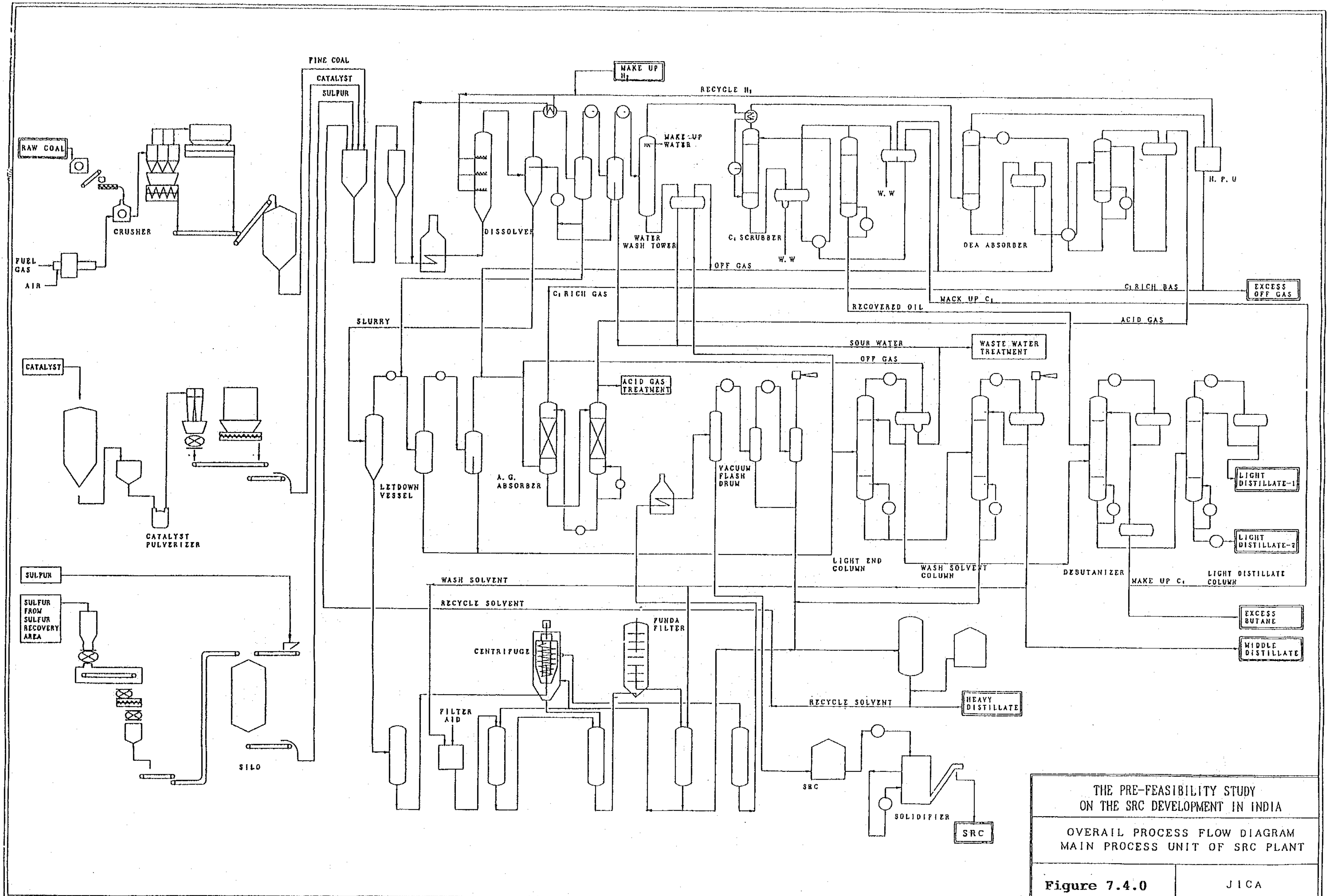
The total amount of light, middle and heavy distillates, and some amount of filter cake are estimated to be consumed inside plant as fuel.

A net heating value of filter cake is approximately 3,450 kcal/kg which is higher value because of high IOM contents.

(8) Plant Construction Cost

The plant construction cost is estimated as follows:

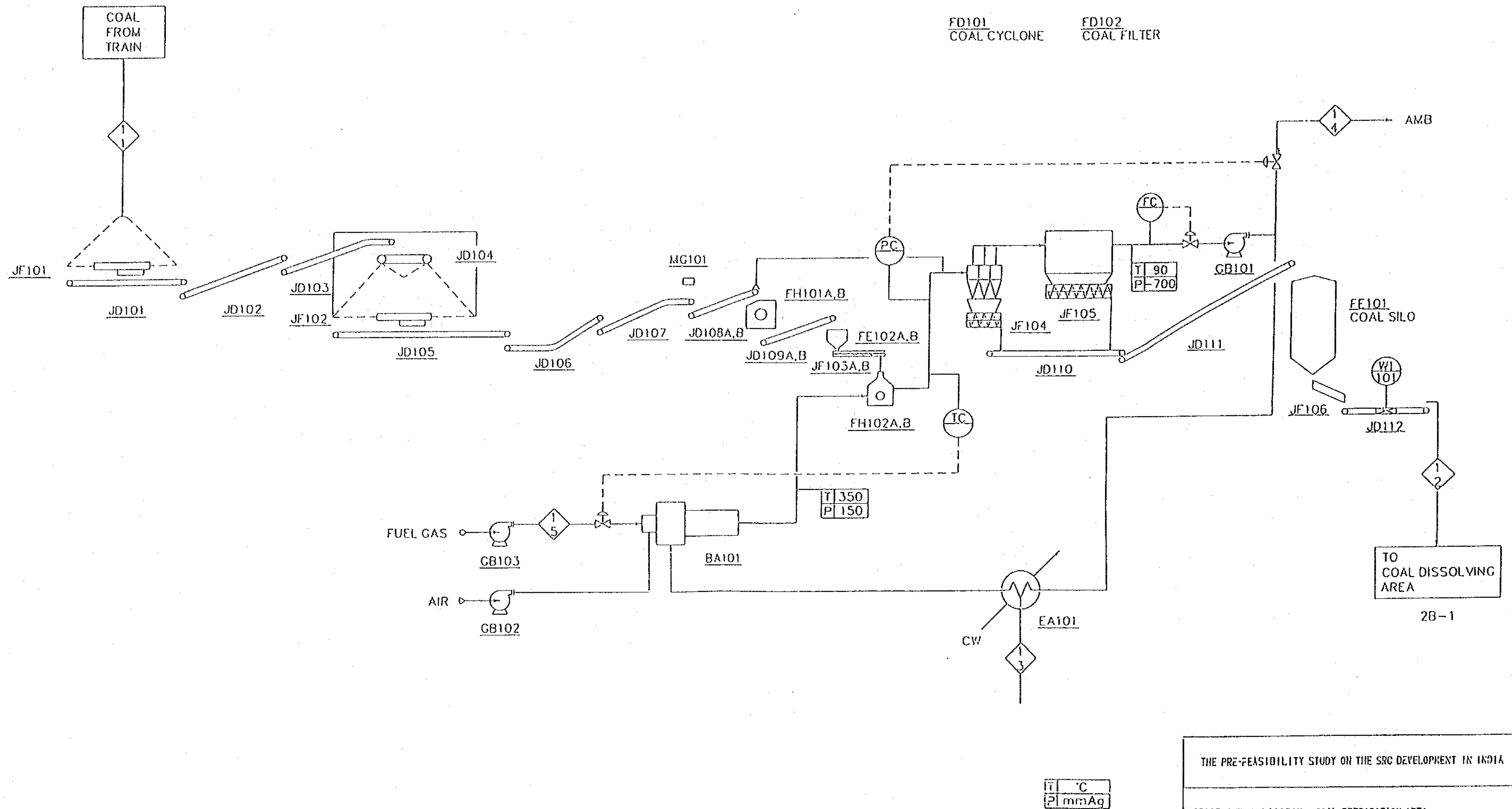
	Foreign C. (million yen)	Local C. (100 thousand Rs)
Plant area #100	0	2,241
Plant area #200	2,733	1,480
Plant area #300	623	721
Plant area #400	218	1,211
Plant area #500	4,415	2,591
Plant area #600	24	273
Plant area #700	1,211	516
Plant area #800	142	0
Process plant total	9,367	9,033
Plant area #1000	43	3,888
Plant area #1100	0	25
Plant area #1200	55	148
Plant area #1300	21	202
Plant area #1400	0	205
Plant area #1500	0	56
Plant area #1600	19	145
Plant area #1700	52	80
Plant area #1900	0	211
Plant area #1950	0	13
Plant area #1980	0	421
Plant area #1990	31	123
Utility plant total	221	5,517
Plant total	9,588	14,550
-- Additional facilities		
Railway siding	0	34
Grand total	9,588	14,584



THE PRE-FEASIBILITY STUDY
ON THE SRC DEVELOPMENT IN INDIA

OVERAIL PROCESS FLOW DIAGRAM
MAIN PROCESS UNIT OF SRC PLANT

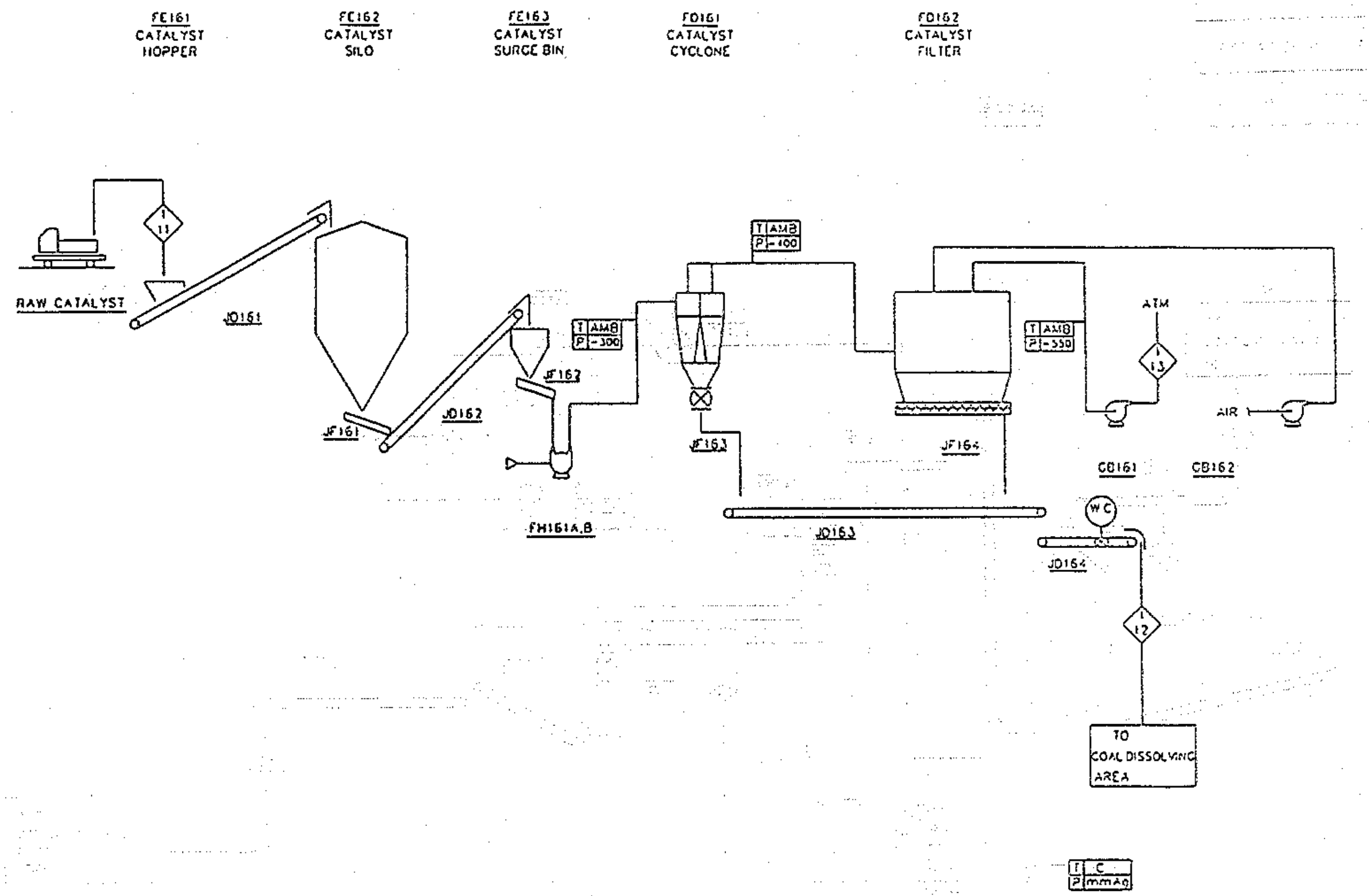
Figure 7.4.0 | JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

PROCESS FLOW DIAGRAM COAL PREPARATION AREA
COAL STORAGE,CRUSHING &DRYING SECTION

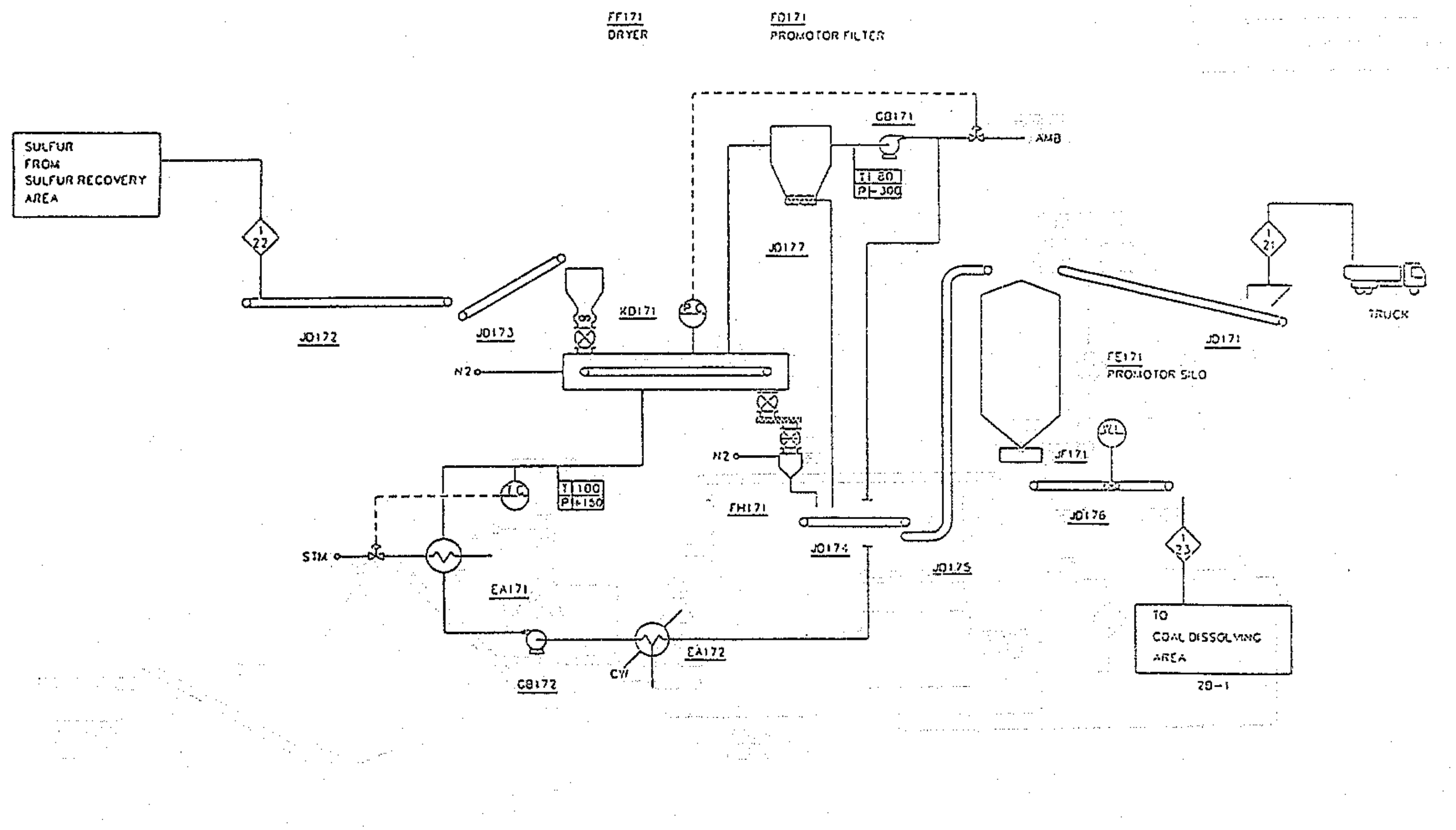
Figure 7.4.1 JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

PROCESS FLOW DIAGRAM — COAL PREPARATION AREA CATALYST PULVERIZING SECTION

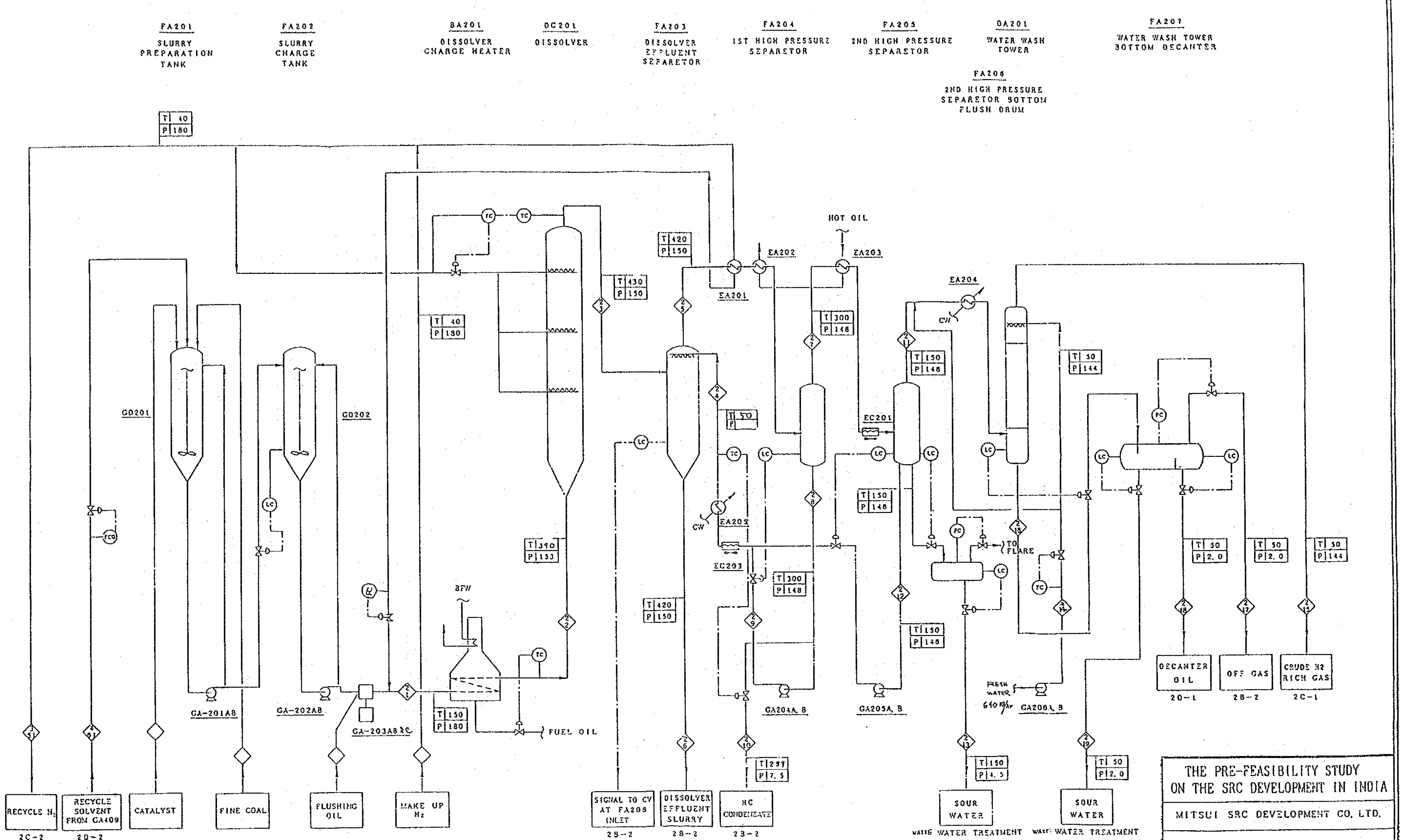
Figure 7.4.2 — JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

PROCESS FLOW DIAGRAM — COAL PREPARATION AREA PROMOTOR SECTION

Figure 7.4.3 — JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

MITSUI SRC DEVELOPMENT CO. LTD.

PROCESS FLOW DIAGRAM
COAL DISSOLVING AREA
DISSOLVING & H. P. SEPARATION SECTION

Figure 7.4.4

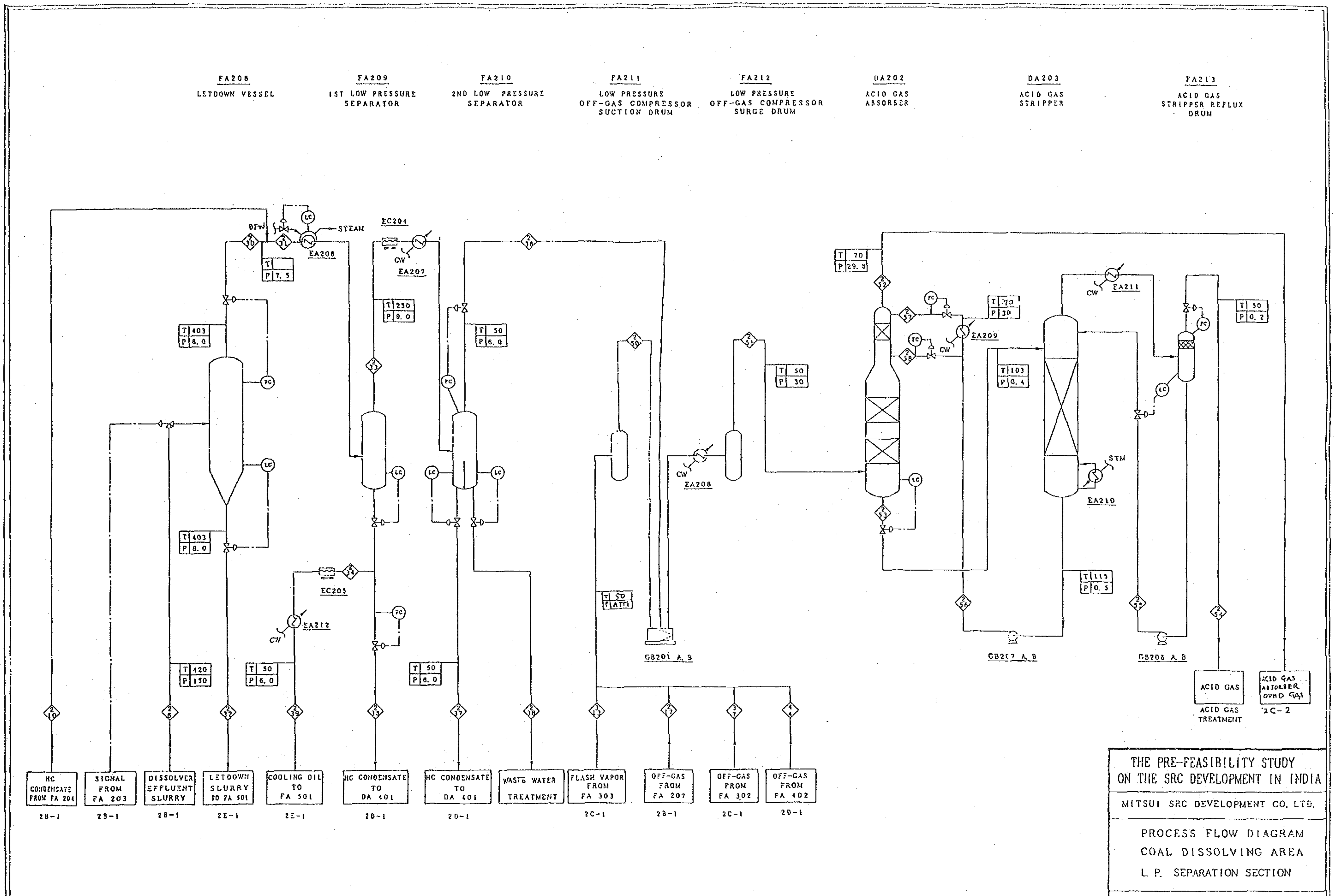
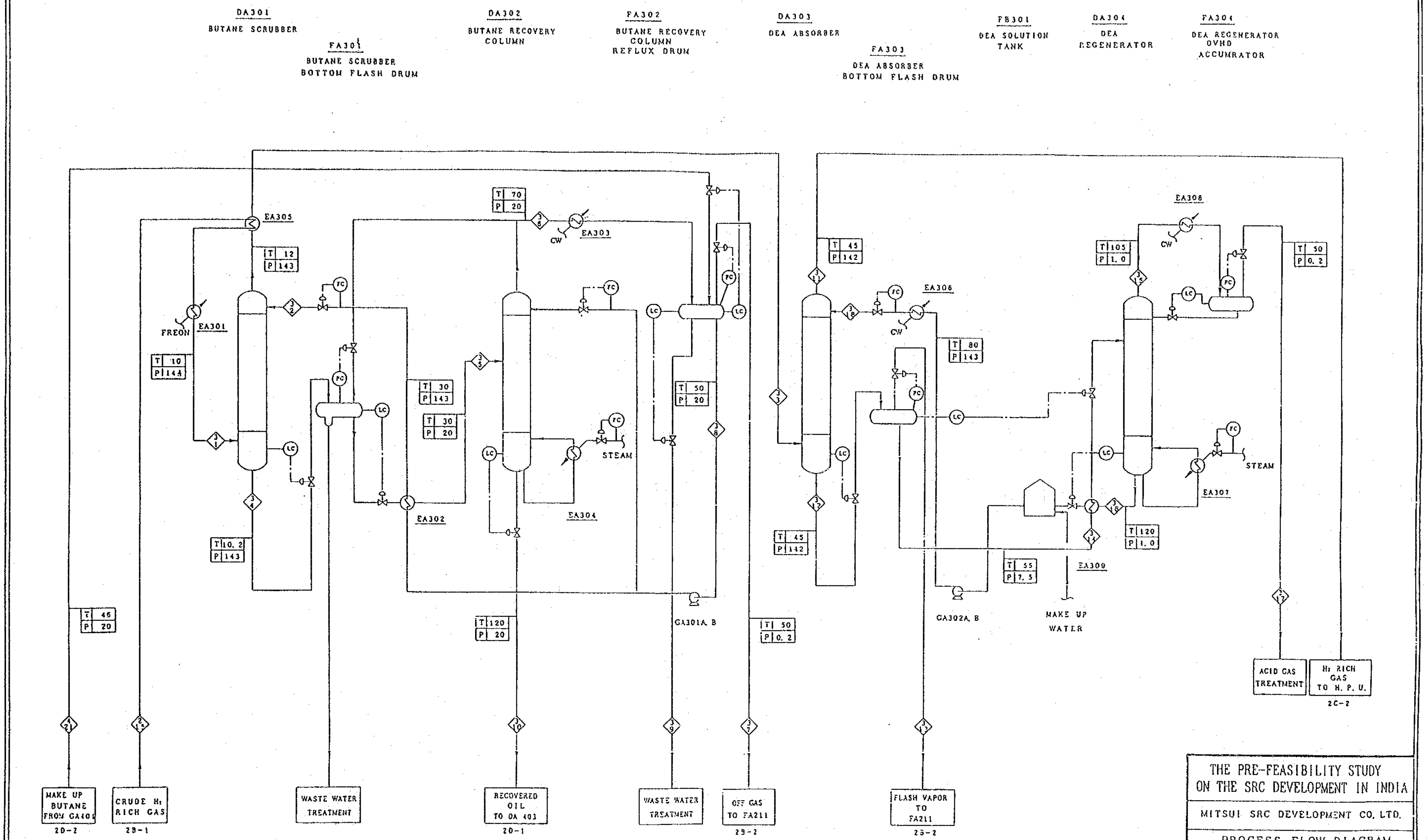

FA208
LETDOWN VESSEL
FA209
1ST LOW PRESSURE SEPARATOR
FA210
2ND LOW PRESSURE SEPARATOR
FA211
LOW PRESSURE OFF-GAS COMPRESSOR SUCTION DRUM
FA212
LOW PRESSURE OFF-GAS COMPRESSOR SURGE DRUM
DA202
ACID GAS ABSORBER
DA203
ACID GAS STRIPPER
FA213
ACID GAS STRIPPER REFLUX DRUM
BFW
STEAM
EA206
EC204
EA207
CW
EC205
EA212
EA208
EA209
EA211
EA210
STM
GB201 A, B
GB207 A, B
GB208 A, B
HC CONDENSATE FROM FA 204
2B-1
SIGNAL FROM FA 203
2B-1
DISSOLVER EFFLUENT SLURRY
2B-1
LETDOWN SLURRY TO FA 501
2E-1
COOLING OIL TO FA 501
2E-1
HC CONDENSATE TO DA 401
2D-1
HC CONDENSATE TO DA 401
2D-1
WASTE WATER TREATMENT
FLASH VAPOR FROM FA 303
2C-1
OFF-GAS FROM FA 207
2B-1
OFF-GAS FROM FA 302
2C-1
OFF-GAS FROM FA 402
2D-1
ACID GAS
ACID GAS TREATMENT
ACID GAS ABSORBER OVHD GAS
2C-2
THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA
MITSUI SRC DEVELOPMENT CO. LTD.
PROCESS FLOW DIAGRAM
COAL DISSOLVING AREA
L. P. SEPARATION SECTION

Figure 7.4.5

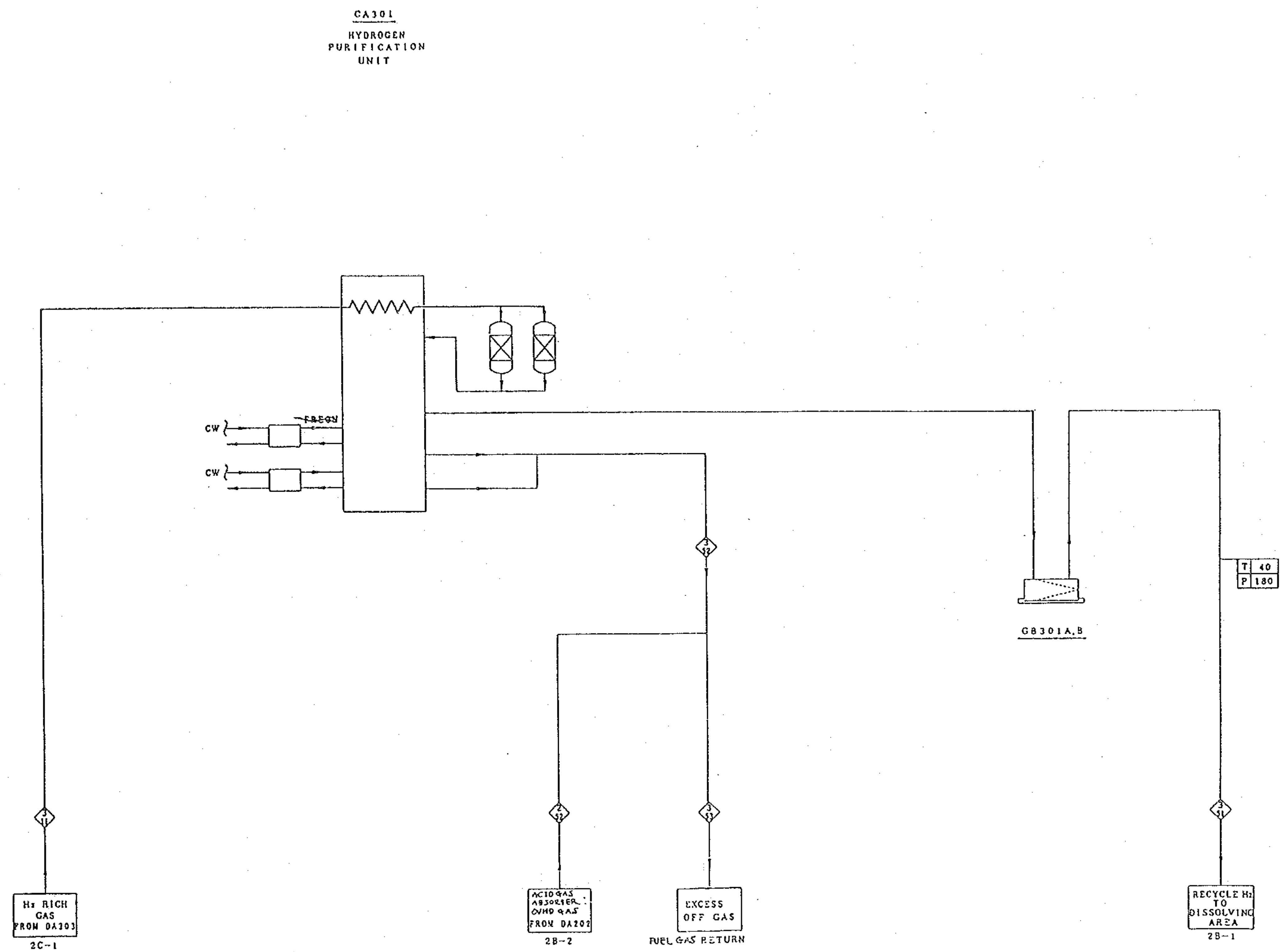


THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

MITSUI SRC DEVELOPMENT CO. LTD.

PROCESS FLOW DIAGRAM
HYDROGEN RECOVERY AND PURIFICATION AREA
GAS WASHING SECTION

Figure 7.4.6

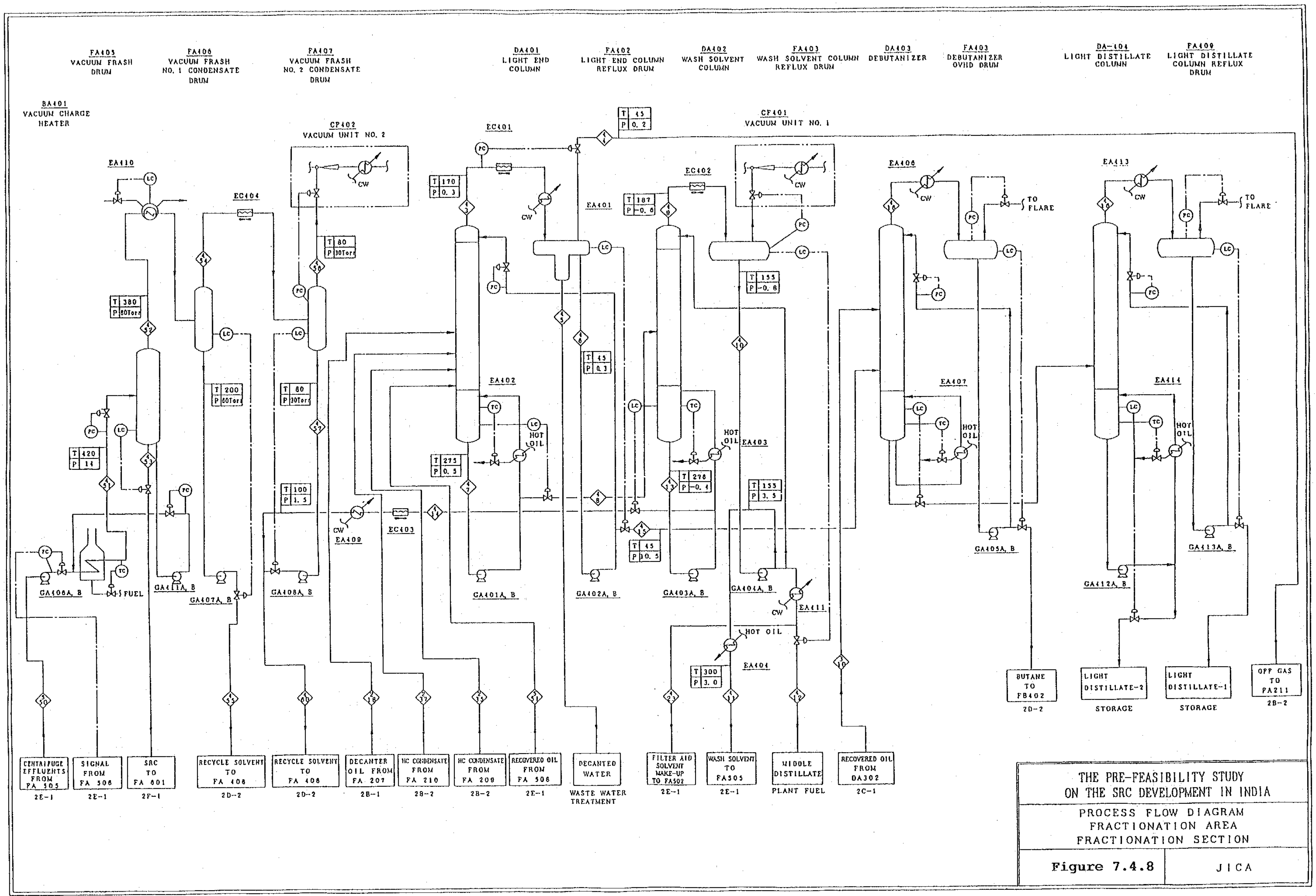


THE PRE-FEASIBILITY STUDY
ON THE SRC DEVELOPMENT IN INDIA

MITSUI SRC DEVELOPMENT CO, LTD.

PROCESS FLOW DIAGRAM
HYDROGEN RECOVERY AND
PURIFICATION AREA
H. P. U. SECTION

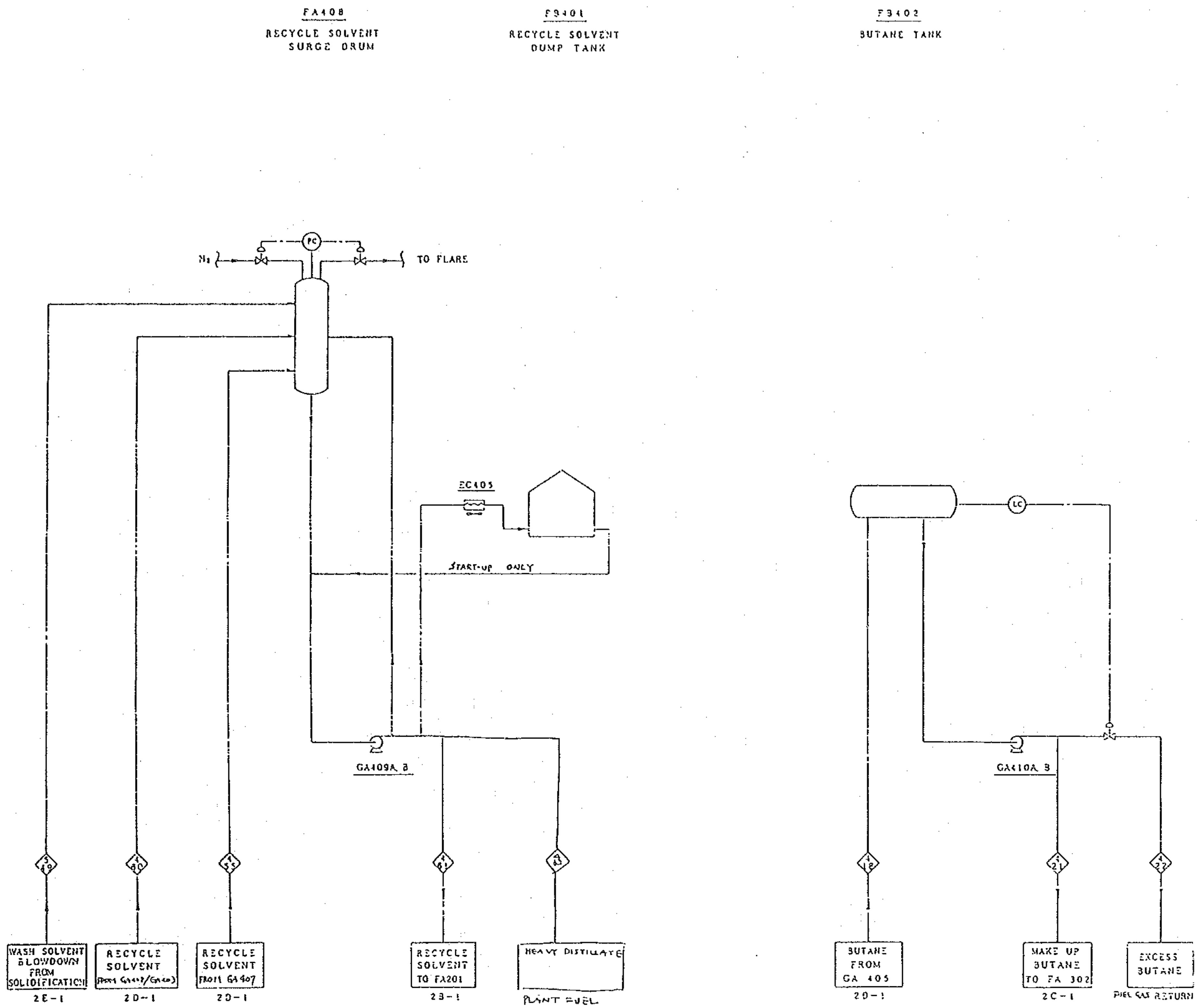
Figure 7.4.7



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

PROCESS FLOW DIAGRAM
FRACTIONATION AREA
FRACTIONATION SECTION

Figure 7.4.8 JICA

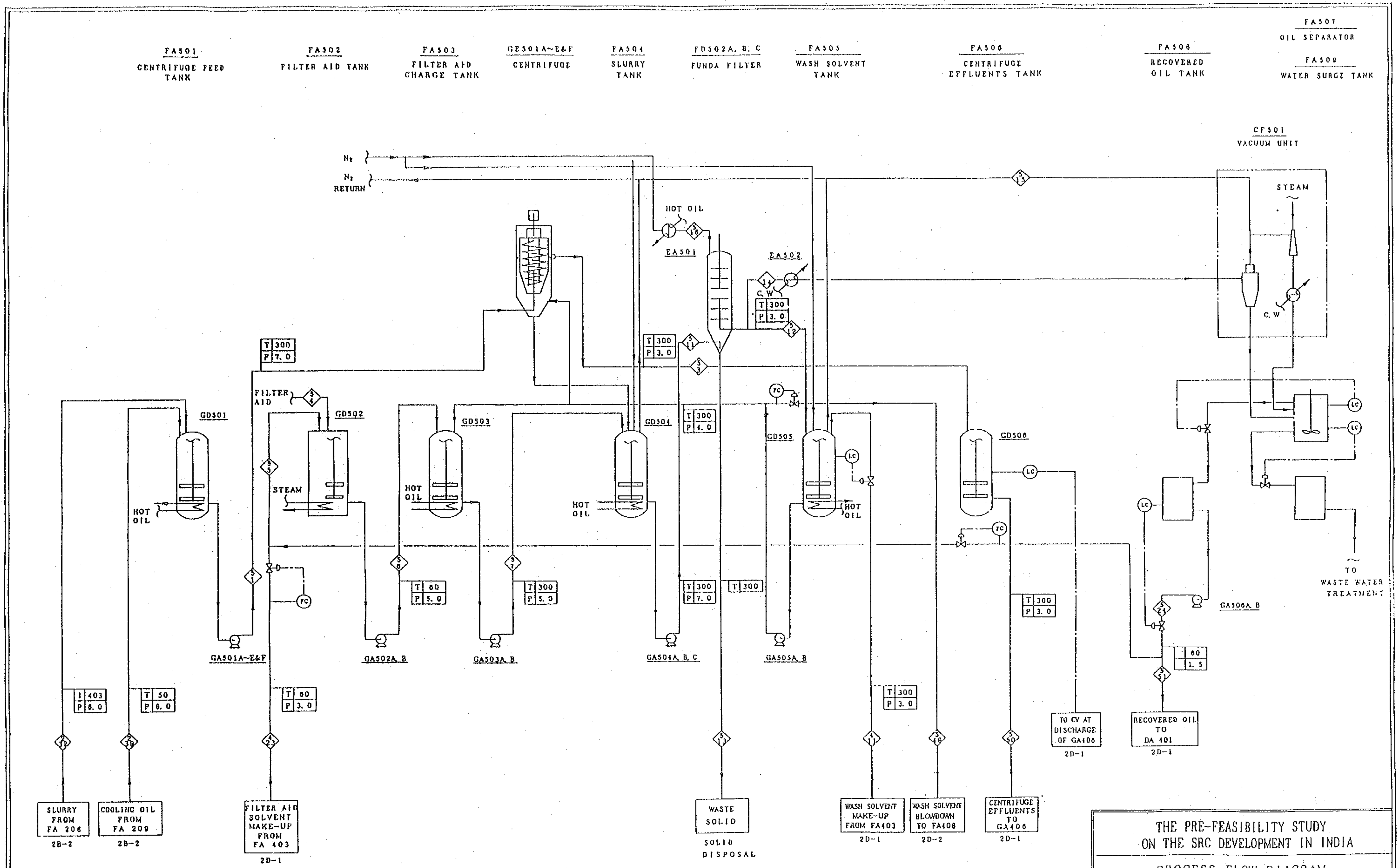


THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

MITSUI SRC DEVELOPMENT CO., LTD.

PROCESS FLOW DIAGRAM
FRACTIONATION AREA
INTERMEDIATE TANK SECTION

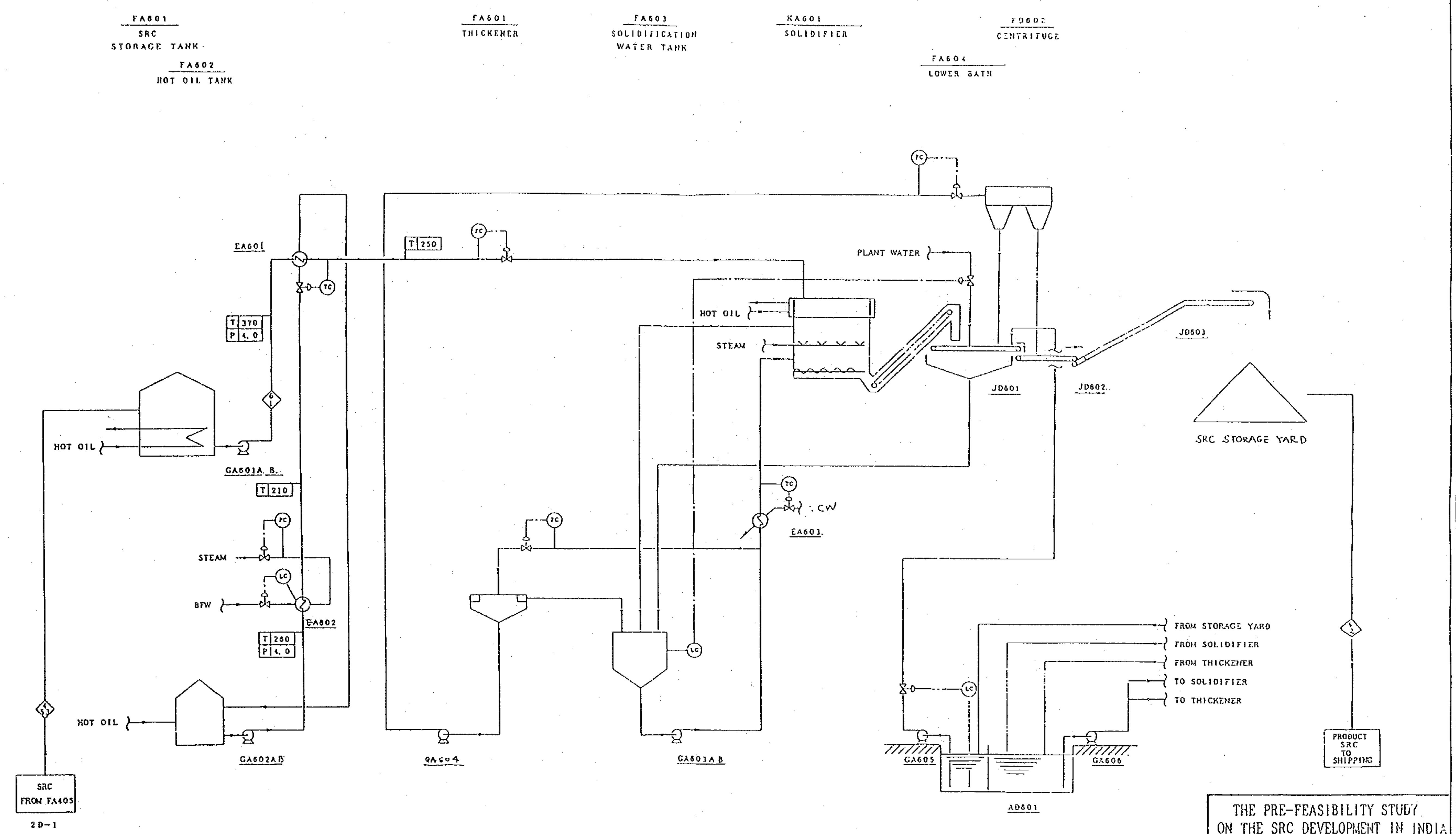
Figure 7.4.9



THE PRE-FEASIBILITY STUDY
ON THE SRC DEVELOPMENT IN INDIA

PROCESS FLOW DIAGRAM
SOLID/LIQUID SEPARATION AREA

Figure 7.4.10	JICA

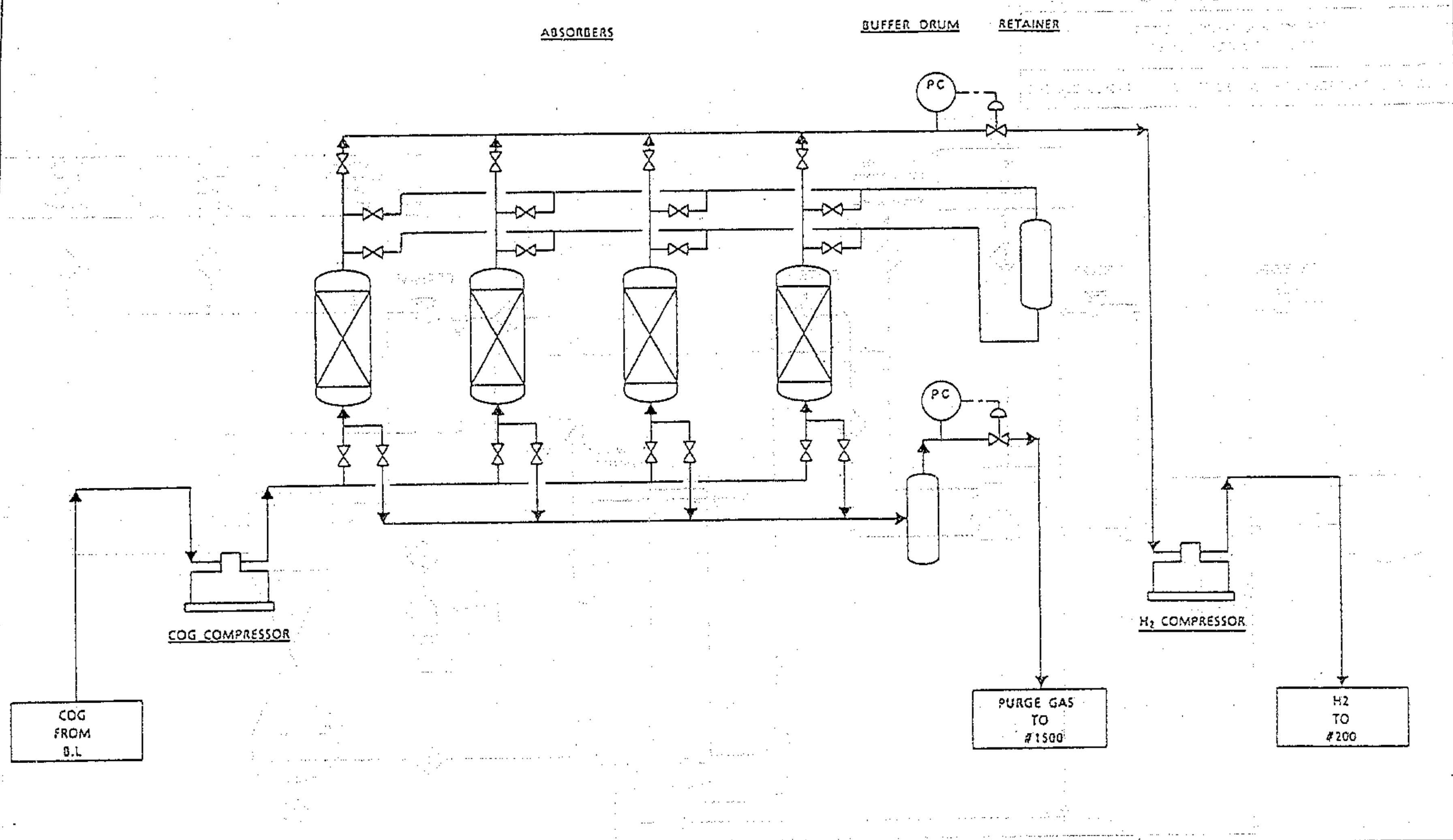


THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

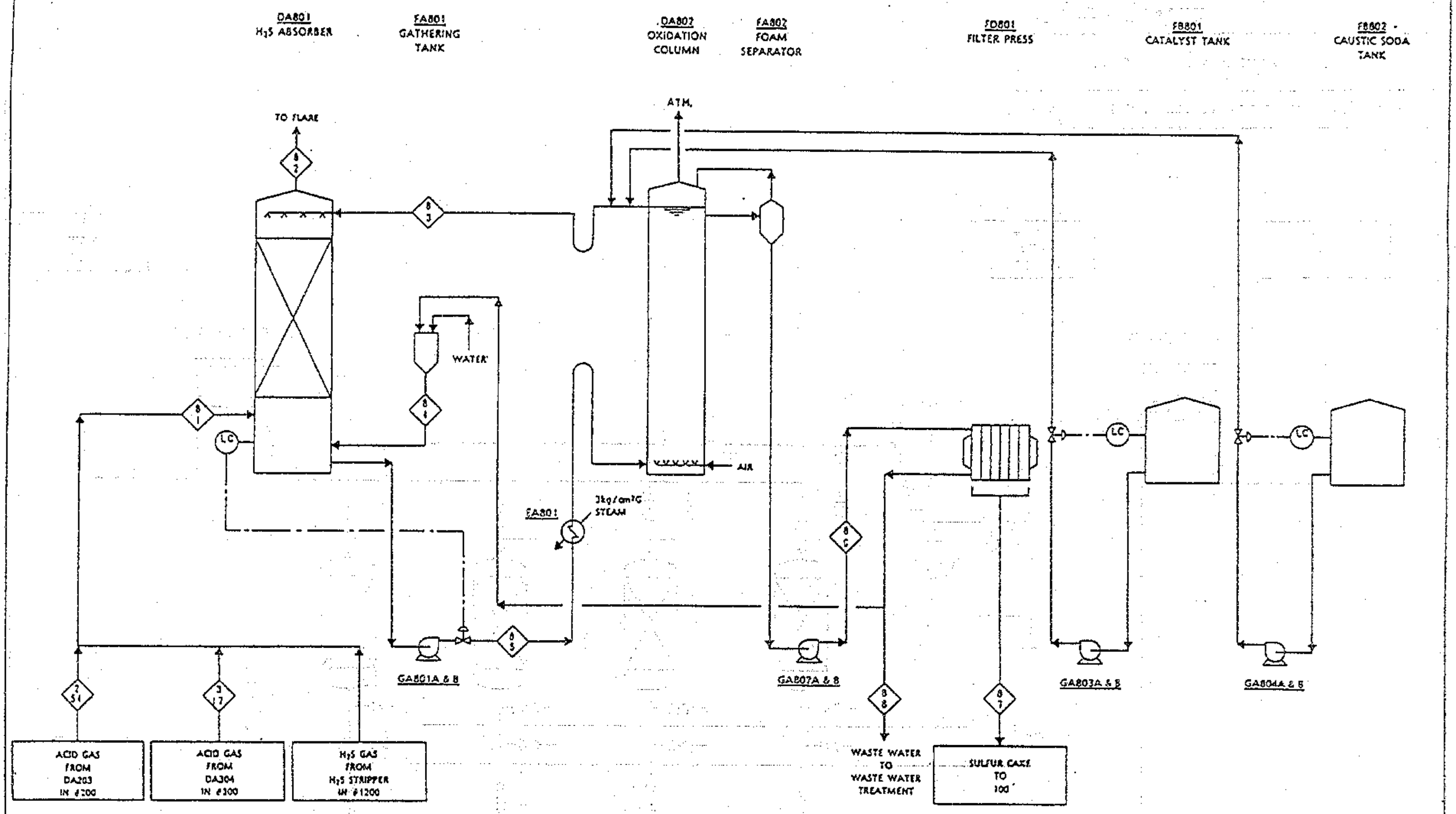
MITSUI SRC DEVELOPMENT CO, LTD.

PROCESS FLOW DIAGRAM
SRC SOLIDIFICATION AREA

Figure 7.4.11



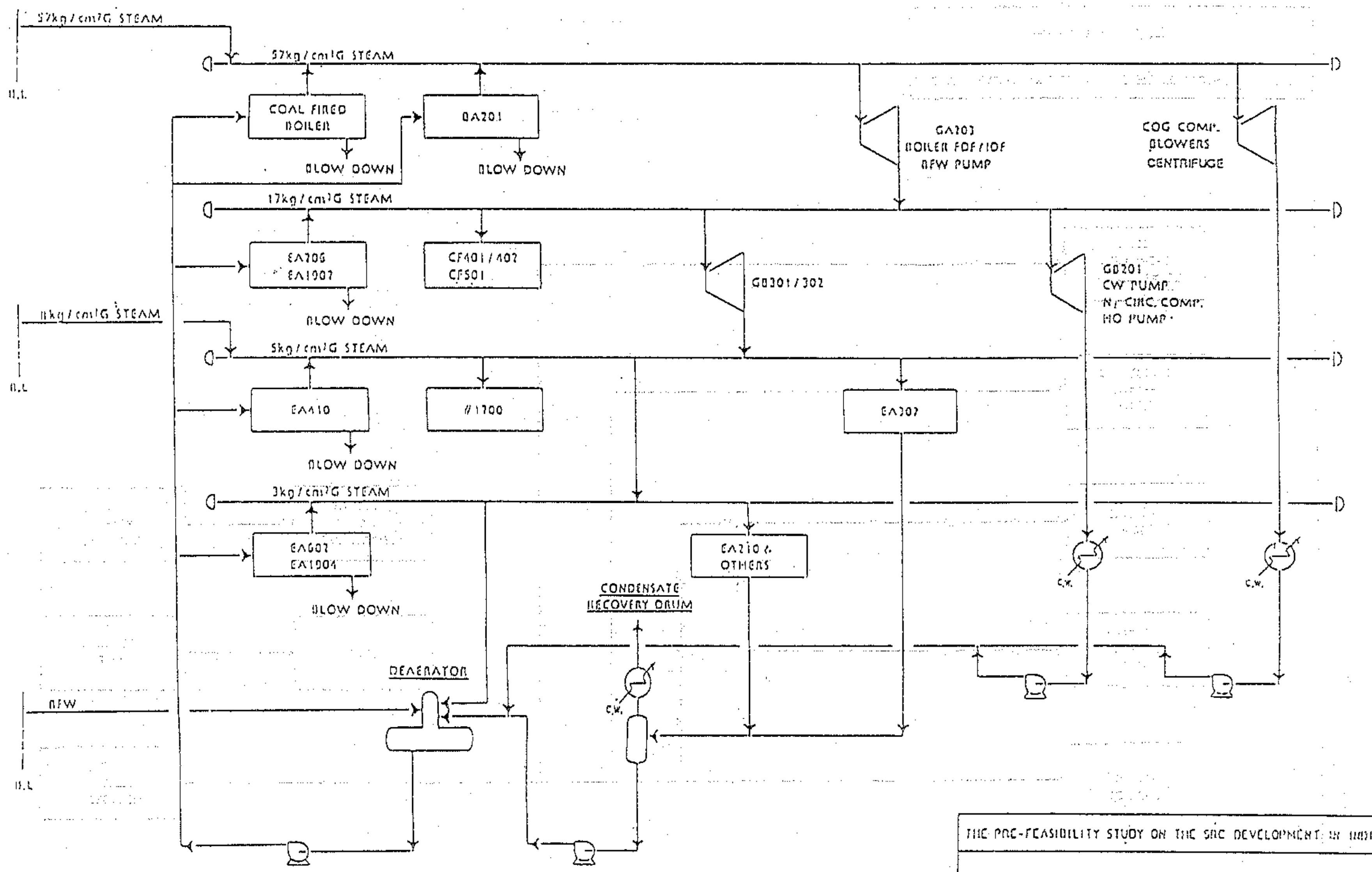
THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA	
HYDROGEN SEPARATION AREA (700)	
Figure 7.4.12	JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

PROCESS FLOW DIAGRAM
SULFUR RECOVERY AREA (800)

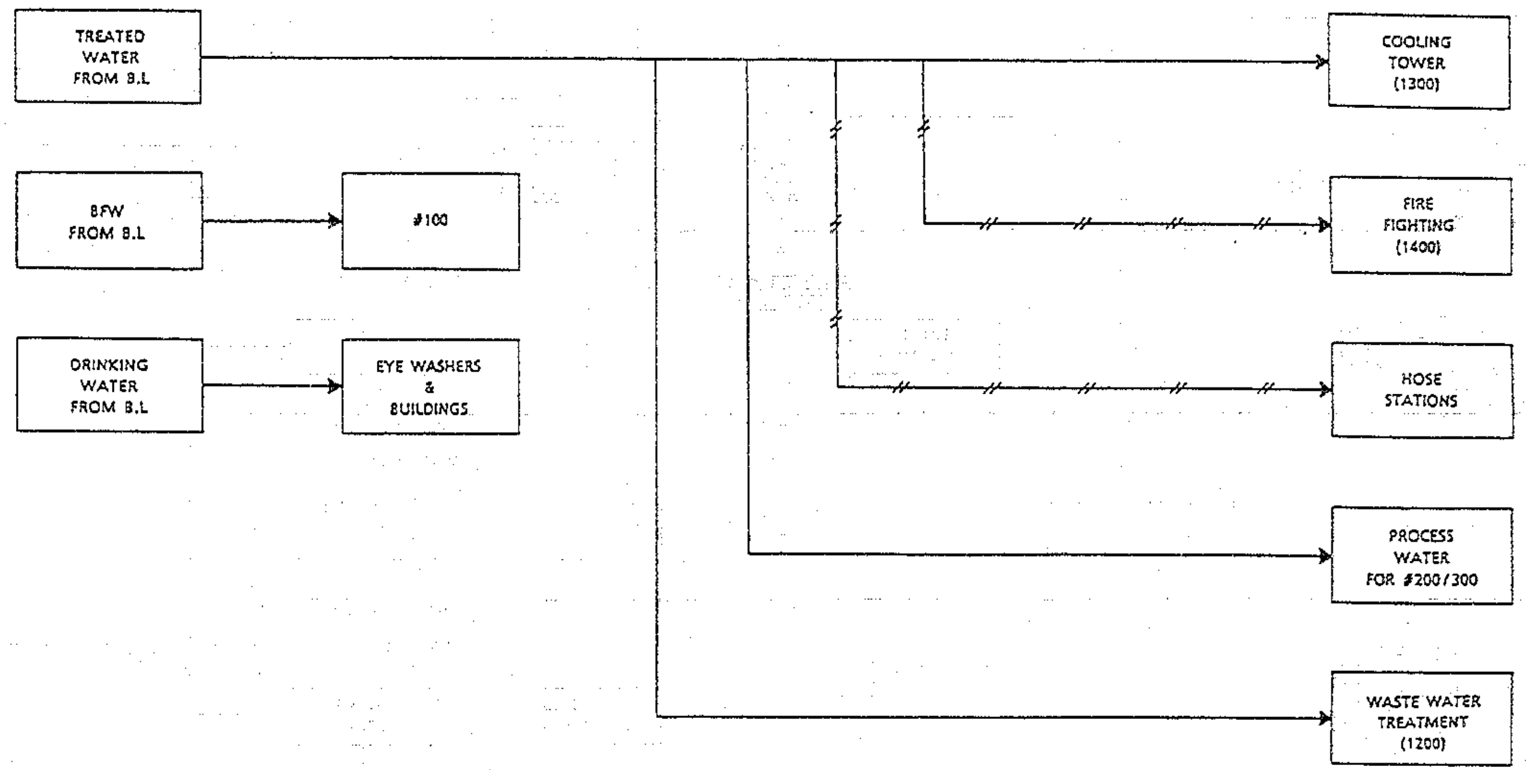
Figure 7.4.13 | JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

STEAM & CONDENSATE SYSTEM (1000)

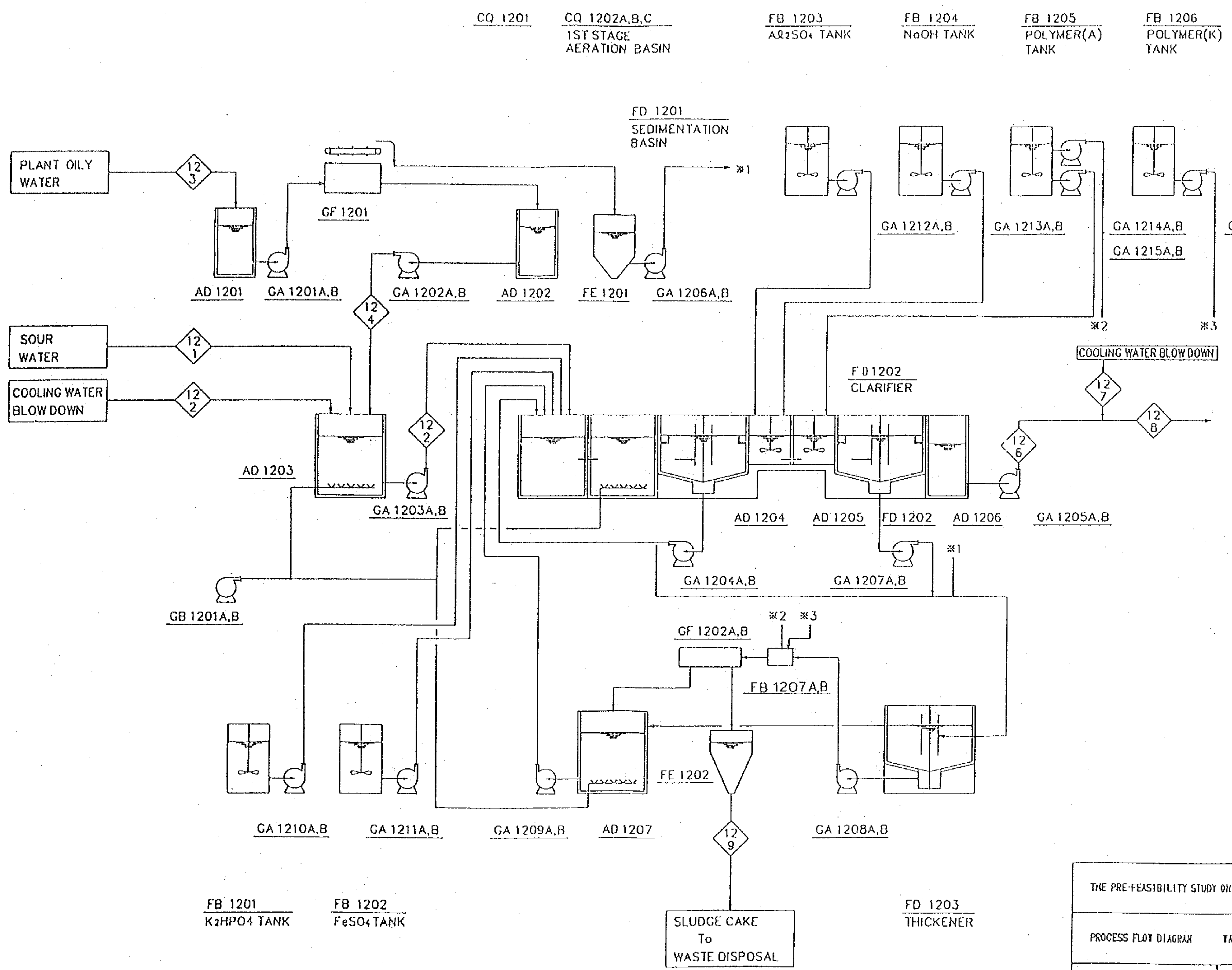
Figure 7.4.14 JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

WATER SYSTEM (1100)

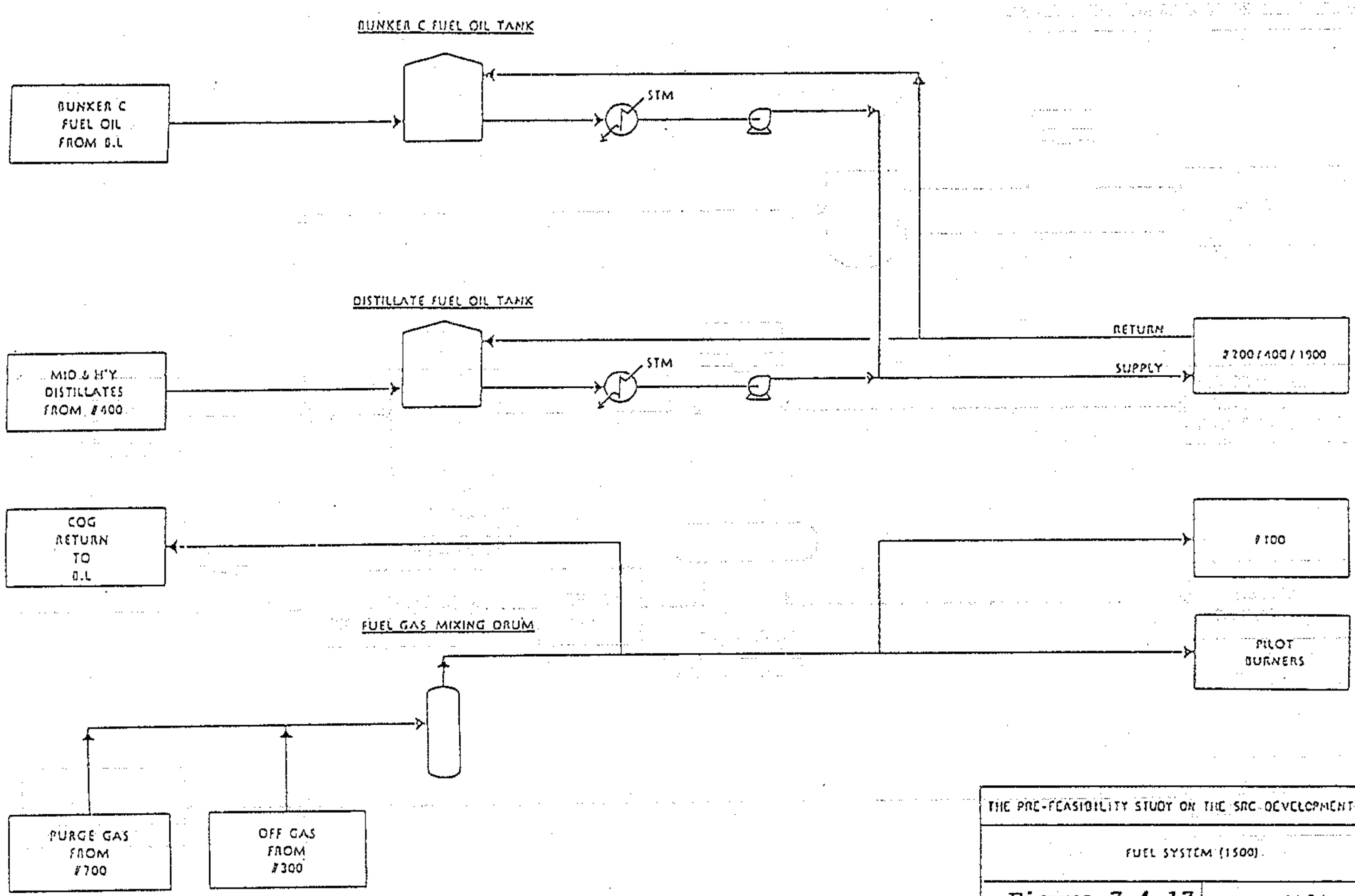
Figure 7.4.15 JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

PROCESS FLOW DIAGRAM WASTE WATER TREATMENT AREA

Figure 7.4.16 JICA

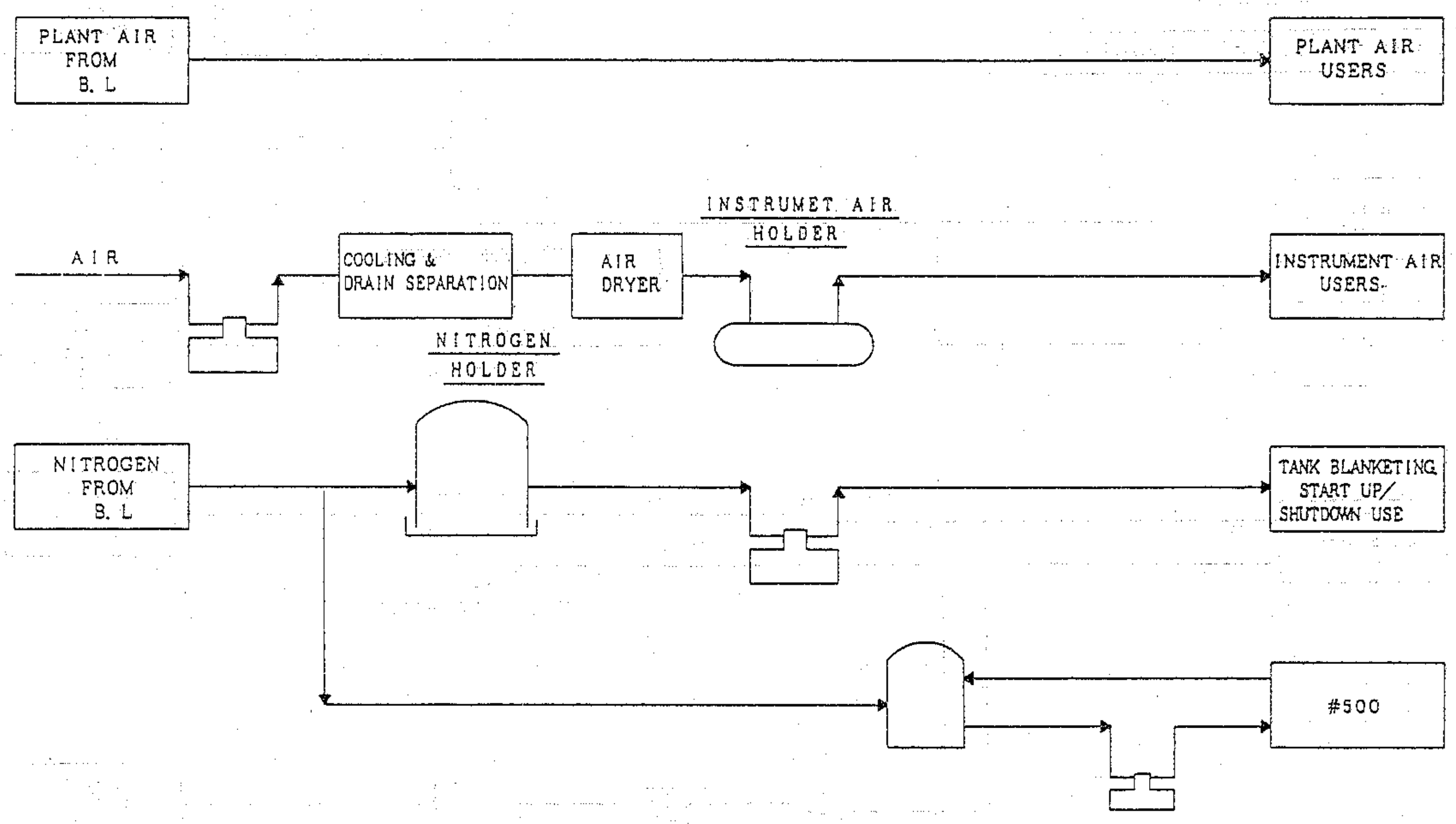


THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

FUEL SYSTEM (1500)

Figure 7.4.17

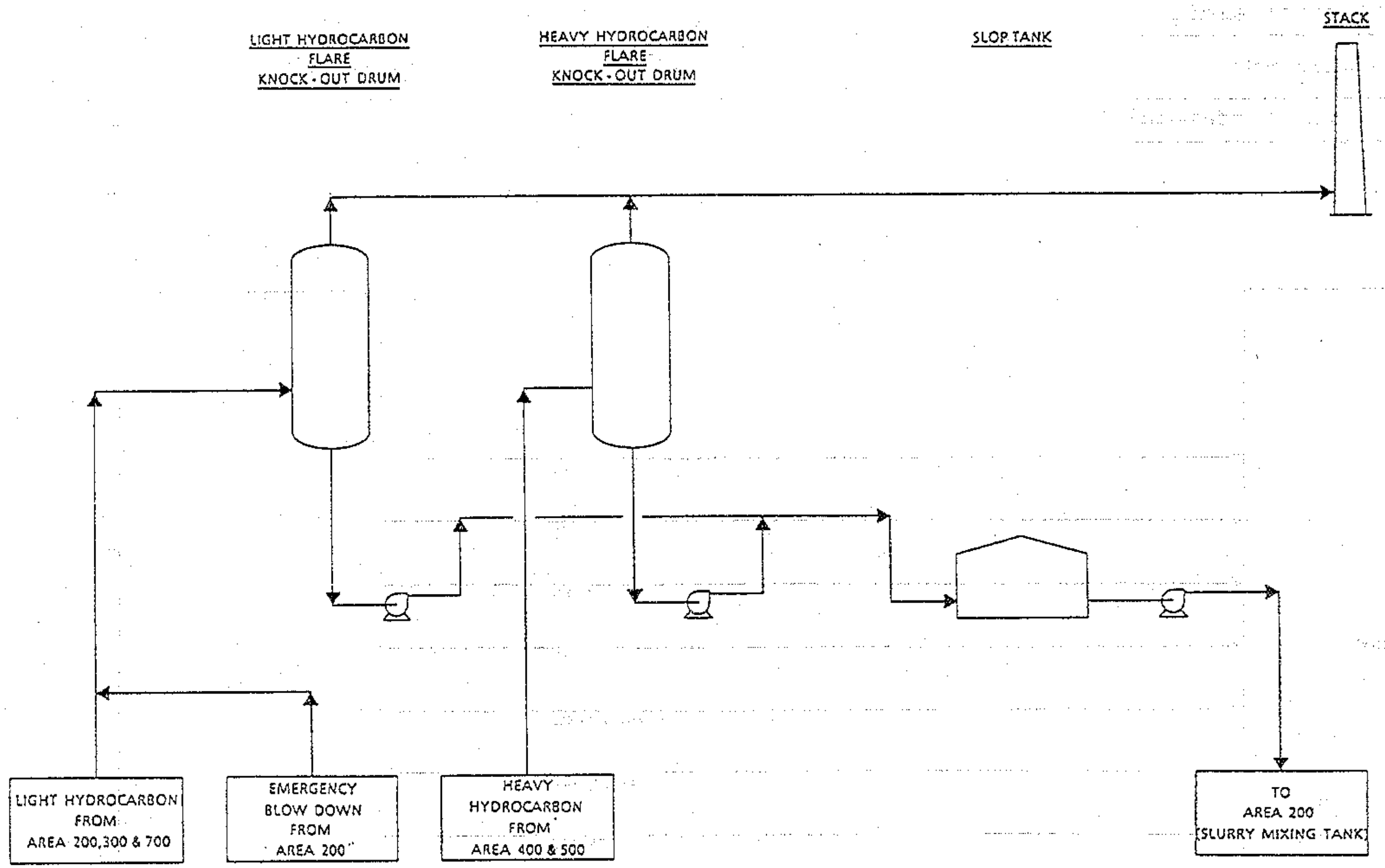
JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

AIR AND NITROGEN SYSTEM (160G)

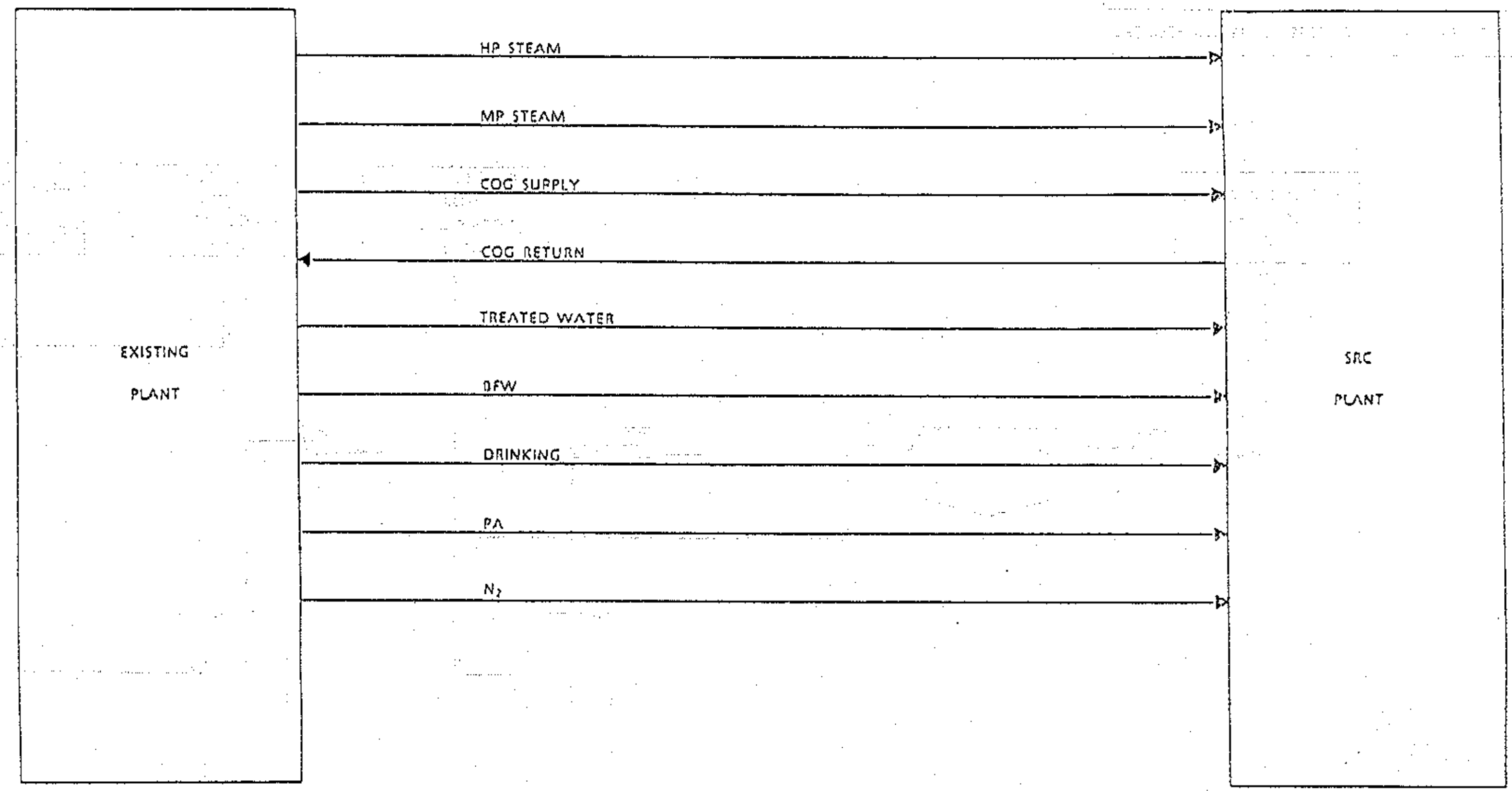
Figure 7.4.18 | J.I.C.A



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

FLARE SYSTEM (1700)

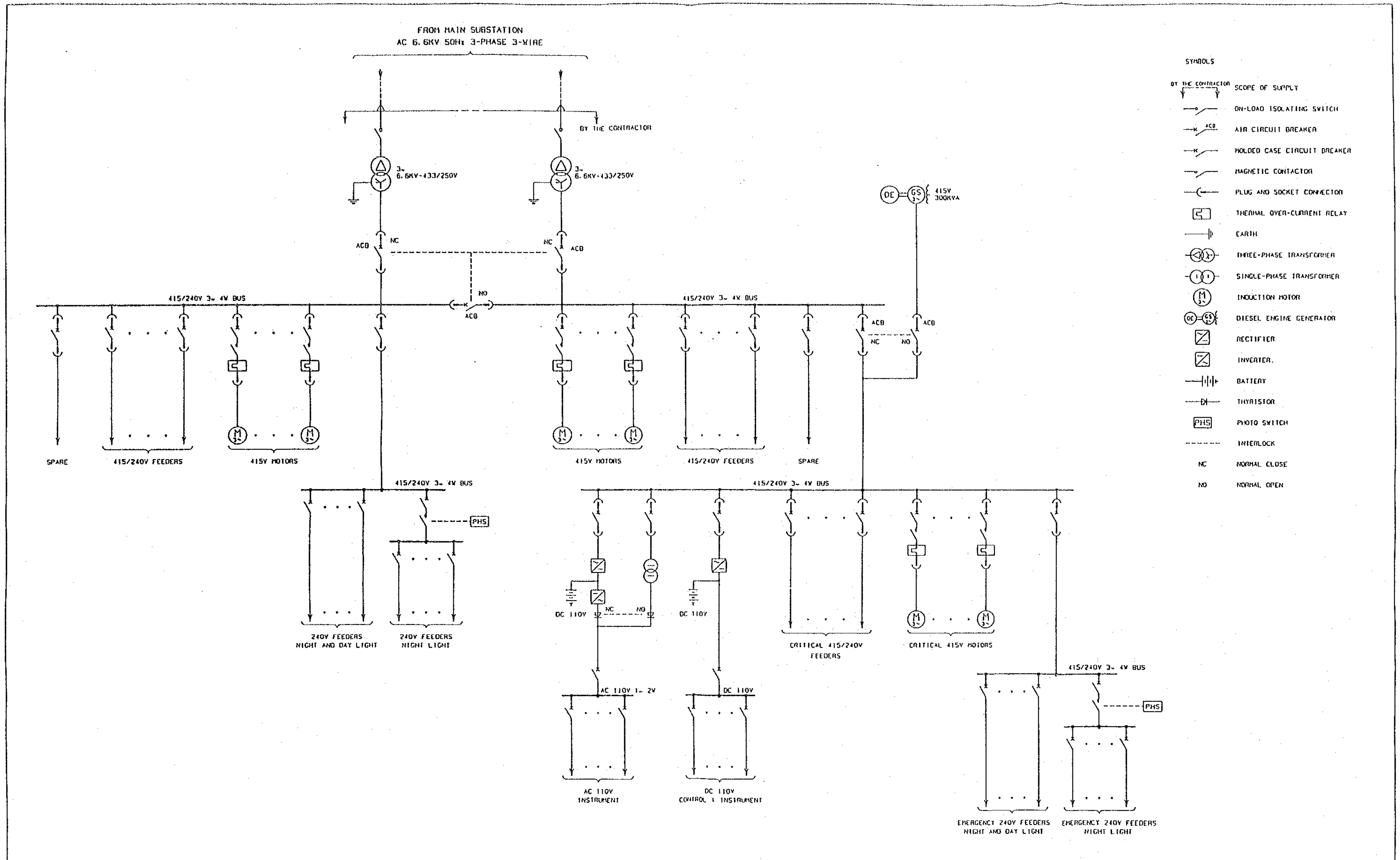
Figure 7.4.19 JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

INTERCONNECTING PIPING SYSTEM (1980)

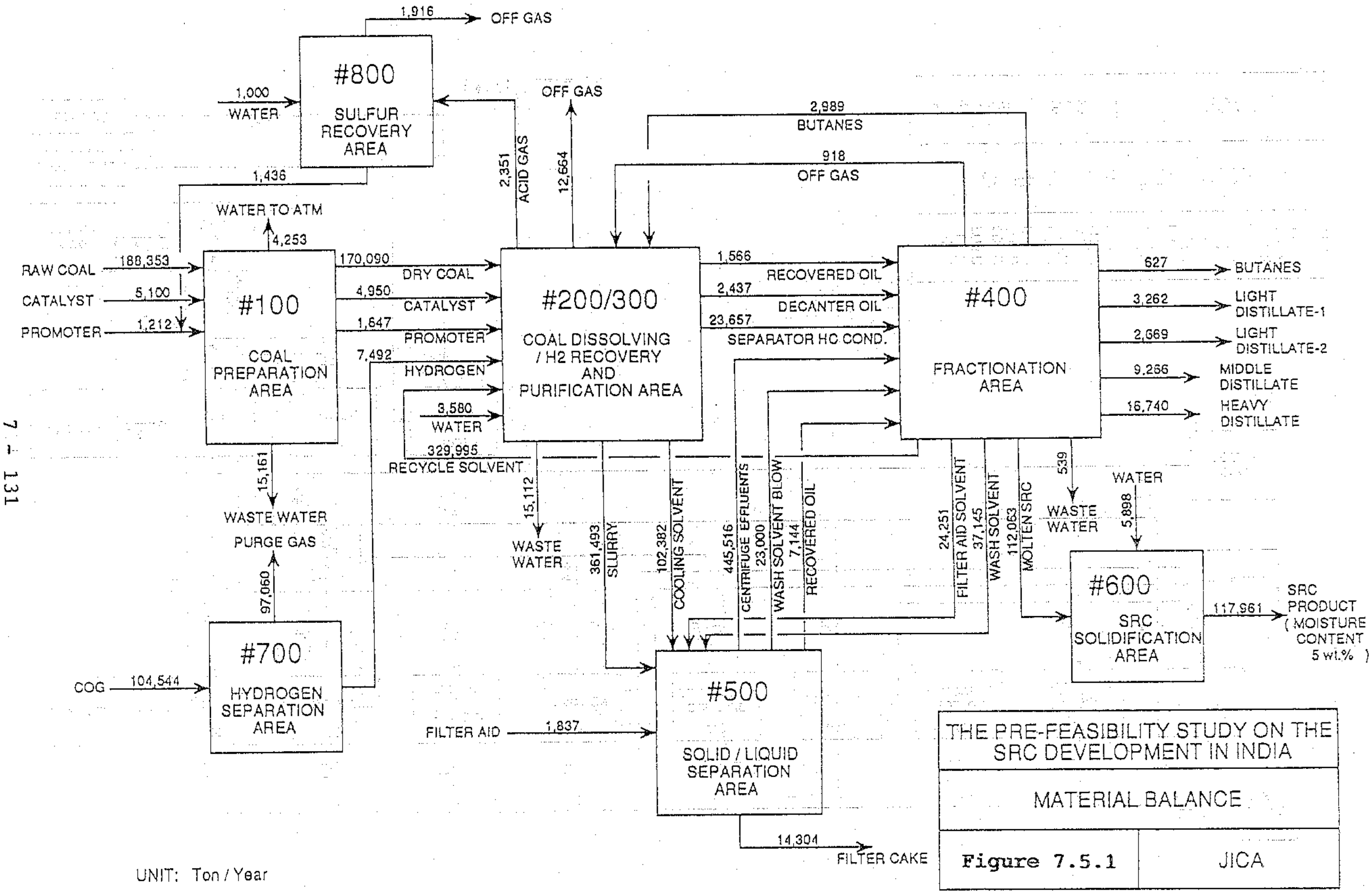
Figure 7.4.20 JICA



THE PRE-FEASIBILITY STUDY ON THE SEC DEVELOPMENT IN INDIA

SINGLE LINE DIAGRAM

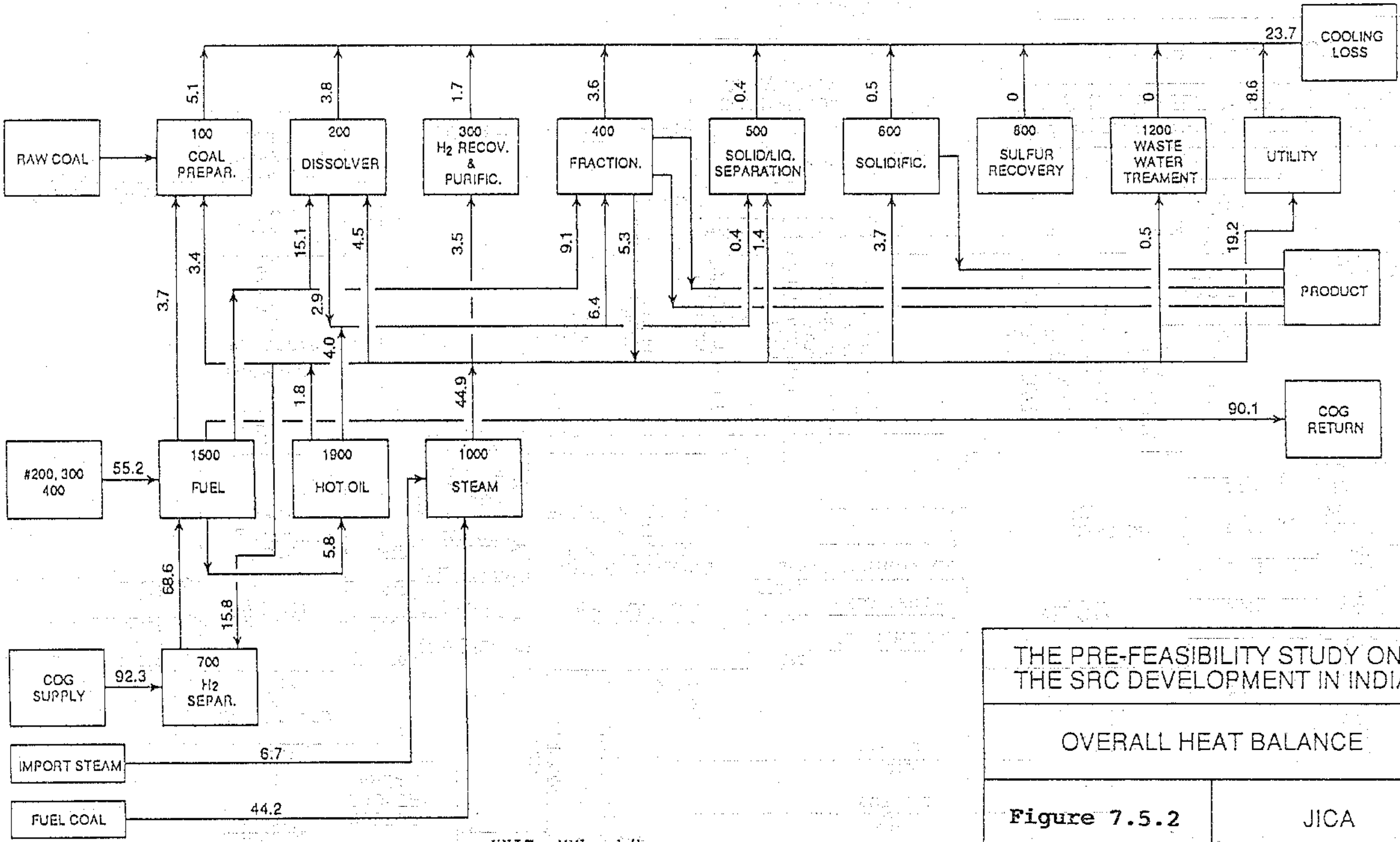
Figure 7.4.21 JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

MATERIAL BALANCE

Figure 7.5.1 JICA



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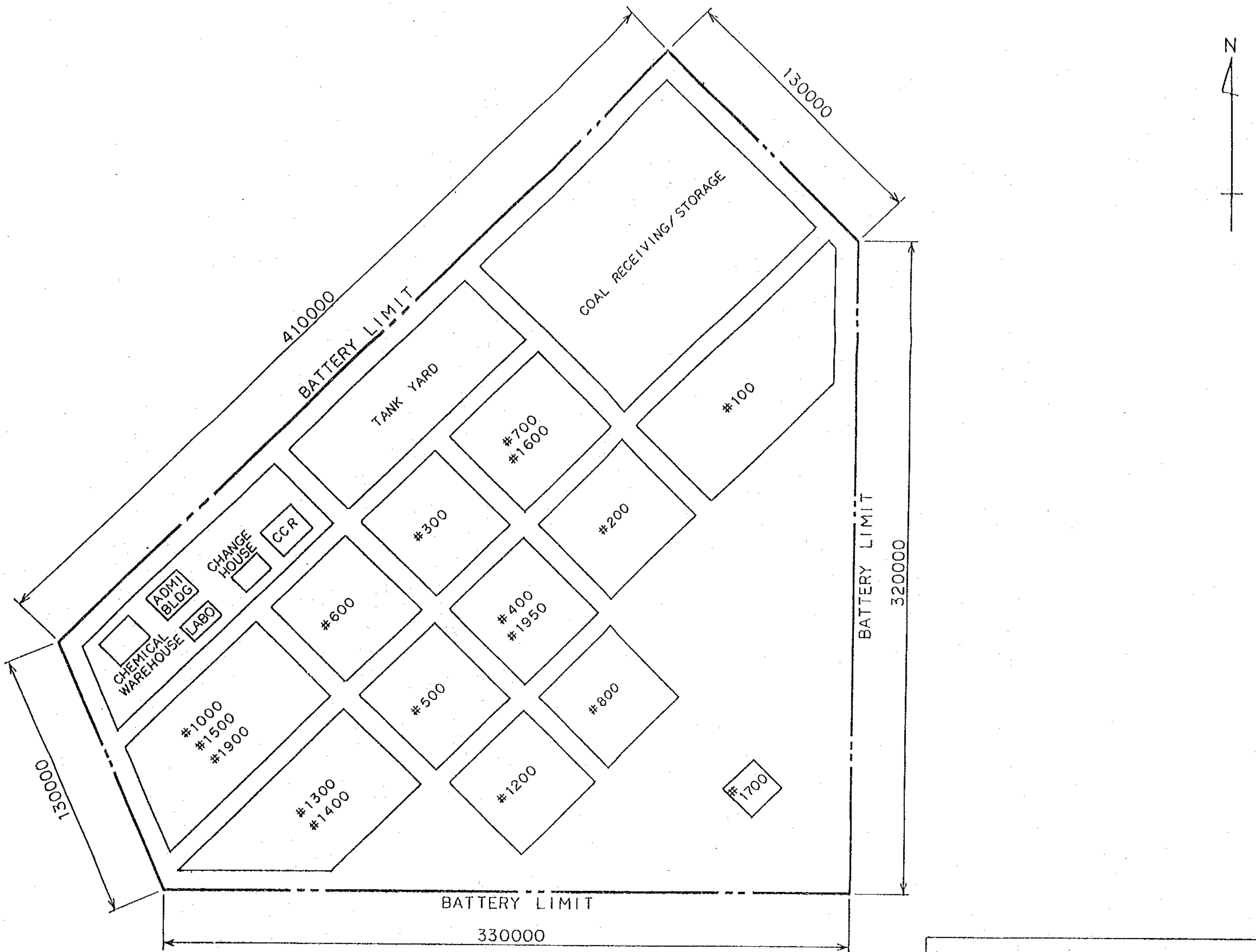
THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA	
OVERALL HEAT BALANCE	
Figure 7.5.2	JICA

Table 7.6.1 UTILITIES SUMMARY

Utility Name	Consumption	Note
Electric Power	1,310 kWh/h	
Steam 57 Kg/cm²G Steam	 10 t/h	
Fuel Bunker C Fuel Oil Fuel Coal	 3.0 t/h 8.3 t/h	 for start up
Water Treated Water Boiler Feed Water Drinking Water	 200 t/h 42 t/h as required	 for start up (applx. 7 days)
Nitrogen and Air Nitrogen Plant air Instrument Air	 500 Nm³/h	
Process Solvent	800 ton	Anthracene oil initial charge
Hot Oil	30 ton	initial charge
Butane	20 m³	initial charge

Table 7.6.2 CHEMICALS SUMMARY

Name	Area or System	Initial Charge	Consumption	Specification
Liquefaction Cat.	200		644 kg/h	Iron ore
Liquefaction Promotor	200		153 kg/h	Sulfur from OSBL
DEA	200 & 300	3 ton	2 kg/d	Commercial grade
Filter Aid	500		5.6 t/d	
Sulfur Recovery Cat.	800	700 kg	1 kg/d	Takahaks catalyst
Molecular Sieve	700	124 ton		
Activated Carbon	700	100 ton		
Corrosion Inhibitor	1300		0.9 kg/h	
Scale Dispersant	1300		0.9 kg/h	
Coaguration Polymer-1	1200		1.1 kg/d	
Coaguration Polymer-2	1200		1.6 kg/d	
Nutriment	1200		8 kg/d	K_2HPO_4
Nutriment	1200		8 kg/d	$FeSO_4$
Floccutant	1200		19 kg/d	$Al_2(SO_4)_3$
Neutralization Agent	1200		15 kg/d	NaOH



UNIT:m

THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA

PLOT PLAN

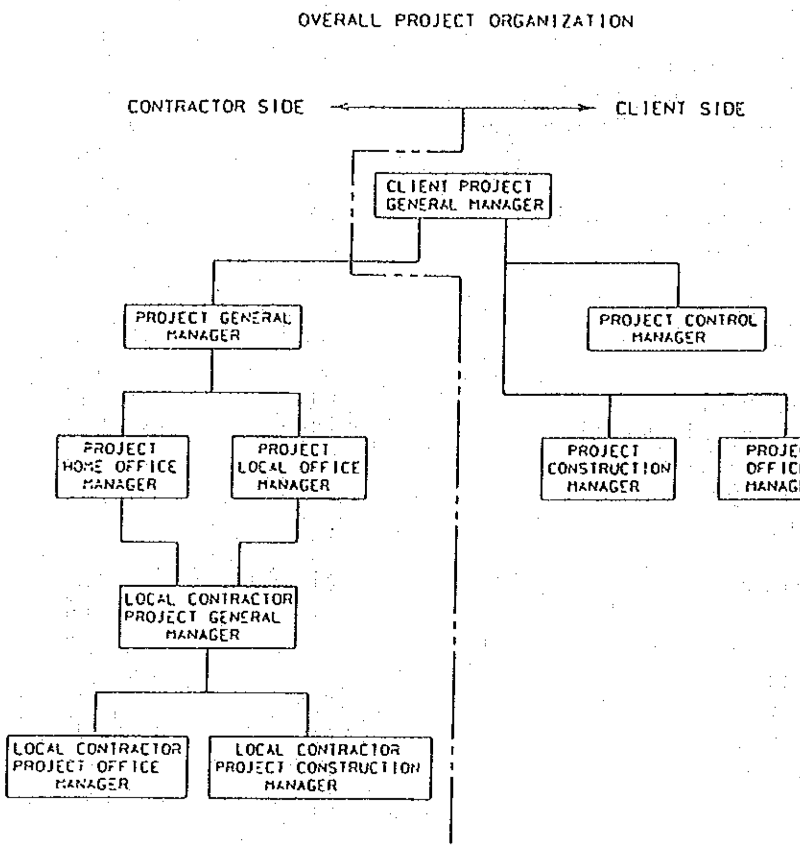
DWG. NO.	**Figure 7.9.1**	JICA

Table 7.10.1 PRICES OF VARIOUS CONSTRUCTION MATERIALS
(3rd Quarter, 1990)

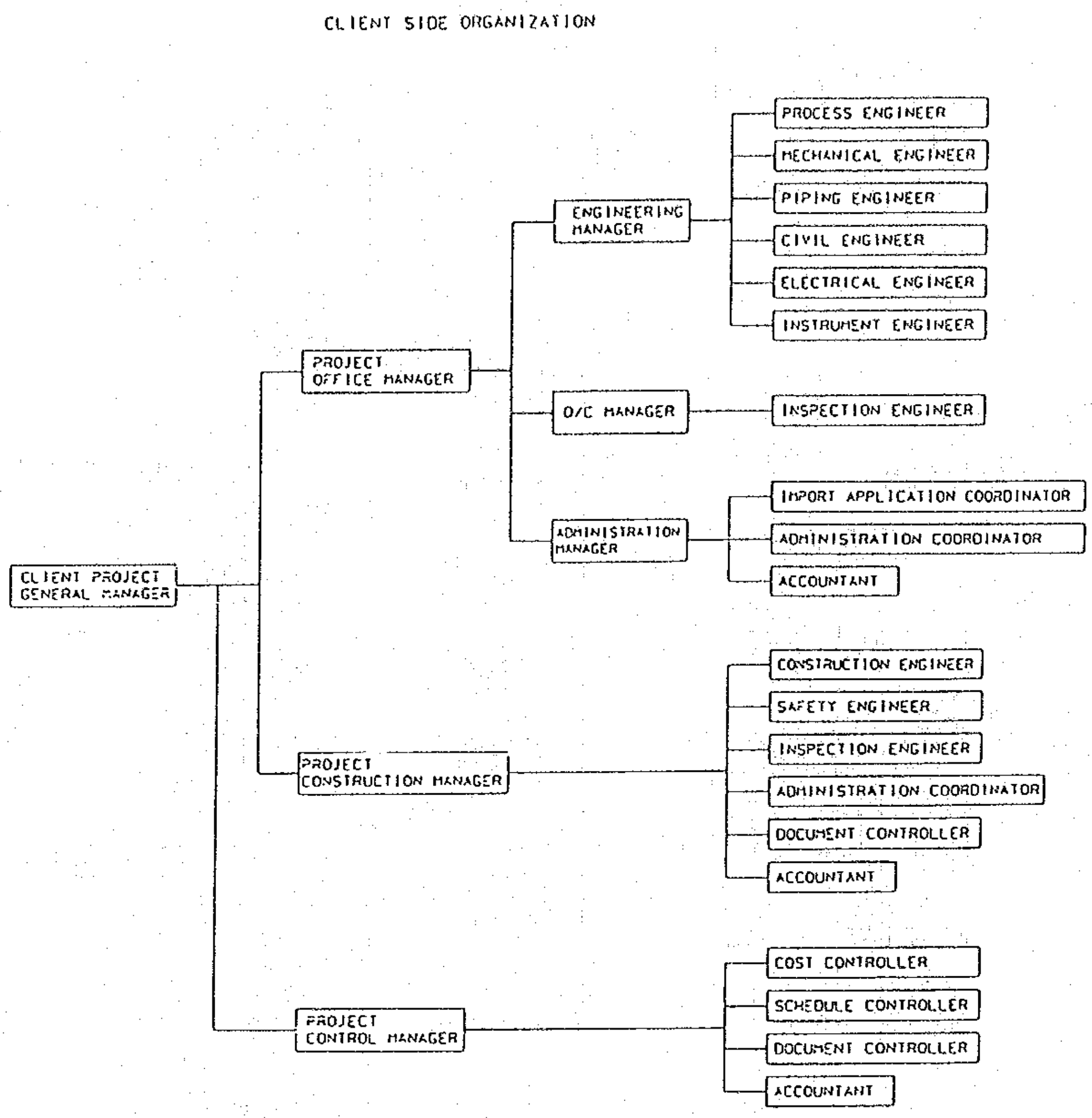
ITEM	UNIT	Rs/UNIT
Cement	ton	1,900
Sand	m3	60
Crush stone	m3	100
Reinforcing bar	ton	13,000
Ready mix concrete	m3	1,500
Concrete pile (60 ton load)	no	16,000
Brick	1000 nos	700
Steel pipe	ton	20,000
Wooden log (Sal wood)	m3	10,000
- Structual steel		
Angle	ton	8,500
I & H beam	ton	8,000
Channel	ton	8,940
Bar	ton	7,000
Steel plate	ton	10,800
Galv. steel sheet	ton	12,000
Ordinary plywood	m3	130
Planed plank	m3	80
- Fuel		
LPG	ton	4,500
Kerosene	kl	3,250
Diesel oil	kl	4,400
Lubricating oil (m/c oil)	kg	40
- Gas		
Acetylene	Nm3	69.33
Oxygen	Nm3	4.77
Nitrogen	Nm3	4.67
Argon	Nm3	53.89

Table 7.10.2 ANNUAL WAGES & SALARIES FOR CONSTRUCTION LABOUR
(3rd Quarter, 1990)

CATEGORY OF EMPLOYEES	ANNUAL SALARY (Rs)
Un-skilled	35,000
Semi-skilled	36,000
Skilled	43,000
Highly skilled	54,000



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA	
OVERALL PROJECT ORGANIZATION	
Figure 7.11.1	JICA



THE PRE-FEASIBILITY STUDY ON THE SRC DEVELOPMENT IN INDIA	
CLIENT SIDE ORGANIZATION	
Figure 7.11.2	JICA