Part 3 Ammonia Project

Chapter 1 Basic Concepts of the Project

Ammonia Project

Chapter 1 Basic Concepts of the Project

1.1 Items and Scale of Production

Zimbabwe has been producing ammonia by water electrolysis up to now, and has used it as raw material in producing ammonium nitrate and NPK fertilizer. Moreover, shortages have been filled by importing ammonia (approx. 30,000 T/Y) or urea, ammonium sulphate, etc. As has been mentioned in Part 1, Chapter 4, when these shortages at present and the demand increase in the future are taken into consideration, the nitrogenous fertilizer requirement amounts to ammonia equivalent 600 T/D. Therefore, this project is to produce ammonia 600 T/D using domestic coal, and the case of producing only ammonia is discussed. Of the 600 T/D of ammonia to be produced, 300 T/D is to be consumed by SABLE as raw material for ammonium nitrate and the remaining 300 T/D is to be supplied to project to be planned in Zimbabwe in the future.

The product line and capacities of this project are as follows.

Products	Capacity	Annual Production (330 days basis)
Ammonia	600 T/D	198,000 T/Y
By-product sulphur (as 100%)	18.1 T/D	5,973 T/Y

1.2 Product Quality

The quality of the products is shown below:

(1) Ammonia

- Purity: 99.7 wt.% min.
- Moisture: 0.3 wt.% max.
- Oil content: 5 ppm max.
- Storage conditions: 4.3 kg/cm^2G at 5°C
or
20 kg/cm^2G at ambient temperature

(2) Sulphur

- Purity: 99.5 wt.% min.

1.3 Plant Site

The plant site is planned in the Hwange area. Hwange itself is an industrial city located adjacent to WANKIE, which supplies the raw material of coal for this project, and the Hwange Thermal Electric Power Plant, which supplies the electric power. The coal can be hauled by truck for this short distance. It is also a place of some importance since the railroad leads to Kwekwe city and Bulawayo city, which facilitates the transportation of products to Kwekwe and Harare. The securing of water for industrial use is a very important prerequisite in selecting plant site for a chemical industry. The planned site is located in the Zambezi River Basin, which means that, by drawing water from this river, it is possible to secure water for industrial use even during times of drought. It should be noted that Zimbabwe has low rainfall. The area planned for plant site is a flat land , and there will be no difficulty in securing the required area.

Required area: 400,000 m^2

The surrounding area is also flat with much of the land still vacant. There will therefore be no problem with future expansion.

1.4 Coal for Use as Raw Material

The coal of WANKIE which is the only coal currently being mined in Zimbabwe will be used as the raw material coal for this project.

- Required raw material coal: 727 T/D (240,000 T/Y)

All the coal is supplied to the plant by truck. Of course, coal for use as a raw material has to be examined from the viewpoint of economy, as well as from the technical aspects in terms of the ash content, the ash fusion point, grindability, slurry efficiency, and the calorific value. The type of coal therefore has to undergo a careful selection process.

For this project, based on a field survey on WANKIE, as described in Volume I, Chapter 5, and on the results of sample examinations, the conceptual design was drawn up and the facility specifications were determined with Wankie coal as the raw material, the quality of which is shown in Table III-1-1. To maintain designed production and efficiency of the plant, the ash content of raw material coal should be maintained below 20%.

Table III-1-1 Specification of Feedstock Coal for Conceptual Design

Name	Dry Coal For Domestic Use		
Particle Size			
50 mm Pass	min.	99	wt%
Moisture as received		1.4	wt%
Proximate Analysis			
Inherent Moisture		1.5	wt%
Ash		13.8	wt%
Volatile Matter		24.2	wt%
Fixed Carbon		60.5	wt%
Gross Heating Value		7,090	kcal/kg
(Inherent Moisture Basis)			
Hardgrove Grindability Index		57	
Ultimate Analysis (Dry Basis)			
Ash		14.0	wt%
Carbon		73.0	wt%
Hydrogen		3.8	wt%
Oxygen		5.08	wt%
Nitrogen		1.4	wt%
Inflammable Sulphur		2.59	wt%
Total Sulphur		2.70	wt%
Non flammable Sulphur		0.11	wt%
Chlorine		0.021	wt%
Ash Fusion Temperature	Reducing		Oxidizing
Initial Deformation Temperature	1,100 °C		1,320 °C
Softening Temperature	1,300 °C		1,350 °C
Hemispherical Temperature	1,320 °C		1,360 °C
Fluid Temperature	1,330 °C		1,365 °C

1.5 Utilities

1.5.1 Electric Power

The plant site is to be located near the Hwange Thermal Electric Power Plant along the electric power trunk line. Therefore, the required electric power can be supplied steadily from the power plant direct to the plant by means of two sub-lines, and, for this project, all of the required electric power is planned to be purchased from outside and private electric generators will not be installed except an emergency electric supply facility.

In addition, since the securing of industrial water will cost great deal, the driving systems in the plant are designed to use as much electric power as possible, and the use of turbines should be reduced to a minimum, barely to cope with the steam balance of the entire plant complex.

1.5.2 Water Source

It can be thought that, as the water source for the Hwange District, water can be taken from boreholes and the Zambezi River, as described in Volume I, Chapter 5. However, borehole water cannot be used because of its poor quality, so for this project it was decided to take water from the Zambezi River which offers a stable, good-quality supply even during the dry season.

Chapter 2 Process and Production Facilities

Ammonia Project

Chapter 2 Process and Production Facilities

2.1 History and Present State of Ammonia Production Technology

The technology of ammonia synthesis was developed by Fritz Harber and Carl Bosh and in 1913 a plant with a production capacity of 30 T/D was built in Oppau (Germany).

At that time, the raw material used to produce hydrogen was mainly coke. Hydrogen production through water electrolysis had been a traditional technique for more than 150 years since the days of M. Faraday. In 1927, a large-scale water electrolysis plant for fertilizer production was built by Norsk Hydro. Coal gasification using Winkler Process had started in 1926. After that, the raw materials used in ammonia production have undergone many changes, that is, oil, coal and natural gas. However, the most popular processes today are the steam reforming process of light hydrocarbons (naphtha, natural gas) and the partial oxidation process of heavy fuel oil and coal. Of these, natural gas is the most suitable raw material for ammonia production, and the number of steam reforming plants of natural gas built throughout the world is largest. Their unit capacities are mostly in the range of 900 to 1,040 T/D and as the standard design, capacities of 550 T/D, 900 T/D, 1,040 T/D and 1,360 T/D have been adopted.

Ammonia plants have large scale merits and a capacity of 550 T/D is regarded as the minimum economical scale for the plants. However, thanks to major efforts in research and development by licensors and engineering companies in the field of catalysts and machinery, technology which has a competitive edge over conventional large-sized plants is being researched and developed for ammonia plants of smaller capacities. Therefore, the plant capacity of a minimum economic scale has gradually been reduced. The production capacity of 600 T/D of ammonia for this project offers optimum economic viability.

2.2 Selection of Raw Material for Production of Ammonia Synthesis Gas

Oil has been used as the raw material for ammonia production. However, there was a sharp increase in oil prices as a result of the first oil crisis from 1973 to 1974 and the second oil crisis caused by Iranian Revolution in 1979. Efforts were therefore made to find alternative resources of oil. To be specific, there were plans to convert the raw material from oil to coal, because as shown in Table III-2-1, there is a comparatively wide distribution of coal resources throughout the world, and price fluctuations are small. Strenuous efforts have been made in the field of research and development.

Table III-2-1 Reserves for Fossil Fuel and Uranium in World

	Coal (10^9 T)		OIL (10^9 Barrel)		Natural Gas (10^{12} FT^3)		Uranium (10^3 T)	
Country	Re-serve	Deposit	Re-serve	Deposit	Re-serve	Deposit	Re-serve	Deposit
USA	178	1,285	30		210		643	1,696
Canada	9	57	6	150-250	58	1,800-2,000	182	838
Mexico	1	3	14		30		5	7
South America	10	14	26	80-120	79	800-900	60	74
Western Europe	97	215	27	50-70	138		87	487
Eastern Europe	31	80	3	—	10	500	NA	NA
Africa	34	87	59	100-150	207	1,000	572	722
Middle East	—	—	366	710-1,000	720	1,750	—	—
USSR	110	2,430	75	140-200	920		NA	NA
China	99	719	20	—	25	2,850	NA	NA
Asia (excluding China)	40	41	18	90-140	91		45	69
Australia	27	132	2	—	32	500	296	345
Total	636	5,063	646	1,330-1,930	2,520	9,200-9,600	1,894	4,288
Heating Value (10^{16} Btu)		140.6		7.7-11.2		9.4-9.8		16.7 (LWR) 1,002.6(FBR)

Note: All figures are estimates of recoverable quantities net of past production. All resource figures are cumulative. They include reserves.

Source: Coal-World Energy Conference, World Energy Resources, 1985-2000 (Guilford, England, and New York, N.Y., IPC Science and Technology Press, 1978).

Since then, development has sometimes been accelerated and sometimes slowed down in accordance with oil price fluctuations, and is still continuing today.

From an international standpoint, the price of coal is extremely inexpensive compared to that of other raw materials, as shown in Table III-2-2 the data of the United Nations. Furthermore, the price of coal has been comparatively stable for many years and this tendency can be expected to continue in the future.

Generally speaking, it can be expected that coal will gradually gain a competitive edge over other raw materials in the medium and long term.

Table III-2-2 Energy Price of Feedstock

Fuel and Feedstock	Heating Value*	Cost, US$/Unit (Base Case)	US$/$10^6$ kcal
Natural gas	8,015 kcal/m^3	0.053/m^3	6.6
Naphtha	10,556 kcal/kg	130/t	12.3
Fuel oil	9,722 kcal/kg	80/t	8.2
Coal	6,333 kcal/kg	25/t	3.9

Note: * Low heating value (LHV).

Source: Fertilizer manual No. 13 (United Nations)

In spite of the advantages of the price of coal, the practical application of ammonia production using the coal process has experienced a sharp decline. This is due to the following reasons.

(1) Higher investment cost compared to those of plants using other raw materials.

(2) Low energy efficiency.

(3) Complicated gasification and refining process.

(4) Anxiety for the stability of long-term operation.

(5) Disadvantages with regard to handling and transporting the solid material of coal.

(6) Necessary ash disposal.

However, remarkable progress has been made in coal gasification technology in recent years. High-temperature, high-pressure operation is now possible, while process simplification and improvements in energy efficiency have been significant. The essential disadvantages of coal as a solid raw material has also been reduced, as well as reduction of the cost of facilities.

Nowadays, in countries where natural gas is not available and coal can be easily mined or in landlocked countries where there are coal resources and product prices are very high because of transportation costs, projects using coal as a raw material are recognized advantageous, and many coal-related projects are being planned and some of them have already been materialized, contributing to the growth of national economy. Zimbabwe is a landlocked country, and ammonia is expensive at US$295/T in 1988. On the other hand, the price of domestically produced coal for raw material is Z$25/T (US$13.9/T). When converted into the price of a unit energy, the cost is US$1.96/$10^6$ Kcal, which is comparatively inexpensive. It can therefore be expected that this coal gasification project will be economically viable.

2.3 Comparison and Selection of Coal Gasification Technology

2.3.1 Classification of Coal Gasification Technology

The record of practical applications of coal gasification technology are shown in Table III-2-3. The coal gasification plant already built and those now under construction all use either Lurge, Texaco, Winkler or Koppers-Totzek processes. These processes have been developed on the basis of original technology with special characteristics. In recent years, all these companies have been directing their efforts in the research and development of new technology whereby plants will be capable of operating for long periods at high temperature and under high pressure. In fact, some of companies have already established their technology or have almost reached to the level of technology completion. These new technologies are all being developed in conjunction with conventional technology of each company. Conventional technology is classified as first generation technology, while newly developed technology is classified as second generation technology. The major characteristics of newlv developed technology is the attempt to achieve economic viability of the plant by increasing design pressure and by enlarging the scale of a plant. The classification of coal gasification technology and second generation technologies, which are of special importance nowadays, are given in Table III-2-4.

Table III-2-3 Coal-Based Gasification Plants Commercially Operating or Under Construction

Process	Plant Owner	Plant Location	Start of Construct. Date	Product Type	Estimated(a) Coal Feed Rate MAF to Gasifiers ton/day	Number of Operating and Spare Gasifiers
Lurgi	1. South African Coal, Oil and Gas (SASOL)	Sasolburg, The Republic of South Africa (SASOL I)	1954 1958 1966 1973 1980	F-T liquids town gas " " "	5,200 Total	9 1 3 3 1
	2. South African Coal, Oil and Gas (SASOL)	Secunda, The Republic of South Africa (SASOL II)	1974	F-T liquids	19,600	36
	3. South African Coal, Oil and Gas (SASOL)	Secunda, The Republic of South Africa (SASOL III)	1979	F-T liquids	19,600	36
	4. Great Plains Gasification Associates	Beulah, North Dakota U.S.A.	1981	Natural Gas	8,000	14
	5. China National Technology Import Co.	Beijing, People's Republic of China	1982	Ammonia	1,100	4
						107
Koppers-Totzek	1. Nitrogenous Fertilizer Industry	Ptolemals, Greece	1959 1969 1970	Ammonia	700 Total	4 1 1
	2. Azot Sanayii	Kutahya, Turkey	1966	Ammonia	500	4
	3. NCZ Nitrogen Chemicals of of Zambia	Kefue, Zambia	1967 1974 1975	Ammonia & Methanol	550 Total	1 1 2
	4. Fertilizer Corporation of of India	Ramagundam, India Talcher, India	1969 1970	Ammonia Ammonia	1,300 1,300	3 3
	5. African Explosives and Chemical Ind. (AECI)	Modderfontein, South Africa	1972	Ammonia & Methanol	1,500	6
						26
Winkler	1. Fabrika Azotnih	Gorazde, Yugoslavia	1950	Ammonia	100	1
	2. Azot Sanayii	Kutahya, Turkey	1972	Ammonia	350	2
						3
Texaco	1. Tennessee-Eastman	Tennessee, U.S.A.	1983 (b)	Acetic anhydride	820 (c)	2
	2. Cool Water	California, U.S.A.	1984 (b)	Electric power	910 (c)	2
	3. Ube Ammonia	Ube, Japan	1984 (b)	Ammonia	1,500 (c)	4
	4. SAR	West Germany	1986 (b)	Oxo-chemical hydrogen	730 (c)	1
						9

Note: (a) moisture & ash-free basis
(b) start of operation date
(c) moisture-free (dry) basis

Table III-2-4 Classification of Coal Gasification Processes

	First Generation Process	Second Generation Process
Moving-Bed	Lurgi (Dry Ash)	BGC-Lurgi
Fluidized-Bed	Winkler	———
Entrained-Flow	Koppers-Totzek	Shell-Koppers
	Texaco	Texaco

If we analyze Table III-2-3, it can be seen that Lurgi Process in the SASOL Project in South Africa and Texaco Process introduced into an ammonia project and further improved in Japan are high pressure coal gasification process materialized on commercial basis.

BGC-Lurgi, in Table III-2-4, is a high-temperature, conventional Lurgi Gasifier which discharges ash in the form of slag. It was developed in 1975 by BGC Company (U.K.) in Westfield, Scotland, as a demonstration plant (quantity of coal handled, 300-350 T/D). Shell-Koppers Process has taken advantage of the technology of Shell which has made many achievements in the pressurized gasification of oil on Koppers-Totzek Gasifier, the pressure being 25 atmospheres. This process has still not been commercialized.

2.3.2 Characteristics of the Various Types of Coal Gasification Technology

(1) Lurgi Gasifier (Fig. III-2-1)

It was in 1936 when Lurgi Gasifier was first put into commercial operation for the production of town gas. Since then, more than 100 gasifiers have been built and they have achieved remarkable record. In SASOL Project in South Africa, many pressurized gasifiers of this type were used (a pressure is 30 atmospheres), producing synthetic oil and chemical products.

Fig. III-2-1 shows the structure of the gasifier.

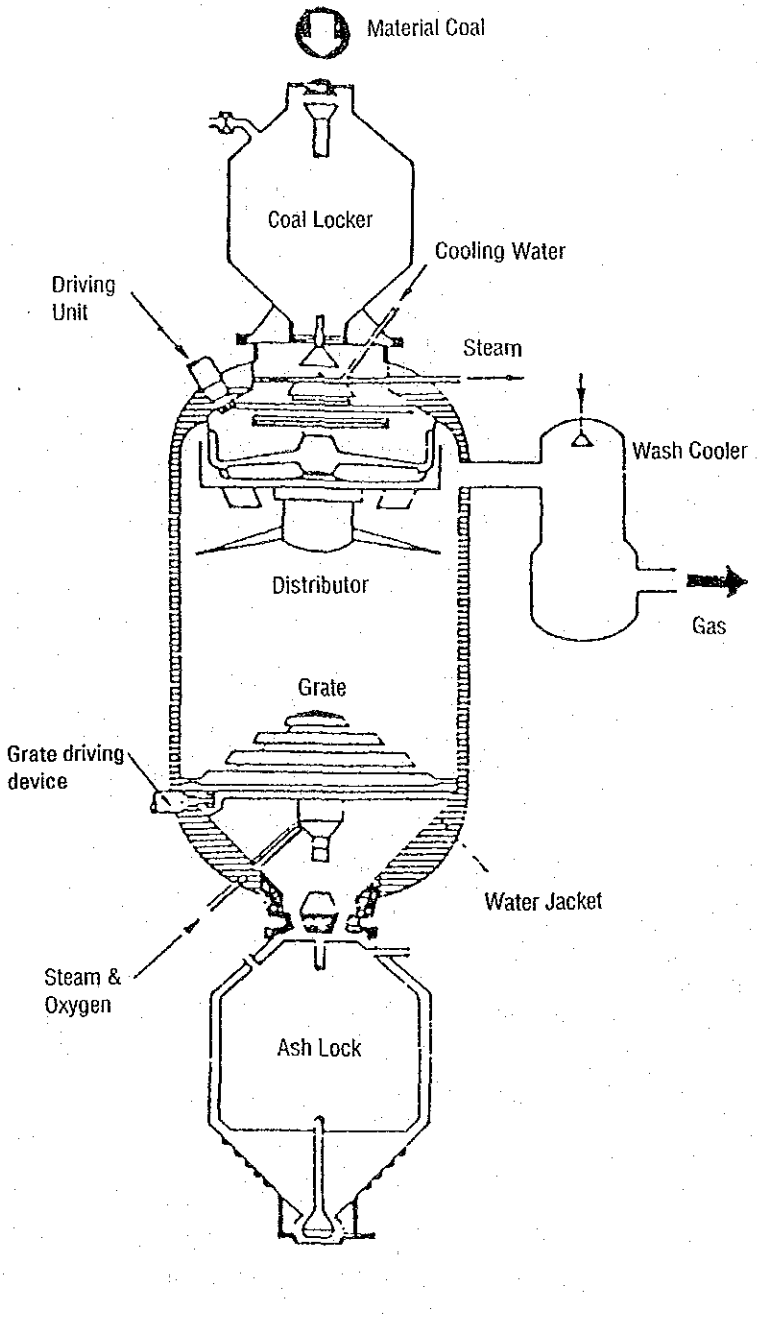


Fig. III-2-1 Lurgi Gasifier

The structure of the gasifier is that of a vertical type gasifier with a water cooling jacket. Lumps of coal measuring 5-30 mm in size are supplied by means of a lock hopper to the gasifier intermittently and go down through the drying zone, dry distillation zone, gasification zone, and finally combustion zone. The whole reaction layer is supported by a rotational grid, while oxygen and steam are supplied from bottom section. Ash from the coal dropped through the rotating grate and is intermittently discharged by the ash lock hopper. The operation temperature in the combustion zone is kept lower than the softening point of ash to prevent clinker occurence, the temperature being maintained usually around 1,000 °C at the maximum.

The temperature of the produced gas emitted from the top of the gasifier is approximately 450 °C. The superior and inferior points of this gasifier are as follows:

Superior points

- Many achievements of pressurized operation at 30 atmospheres.
- Oxygen used is about 1/2 - 1/3 or less compared to other processes.
- Carbon-conversion ratio and thermal efficiency are high.
- Low-temperature operation facilitates maintenance.

Inferior points

- There are limits of quality of coal that can be used.
- Produced gas has a high methane content. It has advantages as a fuel gas, but as a synthetic gas, it has disadvantage due to its methane content.
- Many by-products are produced (tar, phenol).
- Retention time of supplied coal in the gasifier is long which is disadvantageous in terms of a large-scale plant.

(2) *BGC-Lurgi Gasifier*

An improved type of Lurgi Gasifier is now being developed, as described in Section 2.3.1, but there is no commercial application yet. It is operated at a temperature higher than the softening point of ash (1,400 °C), and to dispose of the ash, a wet lock hopper system using quench water has been adopted. The amount of steam used is reduced significantly, while the thermal efficiency is improved. In terms of scale, the gasifier has a capacity which is approximately 2.5 times greater than that of Lurgi Gasifier.

(3) Winkler Gasifier

In 1927, Winkler Gasifier was built for the purpose of ammonia synthesis in Germany. After that, a total of 36 gasifiers were built in a number of countries, but at present only two gasifiers are being operated, as shown in Table III-2-3.

The structure of the gasifier is shown in Fig. III-2-2.

Size of coal supplied to the gasifier measures 8 mm or less, while the operation temperature is lower than the softening point of ash, normally between 700 and 1,000 °C.

The coal is supplied to the gasifier by means of a screw feeder, and oxygen and steam are blown separately into the bottom and central parts of the gasifier.

A radiation-type waste heat boiler is installed in the upper part of the furnace, and it cools gas and ash. Approximately 70% of the ash is discharged from the upper part of the furnace together with the gas. The remaining 30% is discharged from the screw conveyor at the lower part of the furnace. The ash contains non-reacted carbon. A pressurization experiment at 10 atmospheres has been carried out to test the newly developed technology.

The superior and inferior points of this type of gasifier are as follows:

Superior points

- It can be operated at a uniform temperature.
- Comparatively, many kinds of coal can be used.
- Low content of methane and other by-products (tar, phenol).

Inferior points

- Pressure gasification has not been achieved.
- Coal with a low softening point of ash cannot be used.
- Carbon conversion ratio is low.
- To maintain fluidized layer, there is a limit to low-load operation.

(4) Koppers-Totzek Gasifier (T-K Gasifier)

Koppers-Totzek Gasifier is a technology developed by Krupp Koppers GMBH (Germany). The first plant was built in the 1950s in Finland and France, and since then more than 20 plants have been built throughout the world. The structure of the gasifier is shown in Fig. III-2-3.

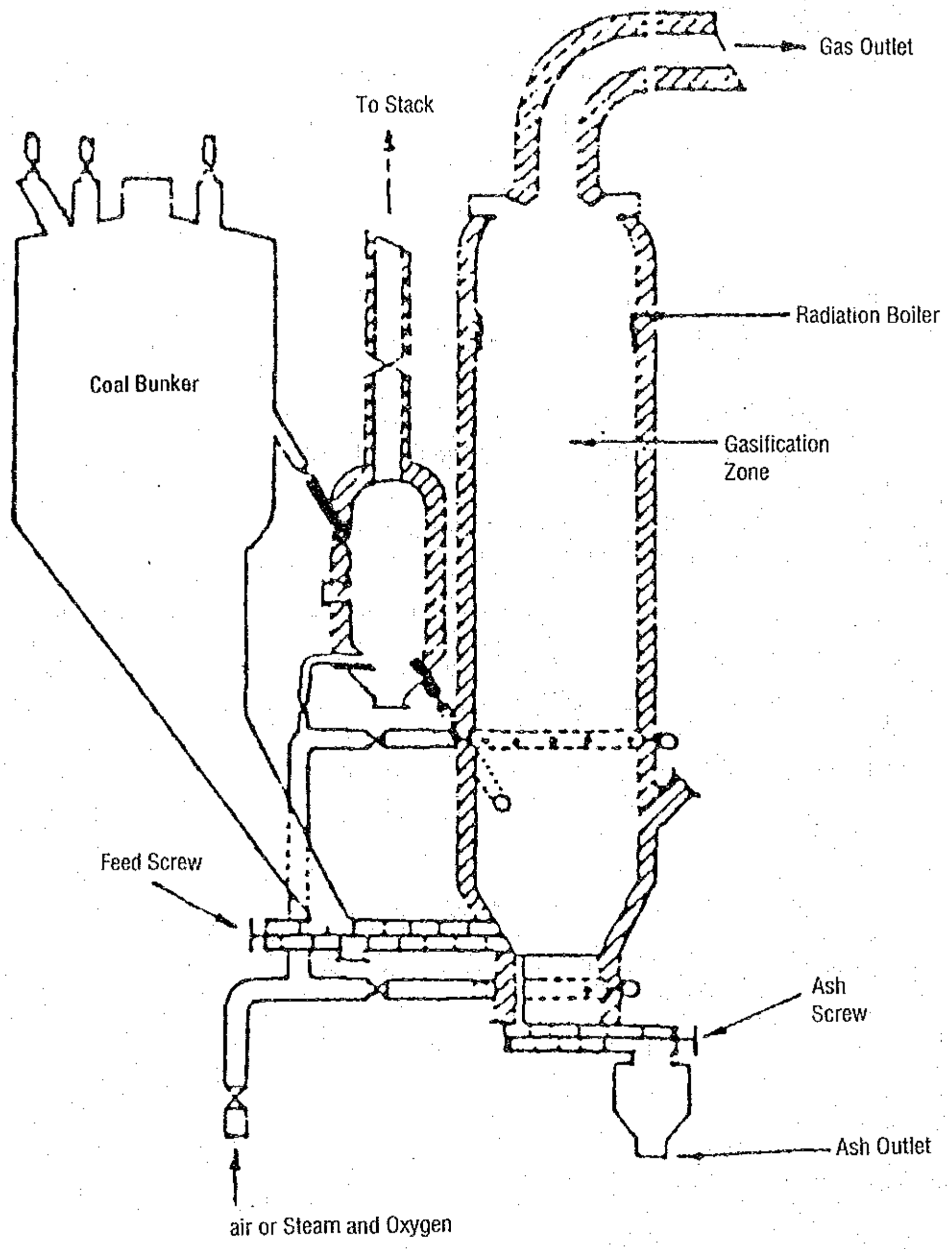


Fig. III-2-2 Winkler Gasifier

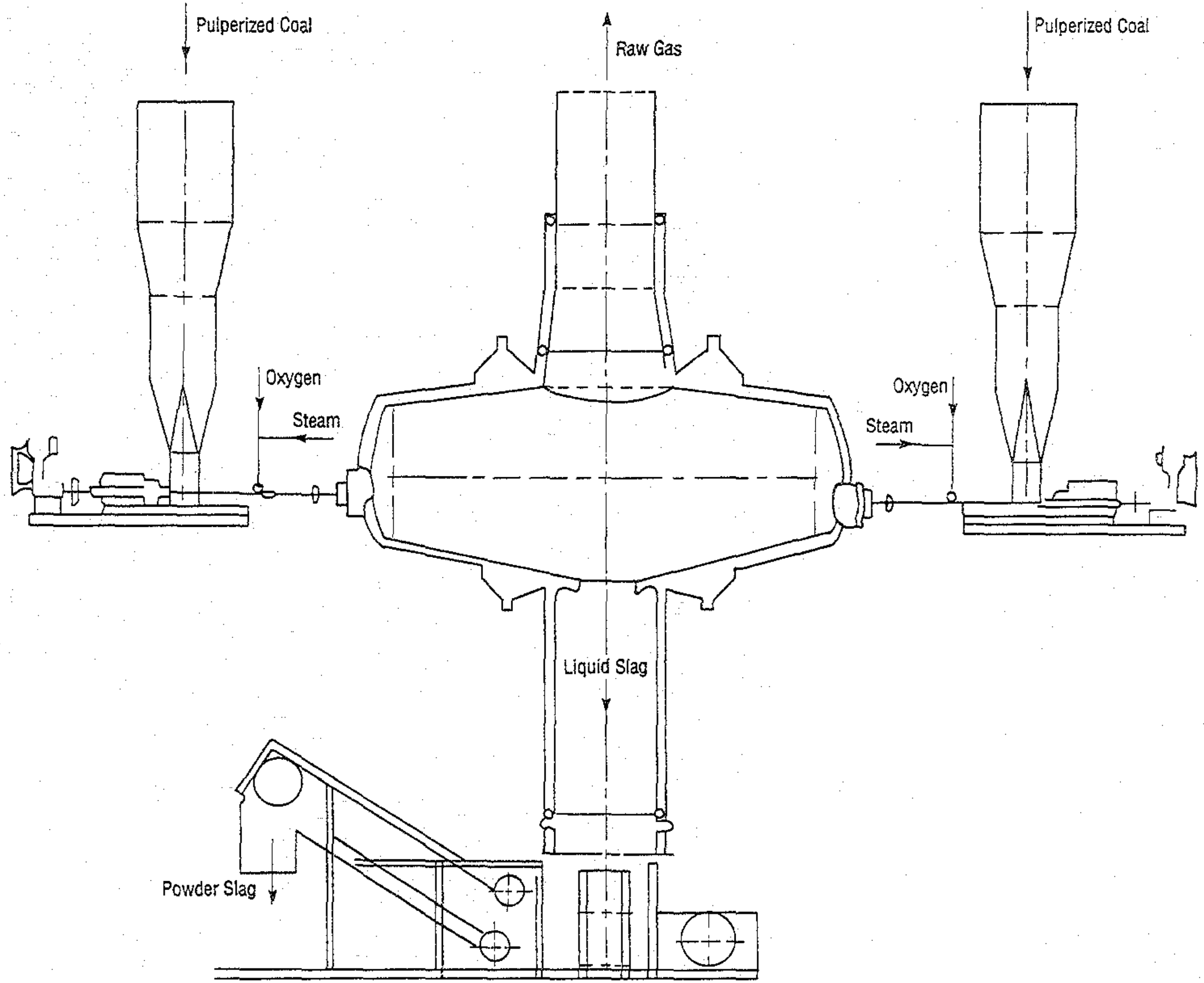


Fig. III-2-3 Koppers-Totzek Gasifier

Koppers-Totzek Gasifier is an atmospheric pressure gasifier using finely pulvelized coal at approximately 75% 200 mesh/pass. The coal is blown with oxygen and steam into the gasifier through a nozzle.

The inside of the gasifier is covered with refractories, while the gasifier itself is a horizontal cylinder vessel with a jacket. There are two types of the furnace, that is, two-burner type and four-burner type. The former has a coal gasification capacity of more than 400 tonnes a day, and the latter a capacity of more than 800 tonnes.

The operation temperature is higher than the fluid point of ash, normally from 1,000 - 1,500 °C, while the reaction time is very short at approximately 1/10th of a second.

The superior and inferior points of this gasifier are as follows:

Superior points

- There is no limit to the kind of coal that can be used.
- Because of the high-temperature reaction, there are few methane content, and there are no by-products (tar, phenol).
- Processing time is short, while the gasified coal amount per unit furnace volume is large.

Inferior points

- Because of atmospheric pressure operation, energy consumption for compression of ammonia synthesis is high.
- Oxygen consumption is high.
- The operating temperature of the gasifier is high, so special quality refractories are to be used as the molten ash is harmful.
- Carbon conversion ratio is low.

(5) Shell-Koppers Gasifier

Shell-Koppers Gasifier is being developed in West Germany, combining Koppers-Totzek gasifier technology with long experienced oil gasifier technology of Shell. Developmental tests with a coal processing capacity of 150 T/D are still being carried out at 25 atmospheres. High performance can be expected of this gasifier, although there are no results available from actual commercialization.

(6) Texaco Gasifier

Texaco Coal Gasifier is the developed technology from its own gasification technology using natural gas and oil. The technology is the same kind of entrained flow technology used by the Koppers-Totzek Gasifier. Texaco's coal gasification technology is called TCGP, while the natural gas/oil gasification process is called TSGGP.

TSGGP

In 1945, Texaco Co. started developing TSGGP using natural gas as the raw material. Later, the range of raw materials that could be used have been extended from light hydrocarbons such as naphtha to heavy hydrocarbons such as crude oil, heavy oil and vacuum residue. In recent years, development has lead to the use of even pitch coke and oil coke. The number of gasifiers built is reported more than 150.

TCGP

Development was started in 1948. A test plant with a coal processing capacity of 15 T/D was built in Montebello, located to the east of Los Angeles. Being of the quenching type, this test gasifier was capable of operating at a pressure of up to 80 atmospheres. In 1956, a demonstration plant with a capacity of 100 T/D started operation in Morgan Town (U.S.A.).

On the other hand, in 1977, in West Germany, Ruhrchemie and Ruhrkohle obtained the support of the West German Government, and built a demonstration plant with a coal processing capacity of 150 T/D in Oberhausen. Being of the waste heat boiler type, it was operated under a pressure of 40 atmospheres and at a temperature of 1,450 °C. This system was commercialized in Sar, West Germany. (Table III-2-3)

The structure of the Texaco Coal Gasifier is shown in Fig. III-2-4.

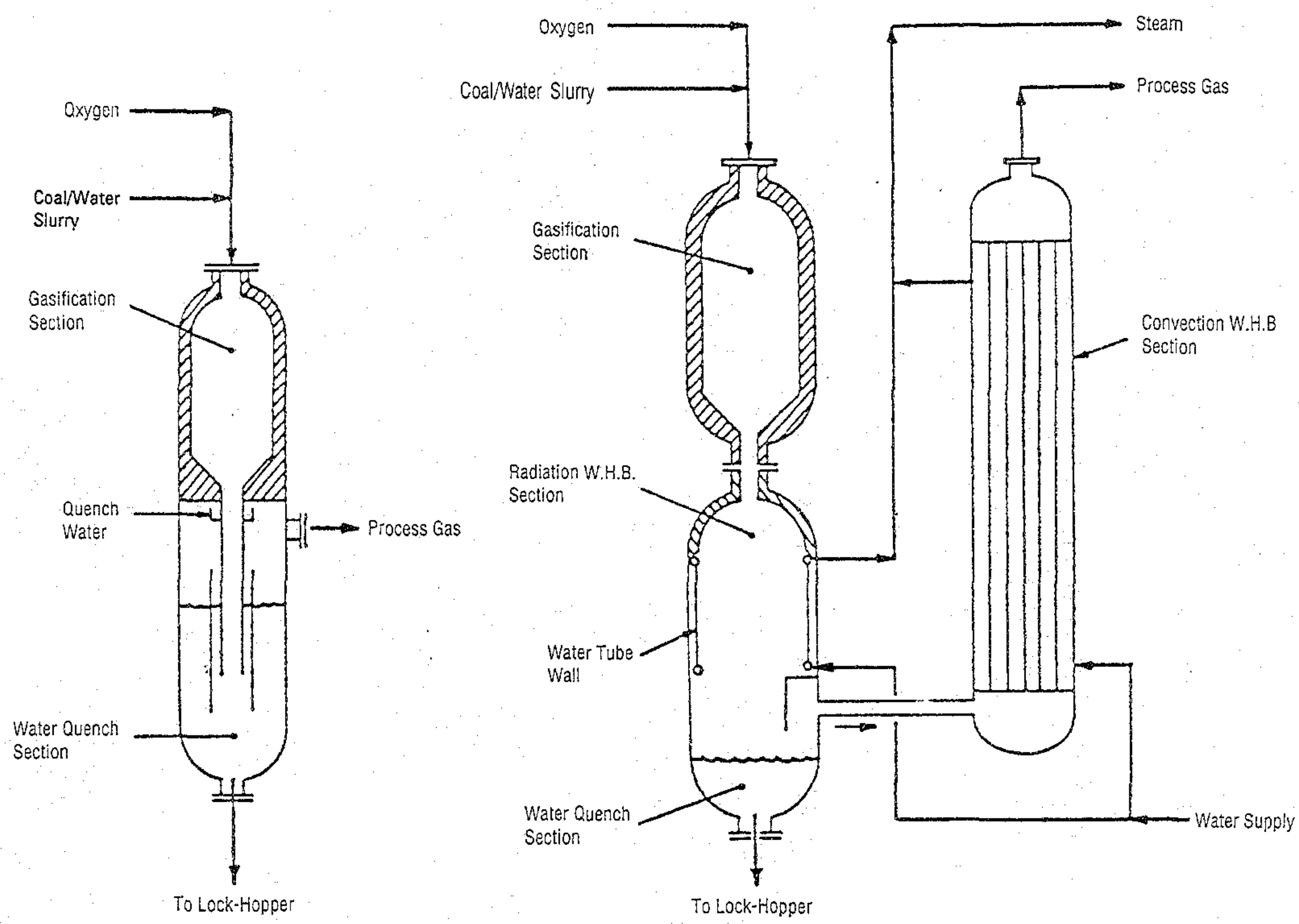


Fig. III-2-4 Types of Texaco Gasifier

Coal finely pulverized by a wet ball mill or a rod mill is blown into the gasifier together with oxygen from the upper part of the gasifier as coal/water slurry.

The gasification part is protected by refractories. The gasification temperature is chosen between 1,350 - 1,500 °C, at the lower temperature as possible above ash fluid temperature. When coal with ash fluid point of more than 1,500 °C is used as the raw material, the refractories are protected by lowering the fluid point of the ash by mixing additive to coal/water slurry. Thanks to the high temperature resulting from the partial oxidation reaction of the coal, the slurry water evaporates and the gasification reaction happens quickly.

The high-temperature produced gas is cooled by quenching directly with water or the waste heat boiler.

1) Quench type

The generated high-temperature gas is rapidly cooled in the water tank in the lower part of the gasifier together with the molten slag. It is then saturated with generated steam, and emitted from the gasifier. The molten slag is formed into fine particles through rapid cooling and then discharged from the furnace by means of the lock hopper system. This process is mainly used to produce hydrogen and, the carbon monoxide in the gas is converted to hydrogen in the CO conversion process using steam.

2) Waste heat boiler type

The high-temperature gas generated by gasification is cooled to a temperature lower than the softening point of ash by means of the radiation-type waste heat boiler located in the lower part of the gasifier. The slag in its molten state is cooled passing through the central part of the boiler and drops into the water tank in the lower part of the gasifier. It is then discharged in the same way as the quench type. The cooled gas containing unburned carbon and fine powder ash in solid form is further cooled by the convection type waste heat boiler. This type is suitable for the production of carbon monoxide gas, fuel gas and mixed ($CO + H_2$) gas. If it is necessary to adjust CO/H2 molar ratio, steam is blown into a part of the gas and CO conversion is carried out.

The superior points of this gasifier are as follows:

Superior points

- Most kinds of coal can be gasified.
- High-pressure processing technology (80 atmospheres) is available.
- There are few methanol content (approximately 0.1%) and no by-products (tar, phenol).
- Thanks to the coal/water slurry supply method, operation is stable and safe.
- The reaction time is short and the system is suitable for a large plant.
- Carbon conversion ratio is high.
- Due to the high-temperature reaction, there are few environmental problems.

Recent applications of this process are shown in Table II-2-5.

Table III-2-5 Plant List of TCGP

Start-up Year	Country	Coal Capacity	Product	Heat Recovery	Company
1982	U.S.A.	170 T/D	Ammonia	Quench	TVA
1983	U.S.A.	800 T/D	Acetic Anhydride	Quench	Tennessee-Eastman
1984	U.S.A.	900 T/D	Elec. power	W.H.B.	Cool Water
* 1984	Japan	1,500 T/D	Ammonia	Quench	Ube Ammonia
1986	W. Germany	700 T/D	Oxo-chemical/ hydrogen	Quench + W.H.B.	SAR
Under construction	China	400 T/D	Ammonia	Quench	Ru Nan

Note: * Supplied by Ube Industries, Ltd.

2.3.3 Comparison and Selection of Coal Gasification Technology

The characteristics of each type of coal gasification process described in the previous section were compared in Table III-2-6.

Table III-2-6 Comparison of Gasifier Characteristics[a]

	Gasifier					
Item	Lurgi	Koppers-Totzek	Winkler	Texaco	Shell-Koppers	BGC-Lurgi
Pressure, bar	30 max.	1	1	80 max.	30 max.	30 max.
Temperature, °C	450/1,300[b]	1,500	950	1,400	1,500	450/1,300
Coal throughput, T/D[c]	600	850	800	1,500[d]	1,000[d]	1,200
Oxygen requirement	Low	High	Moderate	High	High	Low
Steam requirement	High	Low	Moderate	None	Low	Low
Carbon conversion, %	99.7	90	85	99.8[e]	95	99.7
Raw gas quality	Poor	Good	Fair	Good	Good	Poor
Commercial-scale operation	Yes	Yes	Yes	Yes	No	No

Note:

(a) All values shown are typical unless otherwise indicated

(b) Top/bottom

(c) Per gasifier

(d) Maximum projected

(e) With carbon recycle; 98% with no recycle

Source: MONTAN Report VOL. V, Part I

Each comparison item in Table III-2-6 is described as follows.

- Operation pressure

  Since pressurized operation of gasifier becomes possible, gasification facility cost is reduced. The larger the plant capacity is, the effect of this cost reduction is remarkable. For this project, pressurization of gasification system will save the total facility cost.

  In case that this produced gas is used for ammonia synthesis, power consumption to raise the pressure of the feed gas to the pressure of ammonia synthesis reaction will be reduced as gasification pressure becomes high. Therefore, pressurized gasification will reduce the production cost of ammonia.

  Because coal gasification reaction becomes active by increase of partial pressure of oxygen, Texaco process of high operating pressure is considered the most superior technology among many gasification processes.

- Quality of produced gas

  It is desirable that ammonia synthesis gas has high ($CO + H_2$) content and methane, tar and phenol are not produced.

  As an inert gas, methane decreases economic viability of the process, while tar and phenol needs complicated equipments for their removal. Therefore, Lurgi and BGC-Lurgi Processes are not profitable for ammonia synthesis.

- Amount of oxygen required

  The amount of oxygen required affects construction costs and power consumption. It is therefore necessary to reduce the oxygen consumption as much as possible. In Lurgi and BGC-Lurgi Processes, the amount required is small, but since the produced gas is unsuitable for ammonia synthesis gas, as mentioned before, these processes cannot be adopted. In all other processes, however, consumption of oxygen is high.

- Quality of coal

  Almost all kinds of coal can be fed to Koppers-Totzek, Texaco and Shell-Koppers Processes. However, when economic viability is considered, it must be noted that raw material coal is fed as a water slurry in the Texaco Process. Therefore, when the ash content of coal is more than 20%, the amount of oxygen required escalates and, to maintain the required high-temperature operation, a great amount of heat is unfavourably needed.

- Coal conversion ratio

  Lurgi, BGC-Lurgi and Texaco Processes are superior.

- Achievements

  Among these technologies, Texaco Process only has actual application as a large-scale plant and accumulated practical know-how for prolonged operation.

  Considering all of these items, Quench Type Texaco Coal Gasification Process was selected for this project.

2.4 Selection of Other Processes

2.4.1 Ammonia Synthesis Process

Though there are numerous ammonia synthesis processes already established, those which have achieved superior results and have a proven record of commercial achievement can be cited as follows:

- M.W. Kellog (U.S.A.)
- ICI (U.K.)
- Haldor-Topsoe (Denmark)
- Snamprogetti (Italy)

The ammonia synthesis process is to be evaluated not only from process itself, but also from a series of processes on the raw materials and final products and the overall engineering results. All companies are concentrating their efforts to save energy and reduce construction costs. Technology related to ammonia synthesis has therefore made remarkable progress compared to conventional technology.

Some items mentioned below are to be noted.

(1) Efficiency of catalyst

Through the development of a synthesis catalyst of high efficiency, operation pressure has been lowered to a pressure of 150 atmospheres or less compared to the conventional operation pressure of 140-280 atmospheres, and then, the cost of power has been significantly reduced.

In addition, the form of the catalyst has been improved, and the pressure loss through the catalyst layer has been decreased, and the amount of catalyst charge volume is also decreased.

As a result, the volume of converter and the power consumption of the recycle gas have also been decreased. This has had a positive effect on overall economic viability.

(2) The inner appratus of converter is designed that catalyst reaction temperature can be maintained at the optimum temperature, thanks to the removal of the heat of reaction by means of water and gas. At the same time, the heat is recovered as a high-level heat which is then used effectively.

(3) As far as the design is concerned, the design of a radial flow catalyst layer was adopted to decrease the pressure drop, and by installing horizontal type converter, a high steel structure and large-sized hoist are no longer required and all works were simplified and improved.

2.4.2 Acid Gas Removal

The produced gas generated by coal gasification contains CO and H_2, effective raw materials for synthesis gas and acid gas such as sulphur compounds (H_2S, COS) and CO_2 which are to be removed. Furthermore, in case of ammonia synthesis gas, they need to be removed up to the level of harmless to synthesis reaction. In general, the chemical absorption processes, represented by MEA, DEA, and the hot potassium carbonate process, which have been already completed technologically, are used. Recently, however, from the standpoint of saving energy, the physical absorption process is often adopted. The many processes developed are classified and compared in Table III-2-7. Process selection depends on the results of comparing energy cost and construction requirements, but physical absorption is possible to remove sulphur compounds and carbon dioxide selectively, while a high concentration of CO_2 and sulphur compound gases can be obtained separately.

This characteristic is very advantageous when ammonia is produced with coal as the raw material. In the case of Rectisol Process, in particular, the removed sulphur compounds content in the gas can be in a high concentration (30%). Using the Claus Process high purity sulphur is recovered without concentration of the treating gas. These are the advantageous characteristics of the physical absorption process.

A comparison of the efficiency of the physical absorption process and other processes is shown in Table III-2-8.

Table III-2-7 Processes of Acid Gas Removal (CO_2 and H_2S)

System	Solvent	Characteristics (Low or High Temp)	Solution Circulation	Acid Gas Content In Treated Gas	Heat Requirements	General Comments
Reaction Type Systems						
MEA	20% Mono-Ethanalamine	LT Absorption HT Stripping	Medium	Less Than 50 PPM	High	CO_2 pickup excellent. High operating costs due to high utility consumption. Requires extensive use of alloy materials to combat corrosion intermediate size vessels required High exchanger costs.
Promoted MEA	25-35% Mono-Ethanolamine Plus UCAR Amine Guard	LT Absorption HT Stripping	Medium	Less Than 50 PPM	Medium	Additive reduces corrosion and permits increase in circulation for increased CO_2 pickup. Heat requirements lower than 20% MEA system.
DGA	60% 2-(2-Amino-Ethoxy Ethanol-Amine) Diglycol Amine	LT Absorption HT Stripping	Medium	Less Than 100 PPM	Medium	Limited experience with this solvent for synthesis gas treatment. Principally used for natural gas treating for CO_2 and H_2S removal. High acid gas pickup. Operates in similar manner as MEA system
Vetrocoke	K_2CO_3 Plus As_2O_3	Essentially Isothermal	High	500-1000 PPM	Low	Excellent performance Low utility consumption. Use of arsenic additive presents disposal and pollution problems. Considerable experience.
Vetrocoke	K_2CO_3 Plus Glycine	Essentially Isothermal	High	500-1000 PPM	Low	Experience not as extensive as arsenic-based process. Requires somewhat greater steam for stripping than arsenic system.
Carsol	K_2CO_3 Plus Additives	HT Absorption and Stripping	High	500-1000 PPM	Low	Excellent performance and low utility costs. Can be used as a single stage of two stage system Used in NH_3 plants up to 1,500 ST/D capacity.
Catacarb	25-30% K_2CO_3 Plus Additives	HT Absorption and Stripping	High	500-1000 PPM	Low	Excellent performance-low operating costs Has been used in ammonia plants up to 1,700 ST/D capacity.
Benfield	25-30% K_2CO_3 Plus Diethanol-Amine and Additives	Essentially Isothermal	High	500-1000 PPM	Low	Used extensively for ammonia hydrogen, town gas manufacture. Low operating costs. Extensive experience as both single stage and Two stage systems.
Lurgi	25-30% K_2CO_3 Plus Additives	HT Absorption and Stripping	High	500-1000 PPM	Low	Low utility costs. Used in several installations in Germany and other areas.
Alkazid	Potassium Salt of Methyl-Amino Propionic Acid	LT Absorption HT Stripping	Dependent on Service			Other Alkazid solutions available depending on application acid gas constituents and degree of selectivity. All systems are water solutions of Amino Acids. Has been used with partial oxidation process.
Combination Reaction-Physical Type Systems						
Sulfinol	Sulfolane Di-isopropanol-Amine Sol'n	LT Absorption HT Stripping	Medium	Less Than 100 PPM	Low	Excellent performance. Process can be used for CO_2 and H_2S removal applications in synthesis gas and natural gas services Chemicals cost relatively high but CO_2 pickup is good. Vessel sizes relatively small but exchanger costs are high.
TEA/MEA	Triethanol-Amine and Monoethanol-Amine	LT Absorb/Stripping (For TEA), and LT Absorption HT Stripping (For MEA)	High (TEA) Low (MEA)	Less Than 50 PPM	Low	Used in several NH_3 installations with excellent performance. Requires two absorption stages in series operation. A striping system is required for each solvert.
Physical Absorption Systems						
Purisol (NMP)	N-Methyl-2 -Pyrrolidone	LT Absorption	Medium	Less Than 50 PPM	Low	Expensive heat exchange equipment eliminated with this process. Used in high pressure processes such as partial oxidation based plants. Excellent acid gas cleanup. Solvent is non-corrosive.
Rectisol	Methanol	LT Absorption (with Refrigeration)	Medium	Less Than 10 PPM	Low	System circulates refrigerated methanol. Several columns required. Can be used for CO_2, H_2S and COS removal in many applications. High investment but performance is excellent. Specified for many partial oxidation based processes. Can be used also in coal gasification processes. Solvent non-corrosive.
Fluor Solvent	Propylene Carbonate	LT Absorption LT Stripping	Dependent on Pressure		Low	Has high degree of solubility for CO_2. Acid gas desorbed by released of pressure without application of heat. Requires intermediate trash operation. Process works to best advantage at high pressure.
Selexol	Propylene Glycol Dimethyl Ether	LT Absorption	Dependent on Pressure		Low	Suitable for high pressure absorption services. Can operate at low pressure but residual gas content increases. Can also be employed for natural gas treatment.

Source: Developments in Ammonia Production Technology, no date, p. 18-19, The M. W. Kellogg Company, Houston, Texas.

Table III-2-8 Heat Consumption and Characteristics of Acid Gas Removal Processes

	Amine Guard	Modified HPC	New Benifield	Rectisol	Selexol	Fluor
Solvent Composition	MEA $NaVO_3$ Potassium Antimonyle Tartrate Tertaric Acid	K_2CO_3 V_2O_5 MEA	K_2CO_3 V_2O_5 DEA	Methanol	Polyethylen Glycol Dimethyl-ether	Propylene Carbonate
Reaction Method	Chemical Reaction	Chemical Reaction	Chemical Reaction	Physical Absorption	Physical Absorption	Physical Absorption
Outlet CO_2 Content ($ppm-CO_2$)	200	1,000	1,000	500-10	500-10	1,000
Regeneration Heat ($kcal/Nm^3 \cdot CO_2$)	1,000–1,250	1,000–1,350	700–1,000	–	–	–
Refrigeration Heat ($kcal/Nm^3/CO_2$)	–	–	–	160	54	–
Licensor	Union Carbide	Benifield Catacarb	Benifield	Lurgi, Linde	Allide Chemical	Fluor

The physical absorption process has a small energy consumption compared to the chemical absorption process, while there has been only a minor difference in investment cost of these two processes.

When comparing Selexol and Rectisol Processes among physical absorption processes, it appears that Selexol Process is comparatively simple in terms of facilities, and refrigeration energy consumption is rather small when high temperature solvent is used. However, in the case that the cryogenic nitrogen washing process is incorporated into the gas refining process, like in this project, Rectisol Process is preferred. In addition, the solvents used are polyethylene glycol and dimethyl-ether in Selexol Process, and methanol in the Rectisol Process. Methanol is comparatively easy to obtain in Zimbabwe, and it is also inexpensive.

Rectisol Process was therefore selected for this project.

2.5 Conceptual Design

2.5.1 Flow Sheet

In the conceptual design, Wankie Coal of the quality shown in Table III-1-1 is used as the feed coal. The operation conditions at each section and material balance are shown in the Block Flow Diagram Fig. III-2-5.

Fig. III-2-6 and Fig. III-2-7 show the process flow of the ammonia synthesis gas production plant using Texaco Coal Gasification Process.

Fig. III-2-8 shows typical example of the process flow of the ammonia synthesis plant.

2.5.2 Description of Process

(1) Synthesis Gas Production Process (Fig. III-2-6 and Fig. III-2-7)

1) Air Separation Equipment

The air separation equipment supplies the oxygen necessary for coal gasification and nitrogen necessary for nitrogen washing process and acid gas removal process. The cryogenic air separation process is used. The equipment is basically composed of an air-compressor, compressors for the generated oxygen and nitrogen, and a cold box for deep-refrigeration.

The purity requirement is oxygen 98% or more and nitrogen 99.97% or more.

2) Coal Grinding and Slurry Preparation Section

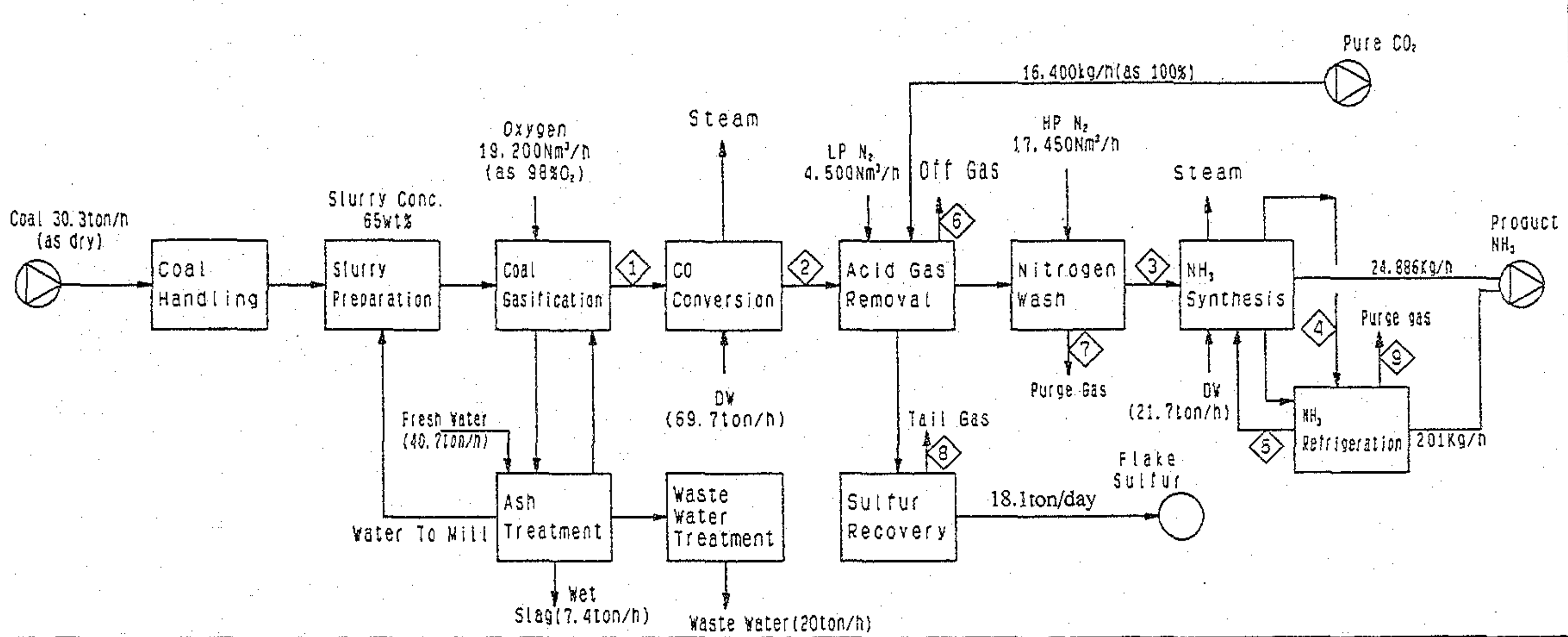
This section prepares coal slurry of the quality required by Texaco Coal Gasification Process.

The raw material coal supplied by truck is first stored in each lot in the coal yard. It is then blended to the quality required and transported by a conveyor to a Coal silo (V-301).

The coal from the silo is preliminarily crushed into under 10 mm lumps by crusher and then finely ground by Wet mill (H-302), into the particle size required. In the wet mill, the slurry concentration is adjusted with gray water from the coal treatment section and fresh water. At the same time, some additives and chemicals are added to adjust viscosity and pH of the slurry.

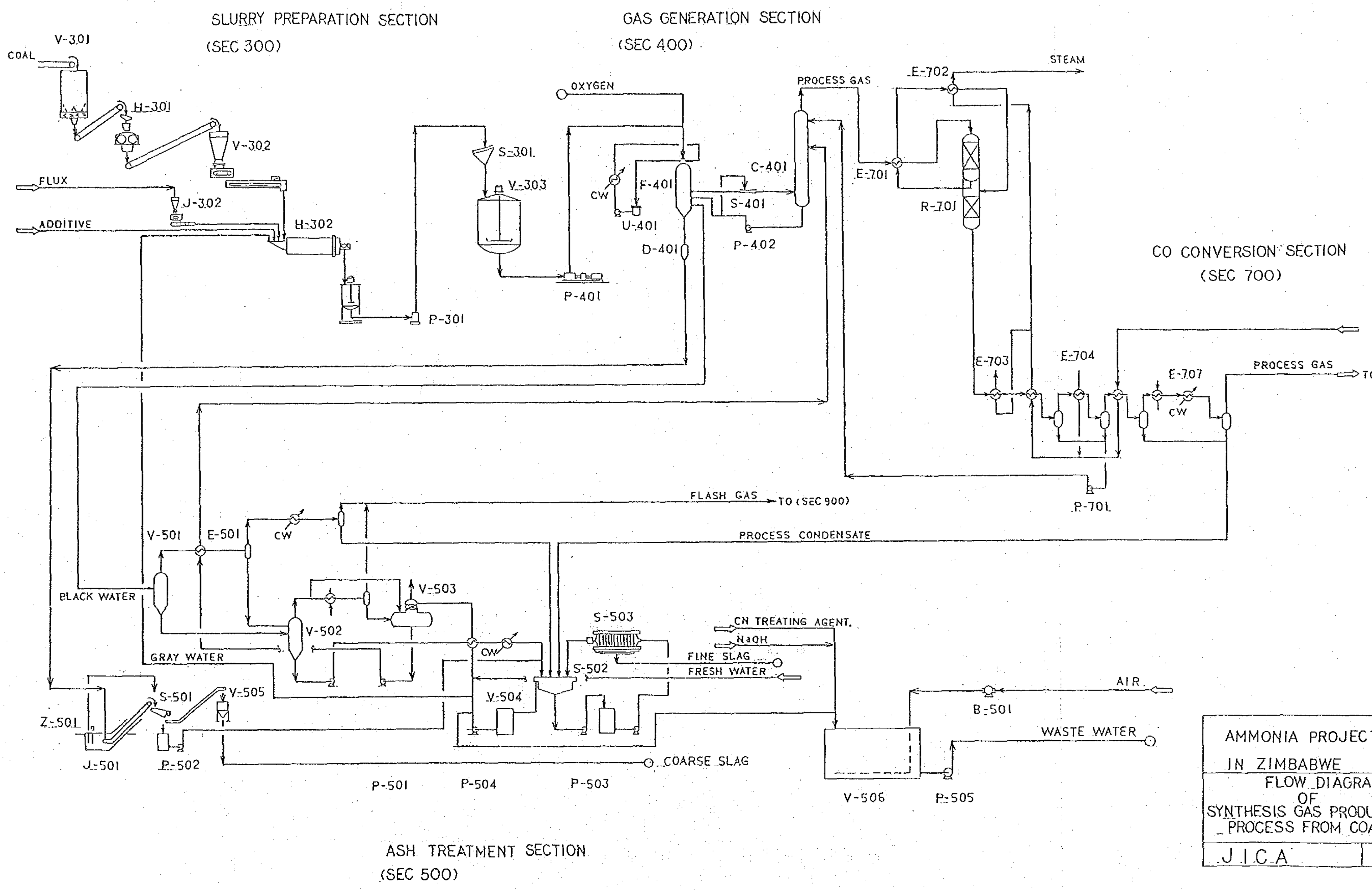
If necessary, some flux is added to lower the fluid point of coal ash.

The slurry produced is sent to the gasification section through a Slurry tank (V-303).



Stream No.		1	2	3	4	5	6	7	8	9
Temperature	(°C)	24.0	40	30	5.0	-14.8	30	30	125	25
Pressure	(kg/cm²G)	60.4	56.2	51	7.0	1.4	ATM	0.7	0.1	ATM
Component H_2	(mol%)	34.0	55.1	74.98	25.49	H_2+Ar+$N_2$0.007	H_2+CO+CH_4max0.4	10	H_2+CO+$CH_4$0.3	60.28
CO	(mol%)	49.8	1.9	-	-	-	-	47	-	-
CO_2	(mol%)	14.9	41.6	-	-	-	87	-	45	-
H_2S+COS	(mol%)	0.8	0.5	-	-	-	max25ppm	-	H_2S+COS+S+$SO_2$0.5	-
N_2	(mol%)	0.6	0.4	25.02	7.02	-	13	32	38	16.60
Ar	(mol%)	0.5	0.4	47ppm	0.55	-	CH_3OHmax150ppm	Ar+CH_4 11	H_2O 16	1.30
CH_4	(mol%)	0.1	0.1	-	-	-	-	-	-	-
NH_3	(mol%)	-	-	-	66.94	99.993	-	-	-	21.82
Total Dry Gas	(Nm³/h)	62,300	91,700	66,700	457	33,912	32,900	3,590	2,800(Wet)	193
Water	(kg/h)	71,000	100	-	-	-	-	-	-	-

Fig. III-2-5 Block Flow Diagram (Ammonia)

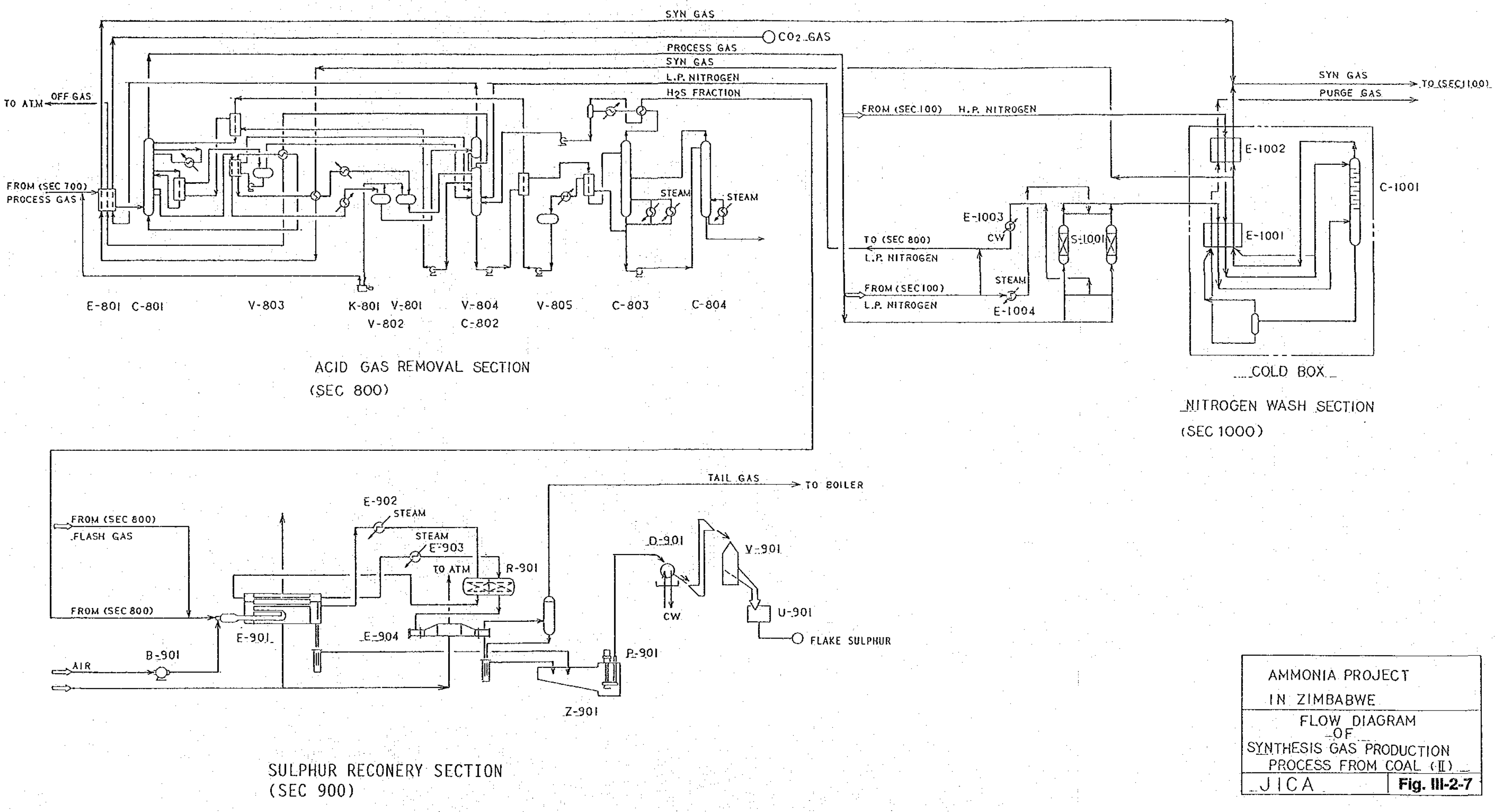


AMMONIA PROJECT
IN ZIMBABWE

FLOW DIAGRAM
OF
SYNTHESIS GAS PRODUCTION
PROCESS FROM COAL (I)

J I C A

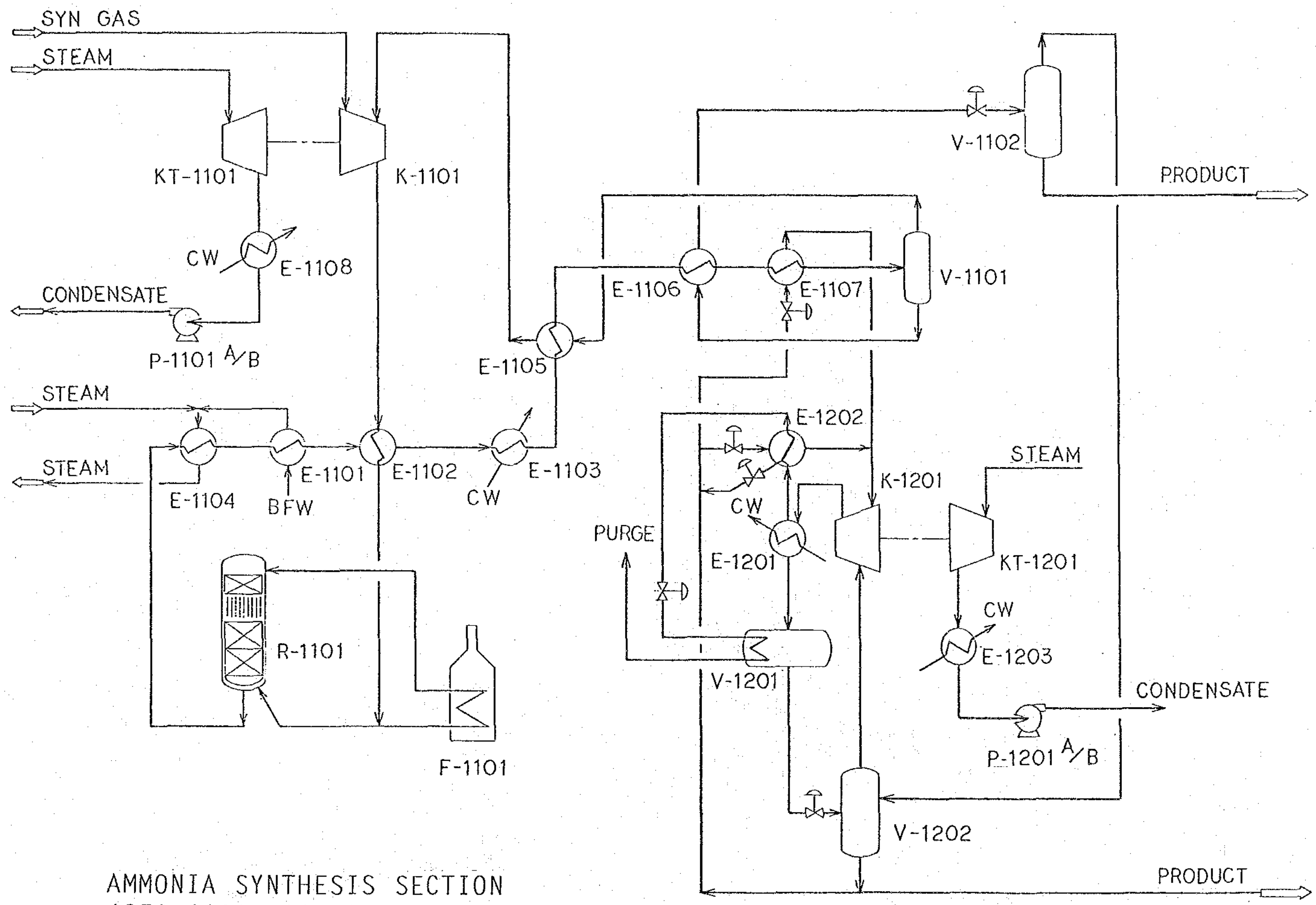
Fig. III-2-6



AMMONIA PROJECT
IN ZIMBABWE

FLOW DIAGRAM
OF
SYNTHESIS GAS PRODUCTION
PROCESS FROM COAL (II)

JICA | **Fig. III-2-7**



AMMONIA SYNTHESIS SECTION
(SEC 1100, 1200)

AMMONIA PROJECT IN ZIMBABWE	
FLOW DIAGRAM OF AMMONIA SYNTHESIS PROCESS	
JICA	Fig. III-2-8

3) Gasification Section

In this section, synthesis gas with CO and H_2 as the principal components is generated from the coal slurry.

The slurry is pumped up by a Charge pump (P-401) and is then supplied together with oxygen to the gasifier. The gasification reaction condition is at a pressure of 65 kg/cm^2 and a temperature of 1,300-1,450°C.

The following is the reaction formula:

$$CmHnSr + \frac{m}{2} O_2 \rightarrow mCO + (\frac{n}{2} - r)H_2 + rH_2S$$

$$CmHnSr + mH_2O \rightarrow mCO + (m + \frac{n}{2} - r) H_2 + rH_2S$$

$$CO + H_2O \leftrightarrow H_2 + CO_2$$

The generated gas is composed of CO, H_2, CO_2 and H_2O, and contains small amounts of CH_4 and H_2S.

The slurry concentration greatly affects the operation. Naturally, the higher the concentration, the greater the economic viability. However, the coefficient of viscosity increases, while handing becomes difficult, which means that there are limitations. The relationship between the concentration and the oxygen requirement, and the relationship between the slurry concentration and the composition of the generated gas are shown in Fig. III-2-9 and Fig. III-2-10.

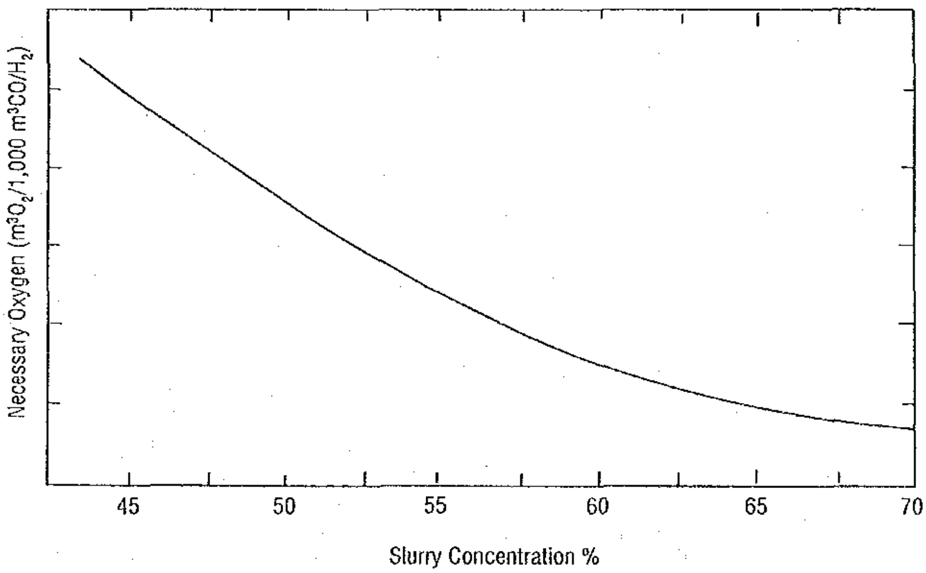


Fig. III-2-9 Slurry Concentration and Necessary Oxygen Volume

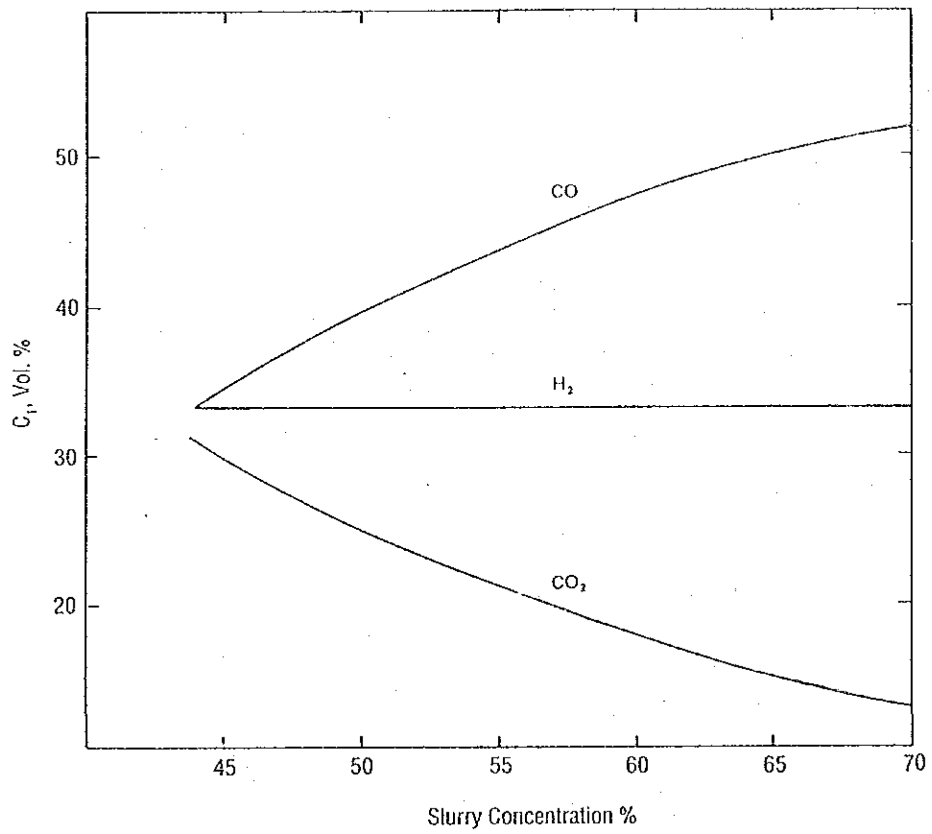


Fig. III-2-10 Slurry Concentration and Composition of Generated Gas (Dry)

The slurry concentration in this project is 65%.

The high-temperature gas leaving the reaction chamber enters the quench chamber, where it is quenched in water. It is then saturated with sufficient steam for subsequent CO conversion. The quench water is supplied from Carbon scrubber (C-401).

The generated ash and unreached carbon are removed as coal slag. Coarse slag is removed and settled in the quenching chamber of the gasifier and then intermittently discharged outside the gasifier using the lock hopper system.

Fine slag is discharged continuously from the quench chamber in the form of water slurry called Black Water.

The ash and unreached carbon in the generated gas leaving the quench chamber is completely removed (1 mg/Nm^3 or less) by means of Venturi scrubber and Carbon scrubber. The gas is then sent to CO conversion section.

4) Ash Treatment Section

In this section, the coal slag discharged from the gasifier is separated and removed through a screen, settler and filter.

The coarse slag discharged from the gasifier with lock hopper enters Slag sump pit (Z-501), and then separated by the screen and disposed of.

Black Water containing the fine slag is concentrated in flash drums and the gas contained is released and sent to the sulphur recovery process. Concentrated Black Water then enters the settler.

The fine slag in the underflow of the settler is removed by a filter press. The overflow, called Gray Water, is sent to Carbon scrubber after description and heating.

Part of Gray Water is used in slurry preparation section and Gasification section. Another part is discharged as waste water to prevent the accumulation of impurities. CN contained in this waste water is decomposed and removed in the CN-treating tank (V-506.) The waste water is further treated in Activated sludge facilities and then discharged outside the plant.

5) CO Conversion Section

Co is converted into H_2 which is necessary for ammonia synthesis. The gas leaving Carbon scrubber exchanges heat with the outlet gas from the first catalyst bed of CO converter, and enters to CO converter at the designated temperature.

There are two catalyst beds of a sulphur activated catalyst in the converter.

The following formula represents the shift reaction:

$$CO + H_2O \rightarrow H_2 + CO_2$$

The reaction is exothermic reaction, while the generated heat is used effectively to preheat boiler feed water and generate the steam.

In addition, the generated condensate is sent to Carbon scrubber and Ash treatment section.

6) Acid Gas Removal Section

In this section, CO_2 and sulphur compounds (mainly H_2S) in the generated gas are removed. The recovered high-purity CO_2 gas is used for urea synthesis and sulphur compounds are recovered as flake sulphur through Claus Process. In this project, Rectisol Process is used.

The generated gas leaving CO conversion process together with the gas from Flash drums (V-801, V-802) is cooled by Gas cooler (E-801) and enters Methanol scrubber (C-801) where the acid gases are removed, then it is sent to Nitrogen washing section.

The methanol solution containing mainly CO_2 from the middle stage of Methanol scrubber is flashed in CO_2 flash drum installed in the upper part of Carbon dioxide tower (C-802), and high-purity CO_2 (purity, 98.5% or more) is stripped out.

The methanol solution from the bottom of Methanol scrubber contains CO_2 and sulphur compounds (mainly H_2S). In Carbon dioxide tower (C-802), CO_2 is stripped out by blowing nitrogen gas.

The H_2S concentrated methanol solution from the bottom of Carbon dioxide tower is sent to H_2S stripper (C-803), and the stripped gas is then sent to Sulphur recovery section. The water contained in the lean methanol solution from which H_2S has been stripped is removed by Methanol/Water separation tower (C-804).

7) Nitrogen Washing Section

CO and CO_2, harmful to the ammonia synthesis catalyst as well as inert gases CH_4 and Ar contained in the ammonia synthesis gas, are removed by liquid nitrogen washing.

At the same time, the composition of the synthesis gas is adjusted into H_2: N_2 molar ratio of 3:1 required for ammonia synthesis.

The ammonia synthesis gas leaving Acid gas removal section is sent to facility called "Cold Box," after the methanol, water and CO_2 is removed to the trace by interchangeable Absorber (S-1001). Inside the "Cold box," purification and ratio adjustment are carried out. In this project, part of the purified synthesis gas is sent to Acid gas removal section and is used as refrigeration source. In addition, the purge gas from the process is used effectively as the fuel for boiler.

8) Sulphur Recovery Section

In this section, the elemental sulphur is recovered from the fraction gas containing sulphur compounds (mainly H_2S) from Acid gas removal section and the flash gas from Ash treatment section.

Part of H_2S gas in the gas fed into H_2S boiler (E-901) is burned to generate SO_2 required for Claus Reaction.

The following formula represents Claus Reaction:

$$H_2S + 3/2\ O_2 \longrightarrow SO_2 + H_2O \quad ①$$

$$2H_2S + SO_2 \longrightarrow 3S + 2H_2O \quad ②$$

In H_2S boiler, sulphur is partly generated. However, the gas leaving the boiler enters Claus Reactor after heated further. Claus Reactor has two-staged activated alumina catalyst beds where two-stage reaction takes place. The cooled and condensed sulphur generated is first stored in a pit and packed into bag after processed into flaked *state by a sulphur flaker.*

(2) Ammonia Synthesis Plant (Fig. III-2-8)

The raw gas leaving the nitrogen washing equipment is sent to the ammonia synthesis plant at approximately 50 kg/cm^2.

The raw gas is compressed to approximately 146 kg/cm^2 by Syngas compressor (K-1101) driven by a turbine. The synthesis gas and recycle gas are mixed and compressed at the final stage of the compressor. The compressed gas enters Ammonia converter (R-1101) after heat exchanging with the ammonia converter outlet gas and increasing the temperature. Inside of the ammonia converter, there is inner apparatus with two catalyst bed, and internal heat exchange system. After the reaction here, the gas leaves the ammonia converter at approximately 480°C, through various heat exchangers, finally cooled down to a temperature of –5°C by NH_3 refrigeration compressor (K-1201), and the compound ammonia is condensed and separated by NH_3 separator (V-1101). After heat exchanging and reducing pressure, it becomes an ammonia product. On the other hand, the reduced gas contains 67% ammonia are sent to the refrigerating system to be compressed and liquefied together with refrigerating system ammonia.

The produced synthesis gas is refined using the nitrogen washing equipment, so it contains very little inert gas (CH_4, Ar) which means that there is no need for purge in the synthesis loop. It is then dissolved into produced ammonia and discharged.

For the refrigeration system, ammonia is compressed and liquefied by NH_3 refrigeration compressor (K-1201) and then stored in NH_3 receiver (V-1201). The inert gas is refrigerated in Purge gas cooler (E-1202), followed by liquefied ammonia separation. After increasing the temperature, it is then used as fuel for the boiler.

The purge gas cooler is operated at 1.4 kg/cm^{2}G –14.8°C.

2.6 Production Facilities

2.6.1 Process Plant

The products listed below are produced by Texaco Coal Gasification Process.

• Ammonia	600 T/D
• By-product sulphur	18.1 T/D

The specifications of the air separator are as follows:

Air separator	One set
• Oxygen generated	21,200 Nm^3/H
Purity	98.0 mol.% min.
• Nitrogen generated	21,950 Nm^3/H
Purity	99.97 mol.% min
Pressure	8.5 kg/cm^2 G (17,450 Nm^3/H)
	5 kg/cm^2 G (4,500 Nm^3/H)

Main machinery for each process is listed below:

1) Synthesis gas production plant (Fig. III-2-6, Fig. III-2-7)

Air Separation Section

K-101	Air Compressor	1	*: Equipment housed in COLD BOX.
K-102A/B*	Expansion Turbine	1+1	
K-103	Oxygen Compressor	1	
K-104	HP Nitrogen Compressor	1	
K-105	LP Nitrogen Compressor	1	
C-101	Washing Tower	1	

C-102	Water Chilling Tower	1
C-103*	Rectifying Column	1
E-101*	Heat Exchanger	1
E-102*	Condenser	1
E-103*	Liquid Air/Nitrogen Exchanger	1
E-104	Regeneration Heater	1
P-101A/B	Washing Water Pump	1+1
P-102A/B	Chilled Water Pump	1+1
S-101	Air Filter (Reinforced Concrete)	1
U-101	Water Chilling Unit	1
V-101A/B	MS Adsorber	2

Slurry Preparation Section (Section 300)

H-301	Coal Crusher	2
H-302	Mill	2
J-301	Flux Feeder	2
P-301	Mill Screen Feed Pump	3
P-302	Additive Feed Pump	2
P-303	Caustic Soda Feed Pump	2
S-301	Mill Screen	2
V-301	Coal Silo	2
V-302	Coal Hopper	2
V-303	Slurry Tank	2
V-304	Additive Tank	1
V-305	Caustic Soda Tank	1

Gas Generation Section (Section 400)

C-401	Carbon Scrubber	3
D-401	Lock Hopper	3
F-401	Gasifier	3
F-402	Start-up Flare	1
P-401	Slurry Charge Pump	3
P-402	Quench Water Pump	6
S-401	Venturi Scrubber	3
U-401	Burner Coolant System	3

Ash Treatment Section (Section 500)

B-501	Air Blower	2
E-501	Scrubber Feed Water Heater	1
J-501	Drag Conveyor	3
P-501	Scrubber Feed Pump	2
P-502	Fine Slag Pump	6
P-503	Settler Bottom Pump	2
P-504	Gray Water Pump	2
P-505	Treated Water Pump	2
S-501	Slag Screen	3
S-502	Settler	1
S-503	Filter Press	2
V-501	No. 1 Slurry Flash Drum	1
V-502	No. 2 Slurry Flash Drum	1
V-503	Scrubber Feed Tank	1
V-504	Gray Water Tank	1
V-505	Slag Hopper	1
V-506	CN-Treating Tank	1
V-507	CN-Treating Chemical Tank	1
Z-501	Slag Sump Pit	3

CO Conversion Section (Section 700)

E-701	CO Convertor Preheater	1
E-702	No. 1 40k Steam Converter	1
E-703	No. 2 40k Steam Converter	1
E-704	10 k Steam Converter	1
E-705	5 k Steam Converter	1
E-706	3.5 k Steam Converter	1
E-707	Gas Cooler	1
H-701	CO Converter Start-up Heater	1
P-701	Condensate Pump	2
R-701	CO Converter	1

Acid Gas Removal Section (Section 800)

C-801	Methanol Scrubber	1
C-802	Carbon Dioxide Tower	1
C-803	H_2S Stripper	1
C-804	Methanol/Water Separator Tower	1
E-801	Feed Gas Cooler	1
K-801	Recycle Gas Compressor	2
V-801	No. 1 Flash Drum	1
V-802	No. 2 Flash Drum	1
V-803	No. 3 Flash Drum	1
V-804	CO_2 Flash Drum	1
V-805	Lean Methanol Drum	1

Nitrogen Wash Section (1000 Section)

C-1001	Wash Column	1
E-1001	Feed Gas/Nitrogen Cooler	1
E-1002	HP Nitrogen Cooler	1
E-1003	N_2 Cooler	1
E-1004	N_2 Heater	1
S-1001	Adsorber	2

Sulphur Recovery Section (Section 900)

B-901	Reaction Air Blower	2
D-901	Sulphur Flaker	1
E-901	H_2S Boiler	1
E-902	No. 1 Steam Reheater	1
E-903	No. 2 Steam Reheater	1
E-904	Sulphur Condenser	1
P-901	Sulphur Sump Pump	2
R-901	Claus Reactor	1
U-901	Bagging & Sewing Unit	1
V-901	Flake Sulphur Bin	1
Z-901	Sulphur Pit	1

2) Ammonia Synthesis Plant

NH_3 Synthesis Section (Section 1100)

K-1101	Syngas Compressor	1
KT-1101	Syngas Compressor Turbine	1
R-1101	Ammonia Converter	1
E-1101	Waste Heat Boiler	1
E-1102	Feed/Effluent Exchanger	1
E-1103	Effluent Cooler	1
E-1104	Steam Superheater	1
E-1105	Effluent/Recycle Exchanger	1
E-1106	Product Exchanger	1
E-1107	Chiller	1
E-1108	Condenser	1
R-1101	Ammonia Converter	1
F-1101	Start-up Heater	1
P-1101A/B	Condensate Pump	1+1
V-1101	NH_3 Separator	1
V-1102	Flash Drum	1

NH_3 Refrigeration Section (Section 1200)

K-1201	NH_3 Refrigeration Compressor	1
KT-1201	Refrigeration Compressor Turbine	1
E-1201	NH_3 Condenser	1
E-1202	Purge Gas Cooler	1
E-1203	Condenser	1
V-1201	NH_3 Receiver	1
V-1202	Flash Drum	1
P-1201A/B	Condensate Pump	1+1

2.6.2 Utilities Facilities

(1) Facilities for Receiving Electric Power

From near Hwange Thermal Electric Power Plant, electric power is supplied to the first terminals of the receiving pannels in the main sub-station inside the plant by two exclusive circuits.

In the plant site, there are facilities for receiving and distributing electric power, and adjusting the voltage and other conditions, then electricity is supplied to each department.

• Facility for receiving electric power	Capacity	30,000 KVA
	Voltage	33 KV
	Cycle	50 Hz

(2) Facility for Emergency Electric Power

If the electric power supply is stopped, plant operations will come to a complete stop. However, a facility for emergency electric power is installed for the measures to deal with a sudden stoppage and for safety.

- Diesel electric power generator for emergency

  Capability 750 kW

(3) Water Facility

1) Water intake facility

Water is taken from the Zambezi river and, after setting treatment, the water is supplied through 10-inch diameter pipe to the reservoir inside the plant. The distance is approximately 45 km, so along the route several intermediate pressure boosting stations will be built.

- Intake water: 350 m^3/H max.
- Capacity of water receiving tank (in the plant): 3,600 m^3

2) Water treatment facilities

The raw water supplied to the receiving water tank is filtered through a filter, and then enters the filtrate tank. It is used to supply the circulated cooling water and is also used for drinking after sterilization. Furthermore, by demineralizer and polisher, the process water and boiler feed water is produced.

• Filter	Capability	300 m^3/H
• Filtrate tank	Capacity	3,600 m^3
• Water demineralizer	Capability	5 m^3/H
• Polisher for condensate	Capability	100 m^3/H
• Demineralized water tank	Capacity	300 m^3

3) Cooling tower facility

• Cooling tower		Capability	11,000 T/H
Inlet temperature	36°C	Pressure	4.5 kg/cm^2G
Outlet temperature	26°C		

4) Supplementary boiler facility

In this project, during normal operation, the steam is self-sufficient and the supplementary boiler is used only at start-up or for supplementary purpose.

• Boiler	Capacity	10T/H
	Pressure	40 kg/cm^2
	Temperature	387°C
	Fuel	Purge gas from the nitrogen washing section

5) Instrumentation and plant air facility

• Compressor	Capacity	1,300 Nm^3/H
	Pressure	7 kg/cm^2G
• Dryer	Capacity	1,100 Nm^3/H
	Dew point	–40°C

2.6.3 Offsite Facilities

(1) Coal Transportation Equipment

Dump trucks Capacity 25 T x 8 vehicles

(2) Coal Storage Facility

Coal brought to the plant by dump trucks from WANKIE is first stored in a coal storage yard and is conveyed to the production area after adjusting the quality by blending.

Coal storage blending yard Capacity 8,000 T

(3) Product Ammonia Storage and Shipment Facilities

Inside the plant, spherical tanks installed as the ammonia storage tank.

At the receiving end (SABLE), there are two 900 T spherical ammonia storage tanks at present, though a more receiving tank will be built for this project.

Production plant side

- Spherical ammonia storage tank (including a refrigeration facility) 2 Nos.
  Capacity 3,000 T x 2 units
  Pressure 4.3 kg/cm^2G
  Temperature 5°C

- Ammonia shipment facility Capability 77 T/H

Tank trucks	Capacity 25.5 T	x	80 vehicles (All diverted from SABLE)
Diesel locomotives	370 PS	x	3 units

(4)Others

- Chemicals warehouse
- Sulphur stockhouse
- Fuel tank

2.6.4 Pollution Prevention Facilities

The land planned for plant construction in Hwange is a vast area bordering the WANKIE Coal Mines and distant from any residential area. On this land, there is a large-scale coal-burning thermal power plant and, a number of facilities belonging to WANKIE. It is a suitable area for an industrial complex. However, Zimbabwe is a land-locked country, so special care must be taken over pollution prevention in the development of the Hwange District as a major industrial area using coal, as in this project.

All the processes to be adopted by this project are already in operation in industrialized countries, and it has been proved that such processes do not cause any serious environmental problems, if proper pollution control facilities are provided.

The regulation standards adopted for this project are based on the pollution prevention standards of Japan.

(1) Air

Gas is discharged into the air as follows.

1) Discharged gas

- Place of discharge: Acid gas removal section
- Temperature : 30 °C
- Gas quantity : 32,900 Nm^3/H
- Composition :

CO_2	87 mol. %
N_2	13 mol. %
$H_2+CO+CH_4$	max. 0.4 mol. %
H_2S+COS	max. 25 ppm
CH_3OH	max. 150 ppm

Countermeasures: The concentration of sulphur compounds is very low in the order of ppm, so the gas is diffused into the air from the discharge vent at the top of the removal tower.

2) Purge gas

- Place of discharge: Nitrogen washing section
- Temperature : 30 °C
- Pressure : 0.7 kg/cm³G
- Gas quantity : 3,590 Nm³/H
- Composition :

H_2	10 mol. %
CO	47 mol. %
N_2	32 mol. %
Ar+CH_4	11 mol. %

Countermeasures: There is about 57% (H_2 + CO), the gas will be used effectively as fuel for the supplementary boiler.

3) Tail gas

- Place of discharge: Sulphur removal section
- Temperature : 125 °C
- Pressure : 0.1 kg/cm²G
- Gas quantity :2,800 Nm³/H
- Composition :

CO_2	45 mol. %
N_2	38 mol. %
H_2+CO+C_2H_4	0.3 mol. %
H_2S+COS+S+SO_2	0.5 mol. %
H_2O (Vapore)	16 mol. %

Countermeasures: The sulphur compounds are mixed in the combustion chamber of the supplementary boiler and SO_2, after burned, will be discharged from a 35 m chimney.

(2) Waste water

In this project, the waste water is 20 m^3/H from the ash treatment section of coal gasification plant, and after 35 m^3/H mainly from cooling tower facility. Total amount of the waste water is 50 m^3/H.

1) Waste water from the ash treatment section

- Place of discharge: Ash treatment section
- Temperature : 40 °C
- Water quantity : 20 m^3/H
- Waste water :

Waste water	pH	8 ~ 9
	COD mg/l	500
	BOD mg/l	250
	S.S. mg/l	200
	Chloride mg/l	300
	Total CN mg/l	1
	N-NH_3 mg/l	500

Countermeasures: Activated sludge facility 20 m^3/H

As shown in Fig. II-2-6, the Total-CN in the 20 m^3/h of water to be disposed is 1mg/l and treated by trace in the CN Treating Tank (V-506), and this water is sent to the activated studge facility.

The quality of the treated water through activated sludge facility.

- Temperature : 35 °C
- pH : 6 ~ 9
- COD mg/l : 60

- BOD mg/l : —
- S.S. mg/l : 25
- T-CN : Trace

2) Other waste

The other 30 m^3/H of waste is collected into a drainage canal and discharged with the activated sludge discharge water.

Further more, the resin regeneration waste water in the pure water production equipment is discharged after neutralization.

(3) By-product slag

The following two kinds of coal slag are discharged from the ash treatment section.

1) Fine slag — Solid 50%, Water 50% — About 2.5 T/H

2) Coarse slag — Solid 75%, Water 25% — About 4.9 T/H

Counter measures: These slags are formed by the high-temperature gasification reaction, so there is no fear of pollution. The slag can be effectively utilized as a mixing material for cement. However, in this project, it is transported to an ash disposal site for land reclamation.

2.6.5 Other Supplementary Facilities

(1) Maintenance Facilities

The plant is equipped with maintenance facilities for general machinery, instruments, electrical machinery, and for the transportation facilities so that periodical maintenance work can be carried out in addition to carrying out inspections and minor repair work during plant operation. However, the maintenance of large-sized machinery and special machinery is undertaken by manufacturers from outside.

In addition, a warehouse is built to store the spare parts and materials necessary to maintain operations.

(2) Fire-fighting Facilities

Fire-fighting facilities that use water sprinklers are installed throughout the plant. Pipelines for fire-fighting water, as well as fire hydrants and water guns are appropriately installed throughout the plant area.

The electric facilities will be provided with fires extinguishers of halogen gas.

Fire alarms are installed at appropriate locations in the plant area.

(3) Offices and Other Buildings

Buildings necessary in the plant such as administration office, laboratory, analysis room, garage, gate house, etc. are constructed.

An outline of the facilities described above is shown in Table III-2-9.

Table III-2-9 Facilities Included in the Project

Facilities	Rated Capacity
1. Process Plants	
1) Ammonia	600 T/D
2) Sulphur (By-product)	18.1 T/D (as 100%)
3) Air Separation	Oxygen 21,200 Nm^3/H Nitrogen H.P. 17,450 Nm^3/H L.P. 4,500 Nm^3/H
2. Utilities	
1) Water Intake	350 m^3/H
2) Filtration	300 m^3/H
3) Demineralizer	10 m^3/H
4) Polisher	100 m^3/H
5) Cooling Water	11,000 m^3/H (Δt=10°C)
6) Start-up Boiler	10T/H (40 kg/cm^2, 387°C)
7) Main Sub-station	30,000 KVA
8) Emergency Diesel Generator	750 kW
9) Instrument and Plant Air	Compressor 1,300 Nm^3/H Dryer 1,100 Nm^3/H
3. Offsite Facilities	
3-1 Product Storage and Loading	
1) Ammonia Storage (Hwange Side)	$3,000^T$ x 2 4.3 kg/cm^2G
2) Ammonia Loading (Hwange Side)	77 T/H
• Railway Tank Car	25.5^T New 20 Nos Used 80 Nos
• Diesel Car	370 PS x 3
3) Others	
• Chemicals storage	
• Fuel oil storage	
• Sulphur storage	
3-2 Common facilities	
1) Waste Water Treatment System (Activated sludge method)	20 T/H
2) Equipment & Machines for Maintenance & Work-shops	
3) Equipment for Laboratories	
4) Drinking Water & Firefighting System	
5) Intercommunication System	
6) Lighting and Lightning System	
7) Miscellaneous Equipment & Machines for Common Facilities	

Table III-2-9 Facilities Included in the Project (Cont'd)

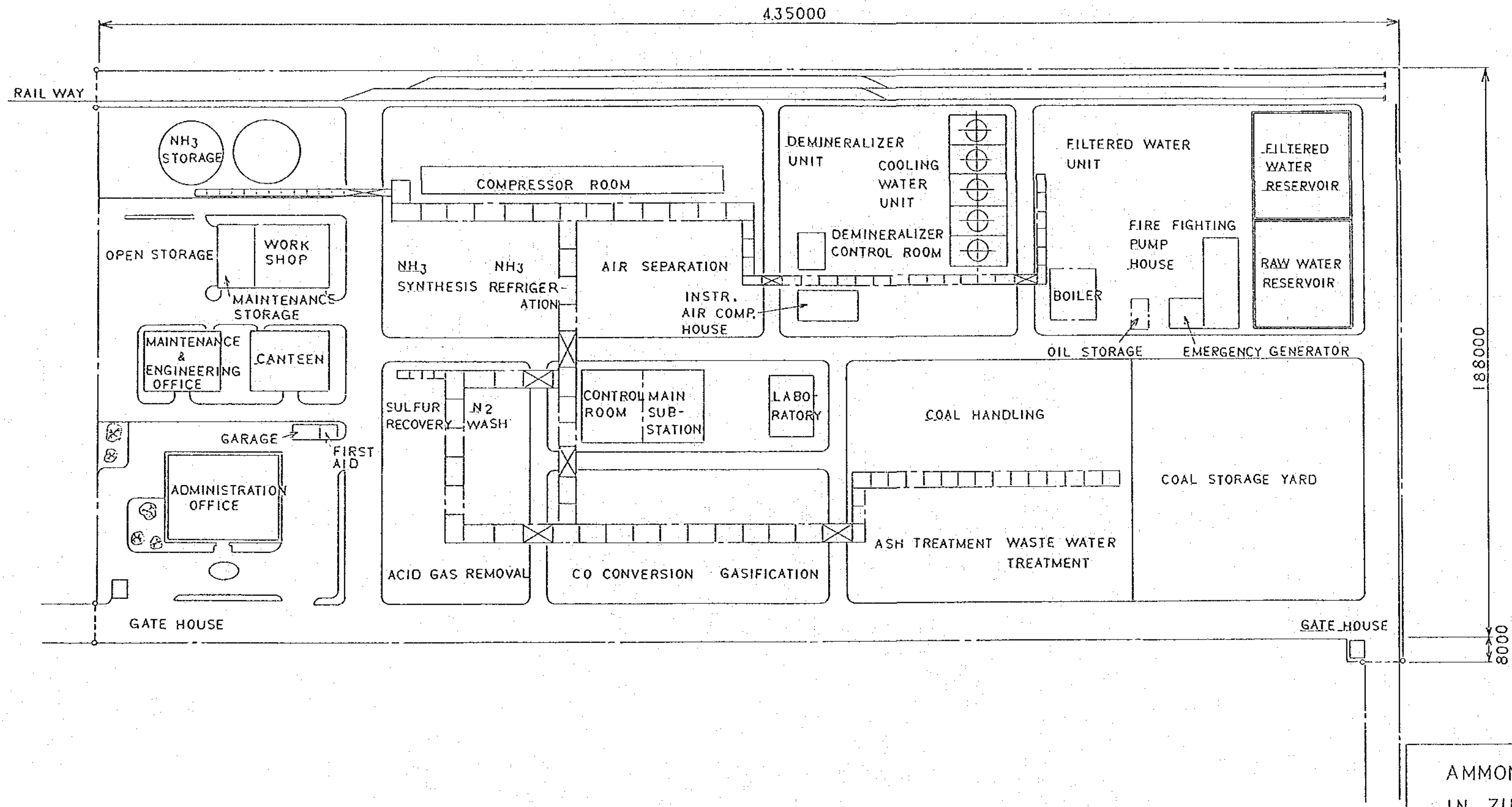
Facilities	Rated Capacity
3-3 Offsite Building and Structures	
1) Maintenance Storage	250 m^2
2) Laboratory	240 m^2
3) Local Laboratories	30 m^2 x 2
4) Gate Houses	30 m^2 x 2
5) Carport	50 m^2
6) Administration Office	1,000 m^2
7) Canteen	500 m^2
8) Workshop	450 m^2
9) First Aid House	30 m^2
10) Maintenance and Engineering Office	500 m^2
11) Fencing	One complete
12) Access Road	12 m^W x 3 km

2.6.6 Plant Site Access Roads and Plant Layout

The outline of the planned plant site and access roads is as follows:

- Site area 400,000 m^2
- Land preparation area 200,000 m^2
- Access roads 12 mW x 3 km

The outline of plant layout is shown in Fig. III-2-11



AMMONIA PROJECT IN ZIMBABWE

PLOT PLAN OF AMMONIA

JICA

FIG. III-2-11

2.7 Unit Consumption of Raw Materials and Utilities

Unit consumptions in accordance with conceptual design of this project are shown below:

(1) Ammonia

Coal	1.21 T/T-NH_3
Raw water	12.0 T/T-NH_3
Cooling water	229 T/T-NH_3
Electric power 813.2 kWh/T-NH_3	(except 870 kWh/H of electric power required to take and supply water)
Methanol	1.32 kg/T-NH_3
Water treatment chemicals	US$2.47 /T-$NH_3$

Chapter 3 Plan for Project Implementation

Ammonia Project

Chapter 3 Plan for Project Implementation

This chapter explains the plan for project implementation, from construction to operations, at the same time discussing the scope of the project and the plant design conditions which form the basis of drawing up the plan for project implementation.

3.1 Scope of Facilities and Construction

(1) Facilities

The ammonia and urea plant facilities have already been discussed in detail in the previous chapter. The scope of the project is shown in Table III-2-9, and includes the following facilities:

1. Process plant
2. Utility facilities
3. Pollution prevention facilities
4. Off-site facilities
5. Common facilities
6. Off-site buildings and roads

(2) Services

For the plant to operate without interruption, the following technical services should be carried out.

1. Training of the necessary operation personnel
2. Guidance on trial runs and plant operations

3.2 Design Conditions

The design conditions of this plant are governed by the following.

(1) Weather Conditions

Design Max. Temp.	:	35	°C
Design Min. Temp.	:	5	°C
Design Wet Bulb Temp.	:	22	°C
Design Dry Bulb Temp.	:	27	°C
Design Atmospheric Press.	:	929	mBar
Design Precipitation	:	30	mm/H

Snow Load	:	None	
Design Wind Velocity	:	110	km/H max.
		40	km/H average

(2) Topography

Sea level	:	730	m
Seismological coefficient	:	0.05	G
Geographical durability	:	10	tonnes/m^2

(3) Conditions of the Transmitted Electricity Received

Voltage	:	33	kV
Phase	:	3	Phase
Frequency	:	50	Hz
Feeder	:	2	Systems

Electricity Supply System

150 kW or more	:	6,600	V, 3 Phases, 50 Hz
Less than 150 kW	:	380	V, 3 Phases, 50 Hz
Lighting and others	:	220	V, Single Phase, 50 Hz
Instrumentation	:	100	V, Single Phase, 50 Hz

(4) Raw Water

Water source	:	Zambezi River	
Water quality pH	:	7	
TDS	:	59	ppm
Total Hardness	:	40	ppm as $CaCO_3$
Ca Hardness	:	22	ppm as $CaCO_3$
Mg Hardness	:	18	ppm as $CaCO_3$
Total Alkalinity	:	13	ppm as $CaCO_3$
Phosphate	:	0.04	ppm
Free Chloride	:	0.1	ppm
Sulfate	:	5	ppm
Langelier Index	:	-2.3	
Distance from the plant site	:	45	km
Level of the water source (sea level)	:	480	m

(5) Raw Material Coal

Particle Size 50 mm pass	:	99%	min.
Moisture as received	:	1.4	wt%
Proximate Analysis			
Inherent Moisture	:	1.5	wt%
Ash	:	13.8	wt %
Volatile Matter	:	24.2	wt%
Fixed Carbon	:	60.5	wt%

Gross Heating Value	:	7,090 kcal/kg (Inherent Moisture Basis)			
Hardgrove Grindability Index	:	57			

Ultimate Analysis (dry basis)

Ash	:	14.0	wt %
Carbon	:	73.0	wt%
Hydrogen	:	3.8	wt%
Oxygen	:	5.08	wt%
Nitrogen	:	1.4	wt%
Inflammable Sulfur	:	2.59	wt%
Total Sulfur	:	2.7	wt%
Non Inflammable Sulfur	:	0.11	wt%
Chlorine	:	0.021	wt%

Ash Fusion Temperature		Redusing	Oxidizing
Initial Deformation temperature	:	1,100 °C	1,320 °C
Softening Temperature	:	1,300 °C	1,350 °C
Hemispherical Temperature	:	1,320 °C	1,360 °C
Fluid Temperature	:	1,330 °C	1,365 °C

(6) Gasification Furnace

Special attention should be paid to the gasification furnace in that it should be able to handle coal containing up to 20% ash.

3.3 System for Project Implementation

This project will be implemented by a new company with investment from the Government and the IDC. While this project is being implemented, the new company will be responsible for it. The most suitable general constructor, chosen out of many from around the world, will be put in charge of construction. For the management of the tasks concerned, it is desirable for a world-class project management consultant to be appointed.

(1) Project Management Consultant (PMC)

Basically, the following three types of tasks are commissioned to the project management consultant.

1) Bidding

In choosing the general constructor under the conditions described above, the following kinds of tasks are required.

1. Specifying the bidding conditions

2. Advertising for participants in the bidding

3. Screening the bidding constructors

4. Conducting the business of bidding

5. Arranging the contents of bidding

6. Evaluating and comparing the contents

7. Evaluating prospective constructors and giving advice

8. Advice on contract business with the constructor who made the successful bid

2) Supervision of the construction work

The work to be implemented by the general constructor should be supervised (as mentioned in 11.1). The main supervisory work is as follows.

1. Review of the technical documentation and plans

2. Confirmation and advice on the quality of the equipment and materials

3. Confirmation and advice on the progress and accomplishments of construction

4. Various kinds of on-the-spot inspection during construction

5. Confirmation of the guaranteed items of equipment and operation

3) Guidance on operations and management during construction

This project involves the following project management consultants.

Supervision of the bidding business and construction work:

4 people, 3 years and 6 months

Guidance on operations and management during operations

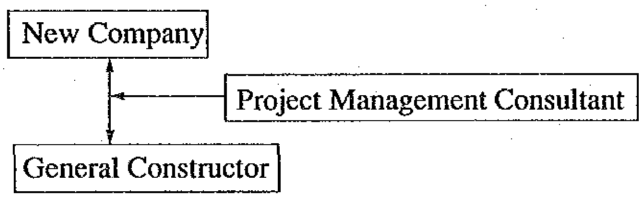
4 people, 1 year

(2) Selection of General Constructor

For the general constructor, a first-class constructor should be selected with a solid background in ammonia and urea projects around the world. The method of selection is commissioned to the project management consultants, although the final decision on selection is made by the new company in accordance with their advice. Finally, it is necessary to obtain the approval of the Government of Zimbabwe.

It is advisable for the general constructor to use local constructors who are very familiar with the circumstances of the place as cooperative constructors. Therefore, in some cases, the general constructor may allow local constructors to participate in the project from the time of bidding in the form of a joint venture with the general constructor. In this case, it is necessary to clarify whether the general constructor has responsibility for the implementation of the project or the responsibility is divided among all the enterprises concerned.

From the above, the relationships among the new company, project management consultants and the general constructor with respect to the implementation of the project are as follows.



3.4 Supply of Equipment and Materials, and Contracting Method

(1) Contracting Method

The two forms of contracting method with constructors are as follows.

Lump sum contract

Cost plus fee contract

The lump sum contract is where a decision is made collectively on all work expenditure and commissions to the general constructor. The construction costs, including the amount of funds required, can be estimated at an early stage. In addition the work under contract is carried out under the responsibility of the constructor.

On the other hand, the cost plus fee contract is often adopted when the rate of inflation is high, since it is a convenient method for both sides of avoiding the risk of soaring prices. However, with this method, many items have to be mutually agreed upon, making a lot of management work necessary. At the same time, many personnel are required for the administration of the project.

In the case of this project, a lump-sum contract would be favorable, judging from the world economic environment.

(2) Supply of Equipment and Materials

The materials and equipment are mainly imported from Japan, as well as many other countries around the world, according to necessity and the economic advantages. The items to be produced in Zimbabwe are as follows:

- Carbon steel tower and tank, less than 10 kg/cm^2 of the design pressure
- Steel structure
- Civil work, concrete structure
- Construction materials
- Certain construction equipment
- On-the-spot construction labor and miscellaneous construction materials

3.5 Construction Work

(1) Transportation

Zimbabwe is a landlocked country, so the equipment and materials imported from overseas are first unloaded at either Beira, Maputo and Durban in the neighboring countries of Zimbabwe. They are then transported overland, mainly by rail. Most of the equipment to be used in this project can be adequately transported by rail. However, there are some equipment that weigh more than twenty tonnes, which means that if rail transportation is impossible, such heavy equipment will have to be transported on special trailers after the roads of transportation routes have been repaired.

(2) Construction Work

Under the guidance of the supervisor dispatched by the general constructor, the local sub-constructors start construction. In Zimbabwe, there are many modern constructors possessing high-level technology and long experience, so there is no problem with construction.

3.6 Trial Run

Once the construction work has been completed, a trial run should be carried out to confirm the performance of the plant. Prior to a general trial run, there should be a no-load run for each process and adjustments should be made to the rotational and gauge equipment. After washing the inside of each facility, the raw material should be loaded and a trial run carried out.

This period is used to complete the training of operators, and under the guidance of the supervisor dispatched by the constructor, the training is conducted by the operators of the new company. The following is an outline of the trial run.

(1) Period of the trial run 3 months

(2) Items to be confirmed during the trial run.

Production capacity

Product specifications

Raw materials and the utilities consumption

3.7 Construction Schedule

The construction schedule is assumed to be the following.

Submission of the F/S report	June, 1989
Decision on project implementation	December, 1989
Completion of the construction contract	December, 1990
Start of construction	January, 1991
End of construction	December, 1993
Start of commercial operations	January, 1994

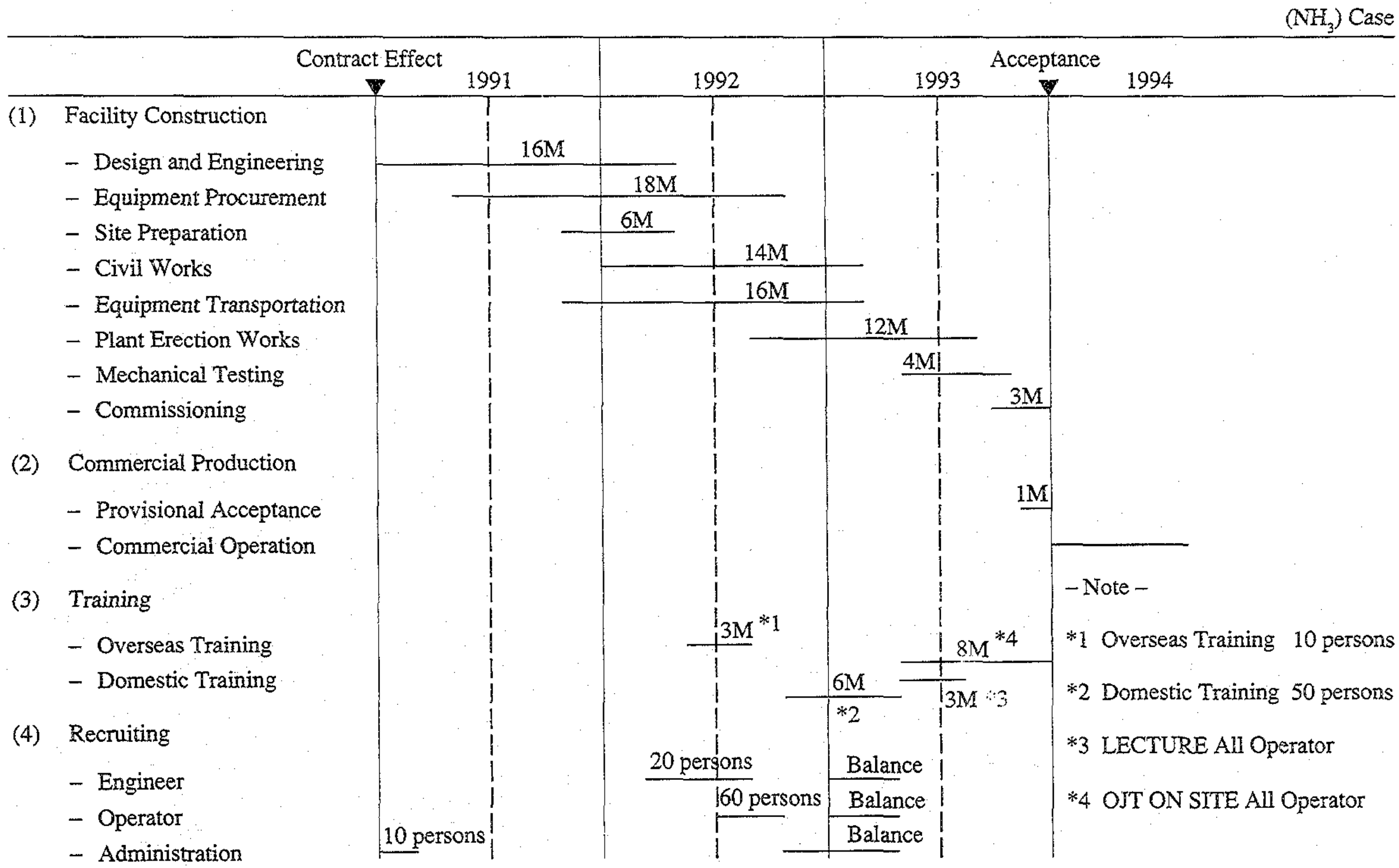
The details of the construction schedule are shown in Table III-3-1

3.8 Organization of Plant Administration

The organization of factory is illustrated in Fig. III-3-1.

The distribution of the operation and maintenance personnel is as follows.

Table III-3-1 Construction Schedule



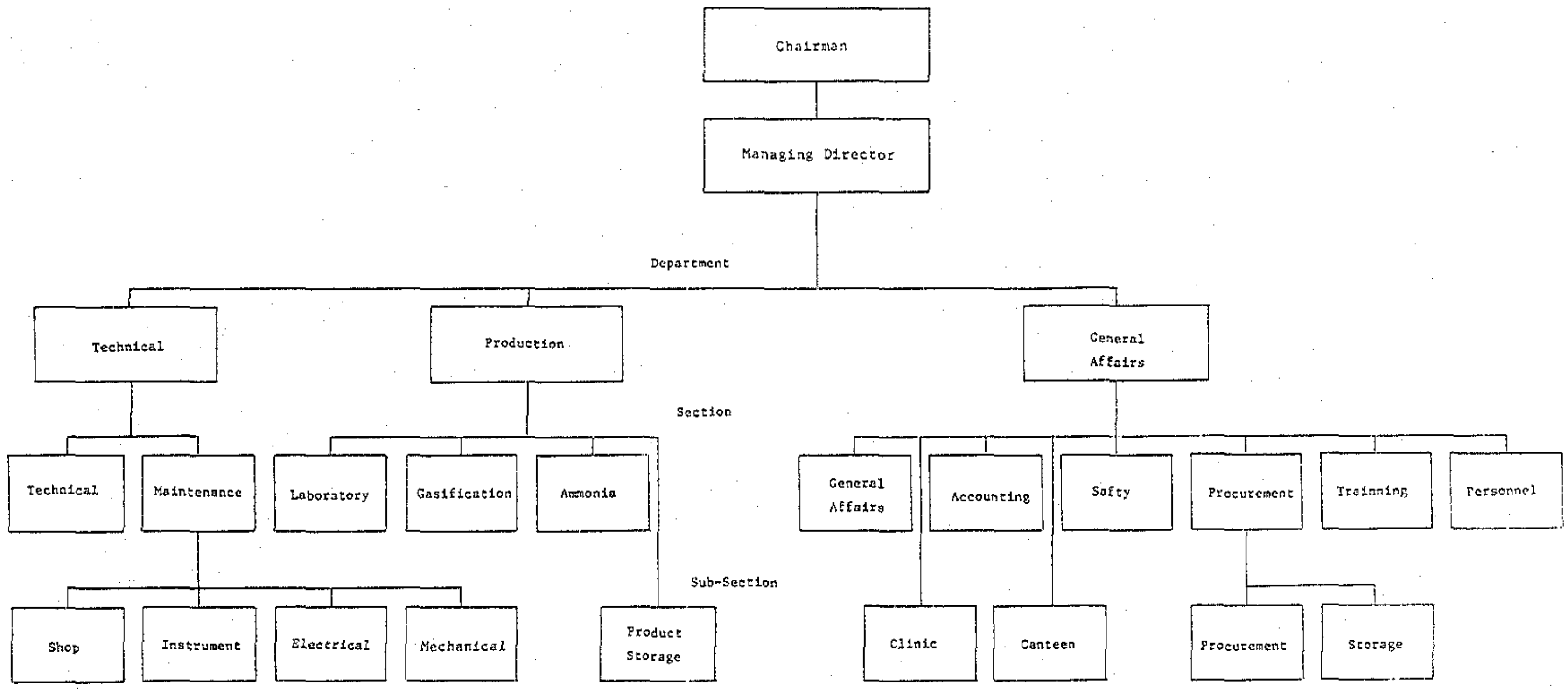


Fig. III-3-1 Typical Organization Chart

(1) Processes and Utilities

Foreman	:	16 (4 shifts)
Operator	:	76 (4 shifts)

(2) Coal Storage

Foreman	:	2 (Day Service)
Wheel Loader Driver	:	3 (Day Service)
Labour	:	10 (Day Service)

(3) Analysis Work

Chief Chemist	:	4 (4 shifts)
Chemist	:	20 (4 shifts)

(4) Maintenance

Mechanic Foreman	:	1 (Day Service)
		3 (2 shifts)
Mechanician	:	6 (Day Service)
		8 (4 shts)
Electric Foreman	:	1 (Day Service)
		3 (2 shifts)
Electrician	:	6 (Day Service)
		8 (4 shifts)
Instrument Foreman	:	1 (Day Service)
		3 (2 shifts)
Instru. Technician	:	6 (Day Service)
		16 (4 shifts)

3.9 Plan for Operator Training

When operations are started, a time limit should be set for the training of operators.

(1) Training Outside Zimbabwe

Of the people in charge of the management, operation, and maintenance departments of the new plant, 10 should be sent overseas for training over a three-month period. These 10 persons will become the trainers for operators upon their return to Zimbabwe and will be responsible for training others.

(2) Training at Company in Zimbabwe

Some of the operators should be dispatched to company in Zimbabwe for training.

(3) Training at the Plant

At the last stage of construction independent efficiency tests on various equipment, a partial trial run and general trial run should be carried out under the guidance of the supervisor of the contractor. During this period, there should be on-the-job training.

3.10 Production and Sales Plan

The production and sales plan for this plant is as follows.

Year		1994	1995	1996
Ammonia				
Production	(T)	158,400	178,200	198,000
Sales	(T)	155,400	178,200	198,000
Stock	(T)	3,000	3,000	3,000

The above production and sales plans are prepared based on the following premises.

(1) Ammonia production

1994	80%
1995	90%
After 1996	100%

(2) Stock

Stock pile at the end of the first year

Ammonia 3,000 T

Chapter 4 Total Capital Requirement

Ammonia Project

Chapter 4 Total Capital Requirement

This chapter describes the total capital requirement of the project to produce 600 tonnes per day of ammonia from Wankie coal.

4.1 General

Total capital requirement is the total investment required until the start of commercial operation. In this study, as outlined below, the total capital requirement is defined as a total of project cost, pre-operation cost, working capital, operation consultant fee and interest during construction.

- Total Capital Requirement
  - Project Cost
    - Land Acquisition and Site Preparation Cost
    - Plant Construction Cost and Plant-Related Cost
  - Pre-operation Cost
    - Pre-startup Cost
    - Trial Operation Cost
  - Working Capital
  - Operation Consultant Fee
  - Interest during Construction

4.2 Major Premises

The followings are assumed for estimating the total capital requirement.

(1) Procurement Method of Machinery and Equipment

By competitive bidding contract.

(2) Price Base

The price at the end of 1988 is used as a calculation base, and required escalations are incorporated in accordance with the payment schedule of each cost item.

(3) Currency and Exchange Rates

Foreign currency portion of capital requirement is estimated in US Dollar and Japanese Yen, and the cost in Japanese Yen is converted into US Dollar by the following exchange rate: US$1 = 130 Yen. Local currency portion is estimated in Zimbabwe Dollar and converted into US Dollar by the following exchange rate: US$1 = Z$ 1.8.

(4) Escalation

In the estimation of total capital requirement a 3.5%-annual escalation rate (for both local currency portion and foreign currency portion) is incorporated.

(5) Customs Duty

Customs duty on production facilities is exempted in Zimbabwe. Therefore the customs duty is not considered in this study.

4.3 Project Cost

The scope of project cost and a basic concept for cost estimation are given below.

(1) Land Acquisition and Site Preparation Cost

The required area for this project is 400,000 m^2. Of this area, 200,000 m^2 requires site preparation work. The scope of site preparation comprises works which can be ordered prior to the completion of basic design. In short, site preparation works consists of the leveling of land, slope reinforcement and digging of drainage ditches around the site.

(2) Plant Construction Cost

The following costs related to the construction of process plant, utility facility, off-site facility, common facility, off-site building and road are counted as plant construction cost.

1) Engineering fee

Engineering fee comprises cost for basic design and detail design. In this study, engineering fee is estimated in the foreign portion assuming that all of the engineering works are conducted in foreign countries.

2) Machinery and equipment cost

This covers the cost of machinery, equipment and material (excluding material for civil work). Most of the machinery and equipment are imported, and the cost is based on FOB prices. On the other hand, the price of locally available goods such as followings are estimated in local currency.

- Carbon steel tower and tank, less than 10kg/cm^2 of the design pressure
- Steel structure, operating platform
- Concrete structure
- Certain construction equipment
- Local labour for construction work and miscellaneous construction materials

3) Civil work cost

(a) Machinery, equipment and material costs for civil works
Among the machinery, equipment and material required for civil works, goods not manufactured in Zimbabwe and goods which are manufactured domestically but are not reliable in terms of quality, quantity and delivery schedule are assumed to be imported.

(b) Labour Cost
Since the cost of foreign construction supervisor is included in the following supervisor cost, this cost covers only the cost for local labour (including fringe benefits).

4) Transportation cost

This cost comprises the costs for freight, landing, inland transportation, and insurance.

5) Plant erection cost

The plant erection cost comprises costs of such matters as of temporary works, loss and damage of tools and construction equipment, installation of construction equipment, installation of columns, installation of small equipment, etc.

6) Supervisor cost

Construction work is executed under the guidance of supervisor dispached by the general constructor. Accordingly, the cost of the above supervisor is counted in foreign currency as a part of plant construction cost.

(3) Spare Parts

Spare parts for two years are included in plant construction cost. The costs for spare parts of the foreign portion and local portion are estimated to be US$ 3,000,000 and Z$ 55,000 (US$ 30,556), respectively.

(4) Catalysts and Chemicals

The costs for catalysts and chemicals are counted in the foreign portion based on the assumption that they are all imported.

(5) Contingency

Contingency comprises physical contingency and price contingency.

1) Physical contingency

Physical contingency is provided in case of the overrun of budget at the construction stage due to the lack of detailed information and unknown factors at the conceptual design stage. The contingency percentage is calculated as 3% of total plant construction cost after evaluating the appropriate percentage of contingency for each item.

2) Price contingency

Price contingency is provided in case of the increase in plant construction cost due to price escalation. In this study, price contingency is calculated by multiplying the assumed escalation rate with the total of the costs (1) through (4) above and the physical contingency. The price escalation rate of foreign currency portion is estimated to be 3.5% p.a. based on the Chemical Engineering Plant Cost Index and information from OECD GDP deflator forecast. On the other hand, higher price escalation is forecast in Zimbabwe dollar basis than in US dollar basis. However, the study team considers that the difference of the escalation rates is counterbalanced by the change of foreign currency exchange rate. In view of the above, price escalation rate of local currency portion in US Dollar basis is estimated the same as foreign currency portion (3.5%).

Based on the above premises, total project cost is calculated. Table III-4-1 shows the summary of project cost excluding contingency. Table III-4-2 shows the expenditure schedule and the project cost including contingency.

Table III-4-1 Project Cost (as of end of 1988)

Unit : US$1,000

	Foreign	Local	Total
Land Acquisition & Site Preparation	0.0	1,486.4	1,486.4
Plant Construction Cost			
Engineering	24,186.2	0.0	24,186.2
Machinery & Equipment	110,887.8	3,594.3	114,482.0
Civil Works	5,955.0	29,603.1	35,558.1
Transportation	11,570.1	9,042.0	20,612.1
Plant Erection Works	3,018.2	20,628.7	23,646.9
Management & S/V	12,269.7	0.0	12,269.7
Total	167,886.9	62,868.1	230,755.0
Spare Parts	3,000.0	30.6	3,030.6
Catalysts & Chemicals	2,421.4	0.0	2,421.4
Total	173,308.3	64,385.1	237,693.4

Note: The following table shows the break-down of machinery and equipment costs by section.

Unit : US$1,000

Machinery & Equipment Cost	Foreign	Local	Total
Gasification Section	53,285.6	1,869.0	55,154.6
NH_3 Section	49,186.7	1,725.3	50,412.0
Off-site Section	8,415.4	0	8,415.4
Total	110,887.8	3,594.3	114,482.0

Table III-4-2 Project Cost & Expenditure Schedule

Unit : US$1,000

		1991	1992	1993	Total
A.	Land Acquisition & Site Preparation				
	- F.C.P. -	0.0	0.0	0.0	0.0
	- L.C.P. -	1,486.4	0.0	0.0	1,486.4
B.	Engineering				
	- F.C.P. -	18,294.3	5,891.9	0.0	24,186.2
	- L.C.P. -	0.0	0.0	0.0	0.0
C.	Machinery & Equipment				
	- F.C.P. -	34,187.3	66,062.4	10,638.1	110,887.8
	- L.C.P. -	1,108.1	2,141.3	344.8	3,594.3
D.	Civil Works				
	- F.C.P. -	618.4	4,182.1	1,154.5	5,955.0
	- L.C.P. -	3,074.0	20,790.0	5,739.1	29,603.1
E.	Transportation				
	- F.C.P. -	1,496.7	8,676.3	1,397.1	11,570.1
	- L.C.P. -	1,169.6	6,780.5	1,091.9	9,042.0
F.	Plant Erection Works				
	- F.C.P. -	0.0	1,029.3	1,988.9	3,018.2
	- L.C.P. -	0.0	7,034.8	13,593.9	20,628.7
G.	Management & S/V				
	- F.C.P. -	4,089.9	4,089.9	4,089.9	12,269.7
	- L.C.P. -	0.0	0.0	0.0	0.0
H.	Spare Parts				
	- F.C.P. -	0.0	0.0	3,000.0	3,000.0
	- L.C.P. -	0.0	0.0	30.6	30.6
I.	Catalyst & Chemicals				
	- F.C.P. -	0.0	0.0	2,421.4	2,421.4
	- L.C.P. -	0.0	0.0	0.0	0.0
J.	Sub-total				
	- F.C.P. -	58,686.5	89,931.8	24,689.9	173,308.3
	- L.C.P. -	6,838.2	36,746.7	20,800.3	64,385.1
	- Total -	65,524.7	126,678.5	45,490.2	237,693.4
K.	Physical Contingency				
	- F.C.P. -	1,760.6	2,698.0	740.7	5,199.2
	- L.C.P. -	205.1	1,102.4	624.0	1,931.6
	- Total -	1,965.7	3,800.4	1,364.7	7,130.8
L.	Price Contingency (3.5% p.a.)				
	- F.C.P. -	6,571.7	13,665.0	4,773.0	25,009.7
	- L.C.P. -	765.7	5,583.6	4,021.0	10,370.4
	- Total -	7,337.4	19,248.6	8,794.0	35,380.1
M.	Total Project Cost				
	- F.C.P. -	67,018.8	106,294.8	30,203.5	203,517.2
	- L.C.P. -	7,809.0	43,432.7	25,445.3	76,687.1
	- Total -	74,827.9	149,727.5	55,648.9	280,204.3

4.4 Pre-Operation Cost

For plant installation, in addition to plant construction cost, various costs and expenses are required. The following costs are counted as pre-operation cost in this study.

(1) Pre-startup Cost

(2) Trial-operation Cost

4.4.1 Pre-startup Cost

Pre-startup cost covers the costs for project management consultant, training of operators, and administration cost of personel to be employed by the project execution company.

(1) Cost for project management consultant

At the execution stage, preparation of tender documents based on the conceptual design, inquiries for the selection of the general constructor, and evaluation of the contents of bidding will be necessary. Management of the constructor chosen after the bidding is also important. The above tasks should be commissioned to the Project Management Consultants. This study assumes that 4 consultants are hired for 3 years and 6 months from the time 6 months prior to beginning of construction to the end of construction work. The annual costs for the consultant are US$ 230,000 per head in foreign currency and Z$ 46,000 per head (US$ 25,556 per head) in local currency.

(2) Training Cost

This cost is divided into the cost for training outside Zimbabwe and the cost for training in Zimbabwe. The training cost outside Zimbabwe covers the cost for training of 10 engineers of the new company for a period of 3 months. The training will be in 1992 (two years previous to commencement of commercial operation). The cost includes living expense of trainees, travelling cost and fee to trainers, and the total amount is estimated to be US$ 1,260,000. The cost for training in Zimbabwe covers the required cost for the training of 50 local operators for 6 months in a domestic chemical company and the cost is estimated to be Z$ 500,000 (US$ 277,777).

In the above estimation, salary and wages of trainees are not included because costs are counted as administration cost shown below.

(3) Administration Cost

The direct labour cost and overhead cost during construction period are counted as administration cost. The direct labour cost is calculated based on the following recruiting schedule, and overhead cost is estimated to be 50% of direct labour cost. The annual cost of each occupation is estimated as follows.

- Director : Z$ 60,000/Y
- Manager : Z$ 45,000/Y
- Engineer : Z$ 28,000/Y
- Operator : Z$ 18,000/Y

Table III-4-3 Recruiting Schedule

Unit: Person

	1991		1992		1993	
	I	II	I	II	I	II
Director	3	3	3	3	3	3
Manager	7	7	7	7	15	15
Engineer	0	0	20	20	32	32
Operator	0	0	0	50	291	291
Total	10	10	30	80	341	341

Table III-4-4 summarizes the pre-startup cost.

Table III-4-4 Pre-startup Cost

Unit: US$1,000

	1990	1991	1992	1993	Total
Project Consultant					
- F.C.P. -	460.0	920.0	920.0	920.0	3,220.0
- L.C.P. -	51.1	102.2	102.2	102.2	357.8
Training					
- F.C.P. -	0.0	0.0	1,260.0	0.0	1,260.0
- L.C.P. -	0.0	0.0	92.6	185.2	277.8
Administration					
- F.C.P. -	0.0	0.0	0.0	0.0	0.0
- L.C.P. -	0.0	412.5	1,254.2	5,824.2	7,490.8
Total					
- F.C.P. -	460.0	920.0	2,180.0	920.0	4,480.0
- L.C.P. -	51.1	514.7	1,449.0	6,111.6	8,126.4
- Total -	511.1	1,434.7	3,629.0	7,031.6	12,606.4

4.4.2 Trial Operation Cost

During the 3-month period provided for trial operation, net operation time is assumed to be 1 month. The average operation rate is assumed 80% of installed capacity and raw material and utility consumption are assumed 120% of requirements in normal operation. During this period 14,400 tonnes of ammonia which meet the specifications, are produced. In this study, the sales revenue of the products are subtracted from trial operation cost assuming that all of the products are sold. The price of ammonia is fixed at US$ 300/T. Labour cost of supervisors and operators for this period is not included in this configuration, because the former is included in project cost and the latter is included in pre-startup cost. The trial operation cost is summarized in the following table.

Table III-4-5 Trial Operation Cost

	Unit Consumption	Unit Price	Cost
Coal	1.21 x 1.2 T/T NH_3	US$ 13.889/T	US$ 290,402
Electricity	848 x 1.2 kWh/T NH_3	US$ 0.027/kWh	US$ 395,643
Product Sales			US$ -4,320,000
Total			US$ -3,633,955

4.5 Initial Working Capital

Working capital is the funds required for smooth operation of the plant. In this study, the following are prepared as the working capital.

(1) Cash on Hand

Cash amounting to Z$ 582,417 (US$ 323,565), which covers the labour cost for one month, is reserved. In addition, the cash equivalent to the estimated account receivable in the first year is reserved. The amount of account receivable is estimated as US$ 4,320,000 based on the following assumptions.

- Sales proceeds of ammonia is collected one month after the sales.
- Sales volume of ammonia is at the first operation year is 14,400 T/M.
- Sales price of ammonia is US$ 300/T.

(2) Catalysts and Chemicals

Catalysts and Chemicals for one year are reserved as inventory. The required cost for this inventory is US$ 1,000,000.

(3) Raw material inventory

Prior to the start-up of commercial operation, 4,000 tonnes of coal is reserved. The required cost to purchase coal, calculated by multiplying the unit price of coal (US$ 13.89 /T) with the above inventory volume, is US$ 55,560.

Table III-4-6 summarizes the cost for initial working capital.

Table III-4-6 Summary of Initial Working Capital

Unit: 1,000 US$

	Foreign	Local	Total
Cash	0.0	4,643.6	4,643.6
Catalysts & Chemicals	1,000.0	0.0	1,000.0
Raw Material Inventory	0.0	55.6	55.6
Total	1,000.0	4,699.1	5,699.1

4.6 Cost for Operation Consultant

The cost for operation consultants (4 personnel, 1 year) hired in the first year of operation is included in total capital requirement. The annual cost for the operation consultant is estimated as the same cost as project management consultant (foreign portion: US$ 230,000 per head, local portion: Z$ 46,000 per head).

4.7 Financing Plan and Total Capital Requirement

4.7.1 Financing Plan

The financing plan for the execution of this project is not established yet. In this chapter, it is assumed that foreign portion is covered by the long-term loan with the appropriate conditions, and local portion and interest during construction is covered by own fund. Following loan conditions are formed provisionally with reference to LIBOR.

- Interest : 10.0 % p.a.
- Repayment : With a grace period of 4 years, repayment is made in 10 years by annual payment equal installments.

4.7.2 Total Capital Requirement

Total capital requirement is calculated by adding interest during construction to the total of each cost mentioned above. Tables III-4-7 to III-4-9 show the total capital requirement.

Table III-4-7 Total Capital Requirement (in 1988 Constant Price Base)

Unit: US$1,000

	1990	1991	1992	1993	Total
A. Base Project Cost					
- F.C.P. -	0.0	58,686.5	89,931.8	24,689.9	173,308.3
- L.C.P. -	0.0	6,838.2	36,746.7	20,800.3	64,385.1
- Total -	0.0	65,524.7	126,678.5	45,490.2	237,693.4
B. Physical Contingency (3% of A)					
- F.C.P. -	0.0	1,760.6	2,698.0	740.7	5,199.2
- L.C.P. -	0.0	205.1	1,102.4	624.0	1,931.6
- Total -	0.0	1,965.7	3,800.4	1,364.7	7,130.8
C. Preoperation Cost					
- F.C.P. -	460.0	920.0	2,180.0	920.0	4,480.0
- L.C.P. -	51.1	514.7	1,449.0	2,477.6	4,492.4
- Total -	511.1	1,434.7	3,629.0	3,397.6	8,972.4
D. Working Capital					
- F.C.P. -	0.0	0.0	0.0	1,000.0	1,000.0
- L.C.P. -	0.0	0.0	0.0	4,699.1	4,699.1
- Total -	0.0	0.0	0.0	5,699.1	5,699.1
E. Operation Consultant					
- F.C.P. -	0.0	0.0	0.0	920.0	920.0
- L.C.P. -	0.0	0.0	0.0	10.2	102.2
- Total -	0.0	0.0	0.0	1,022.2	1,022.2
F. Total Cost (excl. IDC)					
- F.C.P. -	460.0	61,367.1	94,809.8	28,270.6	184,907.5
- L.C.P. -	51.1	7,558.0	39,298.1	28,703.2	75,610.5
- Total -	511.1	68,925.2	134,107.9	56,973.8	260,518.0
G. Interest during Construction	23.0	3,114.4	10,923.2	17,077.2	31,137.8
H. Total Financing Required	534.1	72,039.5	145,031.1	74,051.0	291,655.7

Table III-4-8 Total Capital Requirement (Current Price Base)

Unit: US$1,000

	1990	1991	1992	1993	Total
A. Base Project Cost					
- F.C.P. -	0.0	58,686.5	89,931.8	24,689.9	173,308.3
- L.C.P. -	0.0	6,838.2	36,746.7	20,800.3	64,385.1
- Total -	0.0	65,524.7	126,678.5	45,490.2	237,693.4
B. Physical Contingency (3% of A)					
- F.C.P. -	0.0	1,760.6	2,698.0	740.7	5,199.2
- L.C.P. -	0.0	205.1	1,102.4	624.0	1,931.6
- Total -	0.0	1,965.7	3,800.4	1,364.7	7,130.8
C. Preoperation Cost					
- F.C.P. -	460.0	920.0	2,180.0	920.0	4,480.0
- L.C.P. -	51.1	514.7	1,449.0	2,477.6	4,492.4
- Total -	511.1	1,434.7	3,629.0	3,397.6	8,972.4
D. Working Capital					
- F.C.P. -	0.0	0.0	0.0	1,000.0	1,000.0
- L.C.P. -	0.0	0.0	0.0	4,699.1	4,699.1
- Total -	0.0	0.0	0.0	5,699.1	5,699.1
E. Operation Consultant					
- F.C.P. -	0.0	0.0	0.0	920.0	920.0
- L.C.P. -	0.0	0.0	0.0	102.2	102.2
- Total -	0.0	0.0	0.0	1,022.2	1,022.2
F. Price Contingency (3.5% p.a.)					
- F.C.P. -	32.8	6,671.7	13,986.6	5,306.0	25,997.1
- L.C.P. -	3.6	821.7	5,797.4	5,387.2	12,009.9
- Total -	36.4	7,493.4	19,784.0	10,693.2	38,007.0
G. Total Cost (excl. IDC)					
- F.C.P. -	492.8	68,038.8	108,796.4	33,576.6	210,904.6
- L.C.P. -	54.8	8,379.7	45,095.4	34,090.4	87,620.4
- Total -	547.5	76,418.6	153,891.9	67,667.0	298,525.0
H. Interest during Construction	23.6	3,451.2	12,293.0	19,411.6	35,180.5
I. Total Financing Required	572.2	79,869.8	166,184.9	87,078.7	333,705.5

Table III-4-9 Summary of Total Capital Requirement

Unit: US$1,000

	Foreign	Local	Total
[in 1988 Constant Price Base]			
Project Cost	178,507.5	66,316.7	244,824.2
Preoperation Cost	4,480.0	4,492.4	8,972.4
Working Capital	1,000.0	4,699.1	5,699.1
Operation Consultant	920.0	102.2	1,022.2
Interest during Construction	31,137.8	0.0	31,137.8
Total Financing Required	216,045.3	75,610.5	291,655.7
[Current Price Base]			
Project Cost	203,517.2	76,687.1	280,204.3
Preoperation Cost	5,107.1	5,230.8	10,337.9
Working Capital	1,187.7	5,581.1	6,768.8
Operation Consultant	1,092.7	121.4	1,214.1
Interest during Construction	35,180.5	0.0	35,180.5
Total Financing Required	246,085.1	87,620.4	333,705.5

Note: Project Cost covers following costs.

- Land Acquisition and Site Preparation Cost
- Plant Construction Cost
- Spare Parts for 2 years
- Catalysts & Chemicals (initial charge)
- Physical Contingency

Chapter 5 Financial Analysis

Ammonia Project

Chapter 5 Financial Analysis

5.1 General

In this chapter, profitability of the project to produce 600 T/D of ammonia from Wankie coal is evaluated. The financial evaluation is conducted in a manner normally applied to industrial investment projects. Namely, the following financial statements are prepared to study the financial situations of the project such as cash surplus (deficit) and ordinary profit (loss) in each year.

- Production Cost Accounting Table
- Profit and Loss Statement
- Cash Flow Table
- Balance Sheet

Also, as indicators of financial profitability, Internal Rate of Return by Discounted Cash Flow Method and Pay-back Period are calculated.

5.2 Major Premises

This section describes basic data and conditions for financial analysis.

(1) Project Life

- Bidding Period : 6 months
- Construction Period : 3 years
- Operation Period : 15 years

(2) Price Base

Calculation is based on the costs and prices in 1988. The calculation is made in US Dollar, and the costs estimated in local currency (Zimbabwe Dollar; Z$) or Japanese Yen are converted into US Dollar by using the following exchange rates.

- US$ 1 = Z$ 1.8 = ¥130

(3) Production and Sales Plan

Table III-5-1 shows the production and sales plan of this project.

Table III-5-1 Production and Sales Plan

Unit: T/Y

Project Year	1	2	3-15
On-stream Factor	80%	90%	100%
Production Volume	158,400	178,200	198,000
Sales Volume			
Ammonia-A	76,000	76,000	76,000
Ammonia-B	23,000	23,000	23,000
Ammonia-C	56,400	79,200	99,000
Stock	3,000	(3,000)	(3,000)
Total	158,400	178,200	198,000

The ammonia-A and B shown in the above table are sold to SABLE located in Kwekwe as a raw material to produce ammonium nitrate. The former displaces the ammonia which has been produced by SABLE, and the latter displaces the imported ammonia. The ammonia-C is sold in Hwange. The ex-plant prices of above products established from the Market Study are shown in Table III-5-2.

Table III-5-2 Sales Prices

Unit: US$/T

Ammonia-A	361.3
Ammonia-B	319.2
Ammonia-C	337.3

(4) Income Tax

A 50% corporate income tax is levied against net income before tax. However, in accordance with Zimbabwe's taxation system, the tax is exempted until the investment cost (plant cost) is recovered.

(5) Depreciation

The depreciation rates according to Zimbabwe's tax system are as follows:

Item	Depreciation Method	Salvage Value
Machinery and Equipment	10 years straight line	10%
Civil and Building	20 years straight line	10%
Pre-operation cost	5 years straight line	0%
Interest during Construction	5 years straight line	0%

(6) Running Working Capital

Running working capital is the fund required for the continuation of dairy operation. In this study, running working capital is defined as the balance deducting the current liability from the current assets shown below.

(a) Current asset

- Cash:
  The amount of cash to cover the labour cost for one month excluding the cost for foreign operation consultants is reserved.
- Catalysts and chemicals:
  Catalysts and chemicals equivalent to one year operation are reserved as an inventory.
- Products inventory:
  3,000 tonnes of ammonia is reserved as inventory. The value of product inventory is calculated by multiplying the unit operation cost to the inventory volume.
- Account receivable:
  Sales revenue of one month is counted to be account receivable assuming that sales proceed of ammonia is collected one month after the sales.

(b) Current liability

- Account Payable:
  The equivalent of one month of cost for coal and electricity are counted as account payable.

(7) Financing Plan

The financing plan for the execution of this project is not established yet. In this chapter, based on the discussion during a field survey, and the calculation results of Chapter 4 "Total Capital Requirement," 70% of total investment cost excluding interest during construction is covered by long-term loan, and remaining 30% and interest during construction are covered by own fund. The conditions of the long-term loan are formed as follows:

- Interest : 10% p.a.
- Repayment : 10 times/10 years
- Grace Period : 4 years from loan agreement

In the case that there is a shortage of funds during the commercial operation period, the shortage is covered by short-term loan on the following conditions.

- Interest : 15% p.a.
- Repayment : Total amount in the following year

5.3 Total Capital Requirement

Although total investment cost including price and physical contingencies is calculated in Chapter 4 "Total Capital Requirements", in this chapter, the total cost for the project excluding price contingency in 1988 fixed price base is calculated. Table III-5-3 shows the summary of total capital requirement.

Table III-5-3 Total Capital Requirement

Unit: US$ Million

	1990	1991	1992	1993	Total
Application of Funds					
Project Cost	0.00	67.49	130.48	46.85	244.82
Preoperation Cost	0.51	1.43	3.63	3.40	8.97
Initial Working Capital	0.00	0.00	0.00	5.70	5.70
Interest during Const.	0.02	2.45	9.55	16.21	28.23
Total	0.53	71.37	143.66	72.16	287.72
Source of Funds					
Equity	0.17	23.13	49.79	32.99	106.08
Long-term Loan	0.36	48.25	93.88	39.17	181.65
Total	0.53	71.37	143.66	72.16	287.72

5.4 Operating Cost

(1) Coal

The required coal to produce ammonia is 1.21 tonnes per ton of ammonia. The price of coal is estimated at US$ 13.89/T.

(2) Electricity

The unit consumption of electricity to produce ammonia from coal is shown below.

- Process use : 813.2 kWh
- Water intake : 34.8 kWh

The average price of electricity is estimated at US$ 0.027 /kWh based on the results of raw material study.

(3) Catalysts and Chemicals

The average cost of catalysts and chemicals is estimated at US$ 1.0 million per year.

(4) By-product Subtraction

In this project, 5,973 tonnes per year of sulphur is recovered from the synthetic gas desulphurization unit. The recovered sulphur is assumed to be sold and the sales revenue is subtracted from operating costs. The price of sulphur is specified to be US$ 100/T which is equivalent to international price.

(5) Labour Cost

The labour cost required for this project is summarized in Table III-5-4.

Table III-5-4 Labour Cost

Unit: Z$/Y

Director	(3 persons)	180,000
Manager	(15 persons)	675,000
Engineer	(32 persons)	896,000
Operator	(291 perosns)	5,238,000
Total	(341 persons)	6,989,000

In addition to the above, 4 foreign operation consultants are hired in the first year of operation. The required annual cost for the operation consultants is estimated to be a total of US$ 1,022 thousand.

(6) Overhead

Plant overhead is estimated at 100% of the above labour cost.

(7) Maintenance Cost

Annual maintenance cost is estimated at 1.5% of plant investment cost. The cost covers only costs of material and parts for maintenance work and not the cost of maintenance labour because the latter is included in labour cost shown in Table III-5-4.

(8) Insurance

Insurance cost covers fire insurance premium for fixed assets, and the annual amount is estimated to be 0.7% of plant cost.

5.5 Financial Statements

The results of financial analysis based on the above premises are summarized in the following financial statements in the form of computer output attached at the end of this chapter.

- Production Cost Accounting Table (B-Table 5-1)
- Profit and Loss Statement (B-Table 5-2)
- Cash Flow Table (B-Table 5-3)
- Balance Sheet (B-Table 5-4)

The summary of each financial statement are given in the following:

(1) Production Cost Accounting Table

In this study, production cost is defined as a total of operating cost, depreciation and financial cost. The average production cost of ammonia, based on the above definition, is approx. US$ 242/T. The calculated production cost is considerably cheaper than that of SABLE. Further it is cheaper than the price of imported ammonia. Concluding the production cost analysis, this project is considered to be feasible.

(2) Profit and Loss Statement

Sales revenue can not cover the production cost for the first two years after the start-up of commercial operation. However, ordinary profit can be expected from the third year on-ward. By the eighth year, the plant cost is completely recovered and this project commence the payment of income tax. The sum of profit after tax in the fifteen year period amounts to US$ 168 million.

(3) Cash Flow Table

Although there is a shortage of funds at first year after the start-up of commercial operation, cash surplus is expected from the second year and the project is estimated to be profitable. The total of cash surplus at the end of fifteenth year amounts to US$ 263 million.

(4) Balance Sheet

Balance Sheet also indicates sound profitability for this project. The reserved cash at the end of fifteenth year amounts to US$ 274 million.

5.6 Internal Rate of Return and Pay-Back Period

In this study, as indicators of financial profitability of the project, Internal Rate of Return on Investment (IRROI) and Internal Rate of Return on Equity (IRROE), on both before-tax and after-tax bases, are described. IRROI is defined as a profitability for the investment assuming that all investment is covered by own fund, and is an index of profitability of the project excluding effects due to change in loan terms or equity ratio. IRROE means the profitability for the invested capital under the estimated financing plan.

The internal rate of return is calculated according to the formula shown below.

$$\sum_{i=0}^{N} \frac{(CFE)\ of\ i}{(I+R)^i} + \frac{S+W}{(I+R)^n} = 0$$

(CFE) Represents cash flow element of each year

	IRROI		IRROE
(CFE) =	– Investment	(CFE) =	– Equity
	+ Revenue		+ Revenue
	– Operating Costs		– Operating Costs
	– Income Tax		– Interest
	– W/C Increase		– Income Tax
	+ Salvage Value Return		– Repayment of Debt
			– W/C Increase
			+ Salvage Value Return

On the other hand, pay-back period is defined as the period required to recover the original investment outlay through the profit earned by the project. In this study, pay-back period on Investment and pay-back period on Equity are calculated from cash flow of IRROI after tax and that of IRROE after tax, respectively.

The calculated Internal Rate of Return on Investment (before tax base), as shown below, provide the grounds for the validity of the project.

- IRROI (before tax) : 12.5 %
- IRROI (after tax) : 9.7 %
- IRROE (before tax) : 13.4 %
- IRROE (after tax) : 9.8 %

- Pay-back Period on Investment : 6.2 years
- Pay-back Period on Equity : 8.1 years

5.7 Major Financial Indicators

The following financial indicators for each operation year are calculated, and the results are summarized in Table III-5-5.

(1) Debt Service Coverage Ratio (DSR)

The DSR indicates the payment capability of loan, and are calculated by the following formula.

DSR = (Profit after Tax + Depreciation + Interest –
Increase of WC) / (Repayments + Interests)

The fund generated by the project is sufficient to cover the payment of principal and interest on loan, in the case DSR exceeds 1.0. In the case this project is implemented, additional financing is required at the first year of operation as shown by their calculated DSRs. However, the shortage is covered by the assumed short-term loan, and the available cash exceeds the amount for debt service from the second year. In view of the above, this project is considered capable of repaying a long-term loan.

(2) Break Even Point (BEP)

The BEP is calculated by the following formula.

BEP = Total Production Cost / Sales Revenue

This indicator determines the product price at which sales revenue equals to production cost. In other words, ordinary loss is counted in the case BEP exceeds 1.0. In the case of this project, the average BEP is 0.70.

Table III-5-5 Financial Indicators

Year	Debt Service Coverage Ratio	Break Even Point
1994	0.88	1.30
1995	1.01	1.10
1996	1.41	0.97
1997	1.51	0.94
1998	1.61	0.91
1999	1.72	0.78
2000	1.84	0.75
2001	1.69	0.72
2002	1.67	0.70
2003	1.78	0.67
2004	—	0.34
2005	—	0.34
2006	—	0.34
2007	—	0.34
2008	—	0.34
Average	1.51	0.70

5.8 Sensitivity Analysis

The sensitivity analysis is carried out, evaluating the influence that variations of presumed conditions have on the project by changing the following parameters.

- Product Price (+10% to -10%)
- Plant Investment Cost (+10% to -10%)
- Raw Material (Coal, Electricity) Price (+20% to -20%)
- Financing Condition (Interest; 5%, Grace period; 4 years and 11 years after the signing of loan agreement)
- Equity Ratio (20%, 40%)
- Inflation (3%, 5%)
- Operating rate (1st yr: 60%, 2nd yr: 70%, 3rd yr: 80%, 4th yr: 90%, 5th yr and the after: 100%)

The following is a summary of the sensitivity analysis.

(1) Product Price

The fluctuation of the product price has the largest effect upon the profitability. If product prices increase by 10% compared with the base case, IRROI (after tax) and IRROE (after tax) will increase by 1.8% and 3.5%, respectively.

(2) Plant Investment Cost

If the plant cost decreases by 10%, IRROI (after tax) and IRROE (after tax) increase by 1.4% and 2.9%, respectively.

(3) Raw Material Price

Changing the raw material price does not have a significant effect on profitability. Even in the case, raw material price increases by 20%, IRROI and IRROE decrease by less than 1%.

(4) Financing Conditions (Refer to B-Tables 5-5 to 5-8)

If the soft loan with the above conditions are applied to this project instead of loan conditions of base case, IRROE after tax increases by 9.5%. Further, in the case of a soft loan, shortage of funds does not occur.

(5) Equity Ratio

The effect of changing the equity ratio on the profitability of this project is small.

(6) Inflation

Effects of inflation on the profitability is significant. If the inflation rate of 3% is uniformly multiplied to every item, IRROI (after tax) and IRROE (after tax) will increase by 2.9% and 5.3%, respectively.

(7) Operating Rate (Refer to B-Tables 5-9 to 5-12)

Effects of decrease of operating rate on the profitability are significant. IRROI (after tax) and IRROE (after tax) shows 8.2% and 7.0%, respectively in case that the operating rates are 60% for 1st year of operation, 70% for 2nd year, 80% for 3rd year, 90% for 4th year and 100% for 5th year and the after. IRROE (after tax), however, will be improved from 7.0% to 18.5% in the case of application of long term loan with a interest rate of 5% p.a. and a grace period of repayment of 11 years after the signing of loan agreement.

Table III-5-6 Summary of Sensitivity Analysis

Unit: %

Parameter	IRROI (b/tax)	IRROI (a/tax)	IRROE (b/tax)	IRROE (a/tax)
Product Price				
+10%	14.6	11.5	17.2	13.3
Base Case	12.5	9.7	13.4	9.8
-10%	10.2	7.7	9.4	6.0
Plant Investment Cost				
+10%	11.0	8.5	10.8	7.2
Base Case	12.5	9.7	13.4	9.8
-10%	14.2	11.1	16.5	12.7
Raw Material Cost				
+20%	12.0	9.3	12.5	9.1
+10%	12.2	9.5	13.0	9.5
Base Case	12.5	9.7	13.4	9.8
-10%	12.7	9.9	13.9	10.2
-20%	13.0	10.0	14.3	10.6
Financing Source				
Base Case	12.5	9.7	13.4	9.8
Soft Loan Case	12.5	9.7	22.3	19.3
Soft Loan with 11 yrs Grace of Repayment	12.5	9.7	25.5	23.6
Equity Ratio				
20%	12.5	9.7	13.7	9.9
30% (Base Case)	12.5	9.7	13.4	9.8
40%	12.5	9.7	13.2	9.8
Inflation				
0% (Base Case)	12.5	9.7	13.4	9.8
3%	16.1	12.6	19.6	15.1
5%	18.6	14.4	23.4	18.6
Operating Rate				
1994 1995 1996 1997 1998				
60% 70% 80% 90% 100%	10.9	8.2	10.5	7.0
Soft Loan with 11 yrs Grace of Repayment	10.9	8.2	20.8	18.5

5.9 Summary of Financial Analysis

The following is an evaluation and conclusion of this project.

- The production cost of ammonia, US$242 /T on average, is cheaper than that of SABLE as well as price of imported ammonia. This indicates that the implementation of this project is feasible.
- Internal Rate of Return on Investment (before tax base), an indicator of the project's profitability, exceeds 10%, providing the validility of the project.
- On the early stage of commercial operation, additional financing is required for the repayment of the long-term loan. However, after this period, the loan can be repaid smoothly and favorable profitability can be expected.
- If the soft loan is applied, as mentioned in the sensitivity analysis, profitability of the project will be vastly improved and the shortage of fund will not occur.
- Concluding from the above, this project is considered to be financially feasible unless the premises used in this study change greatly in an adverse direction.

B-Table 5-1 Production Cost Accounting Table (Base Case : Ammonia)

<< Production Cost Accounting Table >>

(Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Average
Operating Rate	-/-	-/-	-/-	-/-	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	98%
Production Volume (kt)	-/-	-/-	-/-	-/-	156.40	178.20	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	194.04
Operating Cost																				
Coal	-/-	-/-	-/-	-/-	2.66	2.99	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.26
Electricity	-/-	-/-	-/-	-/-	3.63	4.08	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.44
Catalyst & Chemicals	-/-	-/-	-/-	-/-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
By-product Subtraction	-/-	-/-	-/-	-/-	-0.48	-0.54	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.59
Labour	-/-	-/-	-/-	-/-	4.90	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.95
Overhead	-/-	-/-	-/-	-/-	4.90	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.95
Maintenance	-/-	-/-	-/-	-/-	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67
Insurance	-/-	-/-	-/-	-/-	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71
Total Operating Cost	-/-	-/-	-/-	-/-	22.01	20.69	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.41
Depreciation																				
Machinery & Equipment	-/-	-/-	-/-	-/-	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	0.00	0.00	0.00	0.00	0.00	13.78
Buiulding	-/-	-/-	-/-	-/-	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Preoperation Cost	-/-	-/-	-/-	-/-	1.79	1.79	1.79	1.79	1.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
Interest during Construction	-/-	-/-	-/-	-/-	5.65	5.65	5.65	5.65	5.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.88
Total Depreciation	-/-	-/-	-/-	-/-	29.94	29.94	29.94	29.94	29.94	22.50	22.50	22.50	22.50	22.50	1.83	1.83	1.83	1.83	1.83	18.09
Financial Cost																				
Interest on L/T Loan	-/-	-/-	-/-	-/-	18.16	16.35	14.53	12.72	10.90	9.08	7.27	5.45	3.63	1.82	0.00	0.00	0.00	0.00	0.00	6.66
Interest on S/T Loan	-/-	-/-	-/-	-/-	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Total Financial Cost	-/-	-/-	-/-	-/-	18.16	17.02	14.53	12.72	10.90	9.08	7.27	5.45	3.63	1.82	0.00	0.00	0.00	0.00	0.00	6.71
Total Production Cost	-/-	-/-	-/-	-/-	70.11	67.65	65.89	64.07	62.25	53.00	51.18	49.36	47.55	45.73	23.25	23.25	23.25	23.25	23.25	46.20
Unit Prod. Cost(US$/ton)	-/-	-/-	-/-	-/-	442.61	379.64	332.75	323.58	314.41	267.66	258.48	249.31	240.13	230.96	117.41	117.41	117.41	117.41	117.41	241.77

B-Table 5-2 Profit and Loss Statement (Base Case : Ammonia)

<< Profit and Loss Statement >> (Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Sales Revenue																				
Product-A	-/-	-/-	-/-	-/-	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	411.88
Product-B	-/-	-/-	-/-	-/-	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	110.12
Product-C	-/-	-/-	-/-	-/-	19.02	26.71	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	479.84
Total	-/-	-/-	-/-	-/-	53.82	61.51	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	1,001.85
Costs of Goods Sold	-/-	-/-	-/-	-/-	21.59	20.76	21.44	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.74	321.10
Initial Product Inventory	-/-	-/-	-/-	-/-	0.00	0.42	0.35	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	-/-
Operating Cost	-/-	-/-	-/-	-/-	22.01	20.69	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	321.10
Final Product Inventory	-/-	-/-	-/-	-/-	0.42	0.35	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.00	-/-
Depreciation	-/-	-/-	-/-	-/-	29.94	29.94	29.94	29.94	29.94	22.50	22.50	22.50	22.50	22.50	1.83	1.83	1.83	1.83	1.83	271.34
Financial Cost	-/-	-/-	-/-	-/-	18.16	17.02	14.53	12.72	10.90	9.08	7.27	5.45	3.63	1.82	0.00	0.00	0.00	0.00	0.00	100.58
Profit before Tax	-/-	-/-	-/-	-/-	-15.87	-6.21	2.28	4.12	5.94	15.20	17.01	18.63	20.65	22.46	44.95	44.95	44.95	44.95	44.62	308.83
Income Tax	-/-	-/-	-/-	-/-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.64	10.32	11.23	22.47	22.47	22.47	22.47	22.31	140.60
Profit after Tax	-/-	-/-	-/-	-/-	-15.87	-6.21	2.28	4.12	5.94	15.20	17.01	11.99	10.32	11.23	22.47	22.47	22.47	22.47	22.31	168.24

B-Table 5-3 Cash Flow Table (Base Case : Ammonia)

<< Cash Flow Table >>

ROI(b/tax)= 12.5% ROE(b/tax)= 13.4% Payout Period(ROI): 6.2 years
ROI(a/tax)= 9.7% ROE(a/tax)= 9.8% Payout Period(ROE): 8.1 years

(Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Source of Funds																				
Profit after Tax	0.00	0.00	0.00	0.00	-15.87	-6.21	2.28	4.12	5.94	15.20	17.01	11.99	10.32	11.23	22.47	22.47	22.47	22.47	22.31	168.24
Depreciation	0.00	0.00	0.00	0.00	29.94	29.94	29.94	29.94	29.94	22.50	22.50	22.50	22.50	22.50	1.83	1.83	1.83	1.83	1.83	271.34
Equity	0.17	23.13	49.79	32.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	106.08
Long-term Loan	0.36	48.25	93.88	39.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	181.65
Short-term Loan	0.00	0.00	0.00	0.00	4.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.51
Total Source	0.53	71.37	143.66	72.16	18.58	23.73	32.22	34.06	35.88	37.70	39.51	34.49	32.82	33.73	24.30	24.30	24.30	24.30	24.14	731.80
Application of Funds																				
Plant Investment	0.00	67.49	130.48	46.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	244.82
Pre-operation Cost	0.51	1.43	3.63	3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.97
Initial W/C	0.00	0.00	0.00	5.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.70
Interest during Construction	0.02	2.45	9.55	16.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.23
Working Capital Increase	0.00	0.00	0.00	0.00	0.41	0.56	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-7.18	-5.70
Repayment on L/T Loan	0.00	0.00	0.00	0.00	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	0.00	0.00	0.00	0.00	0.00	181.65
Repayment on S/T Loan	0.00	0.00	0.00	0.00	0.00	4.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.51
Total Application	0.53	71.37	143.66	72.16	18.58	23.23	18.68	18.16	18.16	18.16	18.16	18.16	18.16	18.16	0.00	0.00	0.00	0.00	-7.18	468.18
Cash Surplus	0.00	0.00	0.00	0.00	0.00	0.50	13.55	15.90	17.71	19.53	21.35	16.33	14.66	15.56	24.30	24.30	24.30	24.30	31.33	263.62
Cum. Cash Surplus	0.00	0.00	0.00	0.00	0.00	0.50	14.04	29.94	47.66	67.19	88.53	104.86	119.52	135.08	159.39	183.69	207.99	232.30	263.62	-/-
Sulvage Value Return	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.69	10.69
Cash Flow(ROI b/tax)	-0.51	-68.93	-134.11	-55.95	31.82	40.20	46.24	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	64.32	437.64
Cash Flow(ROI a/tax)	-0.51	-68.93	-134.11	-55.95	31.82	40.20	46.24	46.78	46.78	39.15	34.64	34.64	34.64	34.64	24.30	24.30	24.30	24.30	42.01	269.25
Cash Flow(ROE b/tax)	-0.17	-23.13	-49.79	-32.99	0.00	0.50	13.55	15.90	17.71	19.53	21.35	23.16	24.98	26.80	46.78	46.78	46.78	46.78	64.32	308.83
Cash Flow(ROE a/tax)	-0.17	-23.13	-49.79	-32.99	0.00	0.50	13.55	15.90	17.71	19.53	21.35	16.33	14.66	15.56	24.30	24.30	24.30	24.30	42.01	168.24

B-Table 5-4 Balance Sheet (Base Case : Ammonia)

<< Balance Sheet >> (Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Current Assets																			
Cash	0.00	0.00	0.00	0.00	0.00	0.50	14.04	29.94	47.66	67.19	88.53	104.86	119.52	135.08	159.39	183.69	207.99	232.30	274.31
Working Capital	0.00	0.00	0.00	5.70	6.11	6.67	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	0.00
Total	0.00	0.00	0.00	5.70	6.11	7.17	21.23	37.13	54.84	74.37	95.72	112.04	126.70	142.26	166.57	190.87	215.18	239.48	274.31
Fixed Assets(Lesss Depr.)	0.53	71.90	215.56	282.02	252.09	222.15	192.21	162.27	132.33	109.84	87.34	64.84	42.34	19.84	18.01	16.18	14.35	12.52	0.00
Total Assets	0.53	71.90	215.56	287.72	258.20	229.32	213.44	199.40	187.17	184.21	183.05	176.88	169.04	162.11	184.58	207.05	229.53	252.00	274.31
Short-term Loan	0.00	0.00	0.00	0.00	4.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long-term Loan	0.36	48.61	142.48	181.65	163.48	145.32	127.15	108.99	90.82	72.66	54.49	36.33	18.16	0.00	0.00	0.00	0.00	0.00	0.00
Shareholders' Equity																			
Capital	0.17	23.30	73.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08
Retained Earning	0.00	0.00	0.00	0.00	-15.87	-22.07	-19.79	-15.67	-9.73	5.47	22.49	34.48	44.80	56.03	78.51	100.98	123.45	145.93	168.24
Total Equity	0.17	23.30	73.08	106.08	90.21	84.00	86.28	90.41	96.35	111.55	128.56	140.55	150.88	162.11	184.58	207.05	229.53	252.00	274.31
Total	0.53	71.90	215.56	287.72	258.20	229.32	213.44	199.40	187.17	184.21	183.05	176.88	169.04	162.11	184.58	207.05	229.53	252.00	274.31

<< Working Capital Table >>

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Current Assets																			
Cash	0.00	0.00	0.00	4.64	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.00
Raw Material Inventory	0.00	0.00	0.00	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.00
Product Inventory	0.00	0.00	0.00	0.00	0.42	0.35	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.00
Catalysts & Chemicals	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
Account Receivable	0.00	0.00	0.00	0.00	4.89	5.59	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	0.00
Total	0.00	0.00	0.00	5.70	6.68	7.32	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	0.00
Current Liabilities																			
Account Payable	0.00	0.00	0.00	0.00	0.57	0.64	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.00
Total Working Capital	0.00	0.00	0.00	5.70	6.11	6.67	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	0.00

B-Table 5-5 Production Cost Accounting Table (Soft Loan Case : Ammonia)

<< Production Cost Accounting Table >> (Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Average
Operating Rate	-/-	-/-	-/-	-/-	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	98%
Production Volume (kt)	-/-	-/-	-/-	-/-	158.40	178.20	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	194.04
Operating Cost																				
Coal	-/-	-/-	-/-	-/-	2.66	2.99	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.26
Electricity	-/-	-/-	-/-	-/-	3.63	4.08	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.44
Catalyst & Chemicals	-/-	-/-	-/-	-/-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
By-product Subtraction	-/-	-/-	-/-	-/-	-0.48	-0.54	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.59
Labour	-/-	-/-	-/-	-/-	4.90	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.95
Overhead	-/-	-/-	-/-	-/-	4.90	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.95
Maintenance	-/-	-/-	-/-	-/-	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67
Insurance	-/-	-/-	-/-	-/-	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71
Total Operating Cost	-/-	-/-	-/-	-/-	22.01	20.69	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.41
Depreciation																				
Machinery & Equipment	-/-	-/-	-/-	-/-	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	0.00	0.00	0.00	0.00	0.00	13.78
Buiulding	-/-	-/-	-/-	-/-	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Preoperation Cost	-/-	-/-	-/-	-/-	1.79	1.79	1.79	1.79	1.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
Interest during Construction	-/-	-/-	-/-	-/-	2.82	2.82	2.82	2.82	2.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94
Total Depreciation	-/-	-/-	-/-	-/-	27.12	27.12	27.12	27.12	27.12	22.50	22.50	22.50	22.50	22.50	1.83	1.83	1.83	1.83	1.83	17.15
Financial Cost																				
Interest on L/T Loan	-/-	-/-	-/-	-/-	9.08	9.08	9.08	9.08	8.17	7.27	6.36	5.45	4.54	3.63	2.72	1.82	0.91	0.00	0.00	5.15
Interest on S/T Loan	-/-	-/-	-/-	-/-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Financial Cost	-/-	-/-	-/-	-/-	9.08	9.08	9.08	9.08	8.17	7.27	6.36	5.45	4.54	3.63	2.72	1.82	0.91	0.00	0.00	5.15
Total Production Cost	-/-	-/-	-/-	-/-	58.20	56.89	57.61	57.61	56.70	51.18	50.27	49.36	48.45	47.55	25.97	25.06	24.16	23.25	23.25	43.70
Unit Prod. Cost(US$/ton)	-/-	-/-	-/-	-/-	367.45	319.23	290.98	290.98	286.39	258.48	253.90	249.31	244.72	240.13	131.17	126.58	122.00	117.41	117.41	227.74

B-Table 5-6 Profit and Loss Statement (Soft Loan Case : Ammonia)

<< Profit and Loss Statement >> (Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Sales Revenue																				
Product-A	-/-	-/-	-/-	-/-	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	411.88
Product-B	-/-	-/-	-/-	-/-	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	110.12
Product-C	-/-	-/-	-/-	-/-	19.02	26.71	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	479.84
Total	-/-	-/-	-/-	-/-	53.82	61.51	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	1,001.85
Costs of Goods Sold	-/-	-/-	-/-	-/-	21.59	20.76	21.44	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.74	321.10
Initial Product Inventory	-/-	-/-	-/-	-/-	0.00	0.42	0.35	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	-/-
Operating Cost	-/-	-/-	-/-	-/-	22.01	20.69	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	321.10
Final Product Inventory	-/-	-/-	-/-	-/-	0.42	0.35	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.00	-/-
Depreciation	-/-	-/-	-/-	-/-	27.12	27.12	27.12	27.12	27.12	22.50	22.50	22.50	22.50	22.50	1.83	1.83	1.83	1.83	1.83	257.22
Financial Cost	-/-	-/-	-/-	-/-	9.08	9.08	9.08	9.08	8.17	7.27	6.36	5.45	4.54	3.63	2.72	1.82	0.91	0.00	0.00	77.20
Profit before Tax	-/-	-/-	-/-	-/-	-3.96	4.56	10.56	10.58	11.49	17.01	17.92	18.83	19.74	20.65	42.22	43.13	44.04	44.95	44.62	346.33
Income Tax	-/-	-/-	-/-	-/-	0.00	0.00	0.00	0.00	0.00	0.00	1.95	9.42	9.87	10.32	21.11	21.56	22.02	22.47	22.31	141.04
Profit after Tax	-/-	-/-	-/-	-/-	-3.96	4.56	10.56	10.58	11.49	17.01	15.97	9.42	9.87	10.32	21.11	21.56	22.02	22.47	22.31	205.29

B-Table 5-7 Cash Flow Table (Soft Loan Case : Ammonia)

<< Cash Flow Table >>

ROI(b/tax)=	12.5%	ROE(b/tax)=	22.3%	Payout Period(ROI):	6.2 years
ROI(a/tax)=	9.7%	ROE(a/tax)=	19.3%	Payout Period(ROE):	3.0 years

(Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Source of Funds																				
Profit after Tax	0.00	0.00	0.00	0.00	-3.96	4.56	10.56	10.58	11.49	17.01	15.97	9.42	9.87	10.32	21.11	21.56	22.02	22.47	22.31	205.29
Depreciation	0.00	0.00	0.00	0.00	27.12	27.12	27.12	27.12	27.12	22.50	22.50	22.50	22.50	22.50	1.83	1.83	1.83	1.83	1.83	257.22
Equity	0.16	21.90	45.01	24.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	91.96
Long-term Loan	0.36	48.25	93.88	39.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	181.65
Short-term Loan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Source	0.52	70.15	138.89	64.05	23.15	31.67	37.67	37.70	38.60	39.51	38.47	31.91	32.37	32.82	22.94	23.40	23.85	24.30	24.14	736.12
Application of Funds																				
Plant Investment	0.00	67.49	130.48	46.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	244.82
Pre-operation Cost	0.51	1.43	3.63	3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.97
Initial W/C	0.00	0.00	0.00	5.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.70
Interest during Construction	0.01	1.22	4.78	8.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.11
Working Capital Increase	0.00	0.00	0.00	0.00	0.41	0.56	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-7.18	-5.70
Repayment on L/T Loan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	0.00	0.00	181.65
Repayment on S/T Loan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Application	0.52	70.15	138.89	64.05	0.41	0.56	0.51	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	0.00	-7.18	449.56
Cash Surplus	0.00	0.00	0.00	0.00	22.74	31.12	37.16	19.53	20.44	21.35	20.30	13.75	14.20	14.66	4.78	5.23	5.69	24.30	31.33	286.56
Cum. Cash Surplus	0.00	0.00	0.00	0.00	22.74	53.85	91.01	110.54	130.98	152.33	172.63	186.38	200.58	215.24	220.02	225.25	230.93	255.24	286.56	-/-
Sulvage Value Return	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.69	10.69
Cash Flow(ROI b/tax)	-0.51	-68.93	-134.11	-55.95	31.82	40.20	46.24	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	46.78	64.32	437.64
Cash Flow(ROI a/tax)	-0.51	-68.93	-134.11	-55.95	31.82	40.20	46.24	46.78	46.78	39.15	34.64	34.64	34.64	34.64	24.30	24.30	24.30	24.30	42.01	269.25
Cash Flow(ROE b/tax)	-0.16	-21.90	-45.01	-24.89	22.74	31.12	37.16	19.53	20.44	21.35	22.26	23.16	24.07	24.98	25.89	26.80	27.70	46.78	64.32	346.33
Cash Flow(ROE a/tax)	-0.16	-21.90	-45.01	-24.89	22.74	31.12	37.16	19.53	20.44	21.35	20.30	13.75	14.20	14.66	4.78	5.23	5.69	24.30	42.01	205.29

B-Table 5-8 Balance Sheet (Soft Loan Case : Ammonia)

<< Balance Sheet >> (Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Current Assets																			
Cash	0.00	0.00	0.00	0.00	22.74	53.85	91.01	110.54	130.98	152.33	172.63	186.38	200.58	215.24	220.02	225.25	230.93	255.24	297.25
Working Capital	0.00	0.00	0.00	5.70	6.11	6.67	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	0.00
Total	0.00	0.00	0.00	5.70	28.85	60.53	98.20	117.73	138.17	159.51	179.82	193.56	207.77	222.42	227.20	232.43	238.12	262.42	297.25
Fixed Assets(Lesss Depr.)	0.52	70.67	209.55	267.91	240.79	213.68	186.56	159.45	132.33	109.84	87.34	64.84	42.34	19.84	18.01	16.18	14.35	12.52	0.00
Total Assets	0.52	70.67	209.55	273.61	269.65	274.20	284.76	277.18	270.50	269.35	267.15	258.40	250.11	242.27	245.21	248.61	252.47	274.94	297.25
Short-term Loan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long-term Loan	0.36	48.61	142.48	181.65	181.65	181.65	181.65	163.48	145.32	127.15	108.99	90.82	72.66	54.49	36.33	18.16	0.00	0.00	0.00
Shareholders' Equity																			
Capital	0.16	22.06	67.07	91.96	91.96	91.96	91.96	91.96	91.96	91.96	91.96	91.96	91.96	91.96	91.96	91.96	91.96	91.96	91.96
Retained Earning	0.00	0.00	0.00	0.00	-3.96	0.60	11.15	21.73	33.22	50.23	66.20	75.62	85.49	95.81	116.92	138.49	160.51	182.98	205.29
Total Equity	0.16	22.06	67.07	91.96	88.00	92.56	103.11	113.69	125.18	142.20	158.17	167.58	177.45	187.77	208.88	230.45	252.47	274.94	297.25
Total	0.52	70.67	209.55	273.61	269.65	274.20	284.76	277.18	270.50	269.35	267.15	258.40	250.11	242.27	245.21	248.61	252.47	274.94	297.25

<< Working Capital Table >>

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Current Assets																			
Cash	0.00	0.00	0.00	4.64	0.32	0.32	0.32	0.32	0.32	0.32	0.32	[illegible]	0.32	0.32	0.32	0.32	0.32	0.32	0.00
Raw Material Inventory	0.00	0.00	0.00	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.00
Product Inventory	0.00	0.00	0.00	0.00	0.42	0.35	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.00
Catalysts & Chemicals	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
Account Receivable	0.00	0.00	0.00	0.00	4.89	5.59	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	0.00
Total	0.00	0.00	0.00	5.70	6.68	7.32	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	0.00
Current Liabilities																			
Account Payable	0.00	0.00	0.00	0.00	0.57	0.64	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.00
Total Working Capital	0.00	0.00	0.00	5.70	6.11	6.67	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	0.00

B-Table 5-9 Production Cost Accounting Table (Decreased Operating Rate Case : Ammonia)

<< Production Cost Accounting Table >> (Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Average
Operating Rate	-/-	-/-	-/-	-/-	60%	70%	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	93%
Production Volume (kt)	-/-	-/-	-/-	-/-	118.80	138.60	158.40	178.20	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	184.80
Operating Cost																				
Coal	-/-	-/-	-/-	-/-	2.00	2.33	2.66	2.99	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.11
Electricity	-/-	-/-	-/-	-/-	2.72	3.17	3.63	4.08	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.23
Catalyst & Chemicals	-/-	-/-	-/-	-/-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
By-product Subtraction	-/-	-/-	-/-	-/-	-0.36	-0.42	-0.48	-0.54	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.60	-0.56
Labour	-/-	-/-	-/-	-/-	4.90	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.95
Overhead	-/-	-/-	-/-	-/-	4.90	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.95
Maintenance	-/-	-/-	-/-	-/-	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67
Insurance	-/-	-/-	-/-	-/-	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71
Total Operating Cost	-/-	-/-	-/-	-/-	20.55	19.24	19.96	20.69	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.07
Depreciation																				
Machinery & Equipment	-/-	-/-	-/-	-/-	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	20.67	0.00	0.00	0.00	0.00	0.00	13.78
Buiulding	-/-	-/-	-/-	-/-	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Preoperation Cost	-/-	-/-	-/-	-/-	1.79	1.79	1.79	1.79	1.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
Interest during Construction	-/-	-/-	-/-	-/-	5.65	5.65	5.65	5.65	5.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.88
Total Depreciation	-/-	-/-	-/-	-/-	29.94	29.94	29.94	29.94	29.94	22.50	22.50	22.50	22.50	22.50	1.83	1.83	1.83	1.83	1.83	18.09
Financial Cost																				
Interest on L/T Loan	-/-	-/-	-/-	-/-	18.16	16.35	14.53	12.72	10.90	9.08	7.27	5.45	3.63	1.82	0.00	0.00	0.00	0.00	0.00	6.66
Interest on S/T Loan	-/-	-/-	-/-	-/-	0.00	2.30	3.58	3.87	3.04	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91
Total Financial Cost	-/-	-/-	-/-	-/-	18.16	18.65	18.11	16.59	13.94	10.00	7.27	5.45	3.63	1.82	0.00	0.00	0.00	0.00	0.00	7.57
Total Production Cost	-/-	-/-	-/-	-/-	68.66	67.82	68.01	67.21	65.29	53.91	51.18	49.36	47.55	45.73	23.25	23.25	23.25	23.25	23.25	46.73
Unit Prod. Cost(US$/ton)	-/-	-/-	-/-	-/-	577.92	489.35	429.37	377.18	329.76	272.30	258.48	249.31	240.13	230.96	117.41	117.41	117.41	117.41	117.41	269.45

B-Table 5-10 Profit and Loss Statement (Decreased Operating Rate Case : Ammonia)

<< Profit and Loss Statement >> (Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Sales Revenue																				
Product-A	-/-	-/-	-/-	-/-	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	27.46	411.88
Product-B	-/-	-/-	-/-	-/-	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	110.12
Product-C	-/-	-/-	-/-	-/-	5.67	13.36	20.04	26.71	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39	433.09
Total	-/-	-/-	-/-	-/-	40.47	48.16	54.84	61.51	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	68.19	955.10
Costs of Goods Sold	-/-	-/-	-/-	-/-	20.04	19.34	20.00	20.72	21.44	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.74	316.01
Initial Product Inventory	-/-	-/-	-/-	-/-	0.00	0.52	0.42	0.38	0.35	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	-/-
Operating Cost	-/-	-/-	-/-	-/-	20.55	19.24	19.96	20.69	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	21.42	316.01
Final Product Inventory	-/-	-/-	-/-	-/-	0.52	0.42	0.38	0.35	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.00	-/-
Depreciation	-/-	-/-	-/-	-/-	29.94	29.94	29.94	29.94	29.94	22.50	22.50	22.50	22.50	22.50	1.83	1.83	1.83	1.83	1.83	271.34
Financial Cost	-/-	-/-	-/-	-/-	18.16	18.65	18.11	16.59	13.94	10.00	7.27	5.45	3.63	1.82	0.00	0.00	0.00	0.00	0.00	113.61
Profit before Tax	-/-	-/-	-/-	-/-	-27.67	-19.77	-13.21	-5.73	2.88	14.28	17.01	18.83	20.65	22.46	44.95	44.95	44.95	44.95	44.62	254.13
Income Tax	-/-	-/-	-/-	-/-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06	11.23	22.47	22.47	22.47	22.47	22.31	124.50
Profit after Tax	-/-	-/-	-/-	-/-	-27.67	-19.77	-13.21	-5.73	2.88	14.28	17.01	18.83	19.59	11.23	22.47	22.47	22.47	22.47	22.31	129.64

B-Table 5-11 Cash Flow Table (Decreased Operating Rate Case : Ammonia)

<< Cash Flow Table >>

ROI(b/tax)=	10.9%	ROE(b/tax)=	10.5%	Payout Period(ROI):	7.2 years
ROI(a/tax)=	8.2%	ROE(a/tax)=	7.0%	Payout Period(ROE):	10.4 years

(Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Source of Funds																				
Profit after Tax	0.00	0.00	0.00	0.00	-27.67	-19.77	-13.21	-5.73	2.88	14.28	17.01	18.83	19.59	11.23	22.47	22.47	22.47	22.47	22.31	129.64
Depreciation	0.00	0.00	0.00	0.00	29.94	29.94	29.94	29.94	29.94	22.50	22.50	22.50	22.50	22.50	1.83	1.83	1.83	1.83	1.83	271.34
Equity	0.17	23.13	49.79	32.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	106.08
Long-term Loan	0.36	48.25	93.88	39.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	181.65
Short-term Loan	0.00	0.00	0.00	0.00	15.34	23.86	25.80	20.26	6.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	91.39
Total Source	0.53	71.37	143.66	72.16	17.61	34.03	42.53	44.47	38.94	36.78	39.51	41.33	42.08	33.73	24.30	24.30	24.30	24.30	24.14	780.09
Application of Funds																				
Plant Investment	0.00	67.49	130.48	46.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	244.82
Pre-operation Cost	0.51	1.43	3.63	3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.97
Initial W/C	0.00	0.00	0.00	5.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.70
Interest during Construction	0.02	2.45	9.55	16.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.23
Working Capital Increase	0.00	0.00	0.00	0.00	-0.56	0.52	0.50	0.51	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-7.18	-5.70
Repayment on L/T Loan	0.00	0.00	0.00	0.00	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	18.16	0.00	0.00	0.00	0.00	0.00	181.65
Repayment on S/T Loan	0.00	0.00	0.00	0.00	0.00	15.34	23.86	25.80	20.26	6.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	91.39
Total Application	0.53	71.37	143.66	72.16	17.61	34.03	42.53	44.47	38.94	24.29	18.16	18.16	18.16	18.16	0.00	0.00	0.00	0.00	-7.18	555.06
Cash Surplus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.49	21.35	23.16	23.92	15.56	24.30	24.30	24.30	24.30	31.33	225.03
Cum. Cash Surplus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.49	33.84	57.00	80.92	96.48	120.79	145.09	169.40	193.70	225.03	-/-
Sulvage Value Return	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.69	10.69

B-Table 5-12 Balance Sheet (Decreased Operating Rate Case : Ammonia)

<< Balance Sheet >>

(Unit:Million US$)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Current Assets																			
Cash	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.49	33.84	57.00	80.92	96.48	120.79	145.09	169.40	193.70	235.71
Working Capital	0.00	0.00	0.00	5.70	5.14	5.67	6.17	6.67	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	0.00
Total	0.00	0.00	0.00	5.70	5.14	5.67	6.17	6.67	7.18	19.67	41.02	64.18	88.10	103.67	127.97	152.28	176.58	200.88	235.71
Fixed Assets(Lesss Depr.)	0.53	71.90	215.56	282.02	252.09	222.15	192.21	162.27	132.33	109.84	87.34	64.84	42.34	19.84	18.01	16.18	14.35	12.52	0.00
Total Assets	0.53	71.90	215.56	287.72	257.23	227.82	198.38	168.94	139.52	129.51	128.36	129.02	130.44	123.51	145.98	168.46	190.93	213.40	235.71
Short-term Loan	0.00	0.00	0.00	0.00	15.34	23.86	25.80	20.26	6.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long-term Loan	0.36	48.61	142.48	181.65	163.48	145.32	127.15	108.99	90.82	72.66	54.49	36.33	18.16	0.00	0.00	0.00	0.00	0.00	0.00
Shareholders' Equity																			
Capital	0.17	23.30	73.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08	106.08
Retained Earning	0.00	0.00	0.00	0.00	-27.67	-47.44	-60.65	-66.38	-63.50	-49.23	-32.21	-13.38	6.20	17.43	39.91	62.38	84.85	107.33	129.64
Total Equity	0.17	23.30	73.08	106.08	78.40	58.64	45.42	39.69	42.57	56.85	73.86	92.69	112.28	123.51	145.98	168.46	190.93	213.40	235.71
Total	0.53	71.90	215.56	287.72	257.23	227.82	198.38	168.94	139.52	129.51	128.36	129.02	130.44	123.51	145.98	168.46	190.93	213.40	235.71

<< Working Capital Table >>

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Current Assets																			
Cash	0.00	0.00	0.00	4.64	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.00
Raw Material Inventory	0.00	0.00	0.00	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.00
Product Inventory	0.00	0.00	0.00	0.00	0.52	0.42	0.38	0.35	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.00
Catalysts & Chemicals	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
Account Receivable	0.00	0.00	0.00	0.00	3.68	4.38	4.99	5.59	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	6.20	0.00
Total	0.00	0.00	0.00	5.70	5.57	6.17	6.74	7.32	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	0.00
Current Liabilities																			
Account Payable	0.00	0.00	0.00	0.00	0.43	0.50	0.57	0.64	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.00
Total Working Capital	0.00	0.00	0.00	5.70	5.14	5.67	6.17	6.67	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	7.18	0.00

Chapter 6 Economic Analysis

Ammonia Project

Chapter 6 Economic Analysis

6.1 General

A financial analysis of the project was provided in the previous chapter, and the next important step is to evaluate what economic impact the project will have on a national level. In other words, it is important to evaluate how the project contributes to Zimbabwe's entire economy by producing ammonia with coal from WANKIE.

The economic analysis in this chapter is comprised of quantitative and qualitative analyses. The quantitative analysis in this study consists of evaluating the project by the calculation of Economic Internal Rate of Return (EIRR) and of Foreign Currency Saving. In addition, benefits are also evaluated by qualitative analysis.

6.2 Quantitative Analysis

6.2.1 Economic Internal Rate of Return (EIRR)

There are two typical economic analysis methods such as:

- Little & Mirrlees Method
- UNIDO Method

In this study, EIRR is calculated mainly utilizing the theory developed by UNIDO.

In the EIRR calculation, the financial prices used to estimate the project's costs and revenues are converted to economic prices. Economic prices for the project costs are estimated by excluding all transfer items such as taxes, customs duties, and interest payments, by calculating labour cost at its opportunity cost and by adjusting the foreign currency portion using the shadow exchange rate (SER). The product prices used to estimate project benefits are adjusted to reflect opportunity price. In other words, the benefits are adjusted to reflect SER and border price.

(1) Conversion to economic price

1) Customs duties and import taxes

All payments for customs duties and import taxes are excluded from the cost of imported goods as well as from the estimated import component of local goods for the conversion to economic price. As import tax of the imported materials for the plant construction are exempted, tax adjustment for these materials are not made, however, the import content of local goods should be adjusted. Imported goods are subject to an average duty of 20 percent. The import component of local goods is estimated at 30 percent. Thus, an effective customs duty of 6 percent is deducted from the cost of local goods.

2) Corporate income tax

As corporate income tax is one type of transfer payment, this tax is not included in the economic cost.

3) Interest payment

All interest payments including interest during construction, interest on loans, and all interest charges are excluded from the economic cost.

4) Insurance

The payments for insurance are regarded as transfer payments and are not included in the economic cost.

5) Foreign currency exchange rate

Since the EIRR calculation is based on the domestic currency, the project's net economic value should be adjusted by an appropriate foreign exchange premium higher or lower than indicated by the official exchange rate. The following formula is a typical approach generally used to obtain a shadow exchange rate (SER).

$$SER/OER = \frac{IMP\ (1 + Tax^{imp} + TQ^{imp}) + EX\ (1 - Tax^{ex})}{IMP + EX}$$

SER = Shadow exchange rate

OER = Official exchange rate

IMP = C.I.F. value of import

EX = F.O.B. value of export

Tax^{imp} = Weighted average of import tax rate

TQ^{imp} = Import tax rate equivalent to import restriction value

Tax^{ex} = Weighted average of export tax rate

The available data for estimating SER was the Standard Factor Cost (SFC) in Zimbabwe, and the SFC was reported to be 0.8 or 0.82 according to a report compiled in MIT.

SFC is defined by the formula as shown below.

$$SFC = \frac{IMP + EX}{IMP\ (1 + Tax^{imp} + TQ^{imp}) + EX\ (1 - Tax^{ex})}$$

It can be noted that the SER/OER is a reciprocal formula of the SFC. Consequently, the SER/OER is 1.25 in case that the SFC is 0.8. Accordingly, the SER/OER is specified at 1.25 in this economic analysis.

6) Wage

There is considerable unemployment of unskilled labour but a shortage of various types of skilled labour in Zimbabwe at the present time.

The project will hire skilled labour (labour with moderate education) and some unskilled labour. One major effect this project will have on the economy is the hiring of previously unemployed or unskilled labour. According to the wage situation of unskilled labour in the rural area around the plant site of the project, it could be assumed that unskilled labour to be employed as unskilled workers for the plant construction, janitors of the plant would receive shadow wage rate of 0.3 of the market wages applied to the project.

This rate is also adopted in a paper of the Ministry of Energy and Water Resources.

On the other hand, the shadow wage for skilled labour is estimated at equal to or more than 1. In this analysis, the shadow wage rate for skilled labor is specified as 1.

(2) Economic benefit and cost

The following economic benefits and costs are identified in calculation of EIRR.

Economic benefits:
  Direct benefits

Economic costs:
  Investment costs
  Operation costs

1) Direct economic benefit

The direct benefits of the project are the economic value of ammonia and by-product sulphur.

Table III-6-1 lists these value for periods of full production. The economic prices are the fertilizer prices at the border of Zimbabwe and are adjusted by use of a SER/OER, which in this case is specified as 1.25.

Table III-6-1 Direct Benefit

	Sales	Economic Price					Economic Value
	(T/Y)	(US$/T)		(Z$/US$)		(*1)	(Million Z$)
Ammonia	198,000	266.1*2	x	1.8	x	1.25	118.5
Sulphur	5,973	100.0*3	x	1.8	x	1.25	1.3
Total							119.8

Note: *1 Shadow Exchange Rate (SER)
*2 Ammonia Border Price (Estimated CIF Price)
*3 Sulphur International Price

	Ammonia border Price
FOB price	175.0
Freight	30.0
Railage	44.4
Others	16.7
	US$ 266.1/T

2) Economic investment cost

Economic investment costs include costs for construction of the fertilizer plant and pre-operating costs, etc. These costs were calculated using the financial investment costs of the previous chapter adjusted by the SER/OER of 1.25 for foreign currency portion, and by 10% deduction from domestic currency portion as the portion of shadow wage of unskilled labour, customs duty included in import content of local goods.

3) Economic operation cost

Operation costs include such items as raw materials, utilities, catalysts and chemicals costs, as well as the costs of labour, maintenance and overhead. Interest and loan repayments are not included in the economic analysis. The economic costs of imported materials are derived by multiplying the foreign costs by the shadow exchange rate. As personnel required for plant operation must be skilled labour, the shadow price is not used for operator costs; however, a 0.3 shadow price is applied to unskilled labour. Furthermore, 20% of maintenance costs are estimated to be domestic procurement. 30% of which, that is 6% should be deducted from the costs regarded as custom duty portion of import component of domestic goods. The balance 80% is foreign procurement which is adjusted using a shadow exchange rate.

Table III-6-2 Economic Benefits and Costs

NH3

EIRR= 11.5% (Unit:Million Z$)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Economic Benefit																				
Ammonia	0.00	0.00	0.00	0.00	94.84	106.69	118.55	118.55	118.55	118.55	118.55	118.55	118.55	118.55	118.55	118.55	118.55	118.55	118.55	1742.65
Sulfur	0.00	0.00	0.00	0.00	1.08	1.21	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	19.76
Total Economic Benefit	0.00	0.00	0.00	0.00	95.91	107.90	119.89	119.89	119.89	119.89	119.89	119.89	119.89	119.89	119.89	119.89	119.89	119.89	119.89	1762.40
Economic Cost																				
Investment	1.08	144.88	248.69	87.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	481.93
Coal	0.00	0.00	0.00	0.00	4.79	5.39	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	88.05
Electricity	0.00	0.00	0.00	0.00	6.53	7.34	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	119.95
Catalysts & Chemicals	0.00	0.00	0.00	0.00	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	33.75
Labour	0.00	0.00	0.00	0.00	9.16	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	105.24
Overhead	0.00	0.00	0.00	0.00	9.16	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	6.86	105.24
Maintenance	0.00	0.00	0.00	0.00	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	104.84
Total Economic Cost	1.08	144.88	248.69	87.28	38.88	35.70	37.11	37.11	37.11	37.11	37.11	37.11	37.11	37.11	37.11	37.11	37.11	37.11	37.11	1039.01
Balance	-1.08	-144.88	-248.69	-87.28	57.03	72.20	82.78	82.78	82.78	82.78	82.78	82.78	82.78	82.78	82.78	82.78	82.78	82.78	82.78	723.40

(3) Results of calculation of EIRR

Economic internal rate of return is calculated from economic benefits and costs as explained in the previous section. Table III-6-2 lists economic benefits and costs of plant operation. EIRR is calculated from this table as a base case, then recalculated to analyze sensitivity by applying 10% increase and decrease in economic benefits and costs. The results of these calculations are shown in Table III-6-3.

Table III-6-3 EIRR

Unit: %

Base Case		11.5
Economic Benefits	+10% -10%	13.6 9.2
Economic Costs	+10% -10%	9.5 13.9

According to guidelines provided by various international organizations, the cut-off rate of EIRR varies according to the type of project, but is often specified in a range between 8 and 12% for the industrial project. The EIRR of base case shows 11.5%.

6.2.2 Effect on Foreign Currency Balance of Payment

The effects on the balance of payment resulted from the implementation of this project are analysed.

Since analysis is based on 1988 constant price, the effects of inflation are excluded. In this analysis, the present ammonia import (100T/D) by SABLE is assumed to be replaced by the ammonia of the project, however, as a reference case, the study is made on the effect on balance of payment resulted from the assumption that ammonia consumption (300T/D) by SABLE will be imported and replaced by the ammonia of the project.

(1) Foreign Currency Outflow

1) Foreign currency outflow during construction

Foreign currency portion in the total capital requirements is covered by the long-term loan. Thus the foreign currency inflow of loan received initially will be payed out again as the payments for plant construction cost, leaving the debt. It should noted that the foreign currency portion of capital requirements which are not covered by foreign loan are covered by equity, therefore these amounts are regared as foreign currency outflow.

2) Foreign currency outflow during operation

During operation, foreign currency will be required for part of the operation costs such as catalysts, chemicals, foreign advisors and 80% of maintenance costs, and for interest and repayment on the long-term loan.

(2) Foreign Currency Savings

Foreign currency saving is defined as foreign currency inflow minus foreign currency outflow. The former is obtained by border unit price of each fertilizer produced multiplied by quantity of each fertilizer. The latter is equal to foreign currency payment as described above. According to calculation, as can be seen in Table III-6-4, US$ 146 million of foreign currency saving is expected.

(3) In case that ammonia (300T/D) is assumed to be replaced

According to calculation as can be seen in Table III-6-5, US$ 407 million of foreign currency saving is expected in case that 300T/D of ammonia, which is consumed to produce ammonium nitrate by SABLE, is assumed to be imported and to be replaced by the ammonia of the project.

6.3 Qualitative Analysis

In addition to direct benefits quantatively shown in terms of economic internal rate of return and foreign currency saving, the following benefits are expected by the implementation of the project.

6.3.1 Mining

In 1986, the percentage of the mining sector to GDP (8,232 million Z$) was 6.9%, and the amount is Z$571 million . The average annual growth rate in constant price base from 1981 to 1986 was 1.1%.

Table III-6-4 Foreign Currency Saving

NH3

<< Base Case >>

Total Foreign Currency Saving : 145.96 Million US$ (Unit:Million US$)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Foreign Currency Saving																				
Ammonia	0.00	0.00	0.00	0.00	28.10	31.61	35.13	35.13	35.13	35.13	35.13	35.13	35.13	35.13	35.13	35.13	35.13	35.13	35.13	516.34
Sulfur	0.00	0.00	0.00	0.00	0.32	0.36	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	5.85
Total	0.00	0.00	0.00	0.00	28.42	31.97	35.52	35.52	35.52	35.52	35.52	35.52	35.52	35.52	35.52	35.52	35.52	35.52	35.52	522.19
Outflow of Foreign Currency																				
Interest during Const.	0.02	3.11	10.92	17.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.09
Catalysts & Chemicals	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	15.00
Labour	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92
Maintenance	0.00	0.00	0.00	0.00	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	44.04
Interest on L/T Loan	0.00	0.00	0.00	0.00	18.40	16.56	14.72	12.88	11.04	9.20	7.36	5.52	3.68	1.84	0.00	0.00	0.00	0.00	0.00	101.19
Repayment on L/T Loan	0.00	0.00	0.00	0.00	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	0.00	0.00	0.00	0.00	0.00	183.99
Total	0.02	3.11	10.92	17.03	41.65	38.89	37.05	35.21	33.37	31.53	29.69	27.85	26.01	24.17	3.94	3.94	3.94	3.94	3.94	376.23
Foreign Currency Balance	-0.02	-3.11	-10.92	-17.03	-13.23	-6.92	-1.53	0.31	2.15	3.99	5.83	7.67	9.51	11.35	31.59	31.59	31.59	31.59	31.59	145.96

Table III-6-5 Foreign Currency Saving

NH3

<< Reference Case >>

Total Foreign Currency Saving : 407.06 Million US$ (Unit:Million US$)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Foreign Currency Saving																				
Ammonia	0.00	0.00	0.00	0.00	42.15	47.42	52.69	52.69	52.69	52.69	52.69	52.69	52.69	52.69	52.69	52.69	52.69	52.69	52.69	774.51
Sulfur	0.00	0.00	0.00	0.00	0.48	0.54	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	8.78
Total	0.00	0.00	0.00	0.00	42.63	47.96	53.29	53.29	53.29	53.29	53.29	53.29	53.29	53.29	53.29	53.29	53.29	53.29	53.29	783.29
Outflow of Foreign Currency																				
Interest during Const.	0.02	3.11	10.92	17.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.09
Catalysts & Chemicals	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	15.00
Labour	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92
Maintenance	0.00	0.00	0.00	0.00	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	44.04
Interest on L/T Loan	0.00	0.00	0.00	0.00	18.40	16.56	14.72	12.88	11.04	9.20	7.36	5.52	3.68	1.84	0.00	0.00	0.00	0.00	0.00	101.19
Repayment on L/T Loan	0.00	0.00	0.00	0.00	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	18.40	0.00	0.00	0.00	0.00	0.00	183.99
Total	0.02	3.11	10.92	17.03	41.65	38.89	37.05	35.21	33.37	31.53	29.69	27.85	26.01	24.17	3.94	3.94	3.94	3.94	3.94	376.23
Foreign Currency Balance	-0.02	-3.11	-10.92	-17.03	0.97	9.06	16.23	18.07	19.91	21.75	23.59	25.43	27.27	29.11	49.35	49.35	49.35	49.35	49.35	407.06

Coal production which was 2.9 million tonnes in 1981 achieved a of 4.0 million tonnes in 1986; the amount in 1986 reached Z$ 89.1 million at current price base, 12.7% of the amount for all mining production.

There are 10,571 million tonnes of coal reserves in Zimbabwe, 2,000 million tonnes of which are estimated as available by open-cast mining. WANKIE is the only company currently producing and suppling coal and therefore the coal sold by WANKIE is Zimbabwe's demand of coal. The reserve of WANKIE coal is 655 million tonnes, 325 million tonnes of which are estimated as available by open-cast mining.

The coal that WANKIE distributes at present can be broadly categorized as fuel coal for Hwange thermal power station and coal for other uses; coal to the power station amounts to 2,400,000 T/Y; that for other uses, 2,400,000 T/Y, coming to a total of 4,800,000 T/Y. The quantity of coal required by the project is approx. 240,000 T/Y, and it is considered that WANKIE is estimated to be capable of increasing its production without making a large investment.

The price of coal is controlled under an agreement with the government and the coal for use by the project is estimated Z$ 25/T. This price was established in 1985 and has not been changed since; however, increasing it is necessary in view of inflation and other reasons, and at present an approx. 10% increase is being negotiated.

Implementation of this project is expected to increase the coal production amount to an equivalent of approximately Z$6 million and contribute significantly to the growth of the mining sector, especially the coal industry.

This project is, therefore, evaluated as one of the projects which utilizes domestic resources, particularly domestic coal.

6.3.2 Energy

In 1986, the percentage of electric power and water-resources sector to GDP (Z$ 8,232 million) was 5.6%, amounting to Z$ 463 million. The average annual growth rate in constant price base from 1981 to 1986 was 8.7%.

Moreover, electric power consumption which was 7.5×10^9 kWh in 1981, reached 8.5×10^9 kWh in 1986.

The electric power of Zimbabwe has been supplied by Kariba South hydroelectric power station and Zambia's hydroelectric power station with relatively low generation costs. As a result of increased power demend in recent years and an aim to decrease dependency on foreign nations for electric power, however, a large-scale thermal power station was installed in Hwange and the relative importance of thermal power generation is gradually being raised. Because of its location in an open-cast mining field, Hwange power station can obtain coal at low price and thus has been able to hold the unit cost of power generation to a low level. A calculation of the charge for industrial power is, for example, Z¢ 4.92/kWh (US¢ 2.73/kWh).

The present power demand is approx. 1,300 MW and is forecasted to grow at an annual rate of about 3.5% in the future. Consequently, ZESA is considering plans to renovate existing small scale power stations, to modernize and expand Kariba South power station, and to expand Hwange power station. The burden of capital cost increase resulting from expansions of thermal power stations and future increases in coal costs having effects on future power generation costs are, however, viewed inevitable.

The industry which currently consumes a large proportion of power is SABLE in Kwekwe. SABLE produces ammonia using water electrolysis process. If this project is realized and SABLE stops the operation of the ammonia plant, about 90 of electricity will be saved which will improve vastly power supply capacity in Zimbabwe. In the case of installing a 100 MW coal thermal power plant, the US$ 150 million investment is estimated necessary. By the realization of this project, this ammount of investment will be saved, and large economic benefits will be expected.

Also, Kwekwe area, which is distant from both of the major power stations, located in the Hwange and Kariba respectively, is receiving power by powerful 330 KV transmission lines. However, as the power demand is large, new demand would not be met without additional installations of transmission lines and substations. Therefore, the termination of ammonia production by water electrolysis and the saving of 100 MW of power in this area, resulted from the implementation of this project, not only will save investment in construction of a new power plant but also that of facilities for power transmission. The benefits by this would be substantial.

6.3.3 Transportation

In 1986, the percentage of the transportation sector to GDP (Z$ 8,232 million) was 5.7%, amounting to Z$ 467 million. The average annual growth rate in constant price base from 1981 to 1986 was 1.6%. Moreover, the revenue of the transportation sector which was Z$ 162 million in 1981 reached Z$ 263 million in 1986, and the percentage of revenue in the railways portion was approximately 95% of the total of the sector.

The economic effects for Zimbabwe furnished by this project in terms of transportation are the transportation of machinery and equipment at the time of plant construction, and the transportation of fertilizer after the start of plant operation. The major cities of Zimbabwe are connected by two-lane automobile roads that are paved with asphalt and are well-maintained; these roads are connected to roads outside the nation. Heavy and long products can be transported using these roads. The effects that the transportation of plant machinery and equipment have on Zimbabwe's economy are only during the construction of the plant and cannot be considered very large.

The number of automobiles is small and since long-distant transportation is mostly by rail, transportation by truck is relatively rare. Roads are not in bad condition though most of the roads pass through the downtown districts of cities and have not been provided with by-pass roads or other roads. Consequently, the long-distance transportation of raw materials and products will be by rail as commonly practiced.

In the case the plant is to be constructed in Hwange and is to produce ammonia, it would be necessary to transport, at least, 300T/D ammonia out of 600T/D production between Hwange and Kwekwe. Since transportaion between Hwange and Kwekwe takes 16 hr one-way, the period of transportation is considered to be two days. Therefore, 24 ammonia-tank cars each with 25.5 t capacity are required; these comprise the two additional trains required in this project. If the above cars as well as two additional locomotives are provided to supplement the trains that already exist, there would be no problems with respect to line capacity.

The transportation cost of fertilizer is; ammonia (Hwange-Kwekwe): Z$ 32.51/T; urea (Hwange-Kwekwe): Z$ 35.23/T; approx. Z$ 3.2 million of annual transportation revenue would be an economic effect resulting from the implementation of this project. The additional revenues will be expected in case that nitrogenous fertilizer produced from another 300T/D of ammonia is transported by rail.

6.3.4 Agriculture

Agriculture in Zimbabwe contributes to the nation substantially as a key industry that supplies food for citizens and obtains foreign currency. In 1986, the percentage of the agricultural sector to GDP (Z$ 8,232 million) was 11.4%, amounting to Z$ 935 million. The average annual growth rate in constant price base from 1981 to 1986 was 1.3%. Moreover, agricultural production which was Z$ 1,021 million in 1981 reached Z$ 1,927 million in 1985; and communal farming, although it accounts for 49% of agricultural land area, had produced 32% of total production amount.

The factors affecting agricultural production consists of such matters as soil, climatic condition, configuration of land ownership, kind and variety of crop, fertilizers and other inputs and agricultural financing. Fertilizer is one factor for increasing agricultural production. For the promotion of agriculture in the future, therefore, the demand of fertilizer is expected to grow significantly.

The implementation of this project is for supplying all the demand of ammonia with domestically produced ammonia, and is expected to contribute especially to agriculture by the stable supply of fertilizer produced using domestic ammonia.

6.3.5 Pollution

The land in Hwange which the plant would be installed is a vast land in the vicinity of WANKIE coal field, distant from residential areas; a large-scale thermal power plant fired solely by coal and WANKIE's facilities are located on this area. Although the land can be considered an appropriate industrial area, since it is in the interior and in order to support the development of Hwange area as a major industrial area based upon coal, measures for preventing pollution are essential to the implementation of this project.

Particular caution for the treatment of exhaust gas, effluent, and refuse solids is needed. In consideration of treating respective pollutants - namely: sulphur in exhaust gases; wast water from the cooling tower and water from the ash treatment facility in the gasification section; and the treatment of coal sludge from the ash treatment facility - standards of industrially advanced nations will be referred to in the designing and installation of the plant so that the adverse effects of implementing this project can be held to a minimum.

6.3.6 Others

Other economic effects such as the increase of employment opportunity, and effects to related industries can be expected.

Annex (Minutes)

Annex

SCOPE OF WORK

FOR

THE FEASIBILITY STUDY

ON

THE ESTABLISHMENT OF AN AMMONIA PLANT

IN

THE REPUBLIC OF ZIMBABWE

AGREED UPON BETWEEN

MINISTRY OF INDUSTRY AND TECHNOLOGY

AND

THE JAPAN INTERNATIONAL COOPERATION AGENCY

Harare , February 15th 1988

Mr. S. Geza
Permanent Secretary
Ministry of Industry
and Technology

Mr KAZUO ISHII
Leader of the Preliminary
Survey Team,
The Japan International
Cooperation Agency

I. Introduction

In response to the request of the Government of the Republic of Zimbabwe (hereinafter referred to as "Zimbabwe"), the Government of Japan has decided to conduct a feasibility study on the establishment of an ammonia plant in the Republic of Zimbabwe (hereinafter referred to as "the Study") in accordance with the laws and regulations in force in Japan. The Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, will undertake the Study, in close cooperation with authorities concerned of the Government of Zimbabwe.

The present document sets forth the scope of work with regard to the Study.

II. The Objective of the Study

The objective of the study is to investigate and compare the technical and economic feasibility in Zimbabwe of processing coal to :-

1. Ammonia only
2. Ammonia and urea
3. Ammonia from cokegas, and coal tar.
4. Ammonia and methanol.

(The above products are to be referred hereinafter as ammonia and co-products).

III. Scope of the Study

In order to achieve the above objectives, the Study will cover the following items:

1. General survey on the background of the Project

1-1 To review present social and economic conditions in Zimbabwe -

(1) Economic growth
(2) Economic structure
(3) Employment conditions
(4) Standards of wage and salary
(5) Import and export balance
(6) Balance of payments
(7) Movement of prices.

1-2. To review five year plan in force in Zimbabwe

1-3. To review relevant laws and regulations

2. Study on market of ammonia and co-products

2-1. To review worldwide supply and demand and price movement of ammonia and co-products

2-2. To review present situation of and policy on ammonia and co-products in Zimbabwe

(1) Ammonia and co-products industry
(2) Supply and demand of ammonia and co-products
(3) Prices of ammonia and co-products
(4) Distribution system and cost

2-3. To review previous studies and/or plans on the supply and demand of ammonia and co-products

2-4 To evaluate factors which determine consumption of ammonia and co-products

2-5 To forecast domestic demand of ammonia and co-products for coming ten years

3. Study on raw materials and utilities

3-1 Coal

(1) Distribution of coal mines
(2) Estimated amounts of coal in each mine
(3) Annual production and price
(4) Quality

(5) Consumption pattern of coal and its trend

(6) Future development plan

3-2 Electric power

(1) Distribution of power plants and their processes and capacities

(2) Supply and demand

(3) Price

(4) Distribution system in work

3-3 Industrial water

3-4 Others

4. Study on plant location and site

Hwange and Kwekwe will be studied as candidate plant locations

4-1 To review previous study reports and/or data of natural conditions at the candidate sites

(1) Meteorology

(2) Geology and topography

4-2 To investigate public policies and socio-economic conditions

(1) Existing regional industries

(2) Availability and sufficiency of labour, including managerial, professional, technical and skilled manpower for the construction and operation of the plant

(3) Relevant public policies and regional development plan

4-3 To investigate infrastructure and utilities

(1) Availability and sufficiency of infrastructure and utilities to set up a plant, transport the materials, operate the plant, and distribute the products

4-4 To select a plant location and site taking into consideration the following matters

(1) Availability of raw materials and utilities
(2) Proximity of principal markets
(3) Existence of basic infrastructure facilities
(4) Other conditions as studied in the above item 4-1,2 and 3

5. Preparation of basic plans and conceptual designs of plants

5-1 To determine the optimum production scheme and scale based on demand of ammonia and co-products, availability of raw materials and utilities, and technology and equipment

5-2 To provide conditions for design of the plants

5-3 To provide conceptual design with process flow-sheet and plot plan

5-4 To provide material balance and utility balance

5-5 To propose procurement and transportation plan of equipment and materials for plant construction

5-6 To estimate construction cost of proposed plants.

5-7 To prepare implementation programme of plant construction

5-8 To prepare operation programme on a commercial basis

5-9 To propose operation and management organization and manpower

6. Financial analysis and economic evaluation

6-1 To provide premises of calculation such as capital requirements, procurement of capital, production programme, sales amount, material costs, wages of employees, and depreciation method

6-2 To provide cash flow and financial internal rates of return

6-3 To provide profit/loss statement and balance sheet

6-4 To provide sensitivity analysis in accordance with changes in the parameters of the premises

6-5 To provide economic effects to the national economy, including direct and indirect effects on other sectors of the economy such as mining, energy, transport, agriculture, and finance as well as social and environmental effects.

7. Conclusion and recommendations

IV. Steps and Schedule of the Study

1. Steps

Step 1 : Preparatory work in Japan
Step 2 : Field work in Zimbabwe
Step 3 : Home office work in Japan
Step 4 : Presentation of and discussion on the Draft Final Report

2. Schedule

Schedule of the Study is shown in Annex

V. Reports

JICA shall prepare and submit the following reports written in English to the Government of Zimbabwe within the time periods indicated below:

1. Inception Report at the beginning of the Step 2 — 10 copies
2. Progress Report at the end of the Step 2: — 10 copies
3. Draft Final Report and its summary within 8 (eight) months after the commencement of the Step 2 — 15 copies
4. Final Report and its summary within 3 (three) months after the receipt of comments on the Draft Final Report from the Government of Zimbabwe — 30 copies

VI. Undertaking of the Government of Zimbabwe

1. To facilitate the smooth implementation of the Study, the Government of Zimbabwe shall take necessary measures:

1-1 To secure the safety of the Japanese study team (hereinafter referred to as "the Team")

1-2 To permit the members of the Team to enter, leave and sojourn in Zimbabwe for the duration of their assignment therein, and exempt them from alien registration requirements and consular fees

1-3 To exempt the members of the Team from taxes, duties and other charges on equipment, machinery and other materials brought into Zimbabwe for the implementation of the Study

1-4 To exempt the members of the Team from income taxes and other charges of any kinds imposed on or in connection with any emoluments or allowances paid to the members of the Team for their services in connection with the implementation of the Study

1-5 To provide the necessary facilities to the Team for the remittance as well as utilization of the funds introduced in Zimbabwe from Japan in connection with the implementation of the Study

1-6 To provide medical services as needed and its expenses will be chargeable on the members of the Team

1-7 To secure permission for entry into private properties or restricted areas for the conduct of the Study

1-8 To secure permission to take all data and documents (including photographs) related to the Study out of Zimbabwe to Japan by the Team

2. The Government of Zimbabwe shall bear claims, if any arises against the members of the Team resulting from, occurring in the course of, or otherwise connected with the discharge of their duties in the implementation of the Study, except when such claims arise from gross negligence or willful misconduct on the part of the Japanese members of the Team

3. Ministry of Industry and Technology (hereinafter referred to as "MIT") shall act as counterpart agency to the Team and also as coordinating body in relation with other governmental and non-governmental organizations concerned for the smooth implementation of the Study.

4. MIT shall, at its own expense, provide the Team with the following, in cooperation with other relevant organization;

4-1 Available data and information related to the Study

4-2 Counterpart personnel

4-3 Suitable office space with necessary equipment

4-4 Identification cards

VII. Undertaking of JICA

For the implementation of Study, JICA shall take the following measures:

1. To dispatch, at its own expense, the Team to Zimbabwe

2. To pursue technology transfer to Zimbabwe counterpart personnel in the course of the Study

VIII. Consulation

JICA and MIT shall consult with each other in respect of any matter that may arise from or in connection with the Study.

JICA