

THE FEASIBILITY STUDY REPORT
ON
THE ESTABLISHMENT OF AN AMMONIA PLANT
IN
THE DISTRICT OF SIKKIM
INDIA

THE FEASIBILITY STUDY REPORT
ON
THE ESTABLISHMENT OF AN AMMONIA PLANT
IN
THE REPUBLIC OF ZIMBABWE
(VOLUME II)

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Volume II
Part 1 Ammonia, Methanol Project

Chapter 1 Market for Coal Chemical Products: Methanol

Ammonia, Methanol Project

Chapter 1 Market for Coal Chemical Products: Methanol

1.1 Preface

Methanol is a typical product produced from coal through coal gasification similar to ammonia. Methanol is the raw material for a wide variety of chemical derivatives and is widely used as a fuel for raising the octane number. By the Twenty-First Century, it is forecast that, methanol as a fuel will gradually assume a position of greater importance. At present, the only plants using coal as raw material are a 1,500 T/D plant owned by AECI of the Federal Republic of South Africa and a plant of Tennessee Eastman Co. producing 150 KT/Y. Apart from these, all methanol is produced in plants that use oil or natural gas as the raw material.

Products produced from the raw material of natural gas in particular have the largest share. This tendency will not change as long as the situation continues where natural gas at low price, partially the result of the decline in the international price of oil, can be used. In free-economy markets, this is only natural, but if one takes the long-term point of view, the process of using coal as the raw material, which exists in far greater quantities under the ground compared to oil and natural gas, will become the mainstream in methanol production. These matters and the fact that the main use of methanol will be in motor fuel have been pointed out by the World Energy Conference (WEC). According to WEC, the potential demand for methanol is shown in Table I-1-1 as a long-term guideline.

Table I-1-1 Potential Demands of Methanol

Unit: million T/Y

Fields of Consumption	Year	
	2000	2020
Blending with Gasoline	24	38
Substitution for Gasoline (M100)	150	550
Substitution for Diesel oil (M100)	100	230
For Heat and Power generation	—	5
For Chemistry	22	46
Total	296	869

Source: WEC, REPORT 1986, "Methanol Prospects"

At present, almost all motor fuel is gasoline, light oil and LPG, while methanol has not been put into practical use generally, except as a low-concentration mixture in gasoline, as will be explained in detail later in this chapter. However, based on the expectation that oil will be in small demand in the latter half of the 1990s, the development of a vehicle that uses methanol as fuel is being promoted in advanced countries such as the U.S.A., West Germany and Japan for preventing air pollution from vehicle exhaust and diversifying the types of motor fuel. In addition, China and Indonesia are keenly interested in introducing methanol fuel in order to meet the sharp rise in the demand for motor fuel in the future, to put their vast coal resources to practical use, and to use oil as an export item even more. These countries are therefore promoting research and exploration.

In this survey, the following items have been clarified as the policy of the Government of Republic of Zimbabwe. In practice the use or the fuel mixture of gasoline and ethanol, which has already been put to practical use in the Otto Cycle Engine (gasoline engine), should be promoted even more, while the ethanol mixture ratio, which at present is 13 Vol. % (279 KKI gasoline + 40 KKI ethanol), should be increased to 20 Vol. % considering the maximal mixture ratio of 25 Vol. %. On the other hand, the main use of methanol should be as a fuel for the Sabathes Cycle Engine (diesel engine), while 20% of the light oil should be replaced by methanol. The Government's policy is to realize these aims by using the process of mixing methanol with light oil. In this project survey, various studies were carried out while bearing in mind the policy of the Government of Zimbabwe described above.

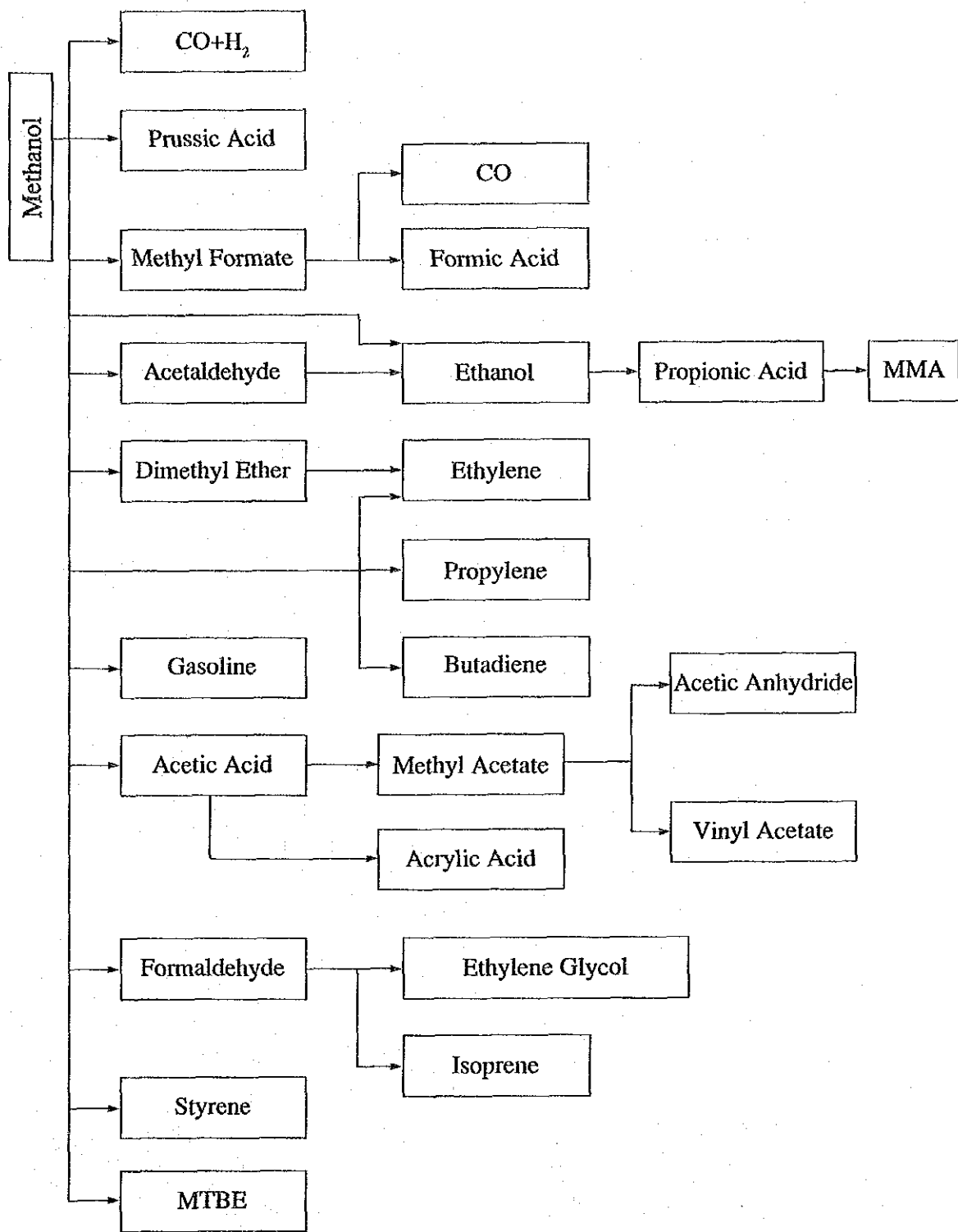
1.2 Uses of Methanol

In this section, a general look at the uses of methanol preceding a review of the demand for methanol is described.

The uses of methanol are roughly divided into use by industry in the production of various chemical products and use as a fuel. The consumption of fuel is expected to increase sharply in the future, though at present use by industry occupies a share of around 80%. Methanol can be the raw material for various derivatives as the basic material for C₁ chemical products.

An outline is given in Fig. I-1-1

The different uses shown in the same figure are not all practical, and many technological developments can be expected in the future such as (CO + H₂), ethanol and styrene. Special attention should therefore be paid to this point.



Source: 'Technology and Demand of Methanol', Kagaku Keizai, April, 1983.

Fig. I-1-1 C₁ Chemicals from Methanol

1.2.1 Industrial Use

To fully understand the demand in chemical use, refer to Table I-1-2, although it must be pointed out that the data is a little old. Among the items indicated, use as a fuel, such as MTBE and as a gasoline mixture are increasing significantly so, for the present supply and demand, reference must be made to the supply and demand of the whole world, which is touched upon later.

Table I-1-2 Demand for Methanol (Estimated value of 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.

(1) Formalin

Formalin occupies the greatest share among the different chemical uses of methanol, and has already been commercially available in the form of about 40% water solution. Formalin is consumed in large quantities as raw materials for resin production such as urea resin, polyacetal resin, phenol resin etc. It is also used as a raw material of chemicals such as urotropin, pentaerythritol and paraform use for fumigants, pharmaceuticals and agricultural chemicals, as well as for paint uses. The unit consumption of methanol for 37% formalin is about 430 kg.

(2) Acetic Acid

Composed of methanol and CO, acetic acid is widely used as a raw material for vinyl acetate, cellulose acetate and acetic ester, as well as a solvent after the production of terephthalic acid. Recently, there has been an increasing demand for methanol as the raw material acetic acid. The methanol basic unit of acetic acid is about 550 kg.

(3) MMA

For methyl methacrylate, the process using isobutylene as a raw material is the mainstream. Through polymerization of MMA glassy transparent, weather-resistant resin is produced. This resin is used in many ways: as a building material and in lighting equipment. Methanol is used in the esterification of methacrylic acid, the methanol basic unit being about 340 kg.

(4) DMT

As the raw material for polyester fiber and film, dimethyl terephthalate is compounded through the condensation of paraxylene and methanol. The methanol basic unit is about 500 kg.

(5) Chloromethane

Chloromethane (the generic name for methylchloride, methylene chloride, chloroform and carbon tetrachloride) belongs to an important group of solvents, and is composed of methanol and chlorine.

1.2.2 Use as a Fuel

Methanol can act as a substitute for gasoline as it is, or can be added to gasoline again as it is, or in the form of MTBE, as an additive to raise the octane number gasoline as an oxygenate. The consumption of methanol for these purposes is increasing in a number of countries. The various characteristics of methanol as a type of motor fuel are shown in Table I-1-3 as a comparison with the characteristics of gasoline and light oil.

Table I-1-3 Properties of Methanol, Gasoline and Light Oil as Fuel

	Methanol	Gasoline	Light oil
Molecular formula	CH ₃ OH	C ₄ -C ₁₂	C ₈ -C ₁₈
Specific gravity (kg/l)	0.792	0.72-0.78	0.82-0.85
Higher calorific value (Kcal/l)	4,290	8,590	9,300
Lower calorific value (Kcal/l)	3,820	7,950	8,650
Theoretical air fuel ratio (Air/Fuel) (kg/kg)	6.5/1	14.5/1	15.0/1
Latent heat of vaporization (Kcal/kg)	263	80 (Approx.)	60 (Approx.)
Temperature drop of mixed gas (°C)	122	18	-
Research octane number	112	91	-
Motor octane number	92	82	-
Cetane number	3	-	40-50
Flashing point (°C)	12	-40	38
Fire point (°C)	464	425-510	210-240
Boiling point (°C)	54.5	27-225	150-390
Freezing point (°C)	-98	< -60	< -20
Explosion limits (Vol. %)	6.7-36.5	1.4-7.6	1.0-7.0
Vapor pressure (37.5 °C) (kg/cm ²)	0.37	0.45-0.8	-
Solubility of water (20°C)	∞	Insoluble	Insoluble

Source: WEC, REPORT 1986, "Methanol Prospects" and others.

Methanol is expected to become a special kind of motor fuel ranking third after gasoline and light oil. A number of research projects are now being undertaken to establish the practical applications of methanol. At present, 20% of the total demand for methanol is consumed by the Otto Cycle Engine (gasoline engine), and in the field of mixing methanol with gasoline, the practical use of methanol has already been found. However at present, the technology of using methanol (M-100) as a total fuel substitute for gasoline in the Otto Cycle Engine has not yet been put to practical use.

In addition, in the case of a gasoline-methanol mixture, when a substantial quantity of methanol is added, such as M-10 (methanol, 10 Vol. % mixture) and M-15, followed by its lengthy use, various problems occur including engine corrosion. However, if the mixture is only about 3-5% there are no problems experienced, hence it is widely used in the U.S.A. and Europe.

In Japan gasoline with a non-lead content is now widespread thanks to improvements to vehicle engines. However, in the U.S.A. and Europe, the promotion of gasoline with a non-lead content is still underway. Thereby a role of additives to raise the octane number of gasoline is sought for in oxygenates mainly methanol and its derivative such as MTBE (methyl tertiary butyl ether), a methanol derivative. As shown in Table I-1-3, the RON (Research Octane Number) of methanol is 112, and the MON (Motor Octane Number) is 92, while those of MTBE are 117 and 101, respectively, considerably higher than the octane number of gasoline. The oxygenates mixed into gasoline in the U.S.A. today are as follows.

Methanol	5 Vol. %	+ ethanol	2 vol. %
MTBE or TBA	7 Vol. %		
Methanol/TBA (1:1)	9.5 Vol. %		
Methanol + higher alcohol	12 + 3 Vol. %		

Of these, the consumption of gasoline with a non-lead content in 1986 exceeded 70 % of the consumption of all gasoline. On the other hand, in the EC, the use of gasoline with a non-lead content will become obligatory as of October 1, 1989, and the maximum permissible concentration oxygenates mixing with gasoline will be regulated as follows:

Methanol	3 Vol. %
Ethanol	5 Vol. %
IPA	5 Vol. %
TBA	7 Vol. %
MTBE and other ether	10 Vol. %

In the case of mixing methanol 3 Vol. %, it will be obligatory at the same time to use a 2% stabilizer such as TBA. In a survey conducted in West Germany, in 1984, alcohol-mixed gasoline occupied a 65% share, with methanol being the mainstream of the alcohol used. Methanol is added to gasoline in West Germany, Belgium, the Netherlands, Switzerland and Austria, with MTBE being the mainstream in Sweden, Denmark, Finland and Italy. In addition to methanol, MTBE is consumed in large quantities as additives to raise the octane number of gasoline and is derived also from methanol. MTBE is synthesized by the reaction of isobutene and methanol, while the methanol basic unit is about 380 kg.

At the same time, research and development are being promoted in a number of countries for the purpose of using methanol as a substitute or partial substitute for light oil in the Sabathes Cycle Engine. However, the stage of practical application has not yet been reached. The results of this survey in this particular area will be described in Section 1-5.

1.3 World Situation of Supply and Demand

1.3.1 Supply and Demand of Methanol

The supply and demand of methanol on a global basis suddenly entered a tight situation in 1987. This was caused by a predicted shortfall in the supply capacity to meet the sharp increase in demand. The forecast that this situation will continue until the first half of the 1990s still holds fast.

(1) Demand

The supply and demand forecast for methanol viewed from the standpoint of demand is shown in Table I-1-4.

Table I-1-4 Forecast World Methanol Supply/Demand Balance

Unit: 1,000 T

Demand	1987	1988	1989	1990	1991
Formaldehyde	4,765	4,881	4,962	4,991	5,077
DMT	621	641	673	679	682
Acetic acid	1,014	1,151	1,255	1,395	1,388
MTBE	1,321	1,681	2,008	2,248	2,348
Methyl methacrylate	379	381	386	388	388
Gasoline/Fuels	1,920	1,563	1,537	1,540	1,547
Solvents	1,788	1,882	1,939	1,985	2,025
Others/Various	4,057	4,400	4,560	4,684	4,786
Non-tabulated countries	220	230	240	255	260
Total demand	16,085	16,810	17,560	18,165	18,501
Nameplate capacity	18,743	19,133	19,950	20,030	20,030
Percent utilization of nameplate (%)	86	88	88	91	92

Source: DeWitt & Co

European Chemical News, April 18, 1988.

The average annual increase in the demand for methanol during this period is broadly estimated as 600 KT/Y.

Items are taken from Table I-1-4 and re-arranged to form Table I-1-5

Table I-1-5 Demand Indices

	Share %		Growth Index	Annual Growth Rate %
	1987	1991	1991/1987	
Formaldelyde	29.6	27.4	1.065	1.6
DMT	3.9	3.7	1.098	2.4
Acetic acid	6.3	7.5	1.369	8.2
MTBE	8.2	12.7	1.777	15.5
Methyl methacrylate	2.4	2.1	1.024	0.6
Gasoline/Fuels	11.9	8.4	0.806	-5.3
Solvents	11.1	10.9	1.133	3.2
Others/Various	25.2	25.9	1.180	4.2
Non-tabulated countries	1.4	1.4	—	
Total demand			1.150	3.6
Nameplate capacity			1.069	1.7

As an industrial use, the demand for acetic acid use exceeds that for other uses by more than twice the growth rate of the total demand. For use as fuel, it is anticipated that the demand for MTBE will increase rapidly at an annual rate of 15.5%. On the other hand, the quantity of methanol to be mixed directly with gasoline will decrease sharply. Use as fuel by pooling MTBE and gasoline/fuel showed an annual rate of increase of 4.7%, being in 1987 at 3,241 KT and the 1991 projection being 3,895 KT.

Data showing the changes in the production capacity of MTBE, for which there has been a major increase in demand, by region, can be found in Table I-1-6 for reference purposes. In addition, the changes in Japan's demand for methanol are shown in Table I-1-7, while the changes in the U.S. demand are shown in Table I-1-8.

Table I-1-6 MTBE Plant Capacity in World

Unit: 1,000 T

	1983/End	1984/End	1985/End	1986/End	1987/End	88/End	89/End	Growth ratio (%/Y)
U.S.A.	987	1,163	2,163	3,352	3,472	3,472	3,472	23.3
Western Europe	582	652	697	762	907	958	958	8.7
Eastern Europe	165	203	288	288	288	288	488	19.8
Central and South America	—	141	141	211	211	693	1,193	53.4
Middle East	—	21	21	30	30	530	530	190.0
Asia (excluding Middle East)	—	—	—	—	90	90	390	—
Total	1,734	2,180	3,310	4,643	4,998	6,031	7,031	26.3
Extension ratio per year	—	1.25	1.52	1.40	1.08	1.21	1.17	

Source: Kagaku Keizai, June, 1987.

Table I-1-7 Past Methanol Demand in Japan

Unit: 1,000 T

Use	1984		1985		1986	
	Quantity	Percentage	Quantity	Percentage	Quantity	Percentage
Formalin	577	44.2	591	45.1	594	46.8
MMA	94	7.2	95	7.2	97	7.6
Acetic acid	117	9.0	122	9.3	97	7.6
Others (note)	516	39.6	503	38.4	482	38.0
	1,304	100.0	1,311	100.0	1,270	100.0

Note: Includes DMT, chemical products pharmaceuticals, agricultural chemicals, chloromethane and methylamine.

Source: Calculated from, "Trends in the Chemical Industry by Industrial Sector," Kagaku Keizai, 1987/88, Special Issue p. 45 (August, 1987)

Table I-1-8 Methanol Demand in U.S.A.

Unit: 1,000 T

		1984	1985	1986	1987	1989
For Fuel	For chemistry	3,485	3,308	3,374	3,440	3,580
	MTBE	270	285	601	840	1,055
	Gasoline mixture	310	225	60	0	225
	Export	99	42	120	120	30
	Total demand	4,164	3,860	4,155	4,400	4,890

Source: Kagaku Keizai, June, 1987.

(2) Supply

In Tables I-1-9 and I-1-10, the methanol plant capacities throughout the world are shown, though the sources of the data are different.

Table I-1-9 Methanol Plant Capacity

Unit: 1,000 T

	83/End	84/End	85/End	86/End	87/End	88/End	89/End
U.S.A.	5,015	4,325	3,575	3,725	3,125	3,125	3,125
Canada	1,820	1,820	1,640	1,640	1,640	1,640	1,640
Central and South America	385	781	781	781	851	851	1,601
Western Europe	2,825	2,750	2,635	2,635	2,320	2,320	2,320
Eastern Europe	4,180	4,930	4,930	5,130	5,130	5,030	5,030
Africa	400	400	730	730	730	730	730
Middle East	660	1,360	1,690	1,690	1,690	1,690	1,690
India	44	44	44	44	194	227	227
ASEAN	-	-	660	990	990	990	990
Oceania	400	400	400	1,900	1,900	1,900	1,900
East Asia	200	260	260	260	260	260	260
Japan	396	396	396	253	253	253	253
Total	16,325	17,466	17,741	19,778	19,083	19,016	19,766
For Acetic Acid	150	150	210	210	270	270	270
For Gasoline	-	-	-	1,500	1,500	1,500	1,500
Retotal (Excluding for Acetic acid and Gasoline)	16,175	17,256	17,531	18,008	17,313	17,246	17,996

Source: Kagaku Keizai, June, 1987

Table I-1-10 World Methanol Supply/Demand Balance

Unit: 1,000 T

Capacity	1986	1988	1990
North America	6,207	5,007	5,007
Western Europe	2,394	2,394	2,394
Far East/Asia	3,908	3,908	3,908
South America	563	643	1,393
Mid East/Africa	2,441	2,441	2,441
Eastern Europe	5,720	5,720	5,720
Total world capacity	21,233	20,113	20,863
Total demand	15,646	17,297	18,350
Percent utilization			
@ 90 percent			
Nameplate (%)	82	96	98

Source: ECN, Apr. 27, 87

From 1982 to 1986, new plants of 9 million T capacities were built and put into operation. At the same time, the operations of inefficient plants around the world with capacities equivalent to 5 million T were suspended or were dismantled, which meant that actual capacity increase remained at 4 million T. As a result, a number of countries including Japan, Spain, Italy and France, which had hitherto enjoyed a situation of self-sustenance, turned into countries forced to import methanol. In addition, the U.S.A. closed plants with capacities equivalent to 2.7 million T and was forced to depend on imports for about 35% of the total demand. The circumstances during that period are illustrated in Tables I-1-11 and I-1-12.

Table I-1-11 Methanol Plant Capacity in U.S.A.

Unit: 1,000 T

Company	Location	82/End	83/End	84/End	85/End	86/End	87/End
Air Products	Pace, FL.	195	195	195	195	195	195
Allemania	Plaquemine, LA	390	-	-	-	-	-
Borden	Geismar, LA.	600	600	600	600	600	600
Celanese	Bishop, TX.	530	530	530	530	530	530
Celanese	Clear Lake, TX.	690	690	-	-	-	- Moth-Balling at Feb., '84
Du Pont	Beaumont, TX.	750	750	750	-	750	750 Moth-Balling at Jan., '85 Re-Start at Mar., '86
Georgia Gulf	Plaquemine, LA	300	300	300	300	300	300
Lyondel Petrochemical	Channelview, TX.	600	600	600	600	600	600
Sterling	Texas City, TX.	300	300	300	300	300	- Start at Jan., '83
Texaco	Delaware City, DE	-	300	300	300	300	- Moth-Balling at DEC., '86
USI (Du Pont/USI)	Deer Park, TX.	600	600	600	600	-	- Moth-Balling at Oct., '86
Tenneco	Pasadena, TX.	450	-	-	-	-	- Moth-Balling at Mar., '83
Tennessee Eastman	Kingsport, TN.	-	150	150	150	150	150 Start at Oct., '83 Raw Coal
Total		5,405	5,015	4,325	3,575	3,725	3,125

Source: Kagaku Keizai, June, 1987

Table I-1-12 Potential 1987 Methanol Suppliers to U.S.A

Unit: 1,000 T

Canada	400
Bahrain	225
Malaysia	200
Trinidad	120
New Zealand	80
Saudi Arabia	50
Various/others	50
Total	1,125
Estimated import requirements	1,572
Shortage	447

Source: European Chemical News, April 27, 1987

In other words, the U.S. demand in 1987 was 4.4 million T (see Table I-1-8), while the supply capacity can be regarded as 90% of the nominal capacity. In terms of actual quantity referring to Table I-1-11, domestic supply could be assumed as $3,125 \text{ KT/Y} \times 0.9 = 2,820 \text{ KT/Y}$.

There was therefore a shortfall of 1,580 KT, equivalent to 36% of the total U.S. demand.

Data on the supply side which created this shortfall can be seen in Table I-1-12. It is a very tight situation since a shortfall in supply has been forecast.

Furthermore, in Western Europe, there was an increase in the demand for methanol for use as vehicle fuel, which meant that this particular region needed to increase imports by about 300 to 400 KT in 1987. It seems that the shortfall was mainly covered by supplies from Eastern Europe. The changes in the methanol production capacities in Eastern Europe are shown in Table I-1-13.

Table I-1-13 Progress of Methanol Product Capacity In Eastern Europe

Unit: 1,000 T

	82/End	83/End	84/End	85/End	86/End	87/End	88/End
Bulgaria	30	30	30	30	30	30	30
Czechoslovakia	100	100	100	100	100	100	-
East Germany	400	400	400	1000	1000	1000	1000
Hungary	70	70	70	70	70	70	70
Poland	280	280	280	280	280	280	280
Romania	300	300	300	300	300	300	300
U.S.S.R.	2100	2850	3600	3600	3600	3600	3600
Yugoslavia	150	150	150	150	350	350	350
Total	3430	4180	4930	4930	5130	5130	5030

Source: Kagaku Keizai, June, 1987

After taking into consideration the balance of supply and demand, as shown in Table I-1-10, a severe situation where the plant operation rate has to be at the 96-98% level will continue until the 1990s, provided that 90% of the nominal capacities of the plants is regarded as the maximum production volume that can be expected. Of course, if a reasonable market price can be maintained for a long period, the balance of the supply and demand might be improved, provided that plants once closed are re-opened and that new plants are built. With this situation serving as the background, the countries in which methanol projects have a high possibility of realization are as follows:

Saudi Arabia: 600 KT/Y

The United Arab Emirates: 500 KT/Y

Trinidad and Tobago: 500 KT/Y

Argentina: 700 KT/Y

Furthermore, over the long term, as concluded by a WEC survey conducted in 1986, as shown in Table I-1-1, the main use of methanol will be as motor fuel, while there is the possibility that both gasoline and light oil will be converted into methanol at a limit of 30%.

(3) Price

The FOB price of methanol is shown in Fig. I-1-2 being the spot price of methanol produced within the EC, free from customs and excise duties and in Fig. I-1-3 as the U.S. domestic price. From the second half of 1987 to 1988, prices suddenly rose, especially U.S. domestic prices. This is a reflection of the tightening of demand since 1987, as mentioned in the part on supply and demand in the previous paragraph, and there is a strong forecast that this kind of situation will last until the mid-1990s.

The average FOB price for the EC tax-free spot price from 1986 to 1988 was roughly US\$ 138.0 and US\$ 144.3 for the U.S. domestic price.

The market price of methanol fluctuates, though not as much as the price of ammonia. However, by taking into consideration the fact that coal will probably be used as a raw material in the future, it is desirable to understand the relationship between production cost, the raw material energy price and the market price of methanol, even if it is only an outline. In the present situation, natural gas is used as the raw material for most methanol, as described above. There are considerable differences in the price of natural gas, depending on the country. The estimated prices are shown in Table I-1-14.

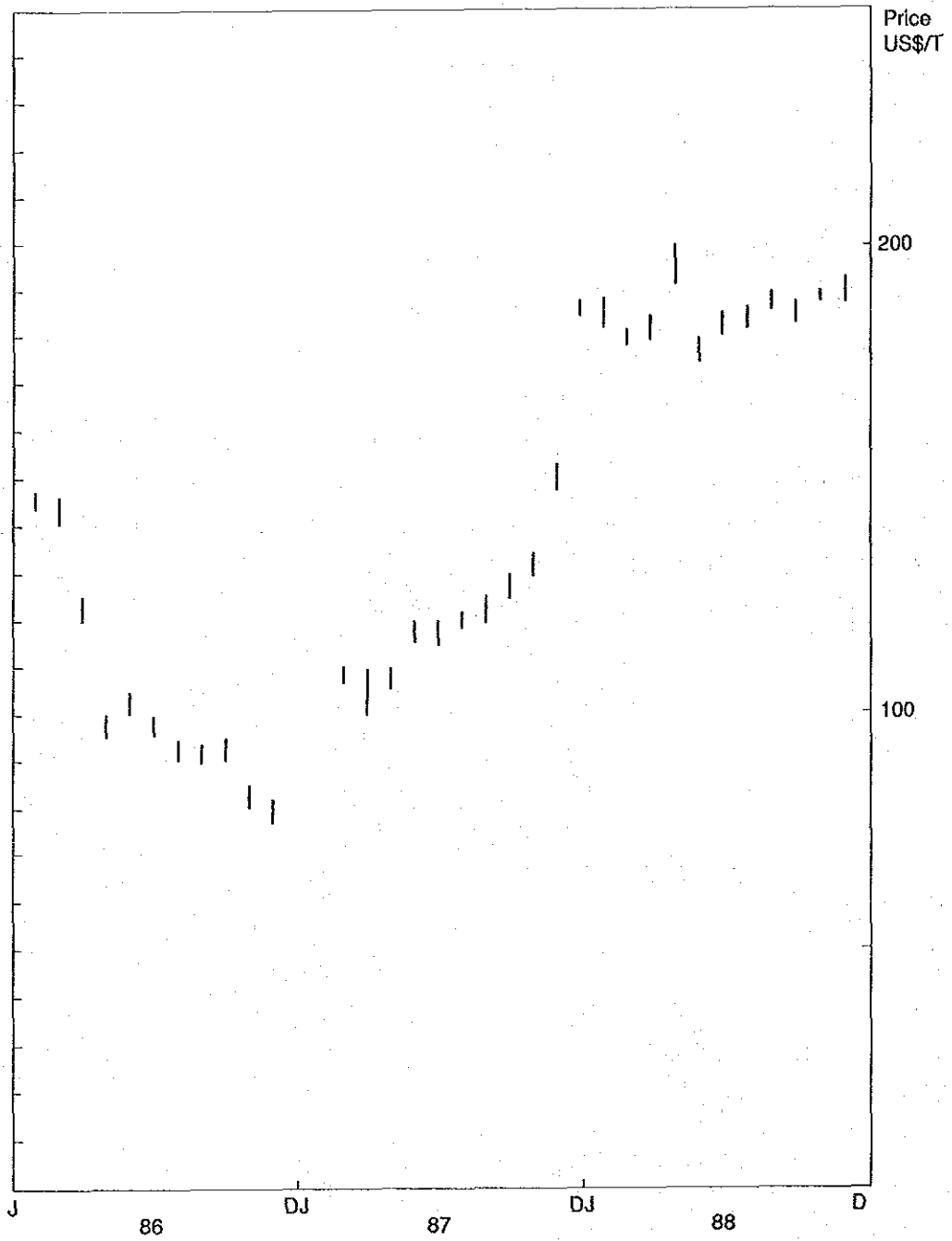


Fig. I-1-2 Methanol, European Spot Price, FOB

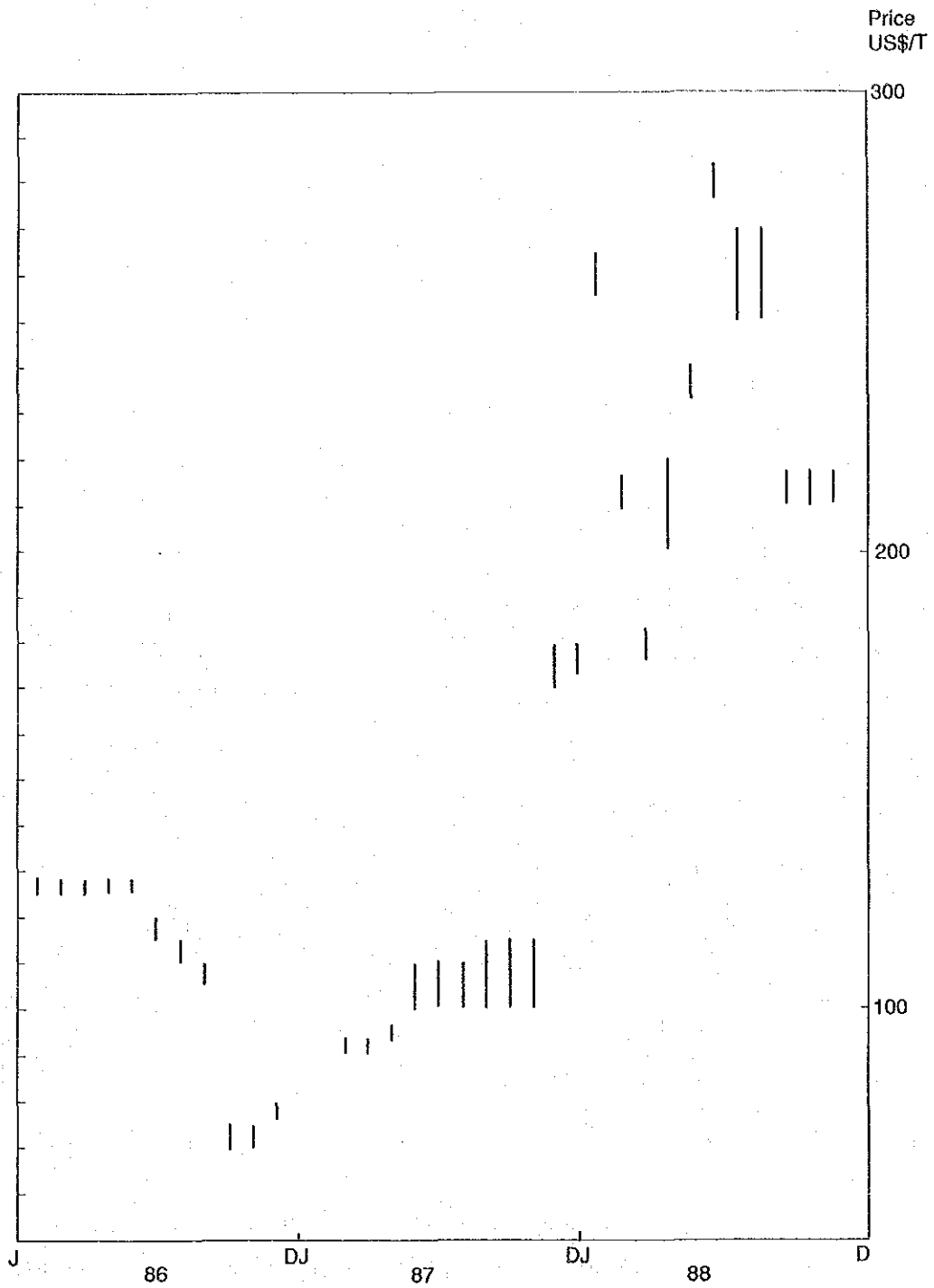


Fig. I-1-3 Methanol, U.S.A. Price Range, FOB

Table I-1-14 Estimated Price of Natural Gas in Various Countries

Countries	US \$/MM BTU
Saudi Arabia	0.50
Trinidad and Tobago	0.50
Mexico	0.40 ~ 0.50
Argentina	0.30 ~ 0.40
Chile	0.30 ~ 0.40
Canada	1.00
New Zealand	1.00
Indonesia	1.00

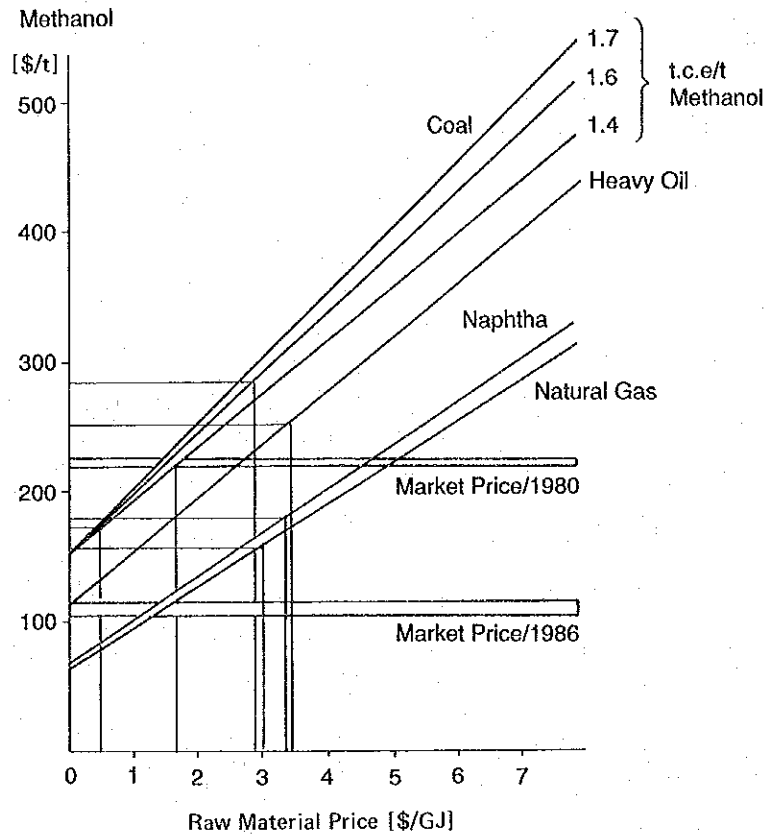
Source: Kagaku Keizai, June, 1987

If the natural gas basic unit of methanol is 35 MMBTU and gas costing US\$ 0.50/MMBTU is used, the cost of natural gas will be US\$ 17.50. If US\$ 10.00 is then added to it as the cost for subsidiary materials and utilities, the variable cost of methanol will become US\$ 27.50/T.

Quoting from the article in ECN 4/27/1987, a comparison of estimated methanol costs at various locations for use on the U. S. Gulf Coast is shown below.

Plant Site	Gas Price (US\$/MMBTU)	Product Cost (US\$/T)
U.S. Gulf coast	2.00	106
Alberta	1.00	153
Saudi Arabia	0.50	107
Trinidad & Tobago	0.50	80

Using the test calculation method of the 1986 WEC Report for methanol production via coal gasification, which is the objective in this project, the methanol production cost can be calculated as in Fig. I-1-4.



Source: WEC, REPORT 1986, [Methanol Prospects]

Fig. I-1-4 Relationship between Raw Material Price and Methanol Production Cost

If coal of a calorific value of 7,000 Kcal/kg. is used, and if it can be supplied at US\$ 15/T (equivalent to US\$ 0.50/GJ), the cost of methanol production using this test calculation method will become about US\$ 170/T, a cost which entails a fairly tough situation.

1.4 Situation in Zimbabwe

1.4.1 Demand and Price

At present, no methanol is produced in Zimbabwe, and the demand is met through imports. However, it goes without saying that the quantity is small, and there has been no increase in demand over the past five years. The statistics on methanol imports and the exchange rate used are shown below.

Table I-1-15 FOB Price of Imported Methanol

Year	Quantity (T)	1,000 Z\$	1,000 US\$	Unit Price (US\$/T)
1983	130	124	122.7	944
84	189	154	123.8	655
85	146	100	62.0	425
86	129	92	55.3	429
87	101	111	66.8	661

Source: CSO

Table I-1-16 Average Exchange Rate

Unit: Z\$/US\$

1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
0.629	0.677	0.680	0.643	0.689	0.757	1.011	1.244	1.612	1.665	1.661

Source: IMF, International Financial Statistics

As for the industrial use of methanol, Section 1-2-1 pointed out no major usage existing and, indeed, there are no plans for development. The production of formalin for use in germicides such as poultry farm disinfectants was once given consideration, but since it was found not having any major economic significance, it was passed up. The main use at present is in airplanes as an engine booster and by the textile industry.

It is notable that the price, compared to international prices is remarkably high (it is assumed that the circumstances were unavoidable due to the small quantity and spot purchasing), as shown in Table I-1-15. Except for the 1983 price, which was abnormally high, the average FOB price from 1984 to 1987 was US\$ 543. Based on this figure, the following is a calculation of the on-rail price upon arrival at Harare. In addition, for the purpose of comparison the same calculation is made with the purchase price of US\$ 250/T FOB which seems to correspond with high international prices from 1986 to 1988, as in Case B.

	Case A	Case B
FOB	543	250
Ocean Freight	30	30
Railage	135	135
Surtax	106.2	62.3
Miscellaneous	15	15
U.S.\$/T	829.2	492.3

The railage examined was between Durban and Harare, and was found to be two times the rate for ammonia (reason unclear). In the consideration that both materials are inflammables and that ammonia is a high-pressure gas whereas methanol is a normal pressure liquid at least the same rate would seem appropriate.

Nevertheless, for methanol to be evaluated as a motor fuel, fuel prices in Zimbabwe, as discussed in the next paragraph, should be the object of comparison.

1.4.2 As a Vehicle Fuel

As is clear from the policy of the Government of Zimbabwe described above, the aim of methanol production by means of coal gasification is to utilize the country's coal resources and to plan foreign currency savings by substituting methanol for light oil, imported for the Sabathes Cycle Engine. In addition, that Zimbabwe intends to substitute methanol for light oil at a target level of 20% has been disclosed by this survey. Therefore, from this point of view, in order to determine the quantity and price of methanol for the possible use as motor fuel in this country the following are investigated.

(1) Methanol Price

First, data on past light oil imports are shown in Table I-1-17. The import quantities from 1984 to 1987 were almost holding level, the average being 472,000 Kl. Generalizations cannot be made about the price because it differs according to the method of purchase (spot or long-term contract), but if one looks at the price for 1987, for example, it is not an especially high price and appears appropriate as a standard.

Table I-1-17 Import of Diesel Oil

Year	Quantity (m ³)	1,000 Z\$	1,000 US\$	Unit Price (US\$/m ³)
1978	n.a	31,777	46,938	—
79	n.a	67,059	98,616	—
80	n.a	75,789	117,868	—
81	n.a	93,400	135,559	—
82	n.a	66,803	88,247	—
83	318,633	69,813	69,053	216.7
84	468,630	124,370	99,976	213.3
85	490,309	159,142	98,724	201.4
86	476,832	88,676	53,259	111.7
87	453,584	94,744	57,040	125.8

- Note:
- In 1987, only January through November is covered.
 - FOB price.
 - Conversion rate of Z\$ into US\$ is as per Table I-1-16.

Source: Statistical Year Book of Zimbabwe, 1987 & Information from CSO.

Secondly, the railage between Beira and Feruka obtained from the National Oil Company of Zimbabwe (Private) Limited is shown in the following table, the value being US\$ 33.3/Kl.

Product	Average Quantity Imported per Year	C & F Beira (Z\$/l)	C & F Landed (Z\$/l)
Diesel (light oil)	438,000,000	25	31
Petrol (gasoline)	237,250,000	20	26
Bitumen	18,000,000	40	44

Based on the above data and certain assumptions, the price of methanol in 1995 as a light oil substitute is calculated below. As one of these assumptions, fiscal 1987 is taken as the base.

The price of crude oil is taken as US\$ 15/bbl in 1987 and US\$ 20/bbl in 1995.

The ocean freight is landed at Beira at US\$ 8.5/Kl, plus a miscellaneous cost of US\$ 10/Kl.

From Table I-1-3

	Specific Gravity	Calorific Value
Methanol	0.792	4,290 Kcal/l
Light oil	0.85	9,300 Kcal/l

Therefore, the weight of methanol equivalent to 1 Kl of light oil is as follows:

$$1 \text{ Kl} \times (9,300 \text{ Kcal/l} / 4,290 \text{ Kcal/l}) \times 0.792 \text{ T/Kl} = 1.717 \text{ T}$$

In addition, the FOB price of light oil is taken as US\$ 125/Kl in 1987, becoming $125 \times 20/15 = \text{US\$ } 166.7/\text{Kl}$ in 1995.

From the above, the 1995 price of on-rail light oil arriving at Feruka is estimated as follows:

FOB Beira	166.7 US\$/Kl
Import tax (150 Z\$)	83.3
Ocean freight	8.5
Rail cost	33.3
Surtax (15%)	43.8
Miscellaneous	10.0
<hr/> Total	<hr/> 345.6

Therefore, the unit price of 1.717 T methanol equivalent to the heat capacity of 1 Kl light oil in 1995 should be as follows:

$$345.6 / 1.717 = 201.3 \text{ US\$/T}$$

By combining these prices, the figure of US\$ 200 is arrived at. Of course, the US\$ value is fixed at the rate for 1987.

(2) Quantity of Methanol

With regard to the demand for light oil, one must first look at the latest statistics available on the number of vehicles owned by Zimbabwe citizens, as shown in Table I-1-18. However, since this data is old, data on the increase in the number of vehicles from 1977 to 1986 is supplemented to form Table I-1-19.

Table I-1-18 Total Number of Registered Vehicles (1978-1983)

Description of vehicle	1978	1979	1980	1981	1982	1983
Light motor vehicle up to 2,300 kg n/mass	210,277	211,694	216,729	221,536	227,619	242,592
Heavy motor vehicle over 2,300 kg up to 4,600 kg n/mass	6,645	6,772	6,923	7,143	7,307	7,801
Heavy motor vehicle over 4,600 kg up to 9,000 kg n/mass	7,928	8,156	8,527	9,309	10,072	11,823
Heavy motor vehicle over 9,000 kg	878	853	868	891	923	1,024
Motor cycles up to 70 cm ³	4,549	4,665	4,866	5,175	5,259	5,497
Motor cycles over 70 cm ³	10,099	10,649	12,060	14,845	15,924	17,872
Light trailers up to 550 kg capacity, including caravans, boat trailers etc.	18,833	19,461	20,499	21,352	22,200	23,247
Heavy trailers	6,524	6,731	7,081	7,903	8,588	9,818
Tractors and Construction vehicles	4,103	4,205	4,340	4,731	4,916	5,393
Vehicles not elsewhere classified	16	52	80	94	78	77
TOTAL	269,852	273,238	281,973	292,979	302,886	325,144

Note: 1984 and 1985 information was not available at the time of compilation. Data are counts on the 31st of July each year.

Source: Ministry of Transport.

Statistical Year Book, 1987

**Table I-1-19 Annual Vehicle Population Analysis by Fuel Type and Tax Class
(1977-1986)**

Description of vehicle/Fuel type	0	1	2	3	Total
Light motor vehicle up to 2,300 kg n/mass	105	74,750	5,884	18	80,757
Heavy motor vehicle over 2,300 kg up to 4,600 kg n/mass	8	228	2,136	2	2,374
Heavy motor vehicle over 4,600 kg up to 9,000 kg n/mass	9	245	7,400	3	7,657
Heavy motor vehicle over 9,000 kg	0	12	537	1	550
Motor cycles up to 70 cm ³	3	1,295	2	4	1,304
Motor cycles over 70 cm ³	13	11,660	24	6	11,703
Light trailers up to 550 kg capacity, including caravans, boat trailers etc.	11,136	90	3	0	11,229
Heavy trailers	5,654	60	14	0	5,728
Tractors and Construction vehicles	10	83	1,845	15	1,953
Vehicles not elsewhere classified	1	17	1	8	27
Unspecified	52	17	12	0	81
TOTAL	16,991	88,457	17,858	57	123,363

Note: Fuel type 1: Petrol
2: Diesel

Source: CSO

From the data above, the demand for light oil in 1995 is estimated, and the quantity of methanol needed for use as a substitute is calculated.

From the data in Table I-1-19, the ratio of vehicles using light oil among all light motor vehicles is found as follows:

$$5,884/80,757=7.3\%$$

From the same table, vehicles of the Sabathes Cycle Engine type are roughly classified as follows:

- 7% of all light motor vehicles
- All heavy motor vehicles
- All tractors and construction vehicles

The numbers of vehicles of the Sabathes Cycle Engine type for the years 1978 and 1983 are calculated from Table I-1-18 using this classification, as the following table illustrates.

Table I-1-20 Savathes Cycle Engine Vehicles

	1978	1983
Light motor vehicles	14,719	16,981
Heavy motor vehicles		
2,300-4,600 kg	6,645	7,801
4,600-9,000 kg	7,928	11,823
over 9,000 kg	878	1,024
Tractors & construction vehicles	4,103	5,393
Total	34,273	43,022

The increase from 1978 to 1983 was at an annual rate of 4.65%/Y which coincidentally is almost the same as the GDP growth rate of 5.1%/Y indicated in the first five-year project. Therefore, in order to estimate the demand for light oil in 1995, one of the assumptions is that the rate of increase in the number of vehicles of the Sabathes Cycle Engine type will be 5%/Y.

Secondly, the number of vehicles registered in Zimbabwe in 1987 to be used as the estimation base is calculated by taking the total number of vehicles for 1978 shown in Table I-1-18 and adding to it the total increase in the number of vehicles from 1977 to 1986 shown in Table I-1-19, taking the latter figure as an approximation to the increase in the number of vehicles from 1978 to 1987, as follows.

$$269,852 + 123,363 = 393,215$$

On the other hand, by assuming that the number of vehicles registered in 1983, as shown in Table I-1-18, will increase at an annual rate of 5%, the total number for 1987 is found, as follows.

$$325,144 \times (1.05)^4 = 395,215$$

Both figures above are almost equal.

Therefore, the number of vehicles registered in 1987 is regarded as 390,000.

Furthermore, the percentage of vehicles of the Sabathes Cycle Engine type out of the total number of vehicles is 14.5% according to Table I-1-19, and when calculated by combining the figures of Table I-1-20 and Table I-1-18, the percentage is 12.7% for 1978 and 13.2% for 1983, inferring that the percentage has recently been increasing.

From the above, the number of vehicles of the Sabathes Cycle Engine type in 1995 is calculated by assuming that the total number of vehicles registered in 1987 is 390,000, the rate of increase is 5%/Y, and the proportion of vehicles with the Sabathes Cycle Engine is 14%, as follows:

$$390,000 \times (1.05)^8 \times 0.14 = 80,700$$

Secondly, the average annual consumption of light oil by vehicles of the Sabathes Cycle Engine type can only be seen for 1983, since that is the only year for which data on the registered number of vehicles and the consumption of light oil can be used at the same time. Using the same method as before, the number of vehicles of the Sabathes Cycle Engine type for that year is counted as follows (Table I-1-18).

Light motor	16,981
Heavy motor	
2300 kg ~	7,801
4600 kg ~	11,823
9000 kg ~	1,024
Tractors & Construction	5,393
<hr/> Total	<hr/> 43,022

The consumption of light oil in 1983 was 318,633 Kl, as shown in Table I-1-17. The unit consumption therefore becomes 7.41 Kl/vehicle.

Thus, the estimated consumption of light oil in 1995 is as follows:

$$7.4 \text{ K Kl/vehicle} \times 80,700 \text{ vehicle} = 597,200 \text{ Kl}$$

If 20 Vol. % of light oil is to be substituted by methanol, the following will be the calculation:

$$597.2 \text{ K Kl/Y} \times 0.2 \times 1,717 \text{ T methanol/Kl light oil} = 205.1 \text{ KT/Y methanol.}$$

However, in order to use methanol in the Sabathes Cycle Engine, various problems must first be solved. These problems are discussed in the following paragraphs.

1.5 Concerning Light Oil Substitution of Methanol

Research and development into the use of methanol in the Sabathes Cycle Engine was started in many developed countries about the same time as the development of technology for the use of methanol in the Otto Cycle Engine. For the Otto Cycle Engine, neat methanol (M-100) has not found yet any practical application. However, the method of mixing methanol with gasoline has already been put to practical use in many countries. Whereas for the Sabathes Cycle Engine, no country has yet found any practical application of methanol, and there is no place where a genuine fleet test has been completed successfully. This fact demonstrated that the use of methanol in light oil substitution is not easily achieved technologically compared to substituting methanol for gasoline.

1.5.1 Superior and Inferior Points of Methanol

The problems of using methanol as a light oil fuel substitution in the Sabathes Cycle Engine are as follows:

(1) Ignition Difficulty due to the Low Cetane Number of Methanol

As shown in Table I-1-3, the cetane number of light oil is from 40 to 50, whereas that of methanol is only 3. Therefore, it cannot ignite by itself inside the engine, which entails that a supplementary means of somehow igniting the methanol is required.

(2) Poor Characteristics as a Mixture with Light Oil

Methanol is essentially not soluble nor mixable in light oil. It has been reported that, if aromatics, gasoline or higher alcohol is added to light oil in the ratio of about 30 to 40%, then at normal temperature, it can dissolve methanol by about 20%. However, if this solution picks up about 0.1% of water or if the temperature is decreased, it separates into two layers. Therefore, even if a solution of light oil/aromatics or others/methanol has a high enough cetane number, the liquid cannot be put to practical use in ordinary Sabathes Cycle Engines.

(3) High Vaporization Heat

As shown in Table I-1-3, vaporization heat of light oil is about 60 Kcal/kg, which is vastly different from methanol at 263 Kcal/kg. If the latent heat from fuel vaporization is high, the engine will not start at low loads.

(4) Corrosive Properties of Methanol

Methanol has polarity, so it corrodes metal and deteriorates materials of plastic and elastomer. The problems arise in materials chosen with a view to using light oil, such as copper, brass, carbon steel, aluminum, methacrylic resin and fluorine-contained rubber used for the fuel system.

(5) Difference in Calorific Values

As shown in Table I-1-3, the calorific value of light oil is 9,300 Kcal/l, whereas that of methanol is 4,290 Kcal/l, or a little less than 1/2 of light oil. However, this difference does not present such a major problem, if the size of the fuel tank is accordingly adjusted, since the theoretical air ratio is 15.0 for light oil to 6.5 for methanol, so that of methanol is less than 1/2 of that of light oil.

On the other hand, methanol has a number of decisive advantages when compared to light oil, as follows;

(6) Clean Exhaust Gas

If the fuel is light oil, the black smoke from the exhaust gas emitted is great, while the NOx density is high, which means that the Sabathes Cycle Engine can be considered a moving source of pollution. Measures to deal with this present a big problem in any country. In the case of methanol, there is absolutely no emission of black smoke and hardly any NOx or other toxic substances. A comparison of measurement examples of exhaust gas is shown below. If progress is made in the development of a more suitable engine to make up for the disadvantages of methanol, then, as a result of such a major advantage, there is the possibility that methanol can immediately find application everywhere focusing on big cities as the third type of vehicle fuel.

Table I-1-21 Analytical Result of Exhaust Gas

	Mode (ppm)		
	Methanol car		Diesel car (Direct Injection type)
	Otto cycle	With spark assist Sabathes cycle	Comparative car
CO	113	62	810
HC	205	83	459
NOx	215	206	391
Black smoke (Urgent acceleration time)	0	0	32

Source: Masayoshi Nagamitsu, "Fleet Test on Cars Running on Methanol by the Japanese Ministry of Transport"
International Symposium on the Use of Methanol in Cars, February 19, 1987.

1.5.2 Technology for the Utilization of Methanol

Developments in technology to overcome the disadvantages of methanol described above are being promoted. The developmental conditions have been put in order according to each concept, as shown in Table I-1-22.

Table I-1-22 Classification (Concepts) of the Technology for Methanol Utilization and its Characteristics

Classification of Technology for Methanol Utilization		Different fuel sources to be used
Fumigation process	Carburettor system/Injection system	Light oil + methanol (mixture ratio, 10-60%)
Near neat utilization method (Twin fuel-injection method)	Twin-pump, twin injection method <ul style="list-style-type: none"> • Turbulence chamber • Reservoir chamber • Direct injection 	For combustion: Light oil Main fuel: Methanol Light oil substitution ratio: 70-95%
	Twin-pump, single-injection method	Light oil + methanol (10-50%)
Neat, high-concentration utilization, Forced ignition method	Spark assisting method <ul style="list-style-type: none"> • Cylinder Injection <ul style="list-style-type: none"> Turbulence chamber Reservoir chamber Direct injection • Gasification <ul style="list-style-type: none"> Preliminary mixing Glow assisting auto ignition method 	Neat, high-concentration method
Neat utilization reform method		
Others	Method of adding additives to speed up ignition	

Source: "Trends in the Research and Development of Cars Running on Methanol" Japan Automobile Research Center

Of these methods, the following items are selected from a practical point of view and their development promoted:

(1) Near Neat Utilization, Twin Fuel-injection Method

Methanol (or a light oil mixture) direct cylinder injection, light oil spray/compression/auto ignition.

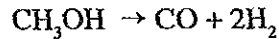
(2) Neat, High Concentration Utilization, Forced-ignition Method

Liquid methanol direct cylinder injection, methanol spray-spark assisting.

(3) Neat Utilization, Reform Gas Method

Suction of Methanol reform gas by exhaust gas heat, liquid methanol direct cylinder injection, methanol spray-spark assisting.

According to specialists, although the technology may find practical applications only after some time possibly in the Twenty-First Century, by then on-board reform gas technology will be the mainstream. This technology involves the endothermic utilization of exhaust gas heat; the reform gas reaction formula is as follows:



This method therefore uses methanol through gasification. Not only does it have the potential of eliminating the numerous disadvantages of methanol as a motor fuel, but by recovering exhaust heat, it could have a possibility that the thermal efficiency of the engine will be drastically improved.

At any rate, the technology of using methanol in the Sabathes Cycle Engine has not reached the stage where the definite direction of application technology, the most suitable engine form, the economic viability of changing the engine type, and durability have been established whereby it can be put to practical use. On the other hand, it should be stressed that there is the possibility of improving energy efficiency.

1.5.3 Viewpoint Prevailing Zimbabwe

Though we did not carry out an extensive survey, having listened to the opinions of people in Zimbabwe related to this project, we discovered that they accept the concept of mixing oxygenates into motor fuel in general but they require that the partial substitution of methanol for light oil be closely examined.

In other words, the problems are as follows:

- (1) It is difficult to mix methanol with light oil.
- (2) More fuel is necessary because the calorific value is low compared to light oil.
- (3) It is difficult to ignite. The cost of adding additives to improve ignition is high.
- (4) Engine remodeling is expensive.
- (5) It is necessary to examine the remodeling procedures based on the differences in the engines of each manufacturer.

As a matter of course, a definitely prudent opinion is prevailing on relation with that having no economic benefits and in light of there being no cases this technology is practically applied in the world.

1.6 Conclusion

The conclusion of the market survey on methanol in the ammonia/methanol project based on the above discussion is as follows.

In this project, the materialization of the methanol plant should not be carried out immediately. A strong industrial demand cannot be counted on under the present circumstances. Therefore, since methanol is to be used only as a substitute for light oil vehicle fuel, one should wait at least another 4 or 5 years until the development and proof of this particular field or technology is finalized.

The following reasons for this recommendation should be noted.

- (1) For its plan of using the energy from coal which exists in abundance in Zimbabwe in order to save the foreign currency used to pay for light oil imports (1986, US\$ 53 million; 1987, US\$ 57 million), the policy of methanol production from coal is highly appraised. Considering that methanol is regarded to be the third type of vehicle fuel sometime by the Twenty-First Century, then one can stress this point even more strongly.

Given the present situation where methanol should substitutes for 20% of light oil, the demand for methanol in 1995 is estimated at about 200 KT/Y. For a methanol plant, this amounts to 600 T/D. And the price is assumed to be about US\$ 200/T at the fixed value for 1987.

- (2) Coal gasification technology and methanol synthesis technology are well established and there are no problems in synthesizing methanol from coal by a combination of the two technologies.

Specifically, it is necessary that coal gasification for ammonia use only produces H_2 while coal gasification for methanol use needs a composition of $CO + 2H_2$. These two can be achieved in a same facility by appropriate changes in the operating conditions. However, for the implementation of this project, coal gasification plants for ammonia and methanol should be built individually.

- (3) The partial or total substitution of methanol for light oil as a motor fuel has not yet been established or proven technologically, mechanically or economically. However, among the technologies under study, there are some which are very promising such as the on-board reform gas technology.

Attention should be paid to technologies which could be universally applicable, promising for future and that are practiced and proven.

- (4) There is a new refinery construction plan in Mutare. When it is realized, gasoline and light oil are produced in this refinery. Hence in case of planning methanol production substituting for light oil, due consideration is to be paid on the projected light oil production in this refinery.

Chapter 2 Basic Concept of the Project

Ammonia, Methanol Project

Chapter 2 Basic Concept of the Project

2.1 Production Items and Their Production Scales

The capacity of the ammonia plant, based on an estimate of the nitrogenous fertilizer demand in Zimbabwe in 1995/96, is described in detail in Vol. I. Also, regarding the demand for methanol as a fuel for Sabathes Cycle Engines as of the target point of time, the results of a market survey are described in Chapter 1 of this Part. Accordingly, for the purpose of this project to be established on a sound foundation, the necessary production items and their production capacities are as follows:

Production Items	Capacities	At Annual Working Rate of 330 D/Y
Ammonia	600 T/D	198,000 T/Y
Methanol	600 T/D	198,000 T/Y
Byproduct sulfur (100% S)	36 T/D	11,880 T/Y

2.2 Product Quality

2.2.1 Ammonia

Purity	99.7	wt% min.
Water content	0.3	wt% max.
Oil content	5	ppm max.
Pressure	4.3	kg/cm ² G
Temperature	5	°C

2.2.2 Methanol

Specific gravity	0.798	max.
Methanol content	99.3	% min.
Distillation	at 64.0-66.0 °C, distillate 95 vol/vol% min.	
Free acids	2 ml N/10 NaOH/50 ml max.	
Evaporation residue	0.002	% max.

2.3 Plant Site

When carrying out this project, the plant erection site will most likely be Hwange, as described earlier in Chapter 6, Part 1, Vol. I.

2.4 Raw Material

Quality Wankie coal presently being mined shall be used as the raw material, and it is assumed that coal with the same quality as the feedstock coal preconditioned in the ammonia plant's conceptual design shall be used. Accordingly, the ash content of the feedstock coal shall be less than 20% as in the case of ammonia.

The specifications of the feedstock coal is as shown in Table I-2-1.

Table I-2-1 Feedstock Coal Specifications

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 (inherent moisture basis)	7,090	kcal/kg
Hardgrove grindability index	57	
Ultimate analysis (dry basis)		
Ash	14.0	wt%
Carbon	73.0	wt%
Hydrogen	3.8	wt%
Oxygen	5.28	wt%
Nitrogen	1.5	wt%
Inflammable sulfur	2.29	wt%
Total sulfur	2.40	wt%
Non-flammable sulfur	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

Estimated Volume of Feedstock Coal Required

For ammonia	727 T/D (approximately 240,000 T/Y)
For methanol	750 T/D (approximately 250,000 T/Y)

General Composition of Coal Gasifier Outlet Gas

CO	49.6	vol %
CO ₂	14.0	vol %
H ₂	34.3	vol %

2.5 Similar and Dissimilar Points in Manufacture of Ammonia and Methanol

In the future, when the methanol plant's construction is decided, the construction of this plant, even being in a separate line, alongside the ammonia plant constructed earlier provides various benefits. The basic advantages are clarified hereunder for reference.

Regarding the ammonia process, a detailed description has been given in Chapter 2, Part 2, Vol. I, hence it is not repeated here. Then, regarding the methanol process, please refer to the next chapter whenever necessary.

As observed historically, the manufacture of methanol was started out on a smaller output than the manufacture of ammonia by using ammonia synthesis facilities as its prototype, so both processes comprise very similar production facilities.

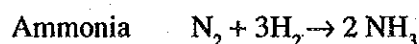
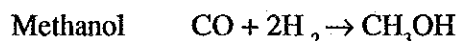
2.5.1 Selection of Raw Materials

Methanol and ammonia both require a hydrogen source, so natural gas, naphtha, heavy oil and coal are usable as the feedstock material. Incidentally, in case when heavy oil or coal is chosen, oxygen has to be added from the atmosphere in order to gasify these feedstock materials.

2.5.2 Process

As can be understood easily by comparing the process flow diagram of methanol described in the following chapter with that of ammonia described in Vol. I, the sections comprised in both these processes are quite similar. Only, in case of ammonia synthesis, the process differs in that it is provided equipped with a nitrogen washing system which functions at the same time as feeding of feedstock nitrogen gas.

The reaction formulas of both processes are as follows:



As is clear from these reaction formulas, the main raw material for both these reactions is hydrogen derived from the feedstock gas. With methanol, nitrogen is unnecessary, but instead it requires carbon monoxide running up to one-half the volume of hydrogen. Accordingly, the equipment composition for the CO shift conversion section and the acidic gas removal section is partially different between ammonia and methanol synthesis. Also, both reactions accompany the generation of considerable amount of heat, and the most essential common points of both these reactions lie in how the heat of reaction is removed and utilized effectively.

2.5.3 Synthesis Reaction

When giving thought to the conditions for compressing of and subsequent reaction of synthesis gases, it should be noted as the common point that both reactions use metal oxides as the catalysts. Consequently, their synthesis pressures are very similar. Up to about 20 years ago, they were as high as roughly 350 atmospheric pressure, but technical improvements have lowered them to the level of 100-150 atmospheric pressure more recently. However, on the catalyst for methanol synthesis, compared with that for ammonia synthesis, sulfur compounds in the synthesis gas act as a strong catalyst poison, making guard desulfurization necessary prior to synthesis.

2.5.4 System Equipment

As described above, both processes are hardly different, making the sizes of the respective equipment for the same output not different much. For example, the production equipment for manufacturing 600 T/D of ammonia can be used as the production equipment for manufacturing 600 T/D of methanol, simply by making partial modifications.

The upstream parts of these processes, namely the respective sections for air separation, slurry preparation, coal gasification and ash treatment, in particular, are almost mutually compatible unless there are big differences in feedstock coal specifications. In addition, when engaging in the synthesis of 600 T/D of methanol, the feedstock gas will be supplied by two coal gasification furnace systems. This is the same as in the case of an ammonia plant.

Accordingly, if a 600 T/D methanol manufacturing plant is to be installed subsequent to having installed a 600 T/D ammonia manufacturing plant, the same design suffices for almost all equipment belonging to the four aforementioned sections, and the standby gasification furnace in the gasification section can be utilized commonly by both ammonia and methanol manufacturing plants.

2.5.5 Operation and Maintenance

Both manufacturing facilities are quite similar in processes and production equipment, and are also operated in the same manner. This condition is highly convenient in the training of plant operators, also for labour conservation. In addition, a large number of spare parts can be utilized commonly by both plants as well as the maintenance techniques.

2.6 Conclusion

In this project, a combination of the manufacture of both ammonia and methanol, the existing situation is that the methanol plant will be constructed much later than the ammonia plant.

Therefore, it will be imperative to prepare the master plan most carefully prior to implementing the project.

Chapter 3 Production Process and Facilities

Ammonia, Methanol Project

Chapter 3 Production Process and Facilities

3.1 Combination of Processes

At the present stage of this project, it is a fact that there is no probability of constructing a methanol plant. Therefore, it will be only troublesome, also unnecessary, to delve deeply into the conceptual design of methanol production facilities in this report, so here only a methanol manufacturing block flow diagram (Fig. I-3-1) is shown, together with a brief description of the methanol process, based on the basic concept described in the preceding chapter in connection with the project.

The methanol synthesis process essentially consists of a combination of the following two processes:

- (1) TEXACO Process in connection with coal gasification.
- (2) ICI Process in connection with methanol synthesis.

3.2 Coal Gasification

A brief description of the methanol process is given here in line with Fig. I-3-1. Incidentally, the results of tests on Wankie coal samples are introduced in Chapter 5, Part 1, Vol. I.

3.2.1 Air Separation Section

The air separation system is provided to supply oxygen that is employed for coal gasification under high pressure. The system essentially consists of an Air compressor, Cold box and Oxygen compressor, and the generated oxygen is pumped to the coal gasification section at a purity of over 99%.

3.2.2 Slurry Preparation Section

Coal supplied from the mines is temporarily stored in a coal yard, then blended into the required gasification quality and fed into a Coal silo with a conveyor system. Coal from the silo is crushed in two stages, first with a Precrusher into particles smaller than 10 mm, next mixed with grey water and makeup water, and then further ground into finer particles with a Grinding mill. In the final stage, this slurry is added with necessary additives, pH conditioner and flux to prepare it into the prescribed quality. The slurry prepared in this manner is temporarily stored in a Slurry tank, then piped to the gasification section.

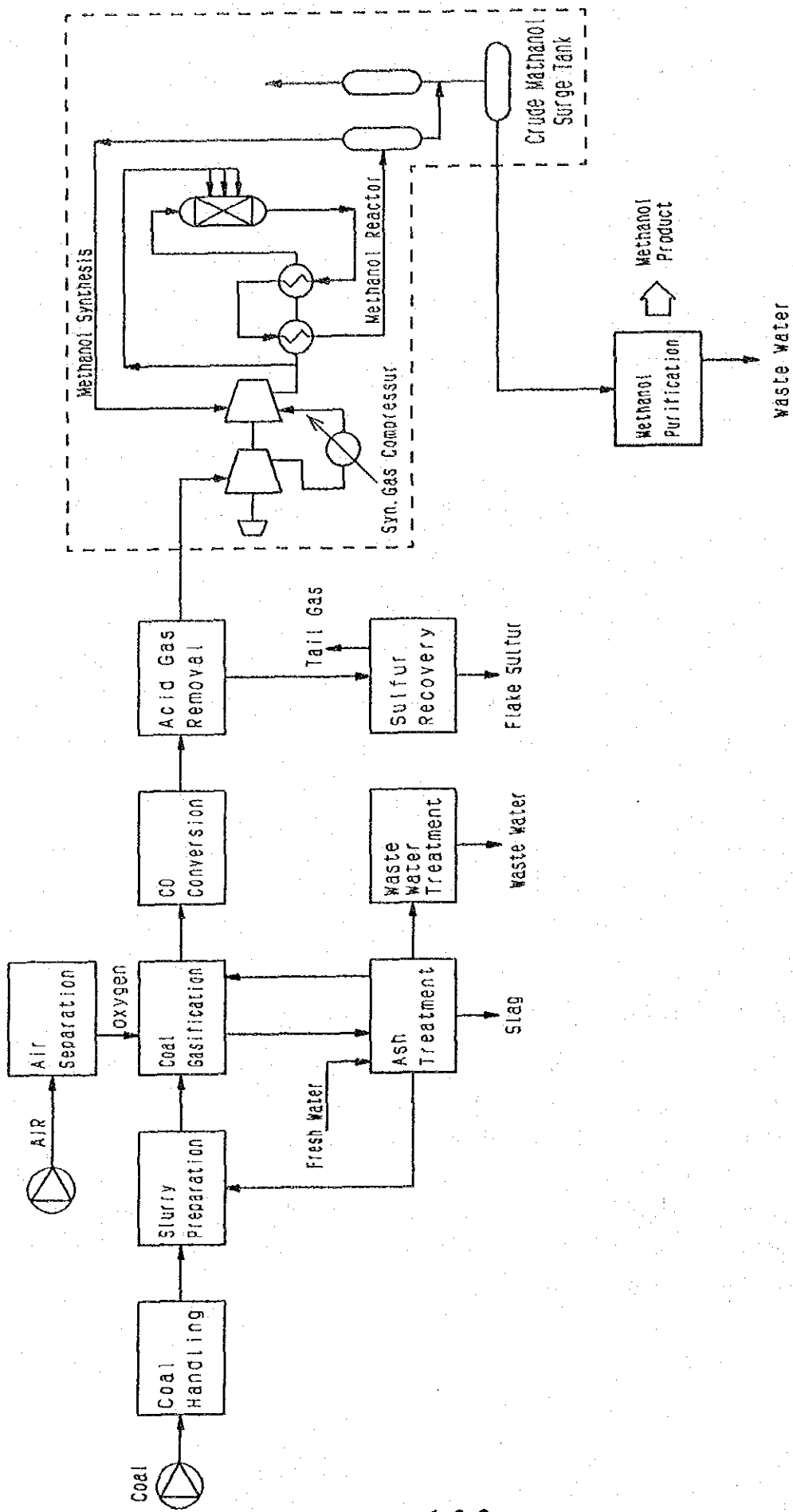


Fig. I-3-1 Block Flow Diagram (Methanol)

3.2.3 Coal Gasification Section

The coal slurry is fed into the Gasification furnace under pressure with a pump, where oxygen is blown in. The gasification reaction occurs instantaneously in the Reaction chamber under high pressure and temperature, and gas is generated. This gas consists of CO, H₂, CO₂, H₂O and small quantities of CH₄ and H₂S. In this stage, the temperature in the Reaction chamber is conditioned to slightly above the melting point of ash by adjusting the feed ratio of coal slurry and oxygen.

The high-temperature gas from the Gasification furnace's reaction chamber is piped into the Quenching chamber where it is cooled with water from a Carbon scrubber. Meanwhile, the ash and non-reacted carbon generated in the Reaction chamber forms a coal slag, with the coarse slag discharged intermittently outside the furnace together with water by the Lock hopper system, and the fine slag discharged continuously from the Quenching chamber as a water slurry known as a black water.

The generated gas discharged from the Gasification furnace's quenching chamber is passed through a Venturi scrubber and the Carbon scrubber, where the gas is washed with the grey water from the ash treatment section and the process condensate water from the CO shift conversion section and completely removed of ash particles and non-reacted carbon particles. The gas treated thus and discharged from the Carbon scrubber is sent into the CO shift conversion section.

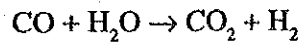
3.2.4 Ash Treatment Section

The coarse slag discharged from the Gasification furnace together with the Lock hopper water falls into a Slag pit, where it is filtered with a Slag screen, then fed into a Coarse slag hopper.

Meanwhile, the fine slag contained in the black water is concentrated and treated in a sedimentation facility, then separated with a Filter press. A part of the overflow water from the sedimentation facility is returned to the Gasification furnace and used as process water.

3.2.5 CO Shift Conversion Section

In order to convert the ratio of CO and H₂ contained in the generated gas to obtain a gas composition suitable for methanol synthesis, about one-half of the gas is sent to the CO shift conversion section. The gas from the Carbon scrubber, free of fine carbon particles, is heat-exchanged in CO shift convertor preheater with the outlet gas from the CO shift convertor's primary catalyst bed before being sent into the CO shift convertor. The catalyst bed is of double-bed construction, and a sulphur activation catalyst is used. The CO shift conversion reaction formula is as follows:



Namely, CO existing in the supplied gas reacts with H₂O and is converted into CO₂ and H₂ of equivalent volume. The reaction being an exothermic reaction, the temperature of the reacted gas at the outlet of the primary stage catalyst bed is considerably high. In order to secure a suitable reaction temperature for the secondary catalyst bed, the gas is cooled with the CO converter's preheater. The temperature of the gas cooled in this manner goes up again during the gas transit through the secondary catalyst bed, and the heat of the high-temperature gas is recovered by generating steam, that is utilized in the plant's other sections.

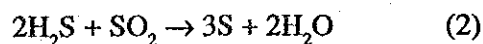
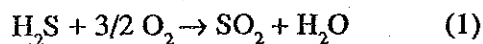
The condensed water generated in this section is separated from the process gas with a Condensate separator, and the high-temperature condensate from this separator is fed into the Carbon scrubber with a Condensate pump. Meanwhile, the low-temperature condensate is returned to the ash treatment section.

3.2.6 Acidic Gas Removal Section

The gas given CO shift conversion is converged with the other portion of gas that bypassed the CO shift conversion section and piped together into the acidic gas removal section. This process gas, of which CO and H₂ ratio is adjusted and made suitable for methanol synthesis, is sent to a Scrubber, where its acidic gas is removed by the Rectisol process. The removed CO₂ is discharged into the atmosphere, while the methanol, containing a large quantity of H₂S, coming from the bottom of the Scrubber is pumped to a H₂S stripper where H₂S is removed. Then H₂S is brought to the sulphur recovery section where sulphur is recovered in a form of flake.

3.2.7 Sulphur Recovery Section

Elemental sulphur is recovered from H₂S separated in the acidic gas removal section and from the flush gas sent from the ash treatment section. The H₂S gas fed into the Combustion chamber of a H₂S boiler is burnt to generate the quantity of SO₂ necessary for the subsequent Klaus reaction. Sulphur is formed in the following formulas:



The combustion gas from the Combustion chamber is passed through the H₂S boiler where it is cooled and a part of it is condensed into sulphur. The gas is then reheated in a Steam reheater to the temperature necessary for causing the formula (2) reaction, then induced into a Klaus furnace.

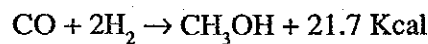
The Klaus furnace consists of two stages of catalyst beds, and the gas passing through the primary bed is sent to the H₂S boiler and its sulphur is condensed. The gas of which temperature has been lowered is reheated with the Steam reheater and sent into the secondary bed to undergo further reaction. The gas from this secondary bed is cooled with a Sulphur condenser condensing its sulphur.

The sulphur condensed in the H₂S boiler and the Sulphur condenser is collected in a Sulphur pit, then pumped to a Sulphur flaker with a Sulphur sump pump. The flaked sulphur produced here is temporarily stored in a Flaked sulphur bin, then subsequently filled into bags with a packaging system. The remaining gas from the Sulphur condenser is sent to a Boiler for use as a fuel.

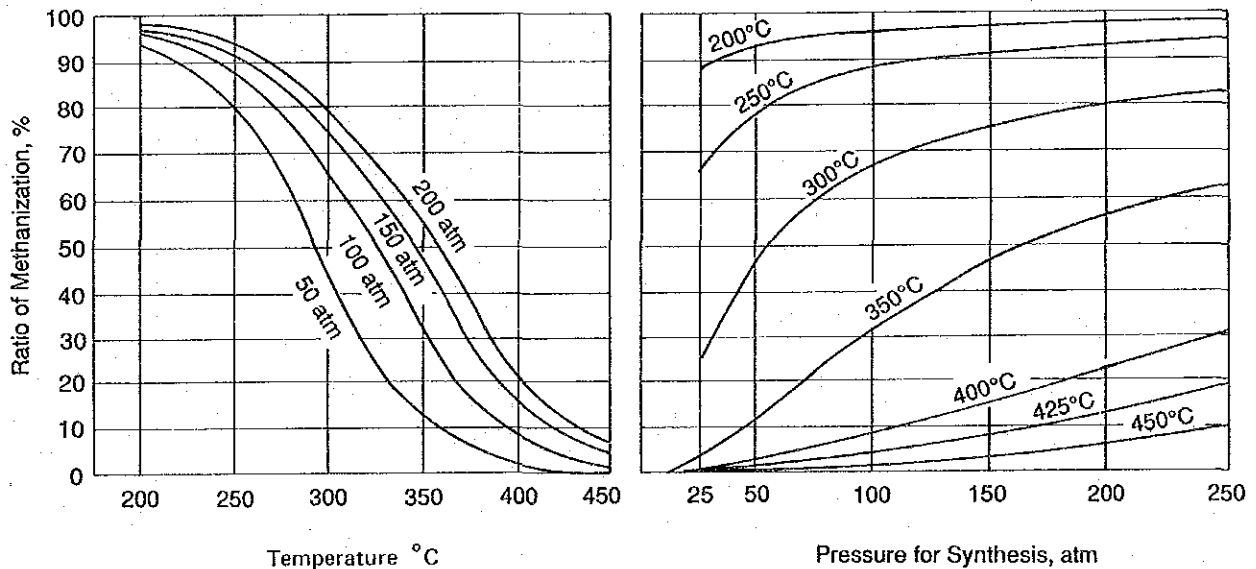
3.3 Methanol Synthesis

3.3.1 Characteristics of Methanol Synthesis Reaction

Methanol synthesis reaction is represented by the following main reaction:



The influences of temperature and pressure on this main reaction's equilibrium are as shown in Fig. I-3-2.



Source: "New Petrochemical Process" published by Japan Petrochemical Society

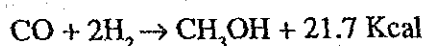
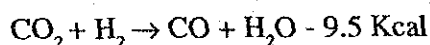
Fig. I-3-2 Relationship between Temperature, Pressure and Ratio at Methanization

A low temperature and a high pressure are advantageous for methanol synthesis, and the temperature, in particular, exerts a big influence. Since the methanol synthesis ratio will be low with only a single pass of synthesis gas through a convertor, in practice the synthesis gas, after being removed of its initial-pass methanol, is recycled repeatedly through the convertor.

The principal catalyst system for methanol synthesis is the Zn-Cr system developed by BASF, which has been adopted for as long as 50 years. The basic conditions for using this catalyst are a temperature of 320-400°C and a pressure of 300-400 kg/cm².

In the latter 1960s, a three-element Cu-Zn-Al catalyst consisting primarily of reduced copper was developed by ICI, which enabled the adoption of medium to low pressure and low temperature conditions as well as the introduction of a centrifugal compressor driven by a steam turbine. Today, this catalyst is being utilized predominantly.

Methanol is synthesized by the following reaction in the event the feedstock gas contains CO₂ gas.



With this reaction, the heat generation is less and the catalyst's activity gets more compared with the main reaction, hence a portion of the CO₂ gas may be maintained intentionally in the feedstock gas to effect such result. This volume of CO₂ gas to be maintained will have to be determined by giving thought to various process efficiencies.

At any rate, methanol synthesis accompanies the generation of an enormous quantity of heat, so the vital essentials of this process are the method of maintaining the temperature of the catalyst bed inside the convertor uniformly and the method of recovering and utilizing the heat of reaction.

3.3.2 Typical Synthesis Processes

Typical methanol synthesis processes are the ICI Process, the Lurgi Process and the Mitsubishi Gas Chemical (MGC) Process, which feature distinct characteristics in their respective convertor construction and heat recovery methods. Figs. I-3-3~3-5 show the general process flows of these processes, while Table I-3-1 shows the principal conditions applicable to these processes.

Table I-3-1 Comparison of Applicable Process Conditions

Process	ICI	Lurgi	MGC
Pressure (atm)	50 - 100	70 - 100	50 - 150
Temperature (°C)	200 - 300	240 - 270	200 - 280
Synthesis column	Tray type	Shell & tube	Tray type
Temp. adjustment	Quenching by blow-in of cooling gas	Catalyst bed cooling with pressurized water	Quenching by blow-in of cooling gas

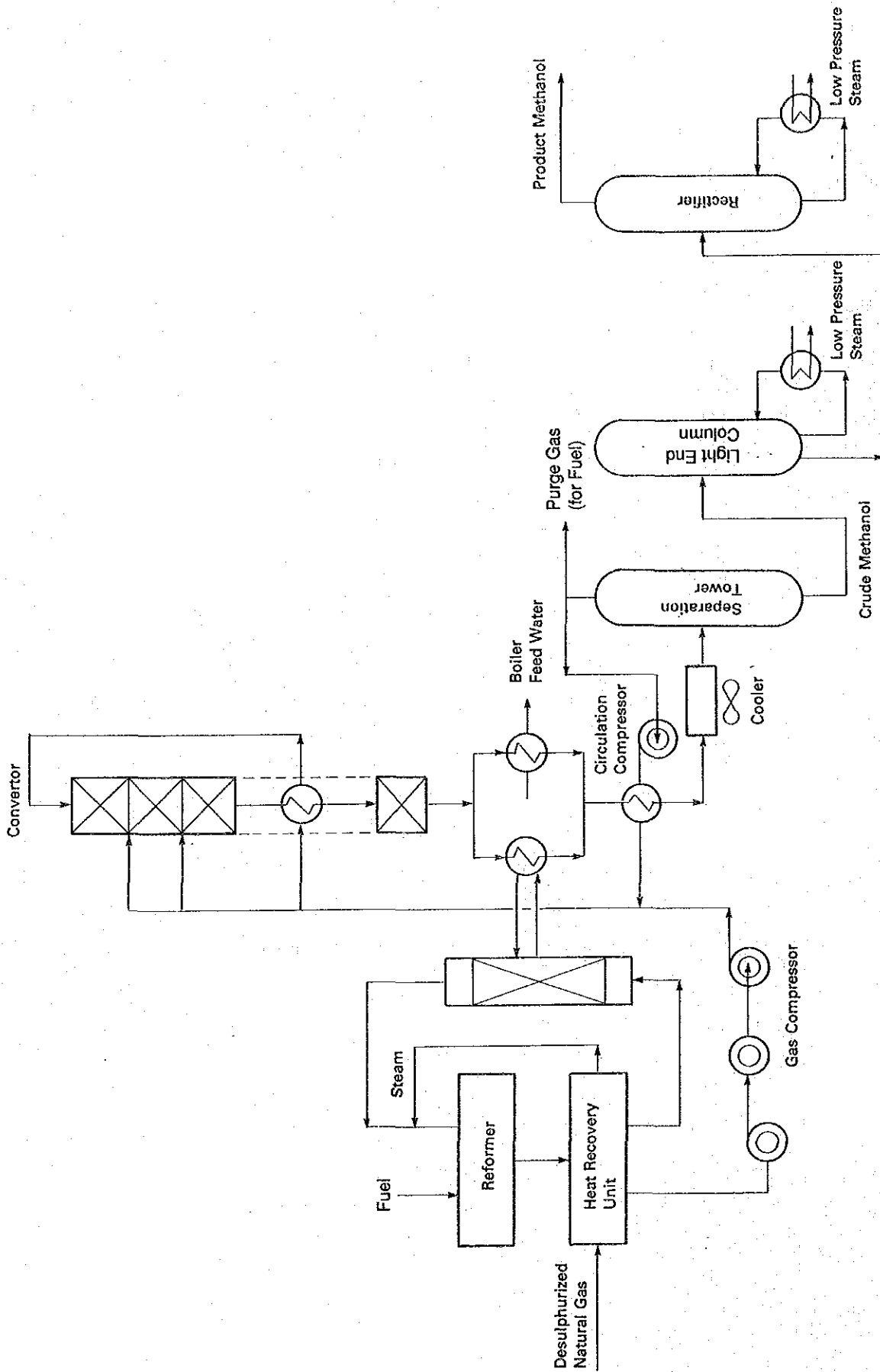


Fig. I-3-3 Flow Sheet of ICI Methanol Synthesis Process

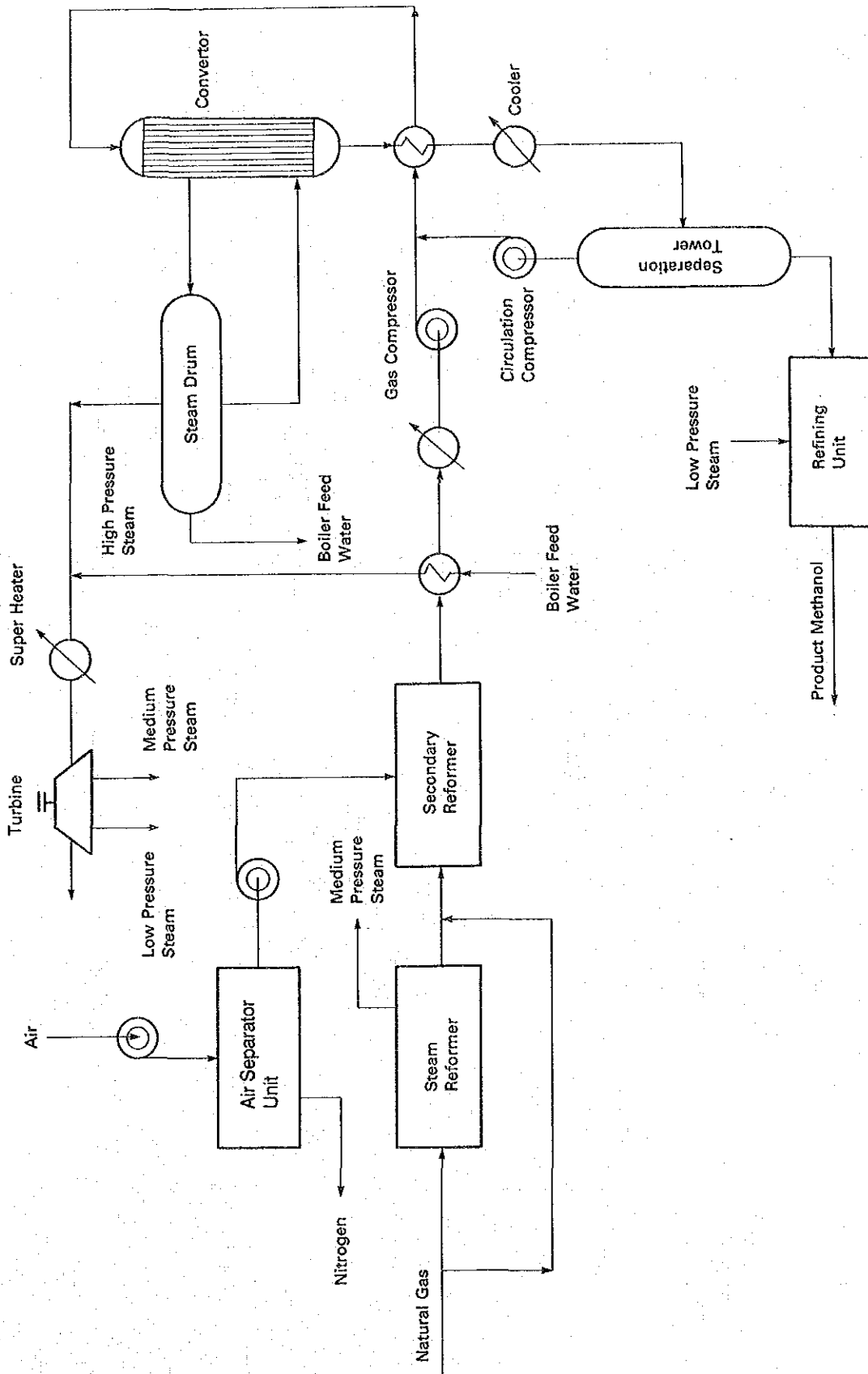


Fig. I-3-4 Flow Sheet of Lurgi Methanol Synthesis Process

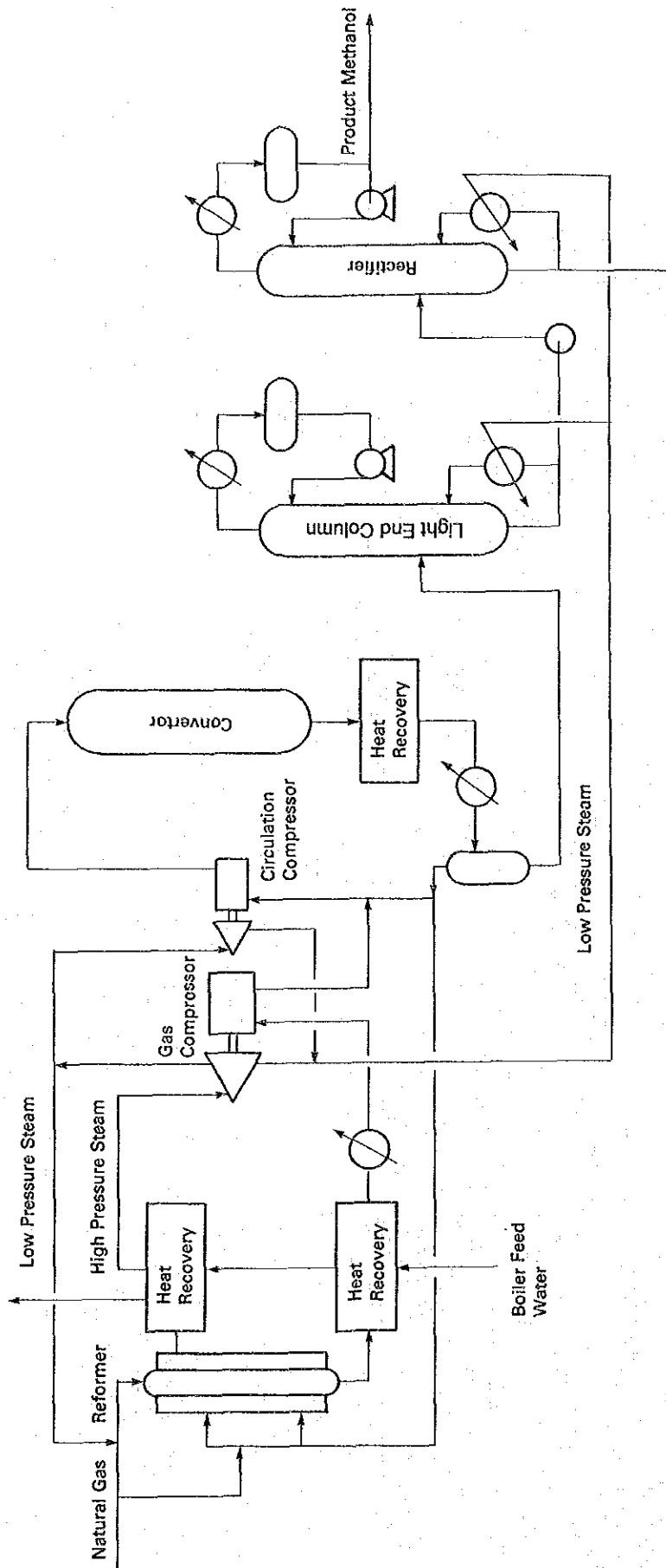


Fig. I-3-5 Flow Sheet of MGC Methanol Synthesis Process

The characteristics of the respective processes may be summarized as follows:

ICI Process

- 1) Simple structure of convertor and easy fabrication.
- 2) Suitable for large plants.
- 3) Easy catalyst packing and taking out.
- 4) heat of reaction usable for preheating of high-pressure boiler feedwater.

Lurgi Process

- 1) Convertor structure rather complicated.
- 2) Temperature distribution comparatively uniform, and methanol conversion ratio is improved.
- 3) The heat of reaction is utilized for generating medium-pressure steam.

MGC Process

- 1) The catalyst features excellent activity and stability, also withstands long use.
- 2) The structure of convertor is simple, cooling gas is introduced effectively and the catalyst bed temperature is maintained uniformly.
- 3) The heat of reaction is recovered as medium pressure steam.

In the event this methanol project is materialized, the most appropriate candidate process conceivable at the present stage is the ICI Process that has been adopted for many methanol plants the world over. However, since much time may elapse before the methanol plant's construction is determined finally, while the development of methanol synthesis technology being continued, it will be necessary to give study to the optimum process at the point the decision is made for the plant's construction. Incidentally, other processes might also be conceivable at the time, such as the Chemical System Process based on the circulation of inert hydrocarbon, the Brookhaven National Laboratory Process that performs extra low-pressure, low-temperature synthesis by using a liquid catalyst, and other processes currently in the stage of their commercialization.

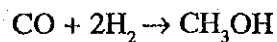
3.3.3 Process Description

A brief description of the methanol synthesis and refining sections is given here in line with Fig. I-3-1.

Since sulphur compounds are highly toxic to methanol synthesis catalysts, the synthesis gas leaving the acidic gas removal section is led into a Guard desulfurizer prior to inducing it into the Converter, by which the sulphur content is decreased to less than 0.5 ppm through dry desulphurization with ZnO.

Then the synthesis gas pressure is raised to about 100 kg/cm² with a two-stage Centrifugal compressor. A recycle gas, five times of synthesis gas in its volume, is introduced to the second stage of this Compressor. One-third of the compressed gas is preheated to 230°C through heat exchange with the converter outlet gas, then induced into the Converter from its top, while the remaining two-thirds of the compressed gas is fed directly into the Converter as a coolant, after which it is mixed with the reaction gas inside the three-stage catalyst beds.

The gas is fed from top of the Converter and its CO fraction is reacted with hydrogen during its transit through the catalyst and is converted into methanol by the following formula:



The catalyst's temperature rises rapidly after the gas is fed into the inlet of the Converter, rising to as high as from 255°C to 260°C, and the heat of reaction is almost entirely recovered as steam.

The ICI converter is of a single cylindrical structure filled with catalyst. The new synthesis gas is blown into the gas undergoing reaction, via a lozenge shaped cold shot distributors arranged respectively in the three stages of catalyst beds, with the result that the temperature inside the catalyst beds fluctuates zig-zag between 235°C to 270°C.

The reaction gas from the bottom of the Converter is cooled with the converter inlet gas and cooling water, and the remaining heat is supplied into the middle stage of an Expansion turbine for the purge gas discharged from the midway of the circulation loop. Finally, this reaction gas is cooled with water or air and condensed into methanol and water. About 5% of the non-condensed gas is discharged via the Expansion turbine, and the remaining gas is recycled to the Centrifugal compressor.

The crude methanol solution is fed into a Light end column of the refining section and its volatile fraction is discharged from the top of the Light end column.

The lower part distillate of the Light end column, running up to about 3.5 kg/cm², is sent to a Rectifier and recovered as methanol of high purity from the column's upper part, while higher alcohols (mainly ethanol) are separated from the central part, with waste water separating at the bottom part.

The heat necessary for a Light end reboiler and a Methanol reboiler is supplied by the synthesis gas, and the heat possessed by the ultimate methanol product is heat-exchanged with the incoming crude methanol.

Chapter 4 Discussion

Ammonia, Methanol Project

Chapter 4 Discussion

4.1 General

The project concept of synthesizing both ammonia and methanol simultaneously on the common base of coal gasification is highly practical and deserves due study. In addition, the soundness of the manufacturing technology of respective products has been fully corroborated and involves no problem. If it becomes possible to substitute methanol for light oil to its 20 Vol % for the use as a fuel for sabathes (diesel) engines in conformance with Zimbabwe's plans and policies, together with a thought of manufacturing ammonia for fertilizer as studied in Vol. I, the plant scale will be as follows for meeting the country's demands in 1995:

Ammonia	600 T/D
Methanol	600 T/D

However, as described in Chapter 2 of Part 1, even if methanol replaced light oil by about 20% for use as an alternative fuel for vehicles in place of light oil, various essential technologies are not as yet established in the world in connection with the supply, combustion and engine remodeling, there is hence no definite outlook for commercialization of methanol fuel. The existing situation is that related research is being promoted by the world's countries, so these technologies would certainly be established sooner or later, but it will be difficult to estimate about when in the 1990s this will be materialized, and it would be premature to give studies to the concrete implementation of the methanol part of this project at least until related technologies and economies have been verified. So the existing state calls for a close followup of information relating to these sectors henceforth.

The benefit of constructing ammonia and methanol synthesis facilities adjacent to each other on the same siting ground, broadly speaking, is that the designs for the coal gasification furnaces will be about the same. However, since both plants are independent facilities, the construction of these plants simultaneously will not necessarily become necessary conditions.

As observed from these observations, it is advisable to give thought to the entire ammonia and methanol synthesis project and to make the decision in future on the construction of the methanol plant.

4.2 Discussion

Since due studies in connection with ammonia synthesis are made in Vol. I, the results of studies only in connection with methanol synthesis are offered hereunder.

- (1) The world's demand for methanol in 1988 ran up to 17 MMT, with 80% of this volume used for industrial purposes as for the manufacture of formalin, acetic acid and solvents, and 20% used as motor fuel, in which case it being mixed into gasoline by 3-5 vol% in various countries as an octane booster. However, due to its poor ignition and poor mixing with light oil, it has not yet been commercialized as a motor fuel for use in place of light oil. On the other hand, methanol is characterized by a clean exhaust gas and may become usable as the third motor fuel in the future, so research is being advanced actively by various circles to develop technologies for its commercialization.

Zimbabwe's policies for decreasing fuel imports through the use of ethanol in place of gasoline and methanol in place of light oil stand out as prudent decisions for coping with existing realities. From a longer perspective there is a certain observation that methanol using coal as the raw material would replace petroleum products as the fuels for internal combustion engines in the future, and that thereby an on-board reforming system mounted on vehicles or, with undergoing further improvement, a more sophisticated fuel cell system would be realized. Therefore, in connection with the methanol part of this project, it is advisable to follow up related technological developments closely without jumping to conclusions.

- (2) The international price of methanol has remained on a high level of US\$180-200/T since 1987 on the basis of European spot FOB prices, and this price trend is observed to continue up till the mid-1990s. The cost of manufacturing methanol by coal gasification, assuming that coal is available at a price of US\$15/T, is estimated at US\$170/T. On the other hand, the domestic FOR price of fuel methanol, when computed as being equal to light oil in unit energy price, is estimated at US\$200/T (1995 price based on 1987 value on basis of US\$).

This situation reflects an extremely severe situation in the profitability of the methanol project even if a go-ahead sign is given for the alternate use of methanol in place of light oil through technology development. The point lies in the unit price of feedstock coal as well as on the relative price of methanol with respect to that of oil, so it will be necessary to adopt adequate measures for the pricing of fuel methanol.

- (3) In order to manufacture 600 T/D of methanol, it will be necessary to use roughly 750 T/D of 7,090 Kcal/kg coal, the same quality of feedstock coal used for ammonia synthesis. In case methanol is synthesized by erecting its manufacturing facilities alongside an ammonia synthesis plant, designing the coal gasification facility with the same specifications as those of the ammonia plant will be more beneficial in the aspects of designing, plant operation and maintenance. For this, the prerequisite will be the erection of two coal gasification furnaces for meeting the needs of the 600 T/D methanol plant and the designing of all methanol synthesis systems beyond gas generation into a single train. Also, whereas two coal

gasification furnaces proper will have to be provided respectively for the ammonia plant and the methanol plant, it will be economical in the long run to erect a commonly usable standby furnace that can be used by either of these plants.

Methanol plants in operation throughout the world today are generally sited in regions where inexpensive natural gas is available, and being operated at capacities of at least 1,000 T/D, and with large plants at capacities exceeding 2,000 T/D. Therefore, this project's estimated capacity of 600 T/D may be regarded as being rather small, and the fixed assets burden for the product, including the investment for the coal gasification facility, will necessarily become considerably heavy. Hence it is advised to conduct a feasibility study matched to existing conditions at the point when Zimbabwe's methanol demand becomes definite. Also, in the events that the methanol plant is designed with a larger capacity or that it is constructed separately from ammonia plant, then the entire methanol plant construction plan, including the plant's conceptual process design, will have to be reassessed.

- (4) As pointed out earlier, in the event the Mutare Oil Refinery Project is materialized, which has a relation not too close to nor too remote from this light oil alternative methanol project, it will become necessary to give due thought to the matter of whether or not the target of substituting methanol for light oil by 20% will still remain appropriate, also on how the price of methanol should be set. That is, it will become necessary to reassess and reconfirm whether the whole plans are compatible in a motor fuel policy.

Finally, regarding the utilization of methanol for industrial purposes, which happens to be the majority of utilization, Zimbabwe hardly has any large-scale consumer at the present stage. In the future, methanol's utilization for the manufacture of formalin and solvents may become promising, but studies will be necessary with due attention given to the diversification of uses, inclusive of industrial uses, and not only for use as a motor fuel, in order to stabilize the foundation of this project.

Part 2 Ammonia, Coal Tar Project

Chapter 1 Market for Coal Chemical Products: Coal Tar

Ammonia, Coal Tar Project

Chapter 1 Market for Coal Chemical Products: Coal Tar

1.1 Preface

Up until now in this survey, ammonia and related coal chemical products based on coal gasification have been discussed. Now in this volume (Part 2, Volume II), a study is made on the process of producing the raw material gas for ammonia synthesis using what is called COG (Coke Oven Gas) generated through coal carbonization.

In this line, a market survey is carried out on coal tar, a by-product from COG production and, at the same time, on coke which is simultaneously produced in large quantities. The capacity of the ammonia plant is 600 T/D, as already discussed in detail in Vol. I. The quantities of by-products produced from the coal carbonization facilities which supply the raw material gas required for the ammonia plant of this capacity are the objective of this survey.

Coal carbonization in Zimbabwe is already being carried out by the two companies of ZISCO and WANKIE for the production of coke. Review in detail of each company at greater length is made in Section 1-3, and now it will suffice to say that even the facilities of ZISCO Company, which has larger capacity, can only produce one half of the required raw material gas for a 600 T/D ammonia plant, while both companies use the gas from coal carbonization as a fuel within the carbonization unit or captive uses. Therefore, as consideration must be given to the fact that the utilization of gas from the existing facilities of both companies is impractical and that new installation of a coal carbonization facility exclusively for use in this project should be the object of this survey.

Furthermore it is possible to scheme supplying of raw material gas for ammonia synthesis with a gas prepared by water gas reaction using by-product coke together with coke oven gas. However, compared to the process of direct coal gasification as discussed in Vol. 1, this scheme involves two stages of coal carbonization and coke gasification, and so we judged that this does not have any logical or economic meaning. We therefore did not make this scheme the object of our survey.

1.2 Use of Coal Tar

The production quantity of coal tar is about 130 T/D corresponding to ammonia production of 600 T/D for this project. This, however, depends on the quality of the raw material coal. Total production reaches about 43 KT a year. Incidentally the quantity of coke produced at the same time is about 990 KT/Y.

Coal tar is mainly used as a raw material in the chemical industry, as a road paving material, and in the casting of carbon electrode and carbon products. Coal tar contains many kinds of chemical compounds with two fused benzene rings (typically naphthalene) and three fused benzene rings (for example, anthracene), which are specific to coal. These chemical compounds are used as raw materials for pharmaceuticals, dyeing materials and agricultural chemicals, after separation and refining by means of distillation. Table II-1-1 shows the many different distillates and their representative elements which are separated according to boiling points through coal tar distillation.

Table II-1-1 Fractions of Coal Tar Distillation

95% Fractionating Temperature	Yields (%)*	Typical Elements of Fraction
Tar light oil (176°C)	0.9	Benzene, Toluene, Xylene, Ethylbenzene, Trimethylbenzene, Indene, Naphthalene
Tar middle oil (198°C)	2.9	Xylene, Ethylbenzene, Trimethylbenzene, Indene, Naphthalene, Phenol, Cresol, Pyridine
Naphthalene oil (245°C)	13.7	Trimethylbenzene, Naphthalene, Methyl-naphthalene, Dimethyl-naphthalene, Acenaphthene, Cresol, Xylenol, Quinoline
Detergent oil (292°C)	4.6	Naphthalene, Methyl-naphthalene, Dimethyl-naphthalene, Acenaphthene, Diphenylene oxide, Fluorene, Anthracene
Anthracene oil (~400°C, 82.7%)	21.7	Acenaphthene, Diphenylene oxide, Fluorene, Anthracene, Phenanthrene, Methylphenanthrene, Fluoranthene, Carbazole
Pitch	56.2	
Total	100.0	

Note: * Yields to dehydrated tar

In addition, the tar used for paving is prepared by removing the light distillates from coal tar so that it reaches the standard of quality. An example of the quality is shown below.

EVT(°C)	8 - 16
Specific gravity (25/25 °C)	1.10 - 1.25
Moisture (%)	Less than 1
Toluene insoluble (%)	Less than 20
Naphthalene (%)	Less than 4
Acid oil (ml/100g)	Less than 3
Distillation test (%)	
Distilled quantity up to 220 °C	2 - 20
Distilled quantity up to 270 °C	5 - 25
Distilled quantity up to 300 °C	10 - 35
Softening point (°C) of the 300 °C distillation residual	35 - 60
Flashing point (°C)	More than 40

The pitch of the distilled residue is used as pitch coke, in electrode casting, coke-combining metallurgy, and in paving.

Furthermore, upon the cooling and washing of coal carbonized gas, creosote oil and coarse benzol are produced as by-products simultaneously with coal tar.

1.3 Present Situation in Zimbabwe

1.3.1 Domestic Production and Consumption

An outline of the present situation of ZISCO and WANKIE, which are producing coke in Zimbabwe, is shown in Table II-1-2.

Table II-1-2 Domestic Production Status

	ZISCO			WANKIE			TOTAL BALANCE
	Production	Disappearance	Balance	Production	Disappearance	Balance	
Coke (KT/y)	540 (45 KT/M)	Captive 100%	0	168 (14 KT/M)	Export 60% Domestic 40%	0	Production to the demand
COG (Nm ³ /y)	(26,400)*1	Captive 100% (as fuel)	0	8,200	Captive 70% (as fuel)	Waste 30%	Wasting
Coal Tar (KT/y)	22	Paving 1.8 Local Fuel 7.2 Captive Fuel 13.0	0	11	Paving 150% Local fuel	Stock 50%	Inexcess
Crude Benzene (kl/y)	1,800	NOCZIM 100%	0*2	2,900	NOCZIM 77% Blending 23% with Tar	Surplus 23%	Production to *2 the demand

Note: *1 Assumed figure, this was not checked with ZISCO directly.

*2 Crude benzene rectifier capacity in ZISCO is 10700 kl/y. The capacity utilization of this plant in 1988 has been less than 1/3, and operated to the quantity acceptable by NOCZIM.

ZISCO produces coke as a raw material used in iron production, while WANKIE produces coke for the ZIMBABWE ALLOY and for export to the extent to meet actual demands. Both companies supply some of the coal tar used in paving, while the rest is sold as fuel or consumed in captive uses. However, their stocks are generally increasing, WANKIE uses the material together with ammonium nitrate to produce explosives used in coal mining, though in a very small quantity. At present, coarse benzol is supplied to NOCZIM and used for denaturation of ethanol, and this is its only use now. There is also a surplus of coarse benzol.

The FOR price has been as follows.

Coal tar	For paving	TP-7 Grade	140 Z\$/T
	As fuel	TP-12 Grade	100 Z\$/T
Coke	In metallurgy		130Z\$/T
	For export		140Z\$/T
Coarse benzol	NOCZIM		38Z\$/l

1.3.2 Imports/Exports

According to the statistics of the CSO, coal tar, creosote oil and benzene are imported, though in small quantities. The situation is presented in Table II-1-3.

Table II-1-3 Import of Coproducts

			1983	1984	1985	1986	1987
Coal Tar	Quantity	T	207	265	401	297	194
	Amount	1000	44	91	120	144	88
	Unit Price	Z\$/T	213	343	299	485	454
Creosote Oil	Quantity	kl	625.9	157.5	118.4	339.6	181.7
	Amount	1000	144	81	58	171	114
	Unit Price	Z\$/kl	230	514	490	504	627
Benzene	Quantity	kl	36,106	33,928	419	494	260
	Amount	1000	1,542	1,449	166	166	89
	Unit Price	Z\$/kl	42.7	42.7	39.6	336	342

Note: In 1987, Jan ~ Nov. only.

Source: CSO

Benzene was imported in rather large quantity in 1983 and 1984. However, after 1985, it marked a sharp decrease, down to 1/100th, while the unit price increased by as many as 10 times. However, the reason for this is not clear. At any rate, the import quantities of these articles are too small to merit consideration as one of the object of the demands in terms of meeting in this project.

The import/export situation of coke is shown in Table II-1-4.

Table II-1-4 Imports and Exports of Coke

			1983	1984	1985	1986	1987
I M P O R T	Quantity	T	39,408	52,950	87,633	175,170	96,140
	Amount	1000 Z\$	2,860	4,066	6,343	14,697	10,049
	Unit Price	Z\$/T	72.6	76.8	72.4	83.9	104.5
E X P O R T	Quantity	T	135,272	101,871	89,612	113,133	24,537
	Amount	1000 Z\$	12,853	11,200	10,849	15,229	3,307
	Unit Price	Z\$/T	95.0	109.9	121.1	134.6	134.8
Export — Import		T	95,864	48,921	1,979	-62,037	-71,603

Note: In 1987, Jan. ~ Nov. only.

Source: CSO

The reason why there have been surplus imports since 1986, in spite of ZISCO and WANKIE both having surplus room for production purposes, are perhaps because of the price which is too high, an insufficient number of freight trains, the sulphur content in coke being high hence low in quality, or the problem with the system where the external sales of coke must go through WANKIE. The real reason is unclear or perhaps it is a combination of all these reasons. The export destinations are the Republics of Zaire and South Africa.

1.3.3 Domestic Consumption of Coal Tar

In addition to use as fuel, the domestic consumption of coal tar is limited to the use in road paving.

Road paving in Zimbabwe is of the tar/bitumen type using petroleum bitumen and with an expected life span of 15 years. In Zimbabwe, since the ultraviolet rays from the sun are strong, coal tar paving would have a short life span of only 3 to 4 years. Bitumen is imported in its entirety, as shown in Table II-1-5.

Table II-1-5 Import of Bitumen

		1983	1984	1985	1986	1987
Quantity	T	15,476	13,757	11,610	16,366	15,433
Amount	1000 Z\$	2,737	2,668	3,382	4,313	3,806
Unit Price	Z\$/T	177	194	291	264	247

Note: In 1987, Jan. ~ Nov. only.

Source: CSO

In addition, the following is an outline of the entire road length and the paving ratio in Zimbabwe in 1986.

Government Jurisdiction	Entire Length (km)	Paving Ratio (%)
MOT	18,500	35
Rural Council	23,700	2
District Council	37,500	2
Municipalities	5,300	50-60
Total	85,000	

The following is an outline of the paving process.

Prime coat. After steam-rolling, 0.8 l/m² of tar for paving is sprayed to provide waterproofing.

Stone layer. 19 mm-thick, stone and bitumen layer laid on top of prime coat

Chip layer. 6 mm-thick, chip and bitumen layer laid on top of stone layer.

The following is a rough estimate of the yearly consumption of tar used in pavements in accordance with the 150 km/Y of new road construction and the 50 km/Y of repaving under the MOT's road construction and maintenance policy.

$$6 \text{ m (width)} \times 200 \text{ km} \times 0.8 \text{ l/m}^2 \times 1.2 \text{ kg/l} \times 10^{-3} = 1,152 \text{ T}$$

In addition, in the assumption that the paving of provincial roads is promoted at the rate of 1% a year, the yearly demand for tar used in this connection can be calculated as follows:

$$4 \text{ m (width)} \times 650 \text{ km} \times 0.8 \text{ l/m}^2 \times 1.2 \text{ kg/l} \times 10^{-3} = 2,496\text{T}$$

The total of both calculations is a mere 3,650 T/Y, a quantity which, at present, can be covered entirely by that supplied from the companies of ZISCO and WANKIE.

1.4 Conclusion

There is no reason to support the case of producing ammonia by means of the coal carbonization process, according to the results of this market survey on coal chemical products.

Major by-products

Coal tar 43,000 T/Y and

Coke 990,000 T/Y

Generated with the raw material gas required for 600 T/D ammonia production are quite in excess to the domestic market somewhat over supplied or at least there are sufficient quantities, at present, with the supply available from the two companies. Therefore, for the market in Zimbabwe the outlook for consumption can not be visualized. At the same time, there is a problem with regard to the implementation of measures for transporting coke in large quantities.

In addition, according to a verbal survey, we found that ZISCO is interested in product development with regard to coal chemical products using coal tar as the raw material. This kind of development and the plan for rehabilitation are being examined. It is considered to be wise to entrust ZISCO with the future plans concerning coal tar and related products, making full use of the available technology, facilities and versatile uses with regard to the coal carbonized products which ZISCO already possesses.

At the same time, it is advisable to pay attention to the potential demand for BTX, an increase in the demand for creosote oil, and research into the paving with pitch compound, the weather-resistance of which is said to be better than that of bitumen.

However, as discussed above, the conclusion of this market survey is that ammonia production through coal carbonization is inappropriate.

Chapter 2 Basic Concept of the Project

Ammonia, Coal Tar Project

Chapter 2 Basic Concept of the Project

2.1 Factors Governing Project Realization

For realization of this project which focuses on ammonia and coal tar production based on coal carbonization, the following two conditions at least will have to be met.

- 1) Cheap coke oven gas must be supplied on a stable basis in the quantities required for ammonia synthesis.
- 2) Coal carbonization gas contains comparatively many impurities, so an inexpensive refining process to prepare ammonia synthesis gas could be chosen.

In addition, the basic conditions under which this case should be examined are as follows.

(1) Capacity of the Ammonia Plant

The capacity of the ammonia plant is 600 T/D.

(2) Quality of the Raw Material Coal

A coking coal which should have the analytical values (dry basis) shown in the following is available.

Ash	9.7%
Volatile matter	26.6%
Fixed carbon	63.7%
Calorific value	31.7MJ

(3) Composition of the Coal Carbonization Gas

The composition of the coal carbonization gas should have the analytical values (Vol.%) shown in the following.

Composition	%
CO ₂	2.5
O ₂	0.1 ~ 0.4
CO	6-8
H ₂	55-58
CH ₄	26-28
C ₂ H ₆	0.8
C ₂ H ₄	2.3
C ₃ H ₈	0.1
C ₃ H ₆	0.1
C ₆ H ₆	0.2
N ₂	1.8
O ₂	0.1
Total calorific value	4,300 - 5,200 Kcal/Nm ³

(4) An Outline of the Production Process and the Material Balance

An outline of the production process and the material balance are shown Fig. II-2-1.

(5) Plant site

The details of the plant site are discussed in Volume I, Part 1, Chapter 6. What should also be noted in this case, however, is that, the raw material coal and the by-product coke are in extremely large quantities compared to the quantities required in coal gasification, so it will be necessary to take into consideration the site of the freight depot and their logistics.

Furthermore, as regards waste water, scrupulous attention should be paid to measures concerning BOD and COD.

The survey results for the 2 items of (a) and (b) described above are shown below.

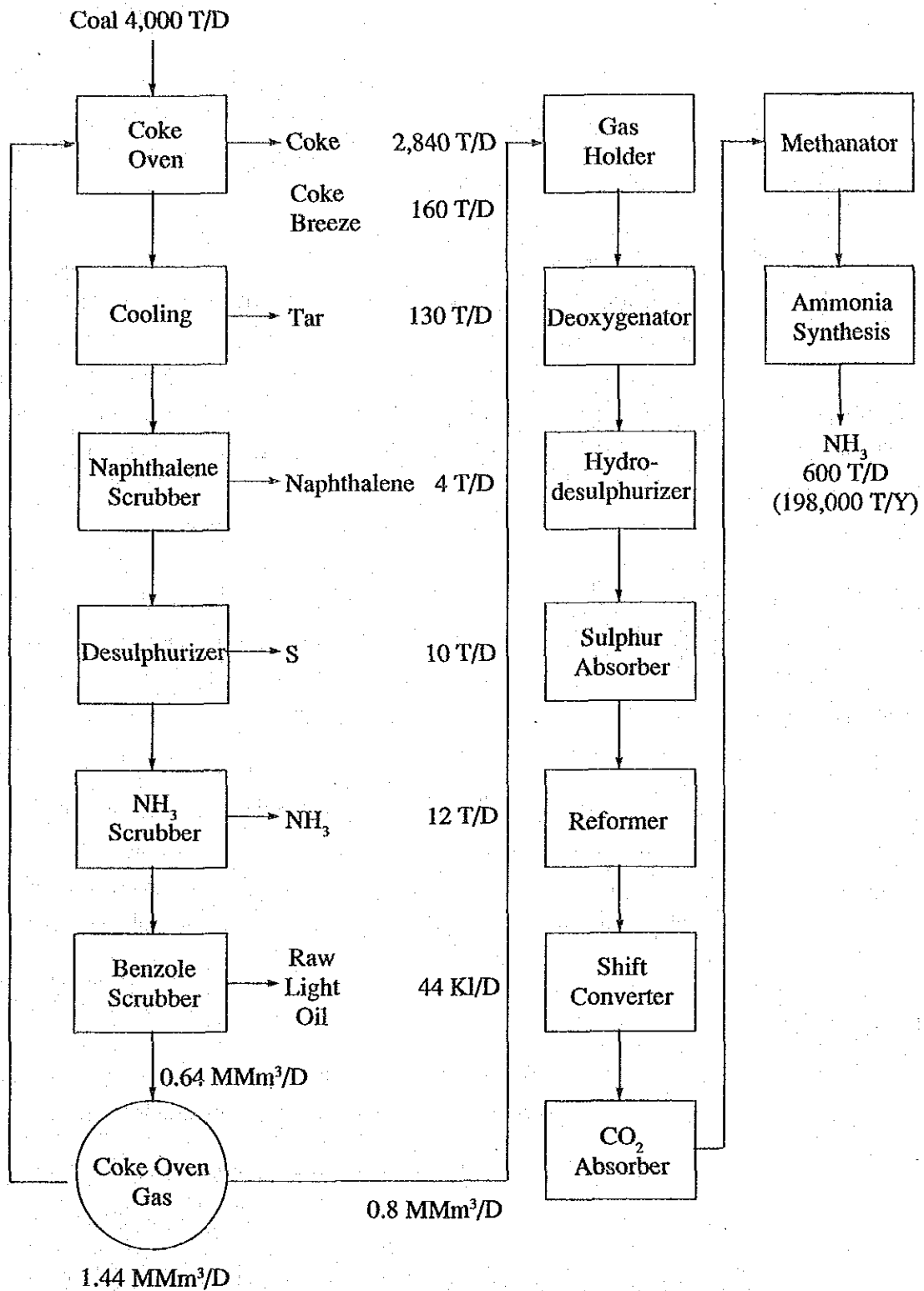


Fig. II-2-1 Ammonia and Tar by Coke Oven Process

2.2 Stable Supply of COG

To supply raw material gas to an ammonia synthesis plant with a capacity of 600 T/D, 1,300,000 tonnes of coking coal a year are necessary (good-quality, low-ash coal may be blended). In this case, the quantity of coke produced for the blast furnace and general metallurgical use will be 1,000,000 tonnes. Of this assuming that the quantity of coke to be exported on a stable basis will be 100,000 T/Y and that for general metallurgical use will be 70,000 T/Y, and designating the rest for the blast furnace, its quantity will be 830,000 T/Y. Therefore under a condition that the coke ratio is 500 Kg/T/pig iron, the quantity of pig iron production will reach 1,660,000 T/Y. This is worth about twice the pig iron production of 800,000 T/Y by ZISCO at present in the operating rate of 80%. At this point, it is very difficult to make a forecast as to whether an increase in demand and the implementation of facility expansion in the first half of 1990 to counterbalance these figures will be possible or not, since it is outside of the scope of this survey. In addition, coke exports cannot be expected to become stable due to competition from other countries and also as a result of the development of iron production technology which does not require the use of coke. Moreover, taking into consideration the fact that molten iron production using the reduction process (using ordinary fine coal and fine iron ore) could find practical application in future, based on the research and development thereof being enthusiastically undertaken on a worldwide basis at present with positive results having already been achieved, then it should be considered that coke consumption will show a downward trend. Therefore it is not realistic to expand the coke ovens beyond the current capacity installed in Zimbabwe.

On the other hand, there might be an idea to make use the generated surplus coke into ammonia synthesis gas through coke gasification. However, this means that tar and light oil have to be separated from coal for the remaining material to be gasified. This is disadvantageous in that expensive coke ovens to be built and coking coal to be consumed compared to coal gasification.

With the present situation of Zimbabwe, as discussed in the previous chapter, there is a surplus of coal tar.

In the future prospects from the viewpoints of economy and technology, it seems advisable to adopt the process of producing ammonia independently from tar and coke.

In other words, (a) of the conditions for project realization cannot be met.

2.3 Gas Refining

Coal carbonization gas contains hydrogen sulphide, organic sulphur compounds (such as thiophene, mercaptan and carbonyl sulphide), unsaturated hydrocarbons, gum formation substances such as nitrogen oxide, and hydrocarbon substances which easily deposit carbon.

Therefore, compared to the coarse gas from the high-temperature gasification of coal, coal carbonization gas is very unclean. Furthermore, each coke oven chamber is operated according to the batch system, which means that the gas composition may change.

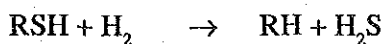
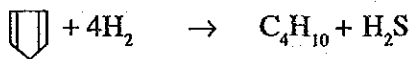
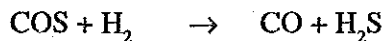
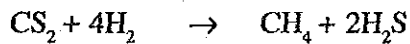
There is a wide choice as to the technology of refining coke oven gas into ammonia synthesis gas as a result of the progress made in the process concerned and in the field of catalysts.

By taking all the above into consideration, it is necessary to establish the gas refining process for this particular case, consisting of the following elements.

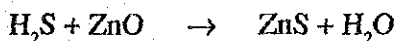
- (1) Normal refining of coke oven gas
- (2) Gas holder for a uniform gas composition
- (3) Deoxygenation by means of a catalyst
- (4) Hydrogenation desulphurization equipment for the selective hydrodesulphurization (for gas containing CO₂ and CO) of organic sulphur
- (5) Dry desulphurization equipment
- (6) Gas reformer
- (7) Shift converter
- (8) Amine carbon dioxide absorption equipment
- (9) Methanator

The following is an outline of reaction in these elements.

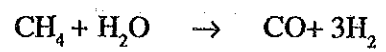
- (4) For the hydrogenation desulphurization of organic sulphur, a nickel-molybdenum catalyst is used.



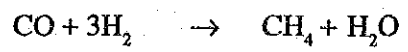
- (5) Adsorption desulphurization reaction



(6) Reforming



(7) Methanation



Chapter 3 Production Process and Facilities

Ammonia, Coal Tar Project

Chapter 3 Production Process and Facilities

As described in Chapters 1 and 2, it would be improper for this case to be put into effect under the current circumstances of supply and demand in Zimbabwe. However, if it will indeed be put into effect, the following will be the outline of the process.

The coal carbonization facilities consist of raw material adjusting facilities, coal feeding facilities located at the top of coke oven, the coke oven itself, tar collection facilities, gas cooling/refining facilities, and waste water disposal facilities etc. Recently, through a construction of coke dry quencher, it is achieved to collect the waste heat and to conserve the environment.

In the world, the major suppliers of processes and facilities are KRUPP KOPPERS and OTTO SIMONS.

3.1 Coke Production

In the production of good-quality coke, the quality of coal is important. And at the same time it is necessary to adjust the raw material blending ratio, moisture and particle size distribution. In most cases, strong coking coal and weak coking coal are compounded for the raw material, although, when the need arises, anthracite and coke breeze are blended. Sometimes there may be as many as 5 to 10 different kinds of raw material. In many cases, the particle size are adjusted, for example, 80 to 95% 3 mm less.

The structure of the coke oven is of a vertical furnace type with a flat columnar shape. Tens of unit oven are made to adjoin each other to form a single line. Each oven is driven one after the other according to a batch operation, and in their entirety a single cycle is created. It is a normal practice that a part of the gas generated from the coke oven is used in cycle to heat the raw materials.

Carbonization is completed in 14 to 20 hours. Recently, however, in order to avoid operations during the middle of the night, the width of the oven chamber has been increased for operations over a 24-hour period.

When carbonization is completed with hardly any gas generation, by closing the valve of the ascent tube and breaking the connection with the gas collecting main, a pusher machine extrudes the red hot coke through the coke guide and loads it into a quenching car. The quenching car transports the coke to the quenching tower located at the end of the line of ovens where the coke is quenched by spraying it with water. Otherwise the quenching car loads it into heat collection equipment (coke dry quencher).

In normal coke production, the width of the coke oven chamber is from 400-480 mm, the length 12-16 m, and the height about 3.7-6.5 m, while the temperature of the flue gas is 1,150-1,250°C.

Coal at normal temperature is charged into an oven chamber heated up to a high temperature, and from a part touching the heating wall, it is gradually heated at an increasing temperature, upon which gas is generated and coke formed. During the first hour of heating, gas is generated in great quantities containing a great deal of methane. However, after this stage, when the temperature inside the oven chamber gets uniform and the chamber temperature is high, the quantity of gas generated decreases, while the hydrogen content increases.

The heat required for carbonization is usually 540-660 Kcal per 1 Kg of coal loaded.

3.2 Coke Oven Gas Refining

The gas evolved from the coke oven has a temperature of 600-700°C, and contains different kinds of compound including hydrogen sulphide, carbonyl sulphide, organic sulphur compounds, cyanide, a gum compound substance, and ammonia, as mentioned above, in addition to large quantities of tar vapor. As a synthesis gas raw material, it differs from oil based raw materials such as natural gas and naphtha in that the gas contains so many of these impurities.

Though it uses the same coal as the raw material, the gas from the coal gasification furnace, as described in Part 1, contains little quantity of methane, a sulphur compound in a form of hydrogen sulphide, an inorganic sulphur compound, and a small quantity of carbonyl sulphide. On the other hand, the coke oven gas contains 0.2-0.7 g/m³ of thiophene, carbonyl sulphide and other organic sulphur compounds in total other than 1-2.5% hydrogen sulphide (15-40 g/m³).

Refer to the production process illustrated in Fig. II-2-1 for a brief explanation of the production process described below.

Circulating ammonia water is sprayed over the high-temperature coke oven gas evolved from the coke oven, and the gas is quenched to a temperature of less than 95°C. The tar and gas liquid are separated and in a cooler the gas is further cooled down to 25-40°C to remove most of the remaining tar. The gas pressure is brought up with a blower while the tar is removed in a tar scrubber and a mist cottrell so that it is less than 0.05 g/m³. Then, in a naphthalene scrubber the naphthalene is removed with creosote oil washing, and then washed with ammonium phosphate solution in an ammonia scrubber. Then hydrogen sulphide is removed by means of Takahax desulphurizer. In the Takahax desulphurizer the hydrogen sulphide is removed using a sodium carbonate or potassium carbonate solution with 1, 4 naphthoquinone-2-sulphonic acid as an oxidizing catalyst in a single or two staged washing towers. The efficiency of desulphurization is 99.9% or more. By blowing air into this absorption liquid to oxidize it and deposit the sulphur, and after separating the fine sulphur through a filter, the filtrate is recirculated as the washing liquid.

In a benzene scrubber, the raw material coke oven gas is then obtained by removing light oil through the circulation of creosote oil.

The coke oven gas thus obtained is first collected into a gas holder for the purpose of uniforming the composition. The oxygen contained in this gas is removed by a catalytic reaction with the hydrogen in the gas. Then, in a hydro desulphurizer the organic sulphur and carbonyl sulphide are converted into hydrogen sulphide by aid of hydrogen which is absorbed and removed in a dry desulphurization equipment using iron oxide or zinc oxide.

In order to utilize the methane in the gas, methane is converted into hydrogen and a carbon monoxide mixed gas by adding steam and through catalytic cracking. Having been put into a shift converter, the carbon monoxide is converted into hydrogen and carbon dioxide.

The carbon dioxide loaded gas in this way is sent to a CO₂ absorber for its removal. In this absorber the use of amine washing liquid (for example, in the MEA Process or an improved process) is advantageous from the point of heat economy.

Finally, the 0.25-0.3% residual carbon monoxide is converted into methane in a methanator and finally refined ammonia synthesis gas is obtained.

3.3 Utilization of Coal Tar

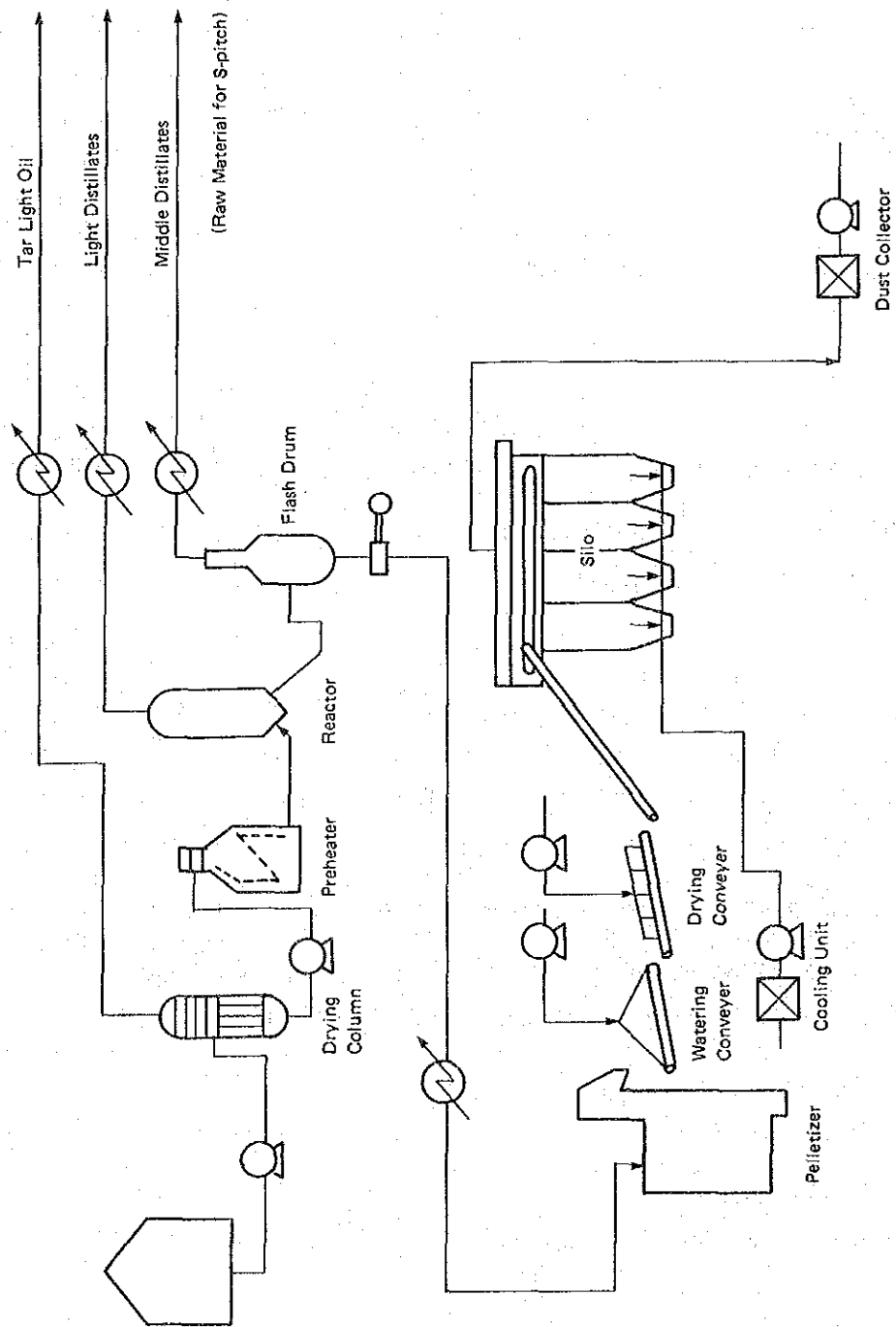
Tar contains useful raw materials for organic synthesis chemistry, including pyridine, phenol, cresol, naphthalene, and anthracene, thus being a convenient source of their supply. Creosote oil is used as an antiseptic for timber, while the residual pitch is a raw material for electrode-casting, briquet coking and pitch coke production.

In addition, dehydrated crude tar and prepared tar are used as road paving materials.

The new process of producing electrode material from tar has been put to practical use, in which the tar separation process has been simplified. This flow of the Cherry-T process is shown in Fig. II-2-2.

Tar is charged into the reaction equipment heated after dehydration.

Here, a thermal polymerization reaction occurs under a high temperature and high pressure, the pitch is reformed, and all volatile matter is flash-removed, whereby the binder pitch is obtained.



Source: The Society of Chemical Engineers, Japan 48 530 (1984)
41 312 (1977)

Fig. II-2-2 Process Flow of Cherry-T

3.4 Alternative Plan for Coal Tar Production

In the process described above, it is clear that the simultaneous production of ammonia and coal tar from coal is impractical when viewed from the balance of supply and demand. Therefore the following brief survey has been carried out, for reference purposes only, into the production process of coal tar, which is separate from ammonia production and unrestricted by the existence of surplus coke.

Research and development are being conducted into direct molten iron reduced production as a measure to deal with an increase in fine coal and an increase in fine iron ore caused by structural changes in coal mining and the means of transportation in the future. In this technology powdered char produced from ordinary coal is used without the use of coke.

For char production, fluid carbonization or flash carbonization will be applied, and this will also serve as the means of producing substitute substances for light oil and tar from the coke oven. Active research and development are therefore being conducted. The development of carbonization technology in future is directed toward partial combustion fluid carbonization using air or oxygen, fluid carbonization using external heat on a joint basis, and the flash carbonization process with the same heat source for fluid carbonization.

In the case of flash carbonization, the temperature is comparatively low at 400-600°C, while the time required is short at about 0.1 second. In the case of fluid carbonization, the time needed is comparatively long lasting several minutes, while catalytic cracking occurs as a result of the char inside. The product is therefore apt to undergo secondary decomposition, hence the yield of light tar oil is small in the case of fluid carbonization.

If pressurized hydrogen is used, the tar yield is said to be high, and it has been reported that when a catalyst is used, the BTX yield exceeded 20%.

As for tar reforming, one process is to reform the tar after separation, while the other is to reform it at the time of carbonization with no separation. At present, the relative advantages and disadvantages are unclear. In any case, the means of obtaining the tar and light oil from coal seem to be diversified, as well as the methods of adding hydrogen directly or indirectly to coal.

Furthermore, the char generated by the carbonization of powdered coal can be used in power plants, in fluid combustion boilers and in the gasification of finely powdered coal, as well as in molten iron reduced production.

Chapter 4 Discussion

Ammonia, Coal Tar Project

Chapter 4 Discussion

4.1 General

According to the results of the above survey, a project for the production of ammonia and coal tar using the coal carbonization process is impractical, even though there are rich coal resources in Zimbabwe. This particular process should not therefore be adopted.

The reasons are summarized as follows.

- (1) There is no market for the consumption of coal tar and the large quantities of coke produced at the same time inevitably.
- (2) A project whose production system does not allow the production quantities of the three products of ammonia, coal tar and coke to be varied independently should not be started.
- (3) Wasteful investments, such as dual investments, should be avoided.

4.2 Discussion

- (1) The use of large quantities of coal tar can be found in road paving. In Zimbabwe, from the standpoint of the weather-resistance of paved roads, there can be no expectations for this particular usage since the country imports bitumen due to its great durability for use as paving material. Another major use for coal tar is the utilization of poly fused benzene rings compounds peculiar to coal such as cresol, pyridine, naphthalene and anthracene which are separated from coal tar through coal tar distillation, as well as the utilization of pitch in the form of a distilled residue. However, the prospects are very poor in this country, not only in the present circumstances, but also during the period up to 1995, for the chemical industries which use these coal chemical products or for the manufacturers of electrodes.

As regards coke, the domestic demand in iron production and metallurgy is, at present, already fulfilled, and coke has been exported to neighboring countries for a considerable time. However, there are various export restrictions, so a sharp increase cannot be expected. Therefore, there is no hope for the demand to increase up to the level of 1,000,000 T/Y.

From the market side for by-products, a plan for the production of ammonia at 600 T/D with coke oven gas serving as the raw material is therefore out of touch with reality.

- (2) The quantity of the coal tar by-product produced in parallel with the demand for ammonia at 600 T/D in 1995 and 1996 will be about 40,000 T/Y, while the quantity of coke will be about 1,000,000 T/Y. The quantities of these compound can be adjusted to a small extent within the working limits of the quality of the raw material coal and changes in the plant operating parameters. However, the degree of adjustment for each product ratio is very small. The compound ratios of these three products are inevitably destined at the initial planning stage. Under a circumstance that the demand for ammonia is very strong but there is a surplus stock of coke, which means that to increase the production of the former and decrease the production of the latter, however it is impossible to do so. This is the basic point of vulnerability of products which generate by-products. It would be of great advantage if this could be avoided.

If the size of the market was much larger so as to absorb the quantity of by-products generated by this project, it would then be unnecessary to think about this problem so seriously. However, the facts speak for themselves.

A plan should not be adopted which aims at reduced ammonia production, even though there is a strong demand, because of the surplus stock of coke produced as a by-product in large quantities.

- (3) ZISCO, which is already directly connected with iron production in Zimbabwe, and WANKIE, which is involved in external product sales and exports for metallurgy use, both produce coke. If this project were implemented, the scale of coke production would by far exceed that of these two companies, thus creating a problem of oppressing both companies in terms of both sales and price. In addition, it seems that ZISCO is planning the diversified utilization of coal tar in the production of coal chemical products. When viewed in this way, with regard to the coal tar and coke production to be undertaken by this project it must clearly be seen as dual investments.

As far as ammonia production is concerned, if coke oven gas is used as the raw material, a great deal of facility investment is necessary for gas refining and production diversification of the coal tar products. This investment is much greater than for the case of coal gasification examined in Vol. I.

In any case, the coal carbonization route is a wasteful investment, and it is recommended that a coal carbonization project not be implemented.

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