NO. 10

# THE FEASIBILITY STUDY REPORT

# ON

# THE ESTABLISHMENT OF AN AMMONIA PLANT

# IN

# THE REPUBLIC OF ZIMBABWE

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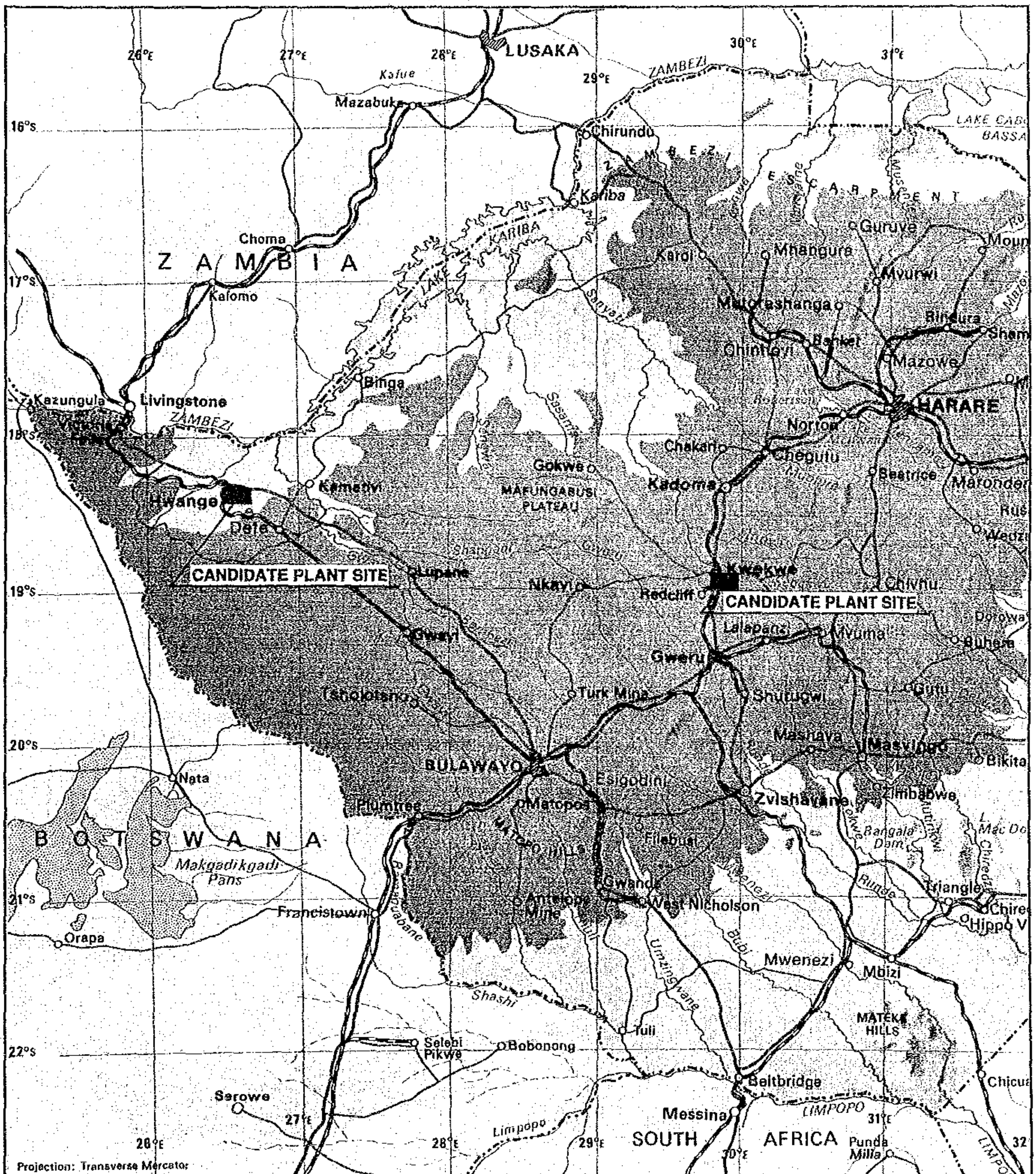
# (SUMMARY)



JUNE 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

## PHYSICAL MAP ZIMBABWE



# SUMMARY

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# Chapter 1 Introduction

## 1.1 Background of This Study

Since gaining its independence in April 1980, the Republic of Zimbabwe has placed agricultural development at the centre of its national economic policy, and has taken measures to increase agricultural production through actively undertaking the redistribution of farmland, soil-improvement practices and the development of irrigation systems, etc. As for the fertilizers necessary for increasing agricultural production, it has engaged in the production of ammonium nitrate, single superphosphate and double superphosphate, meanwhile importing a deficient portion of ammonia (about 100 tonnes daily), urea and potash. With respect to ammonia, Zimbabwe today produces two-thirds of its needs domestically and imports the remaining one third.

With regard to this backdrop, the Government of Zimbabwe requested in September of 1985 the technical cooperation of the Japanese Government for implementing a feasibility study on the establishment of an ammonia plant utilizing domestic coals as raw material, in view to establishing self-sufficiency in providing its fertilizer needs and at more favorable cost. In reply, the Japan International Cooperation Agency (JICA) in February 1988 sent a preliminary survey team to Zimbabwe, and had discussions with the authorities concerned and determined the scope of work of the study. The present study has been carried out in accordance with the scope of work, and the field surveys were conducted in July and August of 1988 and home works in Japan have been carried out based on their findings. The results of the study have been compiled in this feasibility study report.

## 1.2 Objective of Study

The objective of the study is to investigate the technical and economic feasibility of a plan of the establishment of an ammonia plant in Zimbabwe for producing ammonia from coal and if possible other chemical products with added value as co-products. In relation to the production process, the following four cases are considered.

The product(s) as
(1) Ammonia only
(2) Ammonia and urea
(3) Ammonia (from coke oven gas) and tar
(4) Ammonia and methanol

Discussions upon a progress report prepared based on the field survey were held on 25th August 1988 in Harare with Zimbabwe's counterpart, — the Ministry of Industry and Technology, and it was agreed that, for the cases of producing ammonia exclusively and of ammonia and urea being more important, the study should extend to be estimation of plant cost and the evaluation of the project in views from financial and economic aspects in addition to the process study, while, for the cases of ammonia and tar production as well as of ammonia and methanol production, the project evaluation should be made on the basis of carrying out the process study.

## Chapter 2 Zimbabwe's Agriculture and Demand for Fertilizer

### 2.1 Outlook of Agriculture

Agriculture is one of Zimbabwe's key industries and accounts for 12% of the country's Gross Domestic Product, serving not only to provide food for her people but also making up 40 % of her total exports.

The nation's agricultural activities may be broadly classified into the following three areas:

(a) Large-scale commercial farming: practised by settlers of European descent

(b) Small-scale commercial farming: practised by indigenous land-owning farmers practised by farmers on tribal trust lands and also indigenous farmers relocated upon

(c) Communal land farming: practised by farmers on tribal trust lands and also indigenous farmers relocated upon farmland bought up by the government

Of these, communal land farming engages 57% of Zimbabwe's population.

The nation's major agricultural products are as follows:

**Table 2–1 Crop Production by Sector**

Unit: 1,000T

| | 1980 | | | 1983 | | |
|---|---|---|---|---|---|---|
| | Commerc. | Commun. | Total | Commerc. | Commun. | Total |
| Maize | 910 | 600 | 1,510 | 624 | 285 | 909 |
| Sorghum | 16 | 66 | 82 | 7 | 44 | 51 |
| Wheat | 154 | – | 154 | 110 | – | 110 |
| Groundnut | 10 | 67 | 77 | 9 | 22 | 31 |
| Soybean | 89 | 8 | 97 | 78 | 2 | 80 |
| Coffee | 5 | – | 5 | 8 | – | 8 |
| Cotton | 145 | 12 | 157 | 114 | 32 | 146 |
| Tobacco | 119.8 | 0.2 | 120 | 93.3 | 0.6 | 93.9 |
| Sugarcane | 2,528 | – | 2,528 | 3,438 | – | 3,438 |
| Tea | 9 | – | 9 | 10 | – | 10 |

Source: Statistical Yearbook 1987

The planted area in 1986/87 was as follows:

| | |
|---|---|
| Commercial farming | 478,462 ha |
| Communal farming | 1,811,996 ha |

Fertilizer consumption was as follows:

| | Gross | In terms of nutrient |
|---|---|---|
| Commercial farming | 310,000 T/Y | 0.232 T/ha |
| Communal farming | 120,000 T/Y | 0.0237T/ha |

## 2.2 Demand Forecast for Fertilizer

(1) Planted area

Assuming that the planted area grows at a rate of 5% every year, total acreage under cultivation in 1995-96 is forecasted as follows:

| | |
|---|---|
| Commercial farming | 600,000 ha |
| Communal farming | 2,900,000 ha |

(2) Fertilizer consumption per ha

Assuming that the consumption of fertilizers per hectare by commercial farming increases at a rate of 2% per annum and, fertilizer consumption per hectare of communal farmland in 1995/96 become one fifth of that for commercial farming in the same year, the fertilizer consumption per hectare in 1995/96 is estimated to be:

| | |
|---|---|
| Commercial farming | 0.277 T/ha |
| Communal farming | 0.056 T/ha |

(3) Demand forecast of nitrogenous fertilizer

The consumption of nitrogenous fertilizer in 1995/96 is forecasted at:

Commercial farming:

$(0.277 \text{ T/ha-yr}) (0.54)(0.6 \times 10^6 \text{ ha}) \quad =89{,}748 \text{ TN/Y}$

Communal farming:

$(0.056 \text{ T/ha-yr})(0.54)(2.9 \times 10^6 \text{ ha}) \quad =87{,}696 \text{ TN/Y}$

Total: 177,444 TN/Y

≒177,400 TN/Y

Note: Ratio of N to three components is assumed to be 0.54.

The demand for nitrogenous fertilizer in 1995/96 is calculated to 215,400 T/Y in terms of ammonia. The demand for a ammonia is forecasted to be 200,000 T/Y conservatively, taking other estimation results in to consideration.

(4) The demand for urea

The large part of nitrogenous fertilizers used in Zimbabwe today consists of ammonium nitrate manufactured by the Sable Chemical Company (SABLE), while urea is supplied entirely through imports. The urea is used as straight fertilizer for top dressing and also used for compound fertilizer production, as well as for cattle feed. The import volume of urea during the past several years have been as follows:

Unit: T

| 1983 | 1984 | 1985 | 1986 | 1988 |
|---|---|---|---|---|
| 24,000 | 30,265 | 32,182 | 24,106 | 1,031 |

Urea has excellent properties as a nitrogenous fertilizer, and may readily be used in the place of ammonium nitrate. Estimates are given below of the demand for urea in 1995/96 based on the following two assumptions:

1) That urea will replace all nitrogenous fertilizers now in use in Mashonaland and Manicaland, areas where farming, soil and climatic conditions are favorable, and where as much as 76% of Zimbabwe's consumption of nitrogenous fertilizer lies.

2) That urea will replace all nitrogenous fertilizers currently used in straight fertilizer which at present account for 76% of all fertilizers applied in these area.

The estimate of the demand for urea in 1995/96 is as follows:

180,000 TN/Y x 0.76 x 0.76 = 104,000 TN

= 226,000 T of urea equivalent,

Note: 0.46 TN = 1 T urea.

177,400 TN/Y in 2.2 (3) is rounded to 180,000 TN/Y in this calculation.

The demand for urea other than as fertilizer will be:

| | |
|---|---|
| Domestic animal feed: | 15,000 T/Y |
| Export estimated | 54,000 T/Y |

(5) Production capacity of ammonia and urea

Demands for ammonia and for urea in 1995/96 are forecasted as follows:

| | |
|---|---|
| Ammonia | 200,000 T |
| Urea | 226,000 T |

Production capacity are therefore set as follows:

| | | | |
|---|---|---|---|
| Ammonia | 600 T/D | or, | 198,000 T/Y |
| Urea | 525 T/D | or, | 173,250 T/Y |
| | | | (300 T/D of ammonia equivalent) |

Of this daily production of ammonia, 300 tonnes would be supplied to SABLE to maintain the production of ammonium nitrate.

# Chapter 3 Raw Materials and Utilities

## 3.1 Zimbabwe's Coal Reserves

Twenty-two coal deposits are known to exist in Zimbabwe, being distributed mainly in the northwest and southern regions of the country, and with estimated recoverable reserves amounting to 10,571 million tonnes. Only the coal on the Wankie Coalfield, in Hwange in northwest Zimbabwe, has however been mined. The following is a brief description of this coalfield.

| | | |
|---|---|---|
| Recoverable deposits | 655 | million T |
| (Opencastable deposits) | 324.8 | million T |
| Production capacity | 6 | million T/Y |

Coal grades marketed and their prices

| | Ash content | Price (Z$/T) |
|---|---|---|
| Power station coal | under 25 % | 13.41 |
| Run-of-mine coal | 14% (22% max.) | 25 |
| Screened coal | 13% (18% max.) | 25 |
| Washed and screened coal | 12% (15% max.) | 29 |
| Coking coal | 9 ~ 11% | 33 |

Coal gasification in the present project is assumed to use the Texaco process. While this process is capable of utilizing various grades of coals, run-of-mine coal is to be used taking into consideration plant construction cost and unit consumption of feedstock coal. The results of an analysis of this coal, as determined from sampled specimens, have been shown in Table 3-1.

The consumption of coal in both the ammonia and the ammonia with urea production scheme would amount to a yearly 240,000 tonnes, an amount the Wankie coalfield is able to supply.

The ammonia and methanol scheme would by contrast call for greater amounts of coal, and would therefore have to in addition use power station coals.

The scheme to produce ammonia and coal tar would demand an annual 1.32 million tonnes of coking coal, which the WANKIE cannot meet at present unless it undertakes to mine additional coking coal.

## Table 3-1 Coal Analysis

| Number of Coal | | No.1 | No.2 | No.3 | No.4 | No.5 | No.6 | No.7 | No.8 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Total Moisture (Received Basis) | wt% | 1.4 | 1.1 | 1.0 | 1.3 | 1.1 | 1.0 | 1.1 | 1.0 |
| 2. Proximate Analysis | | | | | | | | | |
| (1) Inherent Moisture | wt% | 1.8 | 1.2 | 1.3 | 1.5 | 1.4 | 1.2 | 1.2 | 1.2 |
| (2) Ash | wt% | 37.2 | 11.1 | 11.9 | 14.4 | 13.8 | 7.5 | 7.0 | 9.1 |
| (3) Volatile Matter | wt% | 17.5 | 28.6 | 28.0 | 24.2 | 23.8 | 30.4 | 30.7 | 29.7 |
| (4) Fixed Carbon | wt% | 43.5 | 59.1 | 58.8 | 59.9 | 61.0 | 60.9 | 61.1 | 60.0 |
| 3. Gross Heating Value (Inherent Moisture Basis) | kcal/kg | 4,700 | 7,440 | 7,270 | 7,020 | 7,090 | 7,760 | 7,820 | 7,620 |
| 4. Hardgrove Grindability Index | - | 78 | 57 | 57 | 64 | 60 | 59 | 60 | 56 |
| 5. Crucible Swelling Number | - | 1/2 | 1 | 1 1/2 | 1/2 | 1 | 5 1/2 | 6 1/2 | 1 1/2 |
| 6. Ultimate Analysis (Dry Basis) | | | | | | | | | |
| (1) Ash | wt% | 37.9 | 11.2 | 12.1 | 14.6 | 14.0 | 7.6 | 7.1 | 9.2 |
| (2) Carbon | wt% | 50.7 | 75.7 | 75.4 | 72.9 | 73.1 | 79.9 | 80.3 | 78.4 |
| (3) Hydrogen | wt% | 2.7 | 4.3 | 4.3 | 3.7 | 3.8 | 4.6 | 4.6 | 4.4 |
| (4) Oxygen | wt% | 6.2 | 4.6 | 4.6 | 5.5 | 5.4 | 4.8 | 5.0 | 5.2 |
| (5) Nitrogen | wt% | 1.1 | 1.6 | 1.5 | 1.6 | 1.5 | 1.7 | 1.6 | 1.5 |
| (6) Inflammable Sulfur | wt% | 1.40 | 2.47 | 2.13 | 1.71 | 2.18 | 1.38 | 1.37 | 1.33 |
| (7) Total Sulfur | wt% | 1.42 | 2.58 | 2.25 | 1.83 | 2.28 | 1.44 | 1.44 | 1.43 |
| (8) Nonflammable Sulfur | wt% | 0.02 | 0.11 | 0.12 | 0.12 | 0.10 | 0.06 | 0.07 | 0.10 |
| (9) Chlorine | wt% | 0.021 | 0.021 | 0.014 | 0.014 | 0.021 | 0.021 | 0.021 | 0.014 |
| (10) Fluorine | wt% | 0.013 | 0.014 | 0.015 | 0.012 | 0.012 | 0.015 | 0.009 | 0.009 |
| 7. Ash Mineral Analysis | | | | | | | | | |
| (1) SiO2 | wt% | 55.12 | 35.25 | 38.97 | 40.60 | 44.08 | 44.20 | 43.56 | 42.78 |
| (2) Al2O3 | wt% | 30.90 | 21.70 | 22.48 | 23.40 | 24.80 | 28.76 | 28.25 | 27.40 |
| (3) Fe2O3 | wt% | 8.00 | 19.00 | 16.10 | 13.70 | 18.50 | 3.30 | 2.70 | 4.92 |
| (4) CaO | wt% | 0.90 | 10.80 | 10.17 | 11.90 | 6.60 | 9.50 | 9.10 | 10.83 |
| (5) MgO | wt% | 0.50 | 0.80 | 1.36 | 1.10 | 0.70 | 0.70 | 1.30 | 1.00 |
| (6) SO3 | wt% | 0.16 | 2.48 | 2.56 | 1.99 | 1.71 | 2.13 | 2.61 | 2.82 |
| (7) P2O5 | wt% | 0.80 | 0.35 | 0.40 | 0.38 | 0.30 | 0.35 | 0.35 | 0.30 |
| (8) TiO2 | wt% | 2.10 | 1.10 | 1.17 | 1.43 | 1.37 | 1.56 | 1.66 | 1.30 |
| (9) Na2O | wt% | 0.25 | 1.85 | 1.50 | 0.85 | 1.10 | 1.85 | 1.70 | 1.72 |
| (10) K2O | wt% | 0.70 | 0.38 | 0.40 | 0.30 | 0.30 | 0.50 | 0.58 | 0.55 |
| 8. Ash Fusion Temperature | | RT (OT) | RT (OT) | | RT (OT) | RT (OT) | RT (OT) | | |
| (1) Initial Deformation Temperature | ℃ | 1.430 (1.550) | 1.100 (1.320) | | 1.260 (1.330) | 1.170 (1.310) | 1.350 (1.370) | | |
| (2) Softening Temperature | ℃ | 1.580 (1.600) | 1.300 (1.350) | | 1.330 (1.340) | 1.240 (1.330) | 1.380 (1.400) | | |
| (3) Hemispherical Temperature | ℃ | 1.590 (1.605) | 1.320 (1.360) | | 1.350 (1.350) | 1.260 (1.340) | 1.390 (1.410) | | |
| (4) Fluid Temperature | ℃ | >1.600 (>1.610) | 1.330 (1.365) | | 1.390 (1.370) | 1.310 (1.350) | 1.420 (1.420) | | |

RT : Reducing . (OT) : Oxidizing

## 3.2 Electric Power

Zimbabwe's demand for electric power is currently being met by the Kariba hydroelectric power plant (666 MW), the Hwange thermal power plant (920 MW), small-scale old thermal power plants in the vicinity of large cities, and in addition through purchases of electricity from Zambia.

(1) The supply and demand of electric power

The consumption of electric power in years 1985/86 and 1986/87 are shown in Table 3-2, while Table 3-3 shows the power plants currently in use in Zimbabwe.

Zimbabwe's total power consumption in 1986/87 was 8,180 GWh. Meanwhile, it purchased 2,214 GWh from Zambia. Although increases in power consumption during the seven years following 1980 has averaged an annual 2% or so, Zimbabwe's Five Year National Development Plan foresees annual increases of 3.5% in the future, and it is forecasted that the consumption will reach 10,688 GWh in 1993/94, with the maximum demand in that year at a rate of 1,627 MW. To meet such increases foreseen, plans have been drawn up to modify the Kariba plant (to increase its current 666 MW generating capacity up to 750 MW), for expanding the same hydroelectric plant (by an additional 300 MW), and for constructing a new power plant, the Hwange III Thermal Power Station (440 MW).

(2) Power tariff

Power having mainly been supplied from hydro power station in the past, power tariff in Zimbabwe had been kept at a very low level. With an expanding economy, however, the nation's power consumption rose, necessitating the construction of the coal-fired thermal power plants at Hwange. Since then, the tariff has shown a tendency to increase yearly, although it still remains low. The tariff by sector, for years 1985/86 and 1986/87 is shown in Table 3-4. After the revision of tariff in October 1988, however, that for industry is expected to rise to 0.049 Z$/kWh.

## Table 3-2 ZESA Energy Balance

| 1985/86 Energy in kWh | Source | 1986/87 Energy in kWh | |
|---|---|---|---|
| 3,146,077,790 | Import ex Zambia (1) | 2,214,964,600 | |
| 3,291,318,000 | Kariba entitlement | 3,022,725,700 | |
| 6,437,395,790 | Sub total | 5,237,690,300 | |
| 1,863,618,000 | Hwange power station sent out | 3,441,809,000 | |
| 211,367,210 | Old thermals sent out | 201,777,790 | |
| 8,512,381,000 | Interconnected System Sent Out | 8,881,277,090 | (3) |
| 322,349,576 | Transmission losses (6) | 354,275,065 | |
| 8,190,031,424 | Bulk supply sent out | 8,527,002,025 | (4) |
| 577,191 | Triangle Ltd (2) | 479,621 | |
| 631,410 | ZESCO Chirundu and Victoria Falls (2) | 439,780 | |
| 13,966,306 | ESCOM (Beitbridge) (2) | 16,937,335 | |
| 8,205,206,331 | | 8,544,858,761 | |
| 322,076,823 | Distribution losses (7) | 364,369,873 | |
| 7,883,129,508 | Total sales | 8,180,488,888 | |

NOTE:
1) Excess of Kariba entitlement
2) Imports at distribution voltage
3) Maximum demand on interconnected system 1,342.0 MW
4) Maximum demand at bulk supply points 1,294.5 MW
5) Load factors @ 3) 75.55%
   @ 4) 75.22%
6) Transmission losses 3.99%
7) Distribution losses 4.26%

**Table 3-3 Power Station in Zimbabwe**

| Power Station | Type | Unit x Output MW | Total output MW | Start of operation |
|---|---|---|---|---|
| Kariba South | Hydro | 6 x 111 | 666 | 1960 |
| Hwange-I | Coal | 4 x 120 | 480 | 1986 |
| Hwange-II | Coal | 2 x 220 | 440 | 1988 |
| Munyati | Coal | 2 x 60 | 120 | Before 1966 |
| Harare | Coal | 2 x 10<br>2 x 20 | 60 | ditto |
| Bulawayo | Coal | 2 x 15<br>3 x 30 | 120 | ditto |
| Total | | | 1,886 | |

**Table 3-4 Power Tariff**

Unit: Z$/kWh

| | 1985/1986 | 1986/1987 |
|---|---|---|
| Mining | 0.04886 | 0.04970 |
| Industrial | 0.03456 | 0.03558 |
| Farming | 0.06844 | 0.06805 |
| Municipal | 0.03977 | 0.04447 |
| Commercial & Lighting | 0.07784 | 0.08067 |
| Domestic | 0.07532 | 0.08080 |
| Weighted average | 0.04320 | 0.04594 |

(3) Power supply to the present project

When the present project is implemented to produce ammonia from coal, SABLE will cease its production of ammonia using the hydrogen produced by water electrolysis. This means that the power required today to run water electrolysis unit is not required and some 80,000 to 90,000 kW of balance will become available. There should basically be no problem, therefore, in electricity supply to the present project.

In the case the ammonia plant of the present project is constructed in Kwekwe region, there is no idle capacity with ZESA's substations, but there would be no problem in electricity supply, as the electric power supplied to SABLE will be reduced.

In the case of Hwange is chosen as the plant site, there would be no problem in electricity supply since the candidate site locates near the Hwange thermal power station.

In either case, because supply lines serve both the Kwekwe and Hwange regions, electric power will be supplied stably, making it unnecessary to have an own power station for the plant.

## 3.3 Industrial Water

Industrial water is an essential material for chemical industries, and the production of ammonia and urea of the present project will require some 8,400 T/D of raw industrial water.

(1) Kwekwe region

There are the rivers Sebakwe and Kwekwe in Kwekwe region, but these rivers already supply water to agricultural, household and industrial uses and so have very little supply capacity for the project. When unusually dry years which Zimbabwe regularly experiences are taken into consideration, there is concern about securing a stable supply of water.

(2) Hwange region

It is possible to obtain water from the Zambezi River, but a 45 km pipeline for water supply is required.

## Chapter 4 Plant Site Selection

The regions of Kwekwe and Hwange as candidate sites of plant construction are compared and discussed.

| | Hwange | Kwekwe |
|---|---|---|
| i. Location | | |
| a) Adjacent township | ○ | ○ |
| b) Area availability | ○ | ○ |
| c) Land cost | ○ | ○ |
| d) Weather condition | ○ | ○ |
| e) Soil condition | ○ | ○ |
| ii. Utilities | | |
| a) Water supply | | |
| - Availability | ○ | × |
| - Quality | ○ | ○ |
| - Cost | Δ | × |
| b) Electric power | | |
| - Availability | ◎ | ○ |
| - Cost | ○ | ○ |
| iii. Transport Infrastructure | | |
| a) Road condition | ○ | ○ |
| b) Railway condition | ○ | ○ |
| iv. Transportation and Distribution | | |
| a) Raw coal transportation | ◎ | Δ |
| b) Product ammonia distribution | Δ | ◎ |
| c) Product distribution | Δ | ○ |
| v. Employee Recruiting | ○ | ◎ |

Notes:
◎ Excellent
○ Adequate
Δ Inadequate
× Unavailable

The Kwekwe region emerges economically more favorably with respect to the transport of raw materials and products, but as it presents a problem regarding the supply of industrial water, Hwange is chosen as the candidate site of plant construction.

# Chapter 5 Construction Plan for Ammonia and Urea Scheme

## 5.1 Plant Facilities

(1) Basic concept

| Facility | Capacity | Annual Production (330 days basis) |
|---|---|---|
| Ammonia | 600 T/D | 198,000 T/Y |
| Urea | 525 T/D | 173,250 T/Y |
| By-product sulphur (as 100%) | 18.1 T/D | 5,973 T/Y |
| Shipments of ammonia | 300 T/D | 99,000 T/Y |

In this scheme, 300 of the 600 tonnes of ammonia to be manufactured daily is utilized in Hwange as feedstock for the production of urea, while the remaining 300 tonnes is sent to SABLE as feedstock for the production of ammonium nitrate.

(2) An outline of production processes

A process flow chart is provided in Fig. 5-1. The feedstock coal is finely ground and charged to gasifier in the form of a water slurry. The coal is made to react with high pressure oxygen produced by an air separator. The generated gas containing $H_2$, CO and $CO_2$ is then fed to a CO conversion section in which CO is converted to $H_2$ and $CO_2$. Then, in the acid gas removal section, $CO_2$ and sulphur compounds in the generated gas are removed. The gas leaving the acid gas removal section is purified in nitrogen washing section and mixed with nitrogen gas. A gas mixture containing hydrogen and nitrogen ($H_2$:$N_2$ molar ratio of 3:1) is then sent on to ammonia synthesis tower, where the final product, ammonia, is manufactured.

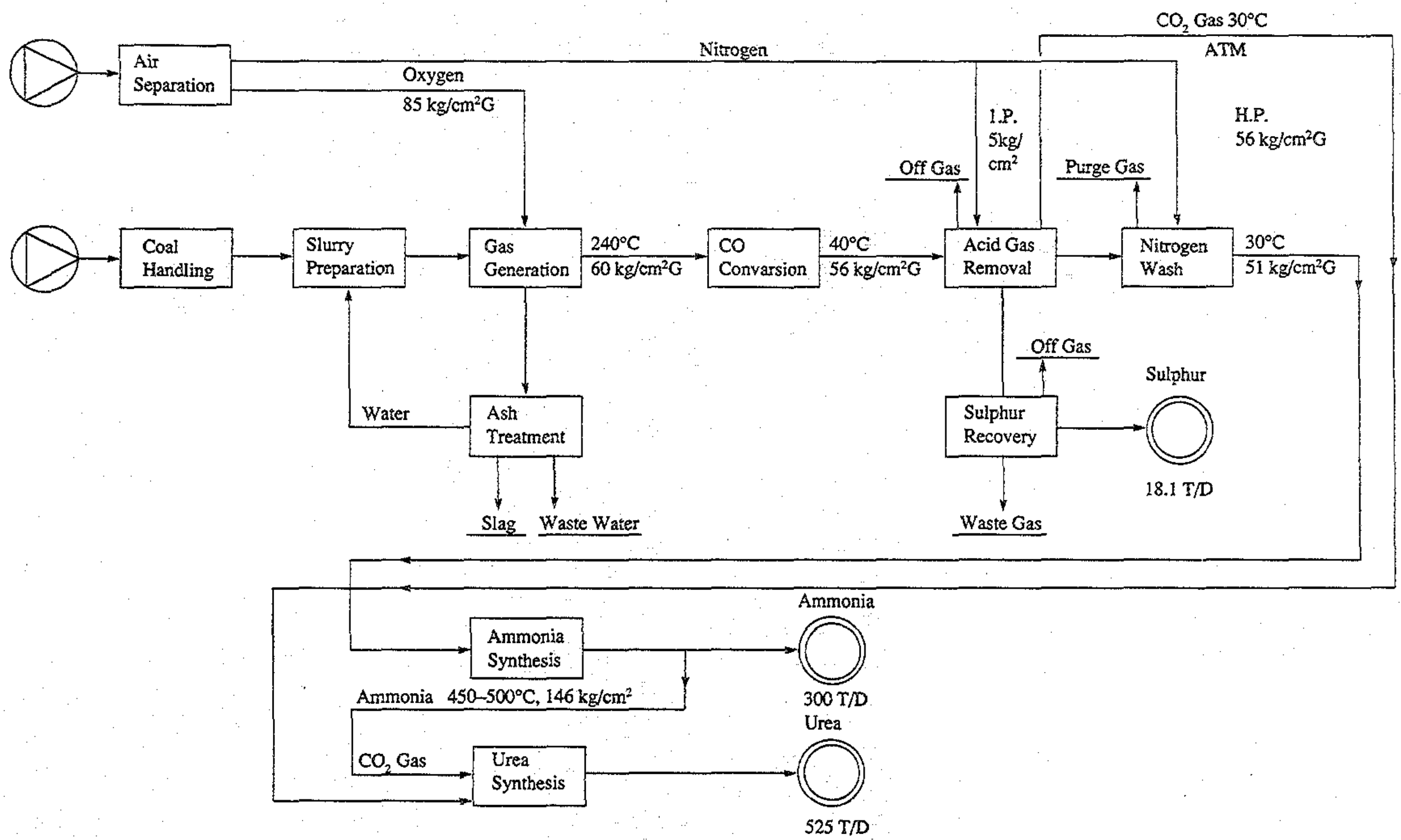


**Fig. 5-1 Block Flow Diagram of Project (Ammonia/Urea Production)**

The following processes were adopted in the conceptual design for the ammonia production.

For the coal gasification, Texaco process is chosen, as this is able to utilize Wankie coals, exhibits a high efficiency of gasification, and greatly simplifies the process since it avoids the generation of such by-products as methane and tars in the generated gas.

The Rectisol process was selected for the desulphurization and $CO_2$ removal. This process uses methanol as solvent, a substance easily obtained, and evolves $CO_2$ and sulphur compounds selectively and in highly concentrated form. Using the Claus process, solid elemental sulphur of high purity is recovered from sulphur compound gases.

The Kellog process, which has a proven record, has been selected for the ammonia synthesis stage. This process affords synthesis pressures of under 150 kg/cm$^2$ and allows the application of a rotary compressor.

Urea production was designed by adopting the Stamicarbon process. The method is both energy-saving and has in the past produced good results. For the manufacture of granulated urea, fluidized-bed granulation process was adopted. This method yields high granule strength and large granules of uniform size that do not easily cake and that can be blended easily with other fertilizers.

## 5.2 Schedule of Project Implementation

| | |
|---|---|
| Submission of feasibility study report | June 1989 |
| Final decision upon project implementation | December 1989 |
| Signatures on construction contracts | December 1990 |
| Starting of construction work | January 1991 |
| Completion of construction work | December 1993 |
| Starting of commercial operation | January 1994 |

## 5.3 Total Capital Requirement

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

(1) Major assumptions for estimating the total capital requirement

- Procurement Method of Machinery and Equipment

  By competitive bidding

- Price Base

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

- Currency and Exchange Rates

  Foreign currency portion 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. Local currency portion is estimated in Zimbabwe Dollar and converted into US Dollar by the following exchange rate: US$1 = Z$ 1.8 .

- Escalation

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

- Customs Duty

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

(2) Project cost

The following costs are counted as project cost.

- Land acquisition and site preparation cost
- Plant construction cost
- Spare parts for two years
- Catalysts and chemicals (initial charge)
- Contingency

(3) Pre-operation cost

Pre-operation cost covers the following costs.

- Cost for project management consultant

  5 consultants for 3 years and 6 months

- Training cost

| | | |
|---|---|---|
| Outside Zimbabwe | : | 12 engineers for 3 months |
| Domestic in Zimbabwe | : | 60 operators for 6 months |

- Administration cost
- Trial operation cost

| | | |
|---|---|---|
| Net operation time | : | 1 month during 3 month period |
| Operation rate | : | 80% on average |
| Raw material/utility consumption | : | 120% of normal operation |
| Product | : | to be sold (ammonia: 7,200T, urea 12,600 T) |

(4) Initial working capital

The following are prepared as initial working capital

- Cash

  Labour cost for one month and estimated account receivable in the first year

- Catalysts and chemicals (for one year)
- Raw material (4,000 tons of coal)

(5) Cost for operation consultant

The cost for operation consultants (5 personnel, 1 year) hired in the first year of operation is included.

(6) Interest during construction

Interest during construction is calculated assuming that foreign portion is covered by a long-term loan at the interest rate of 10% p.a.

(7) Total capital requirement

A summary of the total investment cost based on the financing plan as described above is shown in Table 5-1.

**Table 5-1 Summary of Total Capital Requirement**

Unit : US$1,000

| | Foreign | Local | Total |
|---|---|---|---|
| [in 1988 Constant Price Base] | | | |
| Project Cost | 202,114.9 | 76,261.2 | 278,376.1 |
| Pre-operation Cost | 5,315.0 | 7,068.7 | 12,383.7 |
| Working Capital | 1,100.0 | 5,597.4 | 6,697.4 |
| Operation Consultant | 1,150.0 | 127.8 | 1,277.8 |
| Interest during Construction | 35,388.7 | 0.0 | 35,388.7 |
| Total Financing Required | 245,068.6 | 89,055.2 | 334,123.8 |
| [Current Price Base] | | | |
| Project Cost | 230,399.8 | 88,229.9 | 318,629.8 |
| Pre-operation Cost | 6,056.8 | 8,282.4 | 14,339.1 |
| Working Capital | 1,306.5 | 6,648.0 | 7,954.5 |
| Operation Consultant | 1,365.8 | 151.8 | 1,517.6 |
| Interest during Construction | 39,977.8 | 0.0 | 39,977.8 |
| Total Financing Required | 279,106.7 | 103,312.1 | 382,418.8 |

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

## 5.4 Financial Evaluation

(1) Major Premises

1) Project period

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

2) Price Base

Calculation is made in 1988 constant price base. The cost estimated in local currency and Japanese Yen are converted into US Dollar by using the following exchange rates.

US$ = Z$ 1.8 = ¥130

3) Production and Sales Plan

Table 5-2 shows the production and sales plan of this project.

**Table 5-2 Production and Sales Plan**

Unit: T/Y

| Project Year | 1 | 2 | 3-15 |
|---|---|---|---|
| On-stream Factor | 80% | 90% | 100% |
| Ammonia Section | | | |
| 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 |
| Sub-Total | 99,000 | 99,000 | 99,000 |
| to Urea Plant | 56,400 | 79,200 | 99,000 |
| Stock | 3,000 | (3,000) | (3,000) |
| Total | 158,400 | 178,200 | 198,000 |
| Urea Section | | | |
| Production Volume | 98,700 | 138,600 | 173,250 |
| Sales Volume | 88,700 | 138,600 | 173,250 |
| Stock | 10,000 | (10,000) | (10,000) |

The ammonia-A displaces the ammonia which has been produced by SABLE, and the ammonia-B displaces the imported ammonia. The ex-plant prices of above products established from the market study are shown in Table 5-3.

**Table 5-3 Sales Prices**

Unit: US$/T

| | | Weighted Average |
|---|---|---|
| Ammonia-A | 361.3 | 351.6 |
| Ammonia-B | 319.2 | |
| Urea | 237.4 | 237.4 |

4) Income Tax and Depreciation

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. 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% |

5) Working Capital

Working capital is defined as the balance deducting the current liability from the current assets shown below.

① Current Asset

- Cash: labour cost for one month
- Catalysts and chemicals: for one year
- Raw materials inventory: 4,000 tonnes of coal
- Products inventory: 3,000 tons of ammonia and 10,000 tonnes of urea
- Account receivable: sales revenue of one month

② Current liability

- Account Payable: one month of cost for coal and electricity

6) Financing Plan

Based on 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 installments/10 years
- Grace Period : 4 years after 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 : In the following year

(2) Total Capital Requirement

The total cost for the project excluding price contingency in 1988 fixed price base is calculated. Table 5-4 shows the summary of the total capital requirement.

**Table 5-4 Total Capital Requirement**

Unit: US$ Million

| | 1990 | 1991 | 1992 | 1993 | Total |
|---|---|---|---|---|---|
| Application of Funds | | | | | |
| Project Cost | 0.00 | 76.63 | 147.95 | 53.80 | 278.38 |
| Preoperation Cost | 0.64 | 1.69 | 4.01 | 6.05 | 12.38 |
| Initial Working Capital | 0.00 | 0.00 | 0.00 | 6.70 | 6.70 |
| Interest During Const. | 0.02 | 2.79 | 10.85 | 18.49 | 32.15 |
| Total | 0.66 | 81.11 | 162.80 | 85.03 | 329.60 |
| Source of Funds | | | | | |
| Equity | 0.21 | 26.28 | 56.43 | 38.45 | 121.38 |
| Long-term Loan | 0.45 | 54.83 | 106.37 | 46.58 | 208.22 |
| Total | 0.66 | 81.11 | 162.80 | 85.03 | 329.60 |

Note: Operation consultant cost is not included in the above table, but included in operation cost at the 1st year of commercial operation

(3) 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 and to produce urea from ammonia are shown below.

- Ammonia production
  - Process use : 813.2 kWh/T
  - Water intake : 34.8 kWh/T
- Urea production
  - Process use : 217.4 kWh/T
  - Water intake : 6.6 kWh/T

The average price of electricity is estimated at US$0.027/kWh.

3) Urea Bag

All of urea is shipped in 50kg-polyethylene-bags. The purchase price of the bag is Z¢ 83/piece.

4) Catalysts and Chemicals

The average cost of catalysts and chemicals is estimated at US$1.1 million per year.

5) By-product Credit

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

6) Labour Cost

526 personnel is required for this project, and the annual cost is estimated at Z$10,453,000. The maintenance labour cost is included in this category.

In addition to the above, 5 foreign operation consultants are hired in the first years of operation. The required total annual cost for the operation consultants is estimated to be 1,278 thousand US Dollars.

7) Overhead

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

8) Maintenance Cost

Annual maintenance cost is estimated at 1.5% of plant cost.

9) Insurance

The annual amount is estimated to be 0.7% of plant cost

(4) Results of Financial Analysis

The calculated financial indicators shown below provide the grounds for the validity of the project.

- IRROI (before tax) : 10.4%
- IRROI (after tax) : 7.9%
- IRROE (before tax) : 9.8%
- IRROE (after tax) : 6.4%
- Pay-back Period on Investment : 7.2 years
- Pay-back Period on Equity : 10.7 years

(5) Sensitivity Analysis

The following is a summary of the sensitivity analysis.

**Table 5-5 Summary of Sensitivity Analysis**

Unit: %

| Parameter | IRROI (b/tax) | IRROI (a/tax) | IRROE (b/tax) | IRROE (a/tax) |
|---|---|---|---|---|
| Product Price | | | | |
| +10% | 12.6 | 9.7 | 13.6 | 9.9 |
| Base Case | 10.4 | 7.9 | 9.8 | 6.4 |
| -10% | 8.0 | 5.9 | 5.0 | 2.3 |
| Plant Investment Cost | | | | |
| +10% | 9.0 | 6.8 | 7.1 | 3.8 |
| Base Case1 | 0.4 | 7.9 | 9.8 | 6.4 |
| -10% | 12.0 | 9.3 | 12.6 | 9.1 |
| Raw Material Cost | | | | |
| +20% | 9.9 | 7.5 | 8.8 | 5.4 |
| +10% | 10.1 | 7.7 | 9.3 | 35.9 |
| Base Case | 10.4 | 7.9 | 9.8 | 6.4 |
| -10% | 10.7 | 8.2 | 10.2 | 6.8 |
| -20% | 10.9 | 8.4 | 10.7 | 7.1 |
| Financing Source | | | | |
| Base Case | 10.4 | 7.9 | 9.8 | 6.4 |
| Soft Loan Case | 10.4 | 7.9 | 17.4 | 14.4 |
| Soft Loan with 11 yrs Grace of Repayment | 10.4 | 7.9 | 20.8 | 18.8 |
| Equity Ratio | | | | |
| 20% | 10.4 | 7.9 | 9.3 | 5.4 |
| 30% (Base Case) | 10.4 | 7.9 | 9.8 | 6.4 |
| 40% | 10.4 | 7.9 | 10.0 | 6.7 |
| Inflation | | | | |
| 0% (Base Case) | 10.4 | 7.9 | 9.8 | 6.4 |
| 3% | 14.1 | 10.7 | 16.0 | 11.8 |
| 5% | 16.5 | 12.7 | 19.8 | 15.1 |
| Operating Rate | | | | |
| 1994 1995 1996 1997 1998<br>60%, 70%, 80%, 90%,100% | 8.8 | 6.4 | 6.1 | 3.1 |
| Soft Loan with 11 yrs Grace of Repayment | 8.8 | 6.4 | 16.0 | 13.4 |

(6) Summary of Financial Analysis

The following is an evaluation and conclusion of this project.

- Internal Rate of Return on Investment (before tax base), an indicator of the project's profitability, exceeds 10%, providing the validity 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 a soft loan is applied, profitability of the project will be vastly improved as mentioned in the sensitivity analysis, and the shortage of fund will not occur. Therefore, it is important to borrow a loan with favorable conditions to make this project more profitable.
- Concluding from the above, in case that IRROE is improved, this project is considered to be financially feasible unless the premises used in this study change greatly in an adverse direction.

## 5.5 Economic Analysis

The economic analysis is comprised of quantitative and qualitative analyses. The quantitative analysis consists of evaluating the project by the calculation of Economic Internal Rate of Return (EIRR) and of Foreign Currency Saving. The qualitative evaluation of the benefit of the project is also conducted.

(1) Economic Internal Rate of Return (EIRR)

1) Major premises

- Exclusion of transfer cost items
- Shadow exchange rate SER = 1.25 • OER
- Shadow wage SW = 0.3

2) Results of calculation

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%. The EIRR of this project shows 11.4%.

(2) Effects on Foreign Currency Balance

1) Premises

The analysis is based on 1988 constant price, accordingly the effects of inflation are excluded.

2) Results of Calculation

Inplementation of this project will result in a foreign currency saving of US$ 237 million remaining at the end of project.

3) Other economic effects

By the implementation of this project, various kinds of economic benefits will be expected in such related industries as mining (especially coal industry), energy, transportation and agriculture, and increase of employment opportunity is also anticipated. Among these, remarkable effects expected by this project is the stable supply of fertilizer on agriculture sector, and the following effects on energy sector are expected.

If SABLE stops the operation of the ammonia plant, about 100 MW of electricity will be saved, contributing vastly to the supply of power in Zimbabwe. In the case of installing a 100 MW coal thermal power plant, about US$ 150,000,000 investment is necessary. For this reason, this amount of investment will be saved by the implementation of this project. Kwekwe area, which is distant from both of the major power stations of Hwange and Kariba, is receiving power by 330 KV transmission lines. However, as the power demand is large, new demand will not be met without additional installations of transmission line and substations. Therefore, the termination of ammonia production by water electrolysis and saving of 100 MW of power in this area caused by the implementation of this project will result in saving of additional investment in construction of power plant and transmission line. The benefits by this will be substantial.

# Chapter 6 Construction Plan for Ammonia Scheme

## 6.1 Plant Facilities

(1) Basic concept

| Facility | Capacity (T/D) | Annual Production (330 days basis) (T/Y) |
|---|---|---|
| Ammonia | 600 | 198,000 |
| Sulphur recovery | 18.1 | 5,973 |
| Ammonia shipment | 600 | 198,000 |

All the ammonia manufactured at the plant is transported by tank car to Kwekwe, where a 300 T/D of it will be consumed by SABLE as feedstock for the production of ammonium nitrate. The remaining 300 T/D of ammonia will be consumed as feedstock for the production of a nitrogenous fertilizer, which will be planned by the government of Zimbabwe in future.

(2) An outline of the production processes

Refer to Section 5.1 (2) in Chapter 5.

## 6.2 Schedule of Project Implementation

This is as set out in Section 5.2 in Chapter 5.

## 6.3 Total Capital Requirement

(1) Major assumptions

Refer to Section 5.3 in Chapter 5.

(2) Project cost

Refer to Section 5.3 in Chapter 5.

(3) Pre-operation cost

This cost covers the following costs.

- Cost for project management consultant

  4 consultants for 3 years and 6 months

- Training cost

| | | |
|---|---|---|
| Outside Zimbabwe | : | 10 engineers for 3 months |
| Domestic in Zimbabwe | : | 50 operators for 6 months |

- Administration cost
- Trial operation cost

| | | |
|---|---|---|
| Net operation time | : | 1 month during 3 month period |
| Operation rate | : | 80% on average |
| Raw material/utility consumption | : | 120% of normal operation |
| Products | : | to be sold (ammonia; 14,400 T) |

(4) Initial working capital

Refer to Section 5.3 in Chapter 5.

(5) Cost for operation consultant

The cost for operation consultants (4 personnel, 1 year) hired in the first year of operation is included.

(6) Interest during construction

Refer to Section 5.3 in Chapter 5.

(7) Total capital requirement

A summary of the total investment cost is shown in Table 6-1.

**Table 6-1 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

## 6.4 Financial Evaluation

(1) Major Premises

1) Production and sales plan

Table 6-2 shows the production and sales plan of this project.

**Table 6-2 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 displaces the ammonia which has been produced by SABLE, and the ammonia-B 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 6-3.

**Table 6-3 Sales Prices**

Unit: US$/T

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

2) Others

Other premises for financial evaluation is same as those mentioned in Chapter 5.

(2) Total Capital Requirement

Total cost for the project excluding price contingency in 1988 fixed price base is calculated. Table 6-4 shows the summary of total capital requirement.

Table 6-4 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 |

Note: Operation consultant cost is not included in the above table, but included in operation costs.

(3) Operating Cost

1) Electricity

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

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

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

2) Labour cost

341 personnel is required for this project, and the annual cost is estimated at Z$6,989,000. US$ 1,022,000 for 4 operation consultant is required for the year of first commercial operation.

3) Catalysts and Chemicals

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

4) Others

Refer to Section 5.4 in Chapter 5. (Bags for urea are not necessary.)

(4) Results of Financial Analysis

The calculated financial indicators 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) Sensitivity Analysis

The following is a summary of sensitivity analysis.

(6) 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 this project is sound.
- Internal Rate of Return on Investment (before tax base), an indicator of the project's profitability, exceeds 10%, providing the validity of the project.
- During 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 a soft loan is applied, profitability of the project will be vastly improved as mentioned in the sensitivity analysis, and the shortage of fund will not occur. Therefore, it is important to borrow a loan with favorable conditions to make this project more profitable.
- 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.

## Table 6-5 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 |

## 6.5 Economic Analysis

This economic analysis is comprised of evaluating the project by the calculation of Economic Internal Rate of Return (EIRR) and of Foreign Currency Saving.

(1) Economic Internal Rate of Return

1) Major premises

- Exclusion of transfer cost items
- Shadow exchange rate SER = 1.25 • OER
- Shadow wage SW = 0.3

2) Results of calculation

The EIRR of this project is calculated at 11.5%.

(2) Effects on Foreign Currency Balance

1) Premises

This analysis is based on 1988 constant price, accordingly the effects of inflation are excluded.

2) Results of Calculation

Inplementation of this project will result in a foreign currency saving of US$146 million remaining at the end of project.

# Chapter 7 Ammonia and Methanol Scheme

## 7.1 Market for Methanol

(1) The uses of methanol

Table 7-1 sets out the uses of methanol in the world today.

**Table 7-1 Categorical Demand for Methanol (Percentage estimates for 1982)**

Unit: %

| Fields of Demands | U.S.A. | Western Europe | Japan |
|---|---|---|---|
| Formalin | 30 % | 50 % | 47 % |
| Chloromethanes | 9 | 6 | 3 |
| MTBE | 8 | 5 | — |
| DMT | 4 | 4 | 1 |
| Methylamine | 4 | 4 | 2 |
| MMA | 4 | 3 | 6 |
| Acetic acid | 12 | 5 | 10 |
| For solvent | 10 | 6 | 6 |
| Blending with Gasoline | 6 | 5 | — |
| Others | 13 | 12 | 25 |
| Total | 100 | 100 | 100 |
| Demand of Methanol (1,000 T) | 3,155 | 3,257 | 1,070 |

Source: 'World trend of Methanol', Kagaku Keizai, January, 1984.

Methanol had been consumed mainly as raw material for the production of formalin and acetic acid, but recently its use in blended petrols has been increasing.

(2) Methanol as fuel

While the trend toward using unleaded motor gasoline becomes more firmly established worldwide, there has developed a need to increase the petrol's octane rating by some other means. In order to raise the octane ratings in unleaded petrol, cracked gasoline is blended in Japan, while in the United States and Europe, methyl t-butyl ether (MTBE) and various alcohols are being used as additives to effect the same result, and in recent years, 20% of the world's demand for methanol has been for use in blended petrol.

Besides its use as an octane booster, 100% methanol is being studied for possible use as the third motor fuel following petrol and diesel oil today. The technology that would make this possible — including the modifications that would be needed in the conventional petrol or diesel oil engine — is still in its developmental stage.

(3) Methanol demand in Zimbabwe

In order to reduce petrol imports, Zimbabwe has blended domestically produced ethanol in its petrol. Furthermore, in order to make this measure more effective it is planned to increase the proportion of ethanol in petrol to 20 percent within the period of its Five-Year Economic Development Plan. Another one of its objectives is to blend methanol in diesel oil up to a 20% proportion.

Zimbabwe's imports of methanol in the past several years has only been about 100 to 190 tonnes annually. If, however, it becomes possible to mix up to 20% methanol in the diesel oil it consumes, the country's annual demand for methanol would reach 205,000 tonnes.

(4) Production capacity of Zimbabwe's methanol facilities in future

Should the use of diesel oil with a 20% content of methanol become feasible, Zimbabwe's annual demand for the methanol would reach 205,000 tonnes, and the country would need a methanol plant capable of manufacturing 600 tonnes of methanol daily. Methanol production plants being designed outside Zimbabwe today would have daily outputs running from 2,000 to 3,000 tonnes. A 600 T/D plant might be rather too small. When the costs of importing methanol into inland Zimbabwe are taken into account, however, a methanol project may be implemented.

Methanol utilization in diesel engines is still, however, a developing technology, and if it turns out that engines would have to be modified to achieve this, facilities would be also needed to undertake the work. It therefore appears that a project to produce methanol would be better deferred until a suitable engine has been built and its performance tested. Indeed, should an engine capable of being fueled by 100% methanol be developed, the demand for methanol would increase even more, and the methanol plant would then be certainly viable economically.

The manufacture of 600T/D methanol from coal, as stated later, would require three gasifiers (including one spare gasifier), and as the process furthermore requires conditions of synthesis that are different from those of the ammonia synthesis process, and would therefore require a independent line, it would appear that there would be no economic loss involved should two separate plants be constructed — one for methanol and one for ammonia. In conclusion, then, plans for a methanol plant should be deferred until a diesel engine capable of utilizing methanol is developed.

## 7.2 Ammonia and Methanol Plant Facilities

(1) Basic concept of the plant facilities

As already stated, the ammonia synthesis plant and the methanol synthesis plant should be constructed in a same site but separately. Their production capacities would be:

| | |
|---|---|
| Ammonia | 600 T/D |
| Methanol | 600 T/D. |

(2) Production facilities

Block diagram for the methanol production is shown in Fig. 7-1. Its production process is similar to that of ammonia excepting the synthesis process.

1) Coal gasifier for methanol production will be similar to that for ammonia production. However, since down stream conditions are different the number of gasifier will be 2 sets for production and 1 set for spare.

2) Carbon monoxide conversion facility

ammonia synthesis: $3H_2 + N_2 = 2NH_3$

methanol synthesis: $CO + 2H_2 = CH_3OH$

While in the manufacture of synthesis gas for ammonia production the conversion of carbon monoxide to carbon dioxide is carried out completely, in methanol synthesis, reaction conditions are adjusted such as to leave one mole of carbon monoxide for every two moles of hydrogen gas.

It can be seen that the synthesis section of ammonia and of methanol are very similar in the facilities they use, but differ significantly in their reaction conditions. It is not possible, for this reason, to manufacture both products at the same plant.

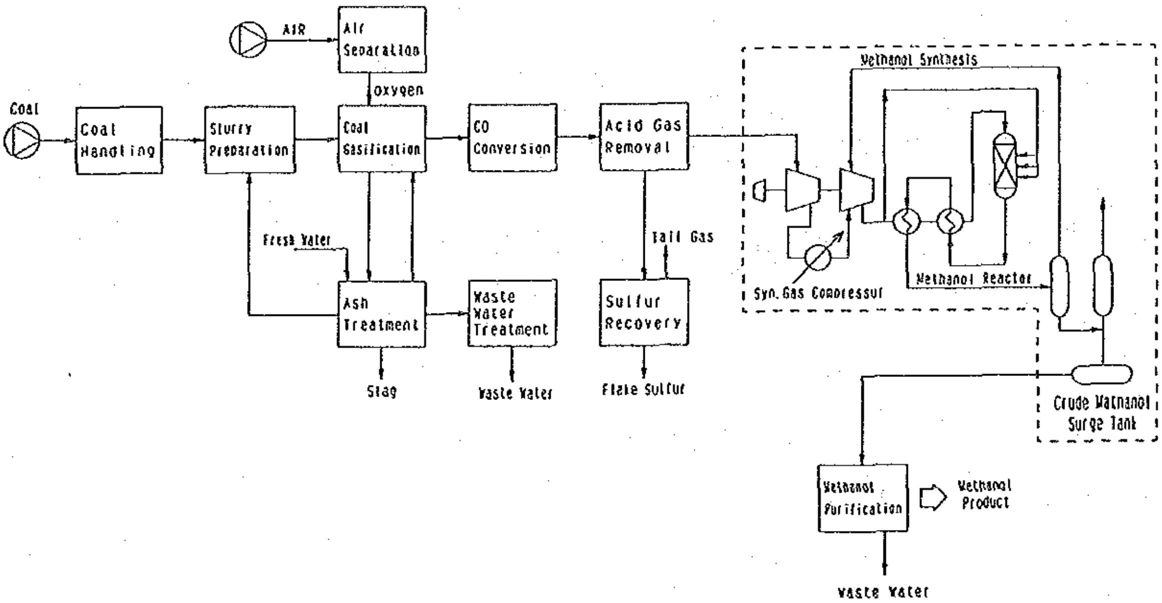


**Fig. 7-1 Block Diagram for the Methanol Process**

## 7.3 Consideration

Should it become feasible to blend diesel oil with methanol in a 20 percent proportion, a methanol plant with a daily capability of 600 tonnes could be built in coordination with an ammonia plant. The utilization of methanol as fuel for diesel engines being however still in its developmental phase, if a methanol project is to be implemented in Zimbabwe, therefore, it would be recommended that construction of the plant be carried out only after the fuel technology for utilizing methanol in diesel engines has been established and the economic viability of the plant fully examined.

# Chapter 8 Coke-Oven Ammonia and Coal Tar Scheme

## 8.1 Market for Coke and Coal Tar

(1) The uses of tars

Coal tar is a liquid substance that is condensed out of the raw gas generated in the decomposition of coal during the high-temperature carbonization of the coal for the manufacture of coke, and contains large amounts of aromatic compounds. Coal-tar distillates produced by precise fractional distillation are used for the production of organic chemicals such as pharmaceuticals, agricultural chemicals and dyestuffs. Coal tar is used for road pavement and wood preservation. It is also used as a raw material of electrode, carbon black and pitch coke.

In Zimbabwe fractional distillation of coal tar is not done. Consequently crude benzene fraction is used for blending in petrol, some tar is used for road pavement and, the remaining tar having no other use is simply used as a fuel.

(2) Supply and demand balance of coke and coal tar in Zimbabwe

Production of coke and coal tar is undertaken by two companies — ZISCO and WANKIE — whose activities are as shown in the table below:

| Company | Product | Output | Mode of consumption |
|---|---|---|---|
| ZISCO | | | |
| | Coke (KT/Y) | 540 | Consumed entirely by ZISCO for the production of iron |
| | Coke-oven gas ($Nm^3/h$) | 26,400 | Consumed entirely by ZISCO as fuel. |
| | Coal tar (KT/Y) | 22 | For fuel: 13 consumed by ZISCO, and 7.2 marketed |
| | | | For road pavement: 1.8 marketed |
| | Crude benzene (Kl/Y) | 1,800 | Sold to NOCZIM Company for blending in petrol |

| WANKIE | | |
|---|---|---|
| Coke (KT/Y) | 168 | 60% exported, 40% domestic-use |
| Coke-oven gas ($Nm^3/h$) | 8,200 | 70% consumed as fuel by Wankie |
| | | 30% wasted after combustion |
| Coal tar (KT/Y) | 11 | 50% sold for road pavement |
| | | 50% sold for use as fuel |
| Crude benzene (Kl/Y) | 2,900 | 77% for blending in petrol |
| | | 23% for blending in tar |

The following table describes Zimbabwe's history in the import and export of coke and coal tar products.

**Import and Export of Coke**

Unit: T

| | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|
| Imports | 39,408 | 52,950 | 87,633 | 175,170 | 96,140 |
| Exports | 135,272 | 101,871 | 89,612 | 113,133 | 24,537 |

**Imports of Tar-related Products**

| | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|
| Coal tar (T) | 207 | 265 | 401 | 297 | 194 |
| Creosote oil (kl) | 625.9 | 157.5 | 118.4 | 339.6 | 181.4 |
| Benzene (kl) | 36,106 | 33,928 | 419 | 494 | 260 |
| Bitumen (T) (asphaltic) | 15,476 | 13,757 | 11,610 | 16,336 | 15,433 |

① Coke

The fact that imports of coke to Zimbabwe have been increasing since 1986 despite idle production capacity at both the companies ZISCO and WANKIE may be thought to owe itself to the quality of the coke made from Wankie coal which is rather high in sulphur and phosphorus content. Zimbabwe has adequate capacity at ZISCO and WANKIE to meet its domestic demand for coke.

② Coal tar

In Zimbabwe today, crude benzene and crude tar are being recovered from coke-oven gas, but its various constituents are not being fractionally distilled. Although the crude benzene is blended in petrols at the NOCZIM, and a part of the crude tar is being used for road pavement , the remainder is consumed as fuel.

The road tar is used on roads as an underlying water-proofing layer, and the amount of it used is estimated at 3,600 tonnes annually. As the life of pavement with coal tar is short, an annual 15,000 tonnes of bitumen have therefore to be imported as a paving materials.

A small amount of creosote oil (wood preservative) and benzene are being imported as well. Currently at ZISCO, there is a plan to subject crude tar produced both by itself and by the Wankie Company to fractional distillation and purification processes, and in this way domestic provision of coal-tar products will become possible.

③ In conclusion, Zimbabwe's supply capacity to coke and coal tar exceeds the country's demand, and the construction of a new coke and coal tar plant would be superfluous.

## 8.2 Coke-Oven Ammonia and Coal Tar Plant Facilities

As stated in the preceding section, Zimbabwe has sufficient capacity to supply both its coke and coal tar needs, and there would be no need to undertake a new project by which coke-oven gas is used as raw material for ammonia production and, coke and coal tar are produced as by-product. Such a project, however, has been studied here in order to obtain a whole picture of this production scheme.

(1) Basic concept of the production plant

The idea is to use coking coal from the Wankie coal mine in order to produce coke in a coke oven, and to produce ammonia from the coke-oven gas that evolves as a by-product. The capacity for ammonia production here has been assumed to be 600 tonnes daily.

(2) Production facilities

An outline of the production processes and of the relationship between the starting material and products, including by products, is given in the flow chart in Fig. 8-1. The synthesis of ammonia from coke-oven gas involves a more complex procedure than to manufacture the ammonia by directly gasifying coal, because coke-oven gas includes a residual fraction of tar and also contains such hydrocarbons as methane.

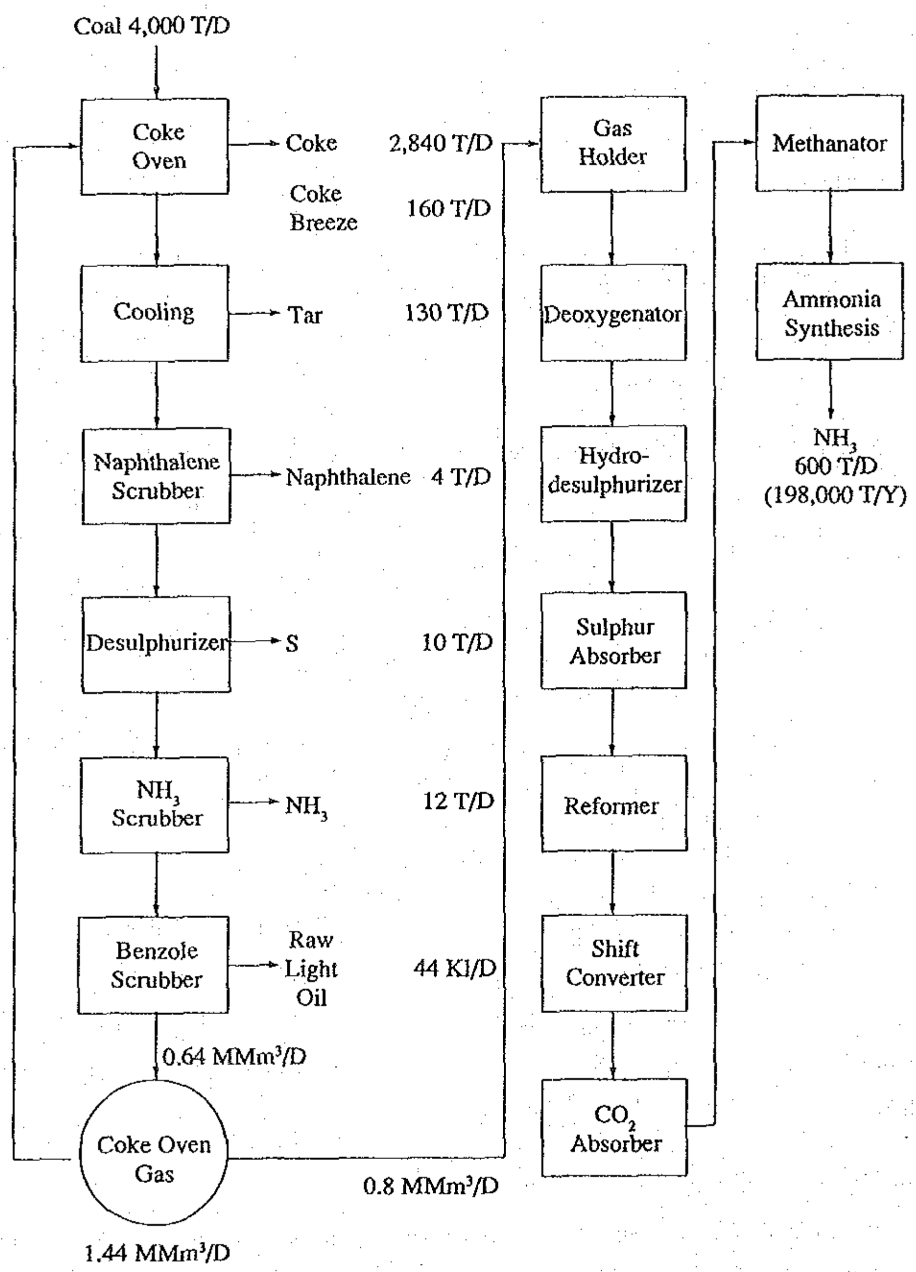


**Fig. 8-1 Block Diagram for the Coke-Oven Ammonia Process**

(3) The relationship between starting material, final products and by-products

| Item | T/D | T/Y (for yearly 330-day operation) |
|---|---|---|
| Raw material: | | |
| Coal | 4,000 | 1,320,000 |
| Final Products: | | |
| Ammonia | 600 | 198,000 |
| Coke | 3,000 | 990,000 |
| Tar | 130 | 42,900 |
| Naphthalene oil | 4 | 1,320 |
| Crude light oil (kl/D) | 44 | 14,520 |
| Ammonia (By produced) | 12 | 3,960 |
| Sulphur | 10 | 3,300 |

## 8.3 Consideration

The table below examines the situation that would obtain should this particular project be implemented in the light of the current state of affairs.

| | Current state | Effect of the project |
|---|---|---|
| Coking coal | Production 840,000 T/Y | An annual 1,320,000 T would be additionally required, an amount that domestic supplies would not be able to meet. |
| Coke | Production 708,000 T/Y | An annual 990,000 T would be additionally made available, an amount that a domestic demand would not be able to absorb. |
| Coal tar | Production 33,000 T/Y | An annual 42,900 T would become additionally available for which there would be no other use than as fuel. |

In conclusion, a scheme to produce coke and coal tar, and to use the by-product coke-oven gas to produce ammonia would not be appropriate for present purposes.

# Chapter 9 Conclusions and Recommendations

## 9.1 Conclusions

A plan of the establishment of an ammonia plant in Zimbabwe has been made for the production from coal of ammonia and possibly other chemical products as co-products with added value. In relation to the production process, the following four cases are considered.

-- ammonia and urea

-- ammonia alone

-- ammonia and methanol

-- coke-oven gas ammonia and coal tar

The results of this study have been as follows:

(1) Market demands

1) The market for ammonia

An estimate was made of the demand for nitrogenous fertilizers in Zimbabwe today based on results of a survey of the country's agricultural use of these fertilizers. The demand for ammonia in 1995/96 was projected at 200,000 tonnes. In order to provide this amount, construction of a 600 T/D ammonia plant becomes necessary.

2) The market for urea

The potential demand for urea in 1995/96 was estimated at 226,000 tonnes. Allowing that future shortages of nitrogenous fertilizers should be met by urea, a 525 T/D urea plant will be needed.

3) The market for methanol

Supposing that it becomes possible to blend methanol in the diesel oil Zimbabwe uses to a 20% proportion, the amount of methanol needed in 1995 would be 205,000 tonnes. This would require a methanol plant having a daily output of 600 tonnes. The technology for utilizing a fuel mixture of diesel oil and methanol still being in its developmental stage, however, plans for the production of methanol would have to wait until such technology becomes available.

4) The market for coal tar

Coal tar is today produced by the companies WANKIE and ZISCO, and because demands for it are low, part of it is being consumed as fuel. For this reason, the manufacture of ammonia from coke-oven gas would place a great overabundance of coal tar and coke on the domestic market. It would mean that the surplus should be exported, but as there are difficulties in doing this as well, implementation of the coke-oven ammonia and coal tar scheme appears inappropriate.

(2) Feedstock coal

1) The ammonia and urea scheme

This scheme will use run-of-mine coal (14% of ash, 22% max.) and consume 240,000 T/Y of the coal, an amount which present facilities at WANKIE are capable of supplying.

2) The ammonia and methanol scheme

The production of methanol itself requires 250,000 tonnes of coal annually, in addition to the 240,000 tonnes needed for the production of ammonia. As there would not be enough run-of-mine coal to supply this amount it will be necessary to also use power station coal (25% or less of ash) to put this scheme to practice.

3) The coke-oven gas ammonia and coal tar scheme

1,320,000 T/Y of coking coal will be necessary, an amount that could not be supplied by the existing facilities currently at the WANKIE Company.

(3) Plant location

For the plant location, the Hwange and Kwekwe regions have been considered. Kwekwe lacking the necessary water for plant processes, however, Hwange has been chosen as the plant site.

(4) Technology

The production from coal of ammonia, urea and methanol all make use of established industrial processes, so that there will be no technical problem involved in carrying them out.

(5) Total capital requirements (Current Price Base) Unit: US$1,000

| | Ammonia-urea scheme | Ammonia scheme |
|---|---|---|
| Foreign currency | 279,106.7 | 246,085.1 |
| Local currency | 103,312.1 | 87,620.4 |
| Total | 382,418.8 | 333,705.5 |

(6) Financial assessment

| | Ammonia-urea scheme | Ammonia scheme |
|---|---|---|
| IRROI (Before tax) | 10.4 % | 12.5 % |
| IRROI (After tax) | 7.9 | 9.7 |
| IRROE (Before tax) | 9.8 | 13.4 |
| IRROE (After tax) | 6.4 | 9.8 |

The reason why the rate of return on the ammonia scheme is higher than that on the ammonia and urea project is that the pricing in Zimbabwe of ammonia is more favorable than that of urea. Of the daily 600 tonnes of output in the ammonia project, 300 tonnes would be supplied to SABLE, while the remaining 300 would be supplied to a project in Zimbabwe yet to be planned.

There is therefore a need to compare the rates of return that would be realized by undertaking a combination of the ammonia scheme and the yet-unspecified ammonia-derivative scheme with that of the ammonia and urea scheme.

Both rate of return and cash flow considerations make either project feasible, and if soft loans were used to obtain foreign currency, the cash flow of this project would be further eased and the return on equity improved.

(7) Discussion

1) In the ammonia and urea project, 300 T/D ammonia will become feedstock for ammonium nitrate at SABLE, while the remaining 300 T/D will be used for urea production at a new plant. Zimbabwe, as a result, would not only be able to provide itself with two sorts of fertilizer — ammonium nitrate and urea — but would be able to do so at reasonable prices, even allowing for future increases in electricity tariff.

   The current feasibility study recommends the ammonia and urea project as being the best project and suggests that it should be implemented.

2) Although the ammonia scheme would show a good rate of return, 300 T/D ammonia will serve to produce ammonium nitrate at SABLE, while the remaining 300 tonnes will furnish raw material for some project which would have to be planned, and this latter project and the ammonia project have to be undertaken in conjunction with one another. Should a 600 T/D ammonia plant be constructed the problem would be that it could not be operated, from facility considerations, at a capacity of only 300 tonnes per day.

3) The ammonia and methanol project would have to be carefully examined only after an engine that could run on a diesel and methanol fuel mixture is developed and its effectiveness established.

4) The coke-oven gas ammonia and coal tar project would not be feasible.

## 9.2 Recommendations

Based on this feasibility study, it has been concluded that the ammonia and urea project is the best of the four alternative schemes. The followings would be recommended as to the project's implementation:

(1) Ammonium nitrate has in the past been used as the choice nitrogenous fertilizer in Zimbabwe's agriculture and farmers are therefore not accustomed to the use of urea. Prior to the production of urea, therefore, the government of Zimbabwe would have to instruct farmers as to the use of this fertilizer.

(2) Even before the production of urea gets underway, the demand for nitrogenous fertilizers will continue to increase every year, and this would call for imports into the country for whatever is short. Urea, then, should be the nitrogenous fertilizer imported to expand the country's demand for urea.

(3) The training of plant operators prior to plant operation is valuable, and training in operating a chemical plant at such plants as SABLE or WANKIE is preferable.

(4) The SABLE has maintained a high efficiency of production under good management practices. Should current project be implemented SABLE would close down its ammonia facilities, but its production of nitric acid and ammonium nitrate would continue. Their facilities for the manufacture of nitric acid and ammonium nitrate have been in use for a good many years and would, however, probably need renovation in future. Suitable repairs should therefore be carried out according to their degree of deterioration.

(5) Implementation of the current project would greatly increase the volume of transport between Hwange, Kwekwe and Harare. Transport of fertilizer from Harare to consuming areas will also increase. Plans should therefore be drawn up at the outset to prepare for this inevitable increase in transport.