However, on the other hand, the development of exhaust-heat reforming equipment which is mountable on a vehicl and improvement in the performance of the heat exchanger is further necessary.

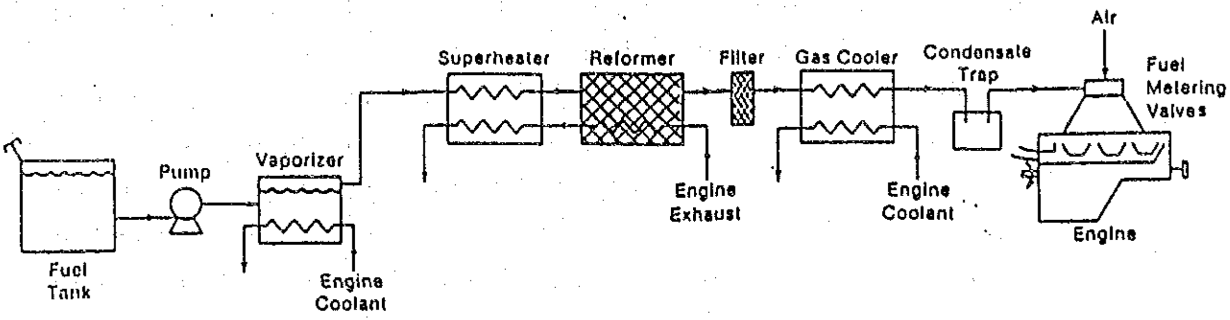

Fig. 8-2-6 Reformed Methanol Fuel System

(3) Utilization Technology on a Diesel Engine Basis(20)(21)

Various methds have been developed to improve the very low ignition capability due to the low cetane number of alcohol and high vapourizing latent heat. These methods are broadly divided into the following three kinds:

- Mixed fuel system (mixing of diesel oil and ignition improving additive)
- Dual-kind fuel injection method (pilot system)
- Forced ignition system (use of spark plug or glow plug)

1) Mixed Fuel System

The mixed fuel system is aimed at improving the ignition capability by mixing alcohol with highly-ignitable light oil or a nitrate-based firing-ignition improver. These two mixing systems are desirable, because they do not demand modifiction of the diesel engine which becmes the basis, but the limit of mixing due to layer separation and the cost of the additvies pose problems in the respective methods.

The mixed fuel of alcohol and diesel oil has the problem of layer sepration as in the case of the mixed fuel of alcohol and gasoline, but the seriousness of the problem depends upon the composition of the diesel oil, fuel temperture and moisture content in the fuel. The layer separation can be avoided to a certain extent, if 15% to 20% of an additive consisting of a higher alcohol such as dodecanol ($C_{12}H_{25}OH$) is used, but even then the mixing ratio of methanol is limited to about 40%.

The use of the ignition improving additive can be immediately implemented, because engine modifications are limited to matching the fuel system. Therefore, this agent is used in Brazil for sugar trucks using ethanol fuel(78)(79). As this improving agent, 4.5% (vol %) TEGDN (Triethyl glycol dinitrate) is mixed, and further, 1% caster oil is mixed to supplement the lubricability of the fuel.

With this method, Benz engines of 5.7 and 9.7 amounting to 1,700 units were used early 1986. Their performance, as shown in Fig. 8-2-7, indicates that the maximum torque was improved by 10% compared with the diesel engine at lower speed by 20% thereby contributing to an improvement in operability. Fuel consumption by a 22-ton truck showed about 15% improvement compared with a 100% ethanol-burning engine provided with a spark discharge plug.

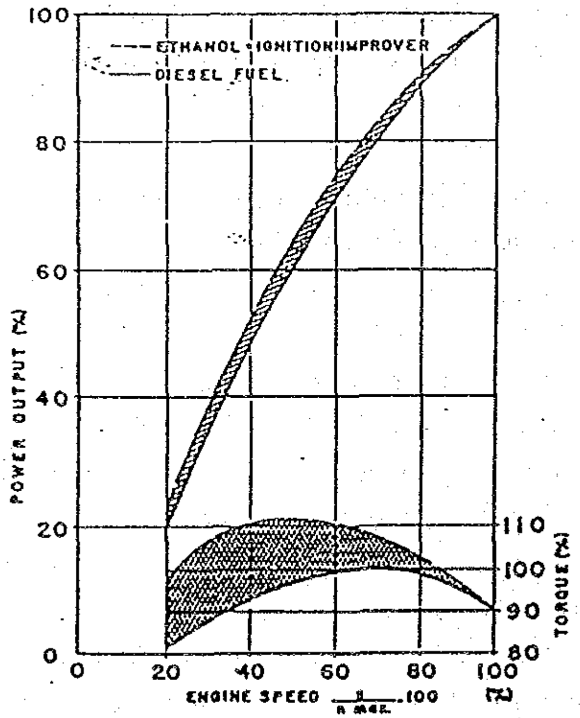

Fig. 8-2-7 Torque Rise due to Ethanol Fuelling (82)

The cost of the ignition improving additive poses a problem, but in the past five years, the price of the improving additive dropped from 18 to 6 times the price of ethanol fuel (ethanol price also dropped from 45 ¢/l to 22 ¢/l). Eventually, the price of the ethanol fuel mixed with the improving additive will be about 24% higher than straigt ethanol.

Development for producing the ignition improving additive has progressed as a by-product of ethanol fuel production at sugar cane factories$^{(82)}$.

A cold starting test was conducted in Finland, using two turbo-equipped direct injection Diesel engines$^{(68)}$ and the fuel containing an ignition improving additive (17% DII-3" (Ethyl Co.)) showed better startability, though only a little, over the diesel oil, and far exceeded the startability of the other dual-fuel type engine.

2) Duel Fuel System

In the injection system, highly ignitable diesel oil and low-firable alcohol have their own respective fuel and injection systems, and alcohol firing is ensured by injecting a slight amount of diesel oil just prior to alcohol injection.

The startability and firing stability of this system are better than the neat utilization system to be explained in the next section.

The F8L413F engine of KHD has the feature that a fixed amount of diesel oil is supplied to its entire operation area. Beside the KHD engines of West Germany, the dual fuel systems of Volvo in Sweden and of MWM in West Germany are used for fleet tests on buses and trucks. On the average, 75% of the diesel oil is being replaced by methanol fuel. The drawback of the dual fuel system is that since two systems, each for injection and fuel supply, are required, the systems have become complicated and more expensive.

3) Forced-Ignition Method

Completion of a forced firing-ignition for neat methanol, using the spark-ignition plug or glow plug, is eagerly expected, because of much volume of diesel oil replaced. The development of this system is vigorously being performed in many companies and laboratories.

In the combustion chamber of MAN shown in Fig. 8-2-8, methanol is injected through an injection-hole nozzle into the combustion chamber above the piston, and the vapor mixture flowing along the combustion chamber wall or the spray mixture of the jet flow from the nozzle is forced-ignited by the plug. The plug position is an important parameter and exerecises various effects upon the engine performance. Low-temperature startability of this system, down to-2°C, is the same as that for diesel oil.

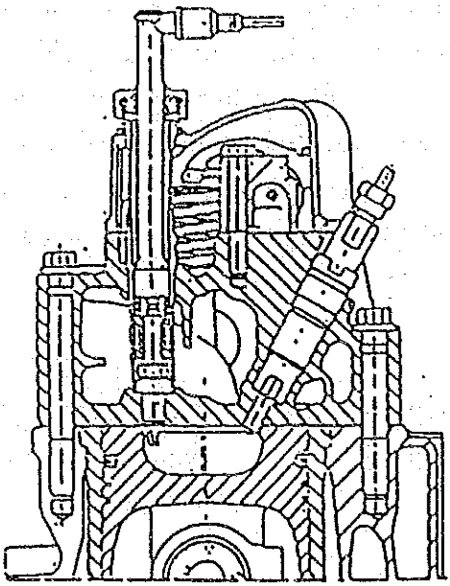

Fig. 8-2-8 M.A.N. D 2566 FMUH Engine (Development status 01/ 1984)

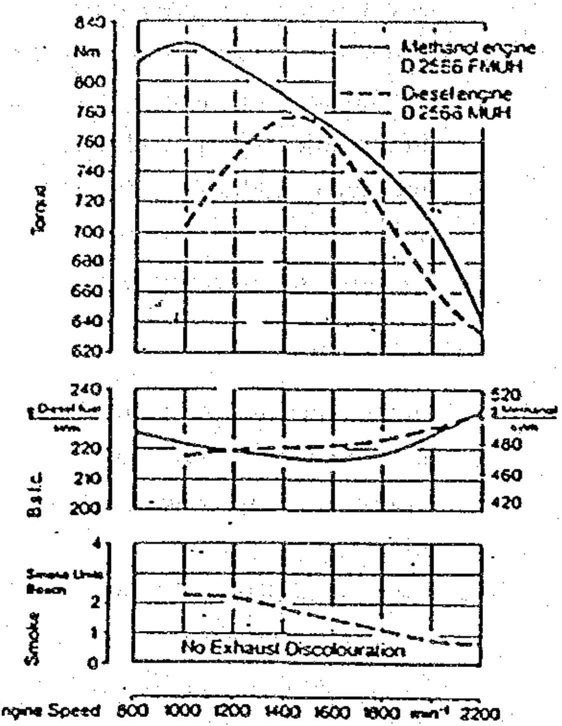

Fig. 8-2-9 Fuel-load curves of D2566 FMUH Methanol Engine and D256 MUH Diesel Version (26)

As can be seen from the total-load torque performance shown in Fig. 8-2-9, this methanol engine with an excellent smoke characteristics gives a very great low speed torque, compared with the diesel engine restricted by smoke at low revolution speed. This MAN's D2566FMUH engine was trial-used in the commercial test on buses in San Francisco, and a travel distance of 72,000 km was accumulated.

However there have been serious problems based on the facts that durability of the spark plug was less than 8,000 km and the deterioration of the plug leads to a catalyst deteriorations.(73)

The engine and system of Komatsu are shown in Fig. 8-2-10, which indicates replaced parts and additionally installed parts.

GM/DDA(11) converted its 2-cycle, 6-cylinder, V-type engine with a compression ratio of 19 into a methanol engine and made it possible to self-ignited methanol by adjusting the scavenging effect and residual gas quantity.

Table 8-2-6 Condition of Oxygenates Utilization in Major Countries [42]

	Methanol	Ethanol	TBA	MTBE	Remarks
Europe					
West Germany	M3/TBA2			×	Under M100 test Supplied by OMV
Austria	M2/TBA2				
The Netherlands			×	×	
Sweden				×	Under M100 Test
Switzerland	M3/TBA2			×	
Denmark				×	
Finland				×	Supplied by NESTE
France					
U.K.					
Belgium					
Norway					
Italy	M3(MAS)			×	{Methanol and Superior Alcohols
North America (note)					
U.S.	M5/TBA5	E10	×	×	Under M100 Test
Canada	×				
South America					
Brazil		E20, E100			
Argentina		E15			
Paraguay		E20, E100			
Guatemala		?			
Africa					
South Africa		E12			
Kenya		E15			
Malawi		×			
Zimbabwe		×			
Far East					
Thailand		×			
Malaysia		?			
The Philippines		?			
Papua New Guinea		×			
New Zealand					Under M100 Test

x = In use. Concentration differs from company to company.

? = Under examination

(Source): Deutsche Shell: Reference Material of AG, etc.

Note: State of use in major petroleum companies

	ARCO	AMOCO	CHEVRON	TEXACO	EXXON	SHELL	Mobil
ETHANOL		0	0	0			0
OXINOL	0						
TBA	0						
MTBE	0	0	0	0	0	0	0

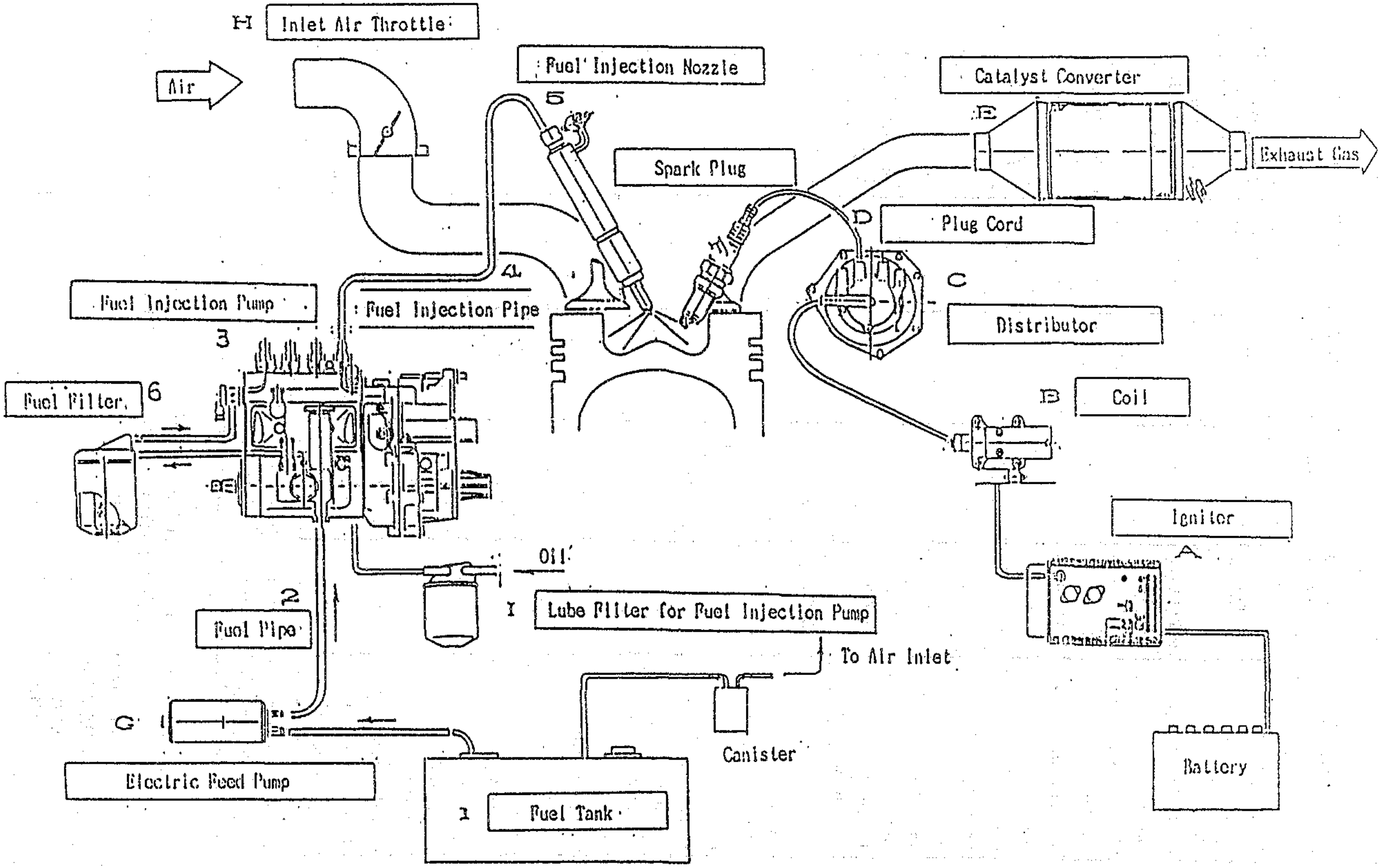

Fig. 8-2-10 Modification Items for Methanol Engine

This success is to the contribution of an active substance contained in the residual gas. In operating conditions under which self-firing deteriorated during a light load operation and during engine start, a glow plug has been inserted for achieving forced ignition. This newly-developed engine has been mounted on a bus in San Francisco and is undergoing a commercial test. According to the company operating the bus, the test result(27) is the same as that of the diesel engine, except that fuel consumption is inferior to that for the diesel engine during light load or ildling. Acceleration shows no significant difference. According to a recent report, the travel distance of 58,000 km has been accumulated, and the problem lies in the 30,000 km life of the injection nozzle. Slight wear on the injection plug has also been reported.(731)

Successive reports with the method of a glow plug have been arriving about tests in Canada on engines made in India(71), by Mitsubishi(74), and in West Germany(75) and also on KHD engines(87) and by Caterpillar(41) of the U.S.

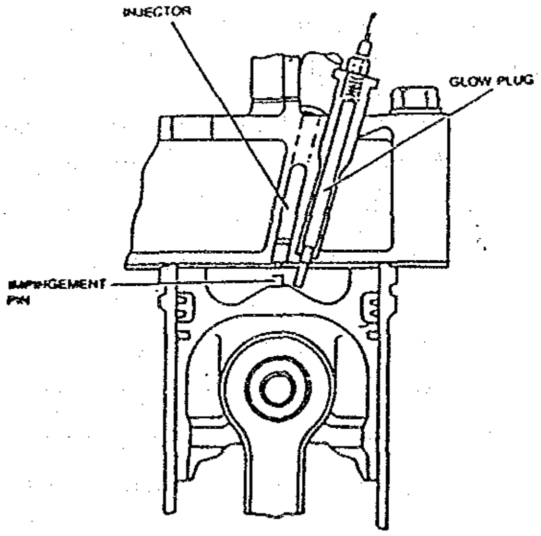

Fig. 8-2-11(a) Cross Section of Combustion Chamber Modified for Methanol

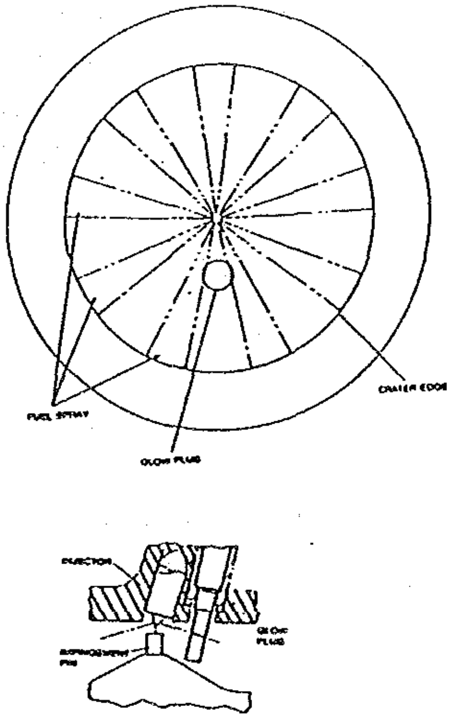

Fig. 8-2-11(b) Glow Plug Location in the Combustion Chamber - Top View

Of these reports, CAT's combustion chamber is caused, as shown in Fig. 8-2-11(a) and (b), to collide a centre spray with the protrusion at the piston head, and the resultant spray reacts by the heat of the glow plug, thereby promoting flame propagation. The emission of NOx is about one third of diesel engine although fuel consumption and HC slightly deteriorate at light load.

Mitsubishi carried out tests on its swirl-flow chamber-type single-cylinder engine using three firing system, namely, the spark assist, glow assist and diesel oil pilot injection. In the new combustion chamber having a newly designed combustion chamber and a mini-injection nozzle, thermal efficiency, smoke and NOx all showed better performances compared with the conventional diesel engies. In the glow assist provided with a ceramic glow plug, ignition and combustion are stabilized up to the high-speed area, and the NOx emission is on the order of 100 ppm, thus showing excellent performance.

JARI(25)(72) is studying a hybrid system in which a reformed gas is supplied through the in-take tube, while methanol is directly injected into the cylinder. A test result has been obtained which shows that the operating method of injecting reformed gas into the cylinder at a medium load or above and of sucking in a reformed gas at a low load has shown better thermal efficiency and exhaust cleaning than only the intra-cylinder injection system.

A gas engine system developed by Mercedes-Benz use a fuel gasified by engine cooling water from which exhaust-heat energy has been recovered. Therefore thermal efficiency is recovered by recovering cooling loss energy and by decreasing the injection work. During low-temperature starting, preheating by an electric heater is used. These engines were mounted on buses in West Germany and put to running tests. Fig. 8-2-12(28) shows the comparison of exhaust characteristics of various systems, when the exhaust gas level is assumed to be 100, and suggests the excellence of the alcohol fuel system in this respect.

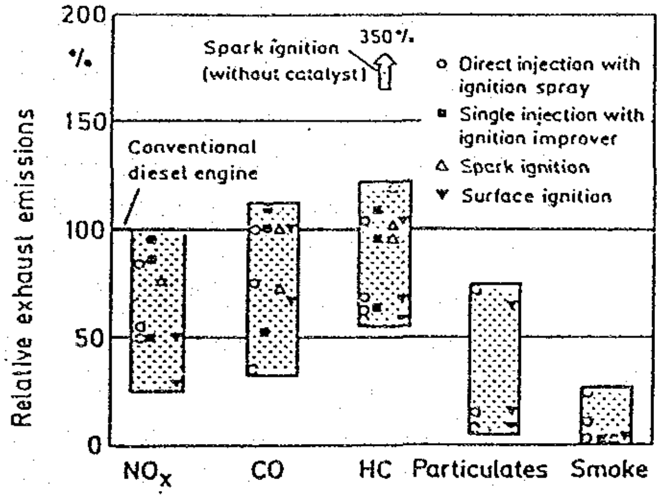

Fig. 8-2-12 Relative Exhaust Emissions for Alcohol-Diesel and Diesel Derived Engines

(4) Developments in Various Countries

1) Sweden(12)(60)(65)

In Sweden, which has no oil, gas and coal resources, similar to Japan, large-scale tests on alcohol fuels have been conducted, and particular attention is given to low temperature startability and wear during the low temperature season. Fleet tests on 1,000 units M15 fuel have already been completed.

Following these tests, running tests on 22 cars, trucks and buses using M100 fuel were started. Two buses travelled 16,000 km in 1980 to 1982. They used Volvo's dual fuel-injection system, and the alternation ratio by methanol was 75%. The performance and durability of these bus engines were similar to those of conventional diesel vehicles; and a decrease in exhaust emission, particularly NOx, and a decrese in the particle sizes of NOx were reported.

The 22-car test commenced in 1984, with the participation of 10 Volvos, 7 Saabs and one each of Ford, Toyota, Mitsubishi and Mazda. The test continued until 1986. Cold-region starting in Northern Europe and repeated stops and starts were difficult for methanol fuel engines, and special lubricants were used. Formaldehyde emission was 6 to 75 mg/km without a catalyst and 3 to 15 mg/km with a catalyst and was favorably compared with 20 to 40 mg/km for the gasoline vehicle. Twelve cars (2 pairs of Saab and 4 pairs of Volvo) were tested on M100 gasoline, and it was confirmed that energy consumption for M100 was less.(65)

2) West Germany(10)(57)(71)(80)

West Germany was eager to study methanol and a hydrogen fuel as alternative fuels on a private-sector initiative basis. In bus demonstrations all over the world, West Germany engine makers are always ahead of the trend.

In tests on methanol vehicles equipped with gasoline-based engines from 1979 to 1983, M100 was used, which consisted of 93% methanol with an addition of 7% hydrocarbon of C_4/C_5. This additive was used, they say, to avoid a combustible atmosphere in the fuel tank and to improve cold-region startability. At tests in California during 1981 to 1983, vehicles designed to pass state exhaust gas regulations were used. Although trouble occurred with the injection system, probably due to the deterioration of fuels during storage, basically these tests were not different from those in West Germany. Since 1984, tests were conducted with the aim of widening the using range and improving startability by equipping a double flow carburetor.

For heavy-duty vehicles, MAN, KHD and Benz developed methanol engines of independent types and participated in fleet tests on buses, trucks, etc. MAN's spark assist type FR engines were mounted on buses, etc., and have accumulated a record of 420,000 km since 1981. A supercharging system is also the object of study. At Aachen Institute of Technology and KHD, studies continue on direct-injection engines ignited by a hot surface (glow plug)(71). Dual-fuel-type engines of KHD were mounted on five trucks in Berlin and accumulated a travelling distance of 800,000 km, and the longest distance per vehicle was 120,000 km. In Köln, buses accumulated 240,000 km during 1981 to 1985.

Three Mercedes-Benz gas engines were mounted on three buses and accumulated an operation record of 500,000 km.

3) Canada(13)(61)(77)(82)(83)

Canada, the major producer of methanol, is vigorously pursuing studies on the possibility and, in particular, the practical use of methanol fuel, in view of the huge resources of natural gas and coal. One of the reasons for her eagerness in this field is that, if the current condition continues, Canada will shift from an oil-exporting to an oil importing country, and to avoid this situation, she is eagerly searching for a method of utilizing the methanol from natural gas and coal.

Recently, six Ford Escorts in three pairs were tested, and the FFV (Flexible Fuel Vehicle) test using M85, gasoline or their mixture was carried out with the aim of testing low-temperature startability in winter.(61)

The MILE (methanol in large engines) program, covering the years from 1985 to 1989, commenced in the spring of 1985, and tests of a 7-pair fleet are in the planning.

For underground mining, a methanol engine, obtained by modifying a KHD engine into a glow assist type' was trial-used(83).

4) U.S.(14)927)(62)(66)(73)(81)

Since gasohol, which is made by mixing lead-free gasoline and 10% ethanol, was introduced in 1979, a billion gallons of ethanol have been used every year mainly as an extender. Table 8-2-7 shows the quantity of oxygen-containing fuel used during the period from 1981 to 1983. The demand for ethanol and methanol will increase further if they prove to be economical as an octane booster.

Ninety-nine cars have participated in the CEC program held in California since 1981, and out of them, forty Fords have run for five years and covered ten million miles. Of them, thirty-seven cars have run the whole distance for four years.

Table 8-2-7 Consumption of Oxygenates (Vehicle Fuel) in the U.S.

Unit: 1 million gallons/year
(1,000 kℓ/year)

Year Oxygen containing fuel	1980	1981	1982	1983
Ethanol	50(189)	110(416)	210(795)	445(1,684)
Methanol	50(189)	65(246)	115(435)	225(852)
G T B A	140(530)	140(530)	140(530)	140(530)
M T B E	80(303)	105(397)	105(397)	190(719)
Total	320(1,211)	420(1,590)	570(2,158)	1,000(3,785)

In 1983, more than five hundred Ford Escorts were mass-produced and their test in the CEC program has entered into the third year. In particular, to check the low-temperature startability with M85 fuel, it is now planned to give startability tests to five cars each of the following three types: Chevrolet Citation, Ford Crown and Chevrolet s-10 pick-up, under the atmospheric conditions of -0°C, -15°C, and -32°C. In addition seven Escorts with electronic injection to control emission were tested in June 1984. In solving the problem of clogging the fuel injection nozzle, the above cars showed, as a result of improvement in the nozzle, a better improvement effect than cars with a carburetor(52).

Commercial operation tests have been made in San Francisco by using two buses (methanol-fueled and diesel fueled) each from GM and MAN, under the CEC plan(27)(37)(73).

It has been proposed to apply the CAFE (Corporate Average Fuel Economy) act, which aims to reduce fuel consumption rate for vehicles, only to the gasoline fuel concentration of M85 methanol-fueled cars. This means that the consumption of gasoline alone comes to the value of 200 mpg, when the average fuel consumption of 30 mpg is imposed on the gasoline-methanol fueled cars, as shown by the following equation: $30/0.15 = 200$ mpg. Over four years from 1987, five thousand cars owned by the Federal Government, which are to be used as methanol-fueled cars, will be subjected to road tests every year, totaling twenty thousand cars. The objects include large-sized engine vehicles such as buses and eighteen long-distance trucks(66).

Nowadays, emission regulations have been intensified. Although methanol fuel is expensive, its exhaust emission characteristics are excellent.

This fact has given rise to the idea that methanol-fueled cars are cost effective, compared to diesel-engine vehicles for which emission measures have already been taken.

5) Japan

In Japan, measures to introduce fuel methanol as a substitute energy for petroleum in the field of transporation have been taken(15), especially in big cities where traffic is heavy. These measures have been taken because it is difficult to clear air pollution regulations, above all, the environmental standard of NOx, and also because the transportation sector in Japan depends almost 100% on petroleum-based fuel(15).

The Ministry of Transport planned a 3-year road test on the following five types, including collection and delivery trucks and buses in cities. Since December 1986, the fleet tests have been executed using eleven gasoline engine vehicles ((1) and (2) below) and twenty-five diesel engine vehicles from Komatsu ((3) below).

(1) 1-ton pick-up type truck	10 units
(2) 1-ton van type truck	10 units
(3) 2-ton cab-over engine truck	80 units
(4) 70 to 80 passenger motor coach	10 units

(5) Specially-equipped vehicle
(2-ton garbage truck) Several units

The Japan Automobile Research Institute (JARI) has been performing basic research since 1973. They have been conducting researches to utilize both neat and high-concentration alcohol for various types of engines, and executed the road tests on the buses mounted with these engines.

Urged by the above-mentioned fleet test plan of the Ministry of Transport, the Ministry of International Trade and Industry reconsidered its policy, and in June 1985, the Agency for Natural Resources and Energy declared "the new energy introduction vision(16)", which is summarized below.

(1) To develop a technology for fuel M85-95 for gasoline engine-based vehicles from middle and long-term points of view
(2) To arrange the necessary system to introduce fuel methanol
(3) To execute required tests for introducing fuel methanol

Based upon this report, the Agency for Ntural Resoruces and Energy is making a concrete plan to execute road tests on methanol engine vehicles in 1988.

6) Others

In Indonesia methanol utilization has been studied in Pertamina and Lemigas for blending into gasoline with/without an additive. This study is undertsood to have two backgrounds. One is the international trend of reducing or eliminating TEL in gasoline and the other one is the consideration how to find out the outlet for methanol from Bunyu. As to fuel ethanol the survey team had some documents and comments on gasoline fleet test done by BPPT.

Besides the above-mentioned nations, other developing countries introduced the development of alcohol engines at the International Symposium of Alcohol Fuels in Paris in 1986.

i) In India, tests have been conducted for utilizing methanol for 2-cycle small-sized gasoline engines used in motorcycles, etc., which now account for 60% of traffic(86). Tests for performance(67) and durability(69) of glow-assist have been executed.
ii) In China the development of fuel methanol produced from vast coal resources, as fuel for transportation has been examined as a long-range plan. The performance of gasoline-based engine has been investigated(55) and practical tests on mixed fuel from gasoline and M15 have been made by using 500 tank lorries since 1983.(74)

iii) In New Zealand, a new carburetor has been developed(58).

A road test of 80,000 km has been executed over two years, using a Toyota Corolla mounted with the newly developed caburetor(63). This caburetor is used for an FFV, designed for using gasoline, methanol and gas fuel. It has already been tested in Norway(63)(85). Since there is no manufacturing plant for automobiles and engines in New Zealand, they find the gasoline based alcohol engine vehicle to be promising because a large-scale modification of the vehicle body is not required, and various kinds of fuel can be used. On the other hand, it is doubtful whether diesel based vehicles will be economical(76).

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8-2-2 Utrilization for Purposes Other Than Vehicle Use

(1) Large Scale Power Generation Plant

Among the usage of methanol for purposes other than vehicle fuel, the largest one will be for power generation.

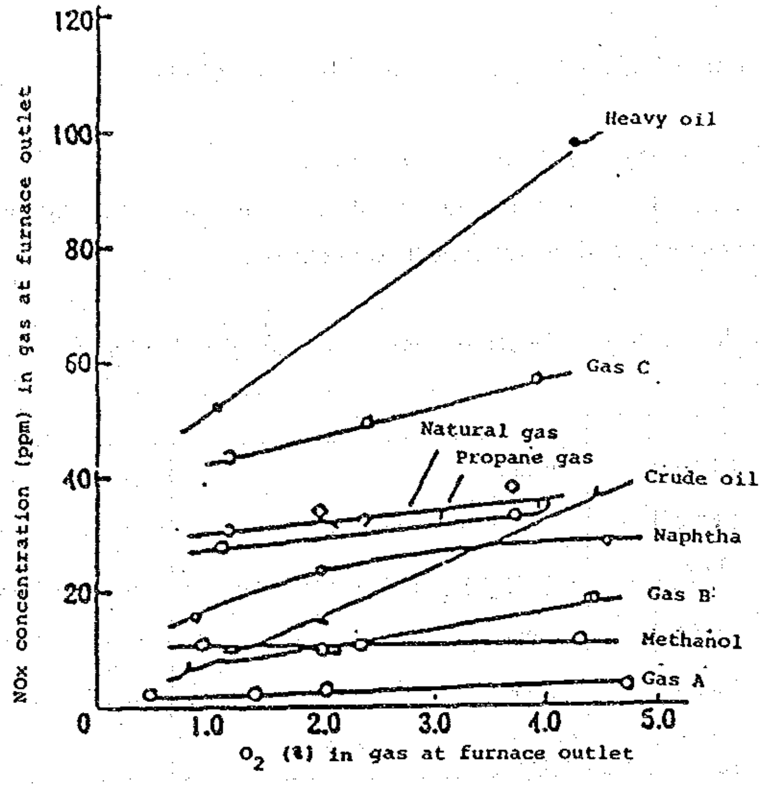
Table 8-2-8 Combustion Test of Methanol in Boiler

Year	Country	Testers	Remarks
1971	U.S.A.	COHEN	Fuel test furnace
1972	"	New Orleans Public Service Power Company	Boiler for 50 MW electric power service
1973 ~74	Japan	Central Research Institute of Electric Power Industry	Small-sized combustion test furnace
1974	"	Company A	Boiler for domestic use
1975	"	Company B	Boiler for electric power service
1981	U.S.A.	Southern California Edison Power Company (40)	10% mixed combustion with heavy oil

Table 8-2-9 Methanol Combustion Test in Gas Turbine

Year	Country	Testers	Remarks
1974	U.S.A	Florida Power Company	34 MW
1978 ~79	"	Southern California Edison Power Company	26 MW
1981	Japan	Company C	1.2 MW combustor
1983	U.S.A.	Solar Energy Research Institute	132 kW, methanol-reformation type gas turbine

To examine the use of methanol fuel for power generation, methanol combustion tests in boilers or gas turbines have been executed in Japan and the U.S., as shown in Tables 8-2-8 and 8-2-9.



Notes: Gas A - CO:24%, H_2:16%, N_2:60%

Gas B - CO:53%, H_2:47%

Gas C - CH_4:14%, C_2H_4:30%, CO:29%, H_2:27%

Fig. 8-2-13 Relationship between O_2 and NOx in Gas at Furnace Outlet

1) Boiler

The combustion tests of methanol in boilers have been executed in Japan and the U.S., and the results have proved the following facts:

i) Exhaust Gas Characteristics

- NOx discharged by methanol fuel is kept down to about less than 50%, compared with NOx discharged by crude oil and heavy fuel oil as shown in Fig. 8-2-13.
- No SOx is generated because methanol dosen't contain sulphur.
- The CO content in methanol is almost the same as that in other fuel oils or slightly more, but the CO content in incompletely burnt methanol is nearly the same as that in other fuel oils or slightly more, but CO content in incompletely burnt methanol is nearly the same or less than that in other fuel oil, as shown in Figs. 8-2-14 and 8-2-15.

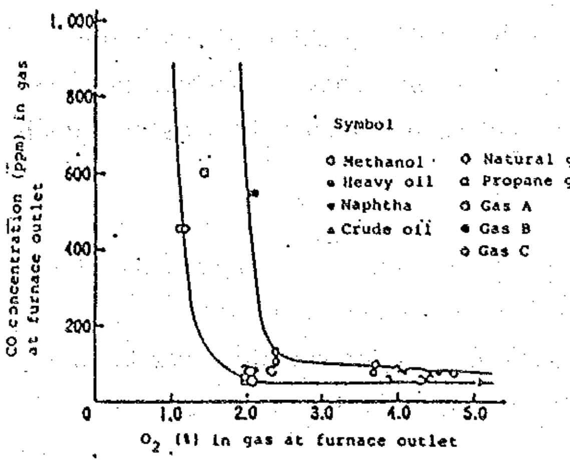


Fig. 8-2-14 Relationship between O_2 and CO in Gas at Furnace Outlet

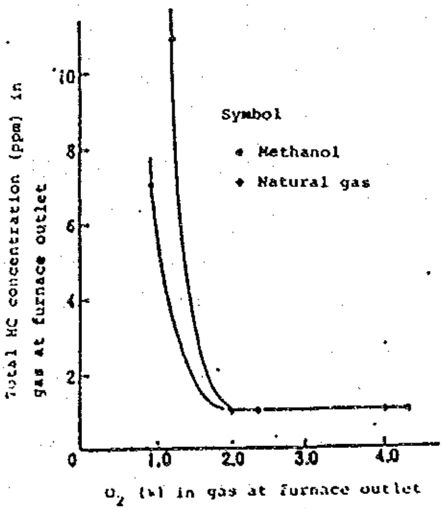


Fig. 8-2-15 Relationship between O_2 and HC in Gas at Furnace Outlet

- o No soot is generated. The above characteristics show that methanol consists of few elements to pollute the air and that it is considered to be an excellent fuel from the viewpoint of environmental protection.

ii) Combustion Characteristics

- o The burning temperature of methanol is lower than that of heavy fuel oil, etc., and a nonluminous flame is one of the characteristics of methanol. Such characteristics cause no problems. However, when using methanol in the existing boiler, it is sometimes necessary to change the size of the heat transfer area, because the flame emissivity of methanol is less than 50%, compared with that of fuel oil.

iii) Boiler Performance

- o Since methanol generates more moisture during burning than other fuel oil, this loss of moisture content results in a boiler efficiency drop by a few percentage.

iv) Modification of Boiler

- o There is no technical problem in modifying the oil-fired boiler to a methanol-fired one, although it requires newly established supply system of fuel methanol or enlarged capacity of existing supply system.

2) Conventional Gas Turbine

Combustion tests of methanol in gas turbines have been executed in commercial gas turbines and combustion chambers in the U.S., and in Japan, the tests have been executed by using combustion chambers. The results of the tests demonstrate the following facts.

i) Exhaust Gas Characteristics

- o About 45 ppm of NOx is detected, with a value less than 25%, compared with the value of the jet fuel (during the rated running).
- o The value of CO emission is 70 ppm, which is slightly higher than 50 ppm of CO emitted from the jet fuel, but is far lower than 175 ppm of CO emitted from natural gas.
- o Hydrocarbon emitted from methanol is slightly higher than that from jet fuel oil, that is, less than 10 ppm (but some data from the combustion chamber test indicate that the hydrocarbon of methanol is four to five times as much as that of jet fuel oil).
- o Emission of aldehyde from methanol lies midway between the order of 10 ppb for jet fuel oil and 10 ppm for natural gas.
- o No SO_2 is detected from methanol, but from jet fuel oil, about 10 ppm of SO_2 is emitted. The quantity of particulates from methanol is a third to a quarter as much as that from jet fuel oil.

ii) Gas Turbine Performance

- o General performances of methanol such as starting and output-increasing speeds of the gas turbine are the same as those of the other fuels.
- o Methanol requires no water injection as an NOx countermeasure, and its thermal efficiency is about 3% higher than jet fuel oil with water injection.

iii) Modification of Gas Turbine

- o To modify the existing gas turbine into a methanol-fired one, it is necessary to newly install a fuel supply system or enlarge capacity due to an increase in the fuel flow. A gas turbine itself, however, needs only a partial and easy modification.

Table 8-2-10 shows the advantages of using methanol as a fuel for the gas turbine and the necessary matters of precaution.

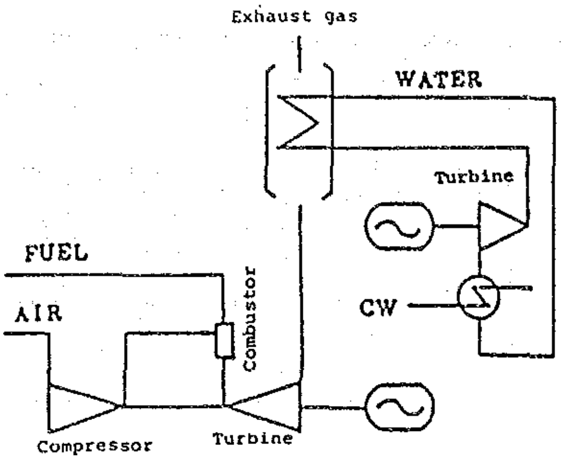


Fig. 8-2-16 Conceptual Drawing of Combined Cycle

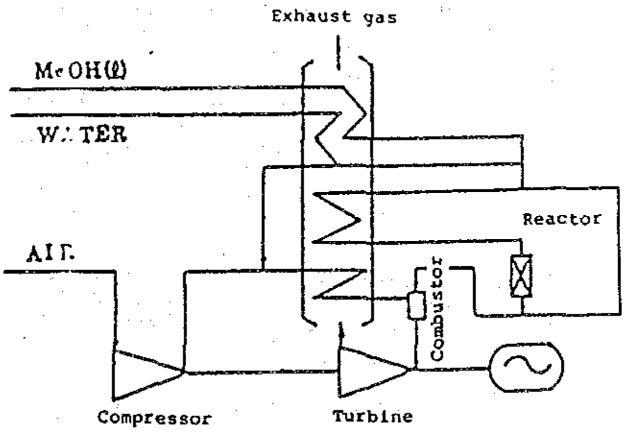


Fig. 8-2-17 Conceptual Drawing of Methanol-reformation Type Gas Turbine

Table 8-2-10 Merits of Methanol as Gas Turbine Fuel and Matters to be attended to

Features	Merits and Matters to be Attended to
• No impurities such as N, S are contained.	• SOx, Fuel NOx, and smoke dust do not occur. • Combustion gas has little high-temperature corrosion behavior.
• Calorific power is small.	• The combustion of methanol, about twice as much as petroleum-based fuel or natural gas, increases the turbine operation fluid and improves the output.
• Latent heat of vaporization is large. • It is dissolved and reformed endothermically at 250 to 350°C.	• Thermal efficiency can be improved by exhaust heat recovery.
• Combustion temperature is low.	• Little thermal NOx occurs.
• Calorific power is small.	• The capacity of the tank, piping, etc., must be increased.
• Lubricity is non-existent.	• Attention must be paid in selecting a pump.
• It is incompatible with some materials.	• It has corrosion behavior against Mg, Al, Zn, and Cu. • With about 10% water contained, methanol corrodes carbon steel at 40 to 50°C or above. • It may swell or deteriorate rubbers and plastics.
• It can be mixed freely with water.	• Once Na and K, which cause high-temperature corrosion of a turbine, blend in methanol, they cannot be removed by flushing.
• It selectively dissolves light-weight ingredient of oil.	• Piping cannot be used in common with petroleum-based fuel.
• Vapor pressure is high.	• Attention must be paid to pump cavitation. • Actuating method requires contrivance.
• Flame is non-luminous. • Ignition point is low. (11°C).	• Attention must be paid to leakage and ignition.

3) Methanol Reforming Type Gas Turbine

Methanol can be reformed (steam reforming) or decomposed at a relatively lower temperature. A new system of gas turbine, which is designed to improve thermal efficiency by reforming and decomposing methanol by using the exhaust heat of the gas turbine, is now attracting attention.

This system fully utilizes the characteristics of alcohol, and it is expected that the efficiency will be widely improve by nearly 10% (the absolute value).

This value is a theoretical calculation. It is desired to make detailed studies on this matter in the future. Fig. 8-2-16 shows the conceptual drawing of a combined cycle, and Fig. 8-2-17 shows that of a methanol reforming type gas turbine. The difference between them is as follows: In the combined cycle, steam is generated by the exhaust gas heat and power is regenerated by a steam gurbine; on the other hand, the methanol-reforming gas turbine causes a heating reaction of methanol by an exhaust gas heat of about 500°C and a reforming reaction at rather low temperatures of 250 to 350°C to decompose the methanol into H_2 and CO, and reforms the methanol into H_2 and CO_2 in the water-vapor reforming process, and then uses the reformed gas as its fuel.

The methanol-reformating-type gas turbine is advantageous over the combined cycle since the former dispenses with a costly steam turbine, thus substantially reducing the construction cost, and gains high heat efficiency (40% or above).

The constituent elemental technologies are not novel but just a combination of existing technologies, and the methanol-reforming-type gas turbine will be ready for practical use without any major technical barriers. In Indonesia, many conventional gas turbines have been installed and, therefore, fuel switching to methanol using this method seems to be promising.

i) Features and Problems of a Power Generation System using Methanol-Reforming-Type Gas Turbine (44)

(Features)

- o The exhaust gas is clean and causes less pollution problems.
- o Package production of machinery and equipment can be easily attained at factories, and the reduction of costs and the construction period can be expected.

- o Maintenance of the system will be simple.
- o Cooling sea water will be dispensed with, and inland application is possible.

(Problems)

- o A large quantity of demineralized water will be necessary for reforming methanol and for water injection.

  (About 0.8 kg/h for a 100,000-ton class system: 4 to 5 times the quantity required for an ordinary thermal power generating system)

ii) Elements for developing a methanol-reforming-type gas turbine and problems with technology development conceivable elements of the technology development for the system are catalyst, heat recovery-/reaction system, and configuration of power generating system etc.

The problems in technology development are shown below.

a) Catalysts must:

- o Be highly active in a wide temperature range (200 to 400°C),
- o Be high-temperature and heat resistant (450°C or above)
- o Possess sufficient resistance against the thermal histeresis due to load change and DSS (daily starts and stops).
- o Be of high performance (They must possess a high invert ratio for a certain space velocity).
- o Be free from side reaction, such as methanation, or carbon deposition.
- o Be easily maintained and controlled during the downtime of the system.
- o Cause no problem in their disposal.

There are two kinds of catalysts; the steam-reforming type and catalytic-cracking type. From the viewpoint of efficiency and system configuration, the catalytic cracking reaction, which uses no water, is essentially advantageous, but the final selection will be made in terms of the merits of practical performance of the catalysts, their economic efficiency, etc.

b) Reactor

As methanol reforming (decomposing) reactors, the following three types are conceivable:

- o A direct heat exchange type which exchanges heat directly with turbine exhaust gas by filling up the heat exchange tube with catalysts.
- o A heating-by-heat-medium type which recovers the exhaust gas heat by heat media, and circulates these heat media through a reactor separately provided outside the exhaust gas system, thereby supplying the heat for reaction.
- o An adiabatic type which recovers heat by a gas-gas heat exchanger for exchanging heat between the turbine exhaust gas and reaction gas, and supplies the heat for reaction to a separately provided reactor.

In principle, the direct heat exchange type is superior from the viewpoint of installation space, quantity of auxiliary machines and their power, but from the viewpoint of design, manufacture, etc., the practicality of the heating-by-heat-medium type seems to be greater.

c) Power Generation System

The possibility of introducing this power generation system may be found in its installation on an isolated island, for scattered system arrangement, for replacing old facilities, etc.

As a power generating facility, the system will be of small and intermediate scale, and in the plant operation, its applicability to the peak or middle load will be requred.

Accordingly, the development of a system with excellent DDS operation and load responsibility will be especially important.

(2) Power Generation on Diesel Engine Basis

Indonesia consists of 13,667 islands scattered over an immense area measuring 1,888 km in the north-south direction and 5,110 km in the east-west direction across the equator. Of these islands about 3,500 islands are inhabited. In view of the fact that even typical islands like Sumatra and Kalimantan do not have well-developed power transmission and distribution networks, diesel engine generators of 100 to 5,000 kW are widely used at various locations in Indonesia, and their future expansion is also in the planning. Most of these diesel generators have been converted from diesel engines for vehicle use, in the case of small-capacity engines, and from marine or railway diesel engines, in the case of large-capacity engines. The features of these diesel engine generators are that their thermal efficiency is higher than that of gas turbine generators and their equipment costs are cheaper.

In view of these special situations, there is a possibility in Indonesia of using methanol as fuel for these power genertors.

The methanol direct-injection-type diesel engines for generating purposes, using methanol as fuel, are, in principle, technically the same as the diesel engines for automobile use.

For the latter two methods, large-scale running tests for determining the applicability of neat or high-blend methanol fuel to gasoline engines are being carried out in the U.S. and Europe. It is expected that methanol fuel will yield better performance than gasoline engines and a cleaner exhaust gas. Further tests are being conducted to verify startability in low temperatures and the durability of some engine parts, and technical problems review on this respect.

For using methanol fuel in diesel engines, on the other hand, various system are being studied.

Research and development, though on a small scale, are being carried out, including practical-use tests for methanol fuel in buses, trucks, etc.

(3) Fuel cell

Table 8-2-11 Typical Fuel Cell

	1st Generation	2nd Generation	3rd Generation	—
Electrolyte	Aqueous solution of phosphoric	Fused carbonate	Solid electrolyte	Alkali aqueous solution
Electric Charge Carrier in Electrolyte	H^+	CO_3^{--}	O^{--}	OH^-
Operating Temperature (°C)	170 — 220	— 650	— 1,000	Normal temperature — 100
Usable Reactant	H_2 (A small amout of CO is contained.)	· H_2 · CO	H_2 · CO Hydrocarbon	Pure hydrogen
Usable Fossil Fuel and Synthetic Fuel	Natural gas Light oil up to naphtha Methanol	Petroleum Natural gas Coal Methanol	Petroleum Natural gas Coal Methanol	—
Expected Time for Practical Use	1980's	Around 1990	Around 1995	Hydrogen Energy Age
Power Generation Thermal Efficiency (%) when Fossil Fuel is used	About 40 (natural gas)	60 (Natural gas Interior re forming method) 45 (Coal gas)	50 (Coal)	—

(Source) Technical report of Electrical Society: "Prospect of Fuel-cell Power Generation Technology" (December, 1982)

Fuel cells oxidize the fuel via electrochemical reaction, and obtain the chemical energy emitted at that time directly as electric energy. Typical example are shown in Table 8-2-11.

Although the molten carbonate type and solid electrolyte type are still in their research and development stage, the alkali type has already been applied such special conditions as the space shuttle, and the phosphoric type is still in its demonstrative test stage.

For power generation, the phosphoric type is alleged to be the first for practical application.

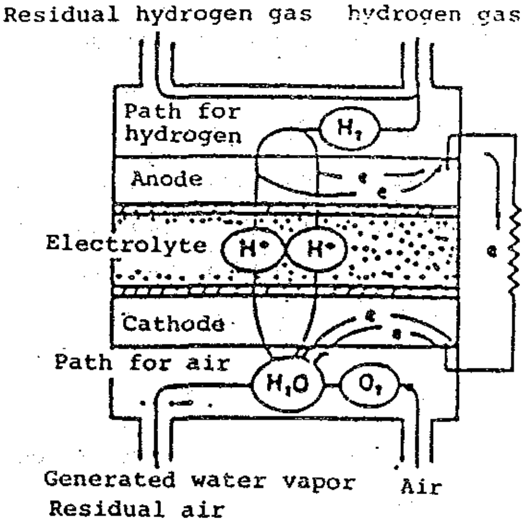


Fig. 8-2-18 Principle Diagram of Fuel-cell Power Generation

As shown in Fig. 8-2-18, the unit cell of the fuel cell is composed of an ion conducting electrode layer, which is placed in the center, sandwitched by a porous fuel pole (anode) and an oxidizer pole (cathode).

The phosphoric type fuel cell uses hydrogen as its fuel, and this hydrogen is produced by steam reforming natural gas, methanol, etc. Fig. 8-2-19 shows the fuel reforming process for the phosphoric type fuel cell. A comparison between natural gas and methanol reveals that methanol has the merit of a simpler production process.

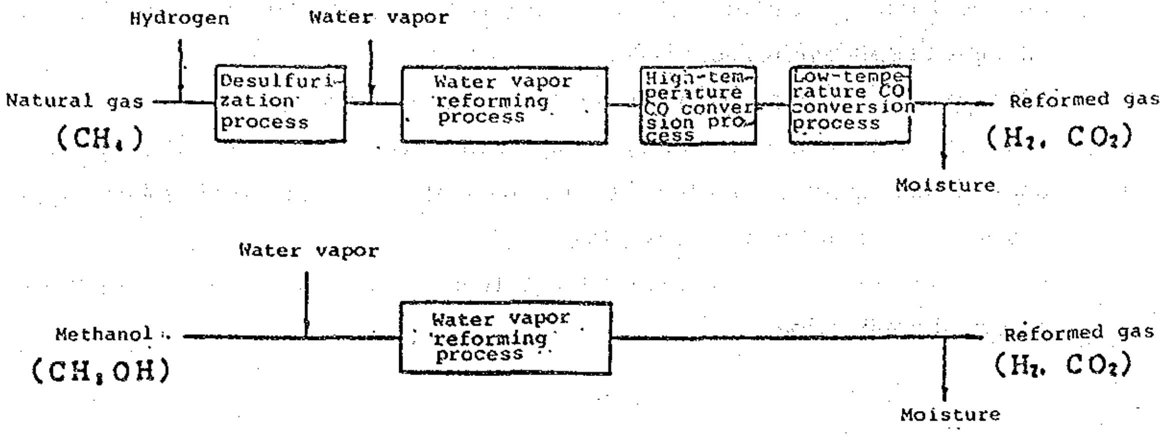


Fig. 8-2-19 Fuel-reforming Process for Phosphoric-acid Type Fuel Cell

As the reforming process of methanol is simpler than that of natural gas, the realization of a compact system and reduction of construction costs are expected. Since the reforming reaction of methanol progresses at a low temperature, a reduction of heat loss and an improvement of power generation efficiency are also expected.

(4) MTBE

MTBE (Methyl Tertiary Butyl Ether) is a kind of octane enhancer obtained by composing methanol and i-butylene.

$$\underset{\text{Methanol}}{CH_3OH} + \underset{\text{i-butylene}}{(CH_3)_2C = CH_2} \longrightarrow \underset{\text{MTBE}}{CH_3O\,(CH_3)}$$

MTBE possesses very excellent properties as an octane booster because MTBE has a high octane value, being soluble in gasoline while being just slightly soluble in water, a higher calorific value and a lower latent heat than methanol and ethanol.

Table 8-2-12 shows an example of the effect of MTBE as an anti-knock additive.

Table 8-2-12 Effect of Methyl-tert.-bytyl ether on the Anti-knock Ratings of Petrol

	Lead gr/l	MTBE % by vol.	FON	MTBE mixing value FON	RON	MTBE mixing value RON	MON	MTBE mixing value MON
80% by vol. isooctane + 20% by vol. n-heptane	0.0	0	–	–	80	–	80	–
80% by vol. isooctane + 20% by vol. n-heptane	0.0	10	–	–	85.7	137	84.6	126
80% by vol. isooctane + 20% by vol. n-heptane	0.0	20	–	–	91.8	139	88.8	124
Straight-run	0.4[2]	0	–	–	84.6	–	84.2	–
Straight-run	0.4	20	–	–	93.5	129	91.2	119
Reformate	0.4[2]	0	–	–	97.0	–	88	–
Reformate	0.4[1]	20	–	–	101.6	120	93.6	116
Regular petrol	0.0	0	–	–	91.0	–	81.3	–
Regular petrol	0.0	10	–	–	93.6	117	83.2	100.3
Premium petrol I	0.0	0	85.6	–	94.3	–	82.2	–
Premium petrol I	0.4[1]	0	86.0	–	99.1	–	86.5	–
Premium petrol I	0.15[1]	0	85.5	–	97.5	–	84.2	–
Premium petrol I	0.15[1]	3	–	–	98.1	117.5	95.0	110.9
Premium petrol I	0.15[1]	5	–	–	98.5	117.5	85.5	110.2
Premium petrol I	0.15[1]	10	91.9	–	99.2	114.5	86.0	102.2
Premium petrol II	0.4[1]	0	84.4	–	99.0	–	87.9	–
Premium petrol II	0.15[2]	0	84.0	–	97.4	–	85.5	–
Premium petrol II	0.15[1]	10	91.6	–	99.2	115.4	87.3	103.5
Premium petrol III	0.0	0	75.8	–	91.5	–	82.3	–
Premium petrol III	0.0	5	81.5	189.8	92.4	109.5	83.2	100.3
Premium petrol III	0.0	10	85.6	173.8	94.0	116.5	83.9	98.3
Premium petrol III	0.0	20	93.4	163.8	96.2	115	85.3	97.3
Premium petrol III	0.4[2]	0	82.0	–	97.3	–	89.0	–
Premium petrol III	0.15[2]	0	78.3	–	94.1	–	85.2	–
Premium petrol III	0.15[2]	5	–	–	95.8	128.1	86.8	113.2
Premium petrol III	0.15[2]	10	–	–	96.6	119.1	87.6	109.2
Premium petrol III	0.15[2]	20	–	–	99.2	119.6	89.3	105.7

[2] As PM 75 (75% TML + 25% TEL)
[1] As TEL

Source: Reference material of Hülus

(5) City Gas

Mitsubishi Petrochemical Engineeering Co., Ltd. and Seibu Gas Co., Ltd. are collaborating in technological development to produce city gas (a substitute for natural gas) from methanol. In this process, methanol is to be dissolved to form a mixture of methane and hydrogen with the aid of a catalyst. Proper selection of a catalyst and reaction conditions permit the generation of hydrogen rich low calorie gas on of methane rich high calorie gas.

The gas currently supplied by local city gas companies in Japan has, in general, a low heating value, and the conversion into high calorie gas is being planned. When imported LNG is to be used, large-scale harbor facilities and stockpiling bases will become indispensable, so the above mentioned process is drawing the attention of local city gas companies.

When fuel methanol is directly used for domestic or commercial use, the toxicity of methanol and its complicated supply system will pose problems, but if methanol is converted into a synthetic natural gas, these problems will be solved, and the convenience of using the gas will be remarkably improved.

For local city gas companies that find difficulties, technically and economically, in introducing natural gas and LNG and the using naphtha and LPG, keen attention is focused on this process as a petroleum-alternative energy (raw material) and also as a conversion measure for use as a high-calorie gas.

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8-2-3 Required Qualities of Fuel Alcohol

In early 1970, the uderstanding that a catalytic converter is necessary to satisfy the "Regulatios of Exhaust Gas, '80" and that the use of lead-free gasoline is required for that purpose triggered a trend of lead-free gasoline use in the U.S., which has led to the current demand for the gasoline quality.

In Japan, the production of lead-free regular gasoline started in 1975. Although the premium gasoline containing lead has been forced to remain as it is without measures for valve seat recession, its sales quantity has dropped to 0.2 to 0.3% of overall gasoline sales. The current amount of gasoline in Japan and the JIS specifications are shown in Table 8-2-13(43)

The trend of using lead-free gasoline started first in the U.S., but the sales volume did not increase, because lead-containing gasoline is less expensive. In 1986, leaded regular gasoline accounted for 30% of the total sales, while lead-free regular gasoline accounted for 50% and lead-free premium gasoline, 20%. The use of lead-free gasoline is expected to expand, as shown in Fig. 8-2-20. In the short term, the use of octane booster such as methanol, ethanol, MTBE and toluene, is intended.

In Europe, the problem of forest destruction due to an acid rain has increased the movement for introducing lead-free gasoline, and actual introduction has been set for October 1989. Until then, the quantity of lead to be added will remain below 0.5 g/l. The said trend and actual uses of oxygenates are shown in Table 8-2-14. Presently, methanol is widely used in West Germany and Austria, whereas MTBE is used in Switzerland.

As mentioned above, the use of alcohol fuel or oxygenates is conceivable for reinforcing measures encouraging the use of lead-free gasoline and preventing exhaust gas.

(1) Required Qualities for Low Blend Alcohol

Fuel alcohol mixed with gasoline increases the vapor pressure and decreases the distillation temperature below the 50% point of distillation curve. Accordingly, when the properties of the mixture are to be kept almost the same as those of gasoline, too large a quantity of fuel alcohol cannot be mixed. Further, unburnt alcohol and aldehydes, which will be inevitably contained in the exhaust gas from an engine, must be kept at a low level. These facts are taken into consideration in each country to regulate the mixing ratio of fuel alcohol. Regulations for mixing oxygen- containing fuel in the U.S. (EPA) and EEC are shown in Tables 8-1-15 and 8-2-16.

Table 8-2-13 Quality Requirements for Revision of JIS Specification [43]

Average Qualities and Specification of Motor Gasolines in Japan (August, 1985)

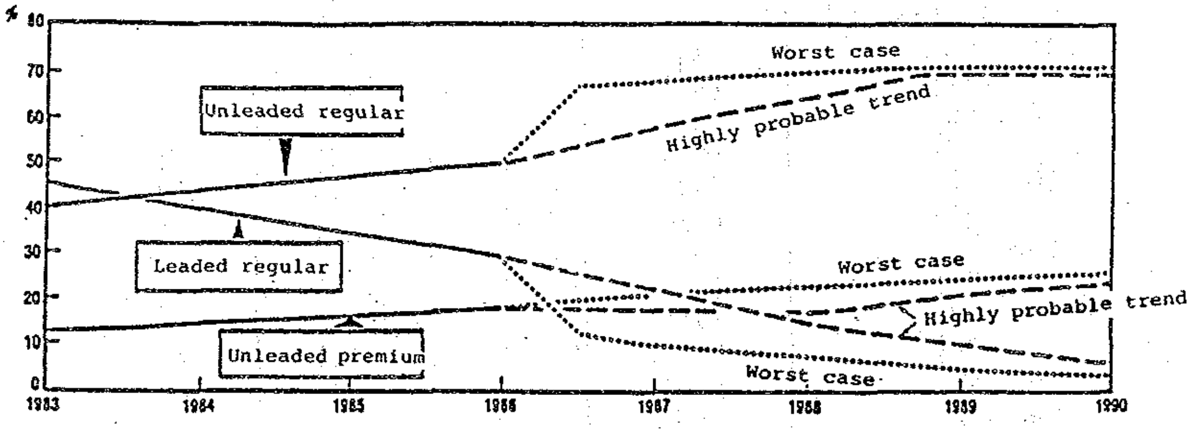
	Regular Grade Unleaded	Premium Grade		JIS Specification *	
		Leaded (1983)	Unleaded	No. 1 (Premium)	No. 2 (Regular)
Octane Numbers					
Research	90.8	97.8	98.2	95 min.	85 min.
Motor	81.6	88.4	86.2	-	-
(R+M)/2	86.2	93.1	92.2	-	-
Sensitivity	9.2	9.4	12.0	-	-
Inspection Data					
Lead, ml/l	-	0.23	-	0.3 max.	
(g Pb/gal)	-	(0.92)	-	(1.20)	
Hydrocarbon					
Aromatics, v%	28.8	42.1	44.8	-	
Olefins, v%	16.9	5.1	15.0	-	
Sp. Gr., 15/4°c	0.7407	0.7605	0.7628	-	
(deg API)	(59.5)	(54.5)	(53.9)		
Distillation					
IBP, °C	34.5	35	33	-	
(°F)	(94)	(95)	(91)		
10%, °C	52	56	52	70 max.	
(°F)	(126)	(133)	(126)	(158)	
50%, °C	92	107	99.5	125 max.	
(°F)	(198)	(225)	(211)	(257)	
90%, °C	156.5	161	150.5	180 max.	
(°F)	(314)	(322)	(303)	(356)	
EP, °C	193	199	187	205 max.@97%	
(°F)	(379)	(390)	(369)	(401)	
Rec., v%	98.0	98.5	98.0	-	
Res.; v%	1.0	1.0	1.0	2.0 max.	
RVP, kgf/cm^2	0.625	0.640	0.650	0.45-0.80 **	
(lb/in^2)	(8.9)	(9.1)	(9.2)	(6.4), (11.4)	

* Proposed to be revised. (in July, 1986)

** 0.95kg/cm^2(13.5 lb/in^2) max. for cold climate use.

Table 8-2-14 Condition of Oxygenates Use in Europe

	West Germany	Switzerland	Austria	Sweden
Sales condition of unleaded gasoline				
No. of filling stations (Sept.'85)				
Sales of premium	500	5400		50
Sales of regular	2500		3500	
Sales q'ty ratio (against the whole gasoline)	About 0.5%	About 16 - 20%	About 23 - 24%	Little
Future prospect	Filling stations selling premium and regular will increase in number. Sales q'ty will increase from 1986 due to a tax reduction.	Sales q'ty ratio will increase in future as the number of catalyst-using cars increases.	Premium has currently been introduced, and the sales of regular may be replaced by those of premium.	KPC alone is selling unleaded gasoline at present. As a reduction in unleaded-gasoline tax is to be introduced in 1986, every company will start selling unleaded-gasoline, thereby increasing its sales q'ty.
Service condition of oxygenates	About 30% of gasoline is blended with ethanol. Some no-brand products contain over 5% of methanol, thus causing problems sometimes.	MTBE has been generally used. Methanol is also used in some cases.	Methanol is widely used. TBA and MTBE are used as compatible agents.	Methanol is not used at all. MTBE, IPA and TBA are used in some cases.



Source: Chevron Corp.

OGJ

Fig. 8-2-20 Transition and Prospect of Share of Each Gasoline Grade in the U.S.

Table 8-2-15 Licensing Condition of Oxygenates by EPA

Oxygen-containing Fuel	Tolerance to be Mixed with Gasoline		Contents	Date of License	Remarks
	Oxygen (wt %) concentration	Tolerance (vol %)			
Ethanol		10.0 max		78. 12. 16 82. 4. 5	EPA waiver is obtained through Energy Policy and Conservation Act.
General rule	2.0 max			80. 10. 10 81. 7. 28	Methanol is excluded.
MTBE	2.0 max	About 11.0 max.			
Aliphatic alcohol	2.0 max				Propyl alcohol, butyl alcohol, etc.
Aliphatic ether	2.0 max				t-amyl methyl ether, etc.
Arconol	3.5	Abt. 16.0 max	GTBA (t-butyl alcohol of gasoline grade)	81. 11. 16	ARCO
Methanol		0.3			General rule
Methanol + C_4, alcohol		3.5	Mixture of methanol and alcohol above C_4, blended equally in q'ty.	81. 7. 28	General rule
Oxinol 50	3.5	Abt. 9.5	Mixture of methanol and GTBA in the ratio of 1:1 (vol ratio)	81. 11. 16	ARCO
Oxinol	3.5	Abt. 9.0 max	Methanol content in GTBA is 50 vol % max.	81. 11. 16	ARCO
Petrocoal		Total alcohol q'ty, Methanol q'ty 12% max	Mixture of methanol and C_4 alcohol in the ratio of 6.5:1 max. (vol ratio), blended with corrosion inhibitor	81. 10. 5	American Methyl Corp
Du Pont	3.7		5% max. of methanol + 2.5% min. of compatible agent + corrosion inhibitor (DGOI-100)	85. 1. 14	As a compatible agent, ethanol is most desirable, and butanol, propanol, GTBA, etc., may also be used.

Table 8-2-16 EEC Standard for Oxygenates

	Min. Mixing Q'ty	Max. Mixing Q'ty Which Permits Sales without Indication of Mixing Q'ty
Methanol (mixed with compatible agent)	3 %	3 %
Ethanol (compatible agent may be necessary occasionally.)	5 %	5 %
Isopropyl alcohol	5 %	10 %
TBA	7 %	7 %
Isobutyl alcohol	7 %	10 %
Ether with carbon number of 5 or above (1)	10 %	15 %
Other oxygenates	7 %	10 %
Mixture of oxygenates (2) Oxygen content	2.5 % oxygen weight, not exceeding the individual limits fixed above for each component	3.7 % oxygen weight, not exceeding the individual limits fixed above for each component

(1) In accordance with national specifications or, where these do not exist, industrial specifications.

(2) Acetone is authorized up to 0.8 % by volume when it is present as a by-product of the manufacture of certain organic oxygenates.

(2) Required Qualities for Neat Fuel Alcohol

Table 8-2-17 Proposal for the Composition of Fuel Methanol (84)

Requirements for Methanol to Meet as a Fuel

- o Ignition limits
  (no inflammable atmosphere in tank)
- o Cold start and warm-up for S.I. engines
- o Low evaporating rate in vehicles
- o Long-term storability
- o Denaturant
- o Odor component
- o Luminosity of the flame during the whole burning process
- o Detergent for intake system
- o Corrosion inhibitor
- o Low variation in density and calorific value
  (stoichiometric air-fuel ratio)
- o Economy
- o Unique worldwide
- o Applicable also in modified diesel engines

As an automotive fuel, the qualities of neat or high blend alcohol fuels were examined in each country, and what attracted special attention was a proposal of required qualities prepared in June 1985 by a work shop, which was comprised of researchers from various countries, set up in the research section of VWs, West Germany(80).

Items required of the methanol fuel are shown in Table 8-2-17. The most important requirement is to raise the inflammable limit value high enough to avoid combustion in the fuel tank, second is to improve the low temperature startability of spark ignition engines, and third is to ensure a cleaner environment and better human health. It is difficult to determine, a fuel that will meet all the requirements from the various studies in this field being carried out around the world, nor we decide on a particular fuel compound or test method at this stage. Definitions made by using the existing test methods are shown in Table 8-2-18.

It must be explained that a certain percentage of hydrocarbon (HC) is required to confine the calorific value within a desired range. A butane is necessary to keep the fuel for a long time without losing its vaporizing characteristics. By keeping the minimum methanol quantity at an 82-wt percentage, level, a space for hydrocarbon and higher alcohol is provided.

Table 8-2-18 Methanol Fuel Standards Proposed by Volkswagen (84)(12)

		summer		winter	Test method
Methanol	wt-%	min. 82			GC
Hydrocarbons HC total*)	wt-%	min. 10	–	max. 13	GC
Butane C_4	wt-%	max. 1.5		max. 2.5	GC
Density d_{15}	kg/m³	700	–	790	DIN 51 757, ASTM D 941
Vapor pressure RVP (Dry)	mbar	550-700 **)		750-900**)	DIN 51 754, PREN12, ASTM D 323
Water	ppm	min. 2000	–	max. 5000***)	DIN 51 777, ASTM D 1744
Higher alcohols	wt-%	max. 5			GC
Formic acid	ppm	max. 5			
Acidity	ppm	max. 20			ASTM D 1613
Existent gum	mg/kg	max. 5			DIN EN5, washed with MEOH
Chlorine	ppm	max. 2			DIN 51408, Teil 1 ASTM D 3120, mod. & ASTM D 2988
Lead	ppm	max. 30			ASTM D 3237
Phosphorus	ppm	max. 10			ASTM D 3231
Sulfur	ppm	max. 100			ASTM D 3120
Additives	%	max. 1			

*) Species, boiling range and quantity of HC depending on cold-start and safety requirements.

**) Data for Central Europe shown here as an example, although different values are possible depending on the gasoline available locally.

***) With corrosion inhibitor.

Source: Volkswagen Methanol Workshop June 4. 1985

Participants:	Governments and Others		Diesel Manufacturers	Passenger-car Manufacturers	Oil Company and Others	
	BMFT (Germany)	TUV Rheinland (Germany)	MAN	VW and VW Brazil	German Shell	Exxon Chemical
	DGMK (Germany)		KHD	GM	German BP	Lubrizol
	Canadian Ministry of Transport (Canada)			Porsche	Exxon Corp.	BASF
	Automobile Fuel Public Corpration (Canada)			Daimler Benz	Aral	Veba Oel
	DOE (U.S.)			Ford	UK Wesseling	
	Santa Clara Univ. (U.S.)				British Shell	

The low temperature startability is related to the quality and quantity of HC to be blended and the Reid Vapor Pressure, but the kind of HC has not been specified. Namely, it does not matter whether the gasoline to be used is a full-range type or highly volatile type. Gasoline with a boiling point up to 110°C is known to cause no problem in the low temperature startability or operability.

Fuel methanol, having a Reid Vapor Pressure identical to that of the gasoline used in the area in question, is considered to be sufficient. The values shown in Table 8-2-18 are applicable in Central Europe and most states in the U.S.

The quality of the fuel mentioned above must be equal to that found at gas stations, and careful attention must be paid to the change of gasoline quality during its transportation from refineries to gasoline stations.

The ideas mentioned so far are tentative, and the final decision will be made in accordance with the fleet tests or other tests being conducted in various places and according to the method for producing methanol most economically. In Indonesia, the problem of low temperature startability seems to be non-existent. Accordingly, when no attention is paid to export, the specifications for fuel methanol most economical to Indonesia will be able to be decided soon.

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Finally as to the fuel ethanol specification, hydrous ethanol of 94-95% purity is generally used for industrial use. However, when it is mixed with gasoline, water content will be separated. Therefore hydrous ethanol cannot be used and anhydrous ethanol is required.

According to examples in Brazil, where much fuel ethanol is used, the specification of ethanol to be mixed in gasoline is as given below.

- Purity: 99.3%
- Acidity as acetic acid: 3.0 max.

And also, where fuel ethanol 100% (neat) is used, hydrous ethanol is used.

8-2-4 Existing Demand for Fuel Alcohol

(1) Fuel Methanol

Methanol used to be mainly produced in such countries as the U.S.A., the U.S.S.R., and other nations in Western Europe. However, one after another newly-constructed plants of methanol in the Middle East, Asia, as well as some communist countries entered on stream since 1980. These countries include Malaysia, Indonesia, Burma, Bahrain as well as Saudi Arabia and New Zealand. Additional plant construction was further promoted in East Germany and the U.S.S.R.

Table 8-2-19 shows that shifts in capacities of methanol plants throughout the world between 1982 and 1986. The table clearly shows that suspension of plant operations in the U.S.A., the Far East, and Japan naturally reduced the output, while expansion of plant capacities in the Middle East, ASEAN menber nations, Oceania, Central and South America, and Eastern Europe countries contributed significantly in increasing the yield. Further, new projects are being promoted in Central and South American countries such as Argentina, Chile, Brazil, Trinidad and Tobago and in Asian countries including India and Iran. These countries are all expected to play major roles as new producers in the 1990's.

1) Methanol Utilization for Automobile Application

i) Low Blend

In the low blend, 3 to 5% methanol is mixed in the gasoline together with an equal part of a co-solvent. The commercial sales of this low methanol blend gasoline has already been commercially available in the U.S. and West Germany. Experimental sales have also begun in Canada.

a) U.S.A.

Table 8-2-20 shows methanol output in the U.S.

The output in 1984 registered at approximately 3.8 million tons (approximately 4.8 million kl). 20% of this amount, approximately 760 thousand tons (approximately 960 kl) was used as fuel. However, approximately 240 thousand tons (approximately 300 thousand kl) of this 760 thousand tons was consumed for MIBE use, so the amount used as actual fuel methanol was approximately 520 thousand tons (approximately 660 thousand kl).

Table 8-2-19 Shifts in Methanol Plant Capacities

(Unit: thousand tons/year)

(As of the end of)

	1982	1983	1984	1985	1986
U.S.A.	4,698	5,793	4,713	3,963	3,963
Canada	1,680	1,680	1,680	1,680	1,680
C & S America	397	397	793	793	793
W. Europe	3,008	2,810	2,810	2,810	2,810
E. Europe	3,245	4,070	4,070	5,095	5,795
Africa	445	445	445	775	775
Middle East	75	675	1,335	1,731	1,731
India and its neighboring countries	135	135	135	135	285
ASEAN	–	–	660	990	990
Oceania	–	396	396	396	1,848
Far East (excluding Japan)	590	200	266	266	266
Japan	1,320	396	396	396	396
Total	15,593	16,997	17,699	19,030	21,232
Increase against the previous year		1,404	702	1,331	2,202
Index against the previous year	100	109.0	104.1	107.5	111.6

Source: Chemical Economics (July 1985)

Table 8-2-20 Shifts in Methanol output in the U.S.
(x 10^3 tons)

	Methanol	MTBE
1972	2,936	n.a.
1973	3,204	
1974	3,120	
1975	2,348	
1976	2,831	
1977	2,927	
1978	2,923	
1979	3,342	
1980	3,245	
1981	3,891	
1982	3,427	n.a.
1983	3,621	381
1984a)	3.756	666

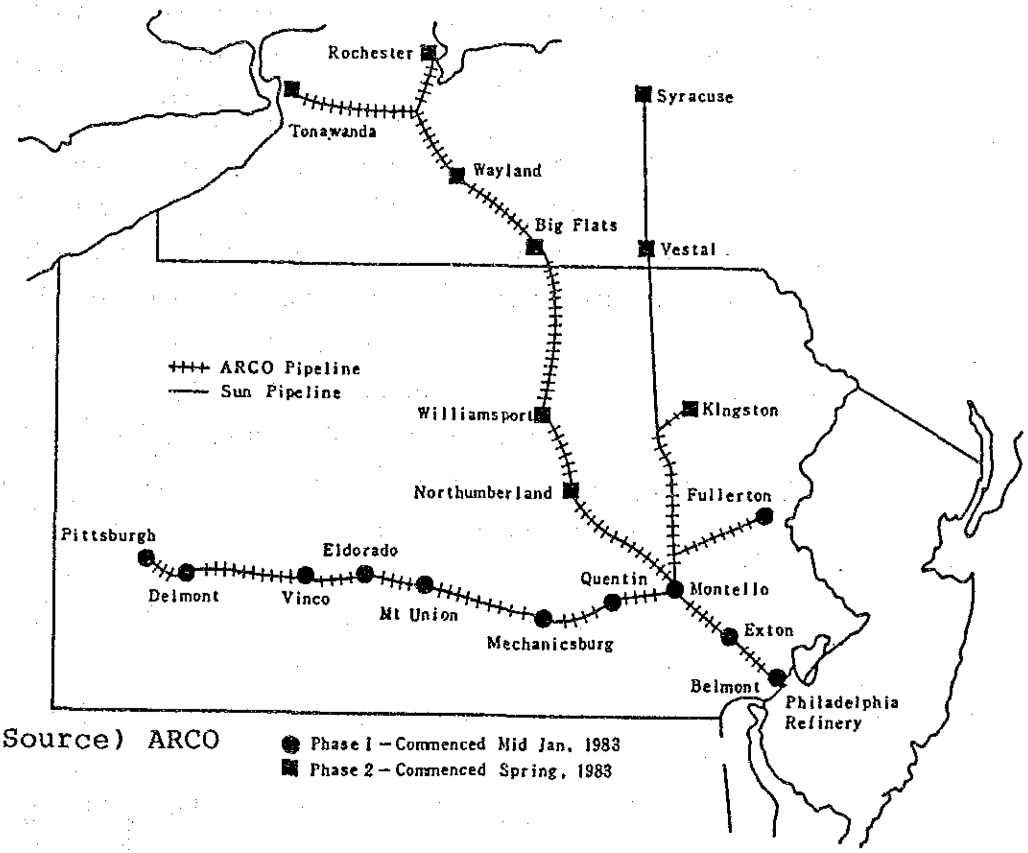
Note: a) Estimation
Source: C&EN

The amount to be mixed in gasoline is regulated by the EPA in the U.S. If methanol alone is to be mixed, the maximum allowable amount is 0.3%. If C_4 plus alcohol is also mixed in as much as same volume of methanol, the mixture of alcohls is acceptable up to 3.5% (methanol 1.75% + C_4 plus alcohol 1.75%). A typical case is Oxinol 50 (methanol and GTBA are mixed by the ratio of 1:1), for which the producing company ARCO was given the permission. They can be mixed in gasoline up to a rate of 9.5%. Consequently, most of the methanol blend gasoline in the U.S. contains oxinol.

ARCO wholesaled oxinol widely and at the same time distributed the oxinol blend gasoline to its own 1,700 service stations in Eastern New York and the State of Pennsylvania through a pipeline network which was sent from ARCO'S Philadelphia Refinery (Fig. 8-2-21). But the reputation of this product among car makers and general consumers was not very high. In the light of a slump in the oil market and an urgent need for drastic restructuring of the industry, the Philadelphia

Refinery was closed in 1985, together with the sale of 2000 service stations in 12 Eastern and mid-Western states. Consequently, the oxinol market was lost at once. MTBE serves more effectively as an octane-rating improver. In the U.S. these days MTBE is preferred over methanol as an oxygenate for the use of additive to gasoline.

Fig. 8-2-21 ARCO's Oxinol Blend Gasoline Distribution Route



(Source) ARCO

b) West Germany

Sales of the methanol blend gasoline started in 1982. The supply is maintained by a gentlemen's agreement between the West Germany Government, the petroleum industry and the automotive industry. The agreement is based on the economical fact that methanol is a cost saving element. The upper limit of the mixture rate is set at 3%. This level of methanol is unlikely to have undesired effects on automobile elements or on gasoline cosumption efficiency. In addition to methanol, 2% TBA (tertiary butyl alcohol), which was 3% at the start of the application, is added as a co-solvent agent. No regulation exists in writing, but methanol blend gasoline must meet the requirement of Gasoline Standard (DIN51600) (See Table 8-2-21.).

In connection with the introduction of M3 gasoline, the wishes of the three companies as mentioned below appear to have worked effectively. These methanol makers deal in gasoline both directly and indirectly.

Production Capacity of Methanol

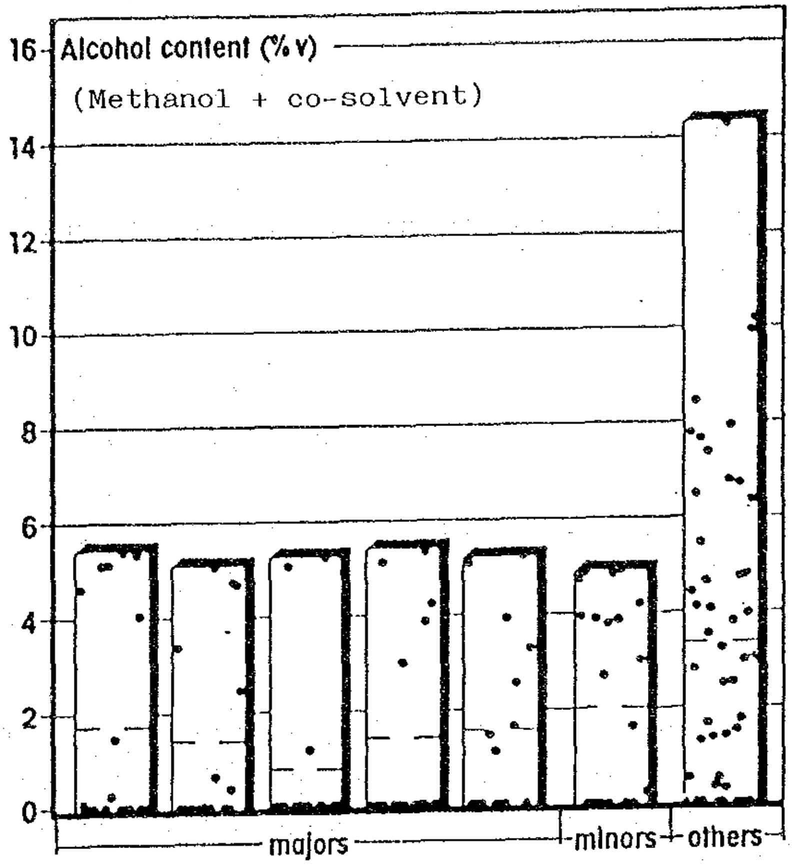
BASF (Ludwigshafen)	200,000 tons/year
URBK (Wesseling)	450,000
Veba (Gelsenkirchen)	200,000

Along with the increased demand for lead-free gasoline, the sales amount of M3 gasoline has been steadily increasing. Today, M3 gasoline amount to approximately 80% of total gasoline sales. And the amount of methanol thus applied reaches approximately 300 thousand tons. The methanol content rate of M3 gasoline is fixed by a gentlemen's agreement as mentioned above. As is shown in Fig. 8-2-22, however, some petroleum dealers sell gasoline with an alcohol content level higher than 5% (methanol + improver), which is obviosly against the practices of the major dealers.

Table 8-2-21 Gasoline Standard (DIN51600)

	DIN 51 600			
	Premium		Regular	
	Summer	Winter	Summer	Winter
Sp. Gr. (15°C), g/ml	0.730 - 0.780		0.715 - 0.765	
RON min. MON min.	98.0 88.0		91.0 82.7	
Lead content max.g/l	0.15			
Distillation				
at 70°C % vol.	15-40	20-45	15-40	20-45
at 180°C % vol.	42-65	45-70	42-65	45-70
at 180°C % vol.	90			
End point max. °C	215			

Fig. 8-2-22 Alcohol Content of Premium Gasoline (1983)



Source: Deutsche Shell

c) Canada

In Saskatchewan Canada, MOHAWK sells a methanol blend gasoline named "EM gasohol (gasoline 92%, methanol 5% and ethanol 3%)." Canada produces 5,700 tons of methanol daily; 85% of which is exported. A major alternative fuel for automobiles is CNG in Canada where, generally speaking, the use of CNG and LPG rather than fuel alcohol has been promoted.

d) Norway

In Norway, a fleet test has been conducted in an attempt to make use of the available North-Sea gas (Remote gas) for the production of methanol, which is ultimately consumed as automobile fuel. The R & D was started in 1979 by the Norway Methanol Group (NMG) consisting of the following five companies.

Den Norske State Oljeselskap (Statoil)
Dyno Industrier A.S.
Norsk Olje a.s. (Norol)
Norsk Hydro a.s.
Saga Petroleum a.s.

M4 gasoline, as low blend gasoline, was employed. The composition is as follows:

	1980 (Study commenced)	1982
Premium gasoline	94%	96%
Methanol	4	4
Ethanol	2	0

The results of the fleet test executed over a period of two years confirmed the safety and efficiency of M4 gasoline in practical application. However, sales in the general market have not yet been started.

ii) Middle Blend

Middle blend means that 10 to 20% methanol is mixed in the gasoline. In most cases, co-solvent is also added.

a) West Germany

Fuel methanol has been focused on as a promising material which would replace petroleum or help control exhaust gas. In this sense, a fleet test for M15 (blend gasoline containing 15% methanol) and M100 was carried out over a period of about three years starting 1979.

The quality of M15 is equivalent to that of premium gasoline (DIN51600). TBA is added as a co-solvent agent only for winter at an amount of 1.7%. The fleet test for M15 employed about a thousand cars and the 30 M15 service stations shown in Fig. 8-2-23.

The results of the fleet test over a period of three years shows that the general aspects of M15 are satisfactory and that the increase rate of the fuel consumption was only 5.6% (equivalent to the reduction of 2.3% in calorific value). However, the government concluded that M15 was not an efficient substitute for ordinary gasoline as it requires cars to be remodeled and in addition that M15 requires a considerable degree of investment in arranging the supply network. So the practical application of M15 was finally turned down.

b) Norway

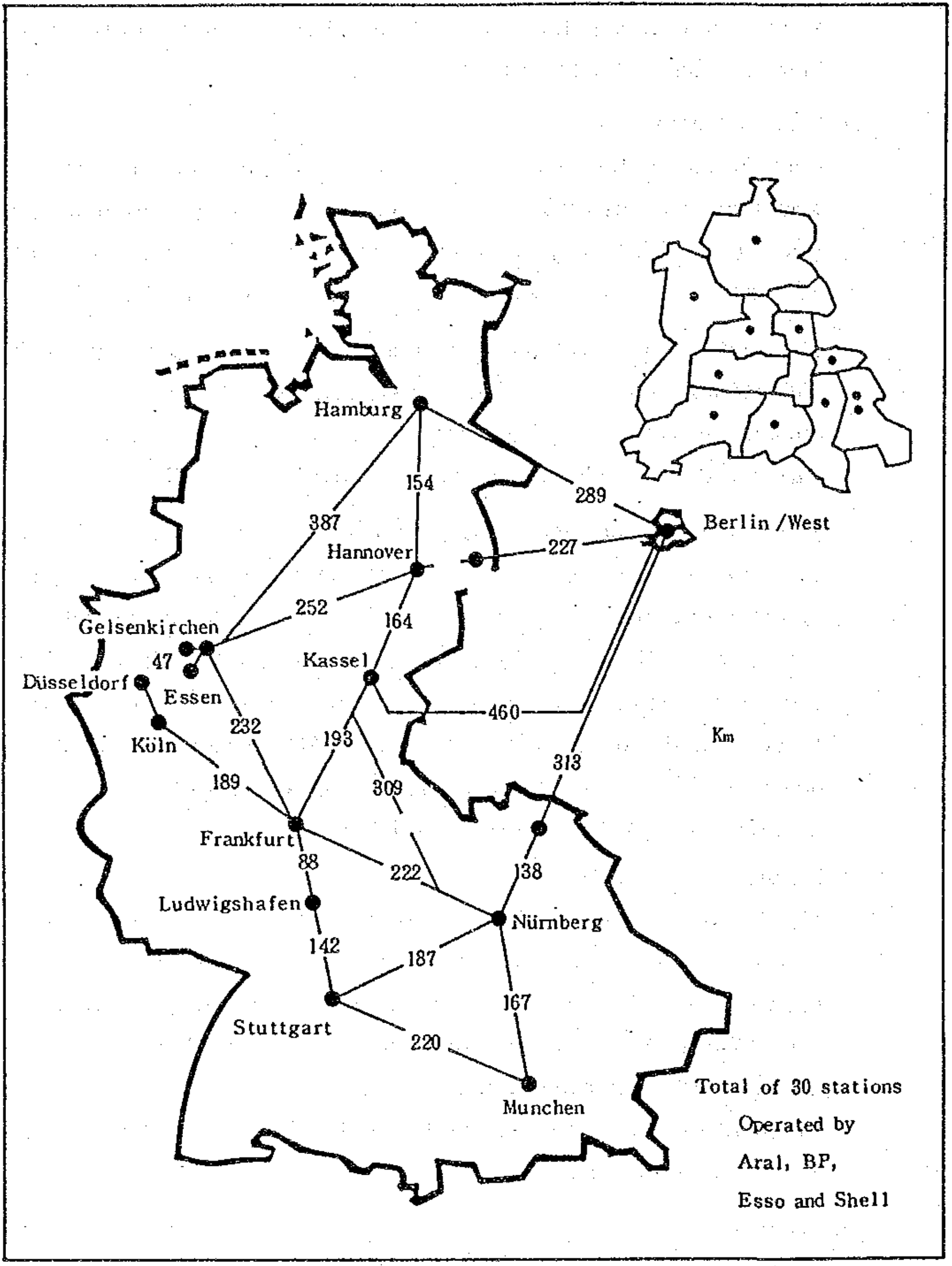
The Norway Methanol Group (NMG) conducted a fleet test for M15 with about 70 test cars used in Oslo city over a period of three years starting 1980. M15 is a premium gasoline containing methanol (15%) and isobutanol (2%). Its octane rating is RON 99. However, the results of the test indicated a increased fuel consumption and a need to remodel the cars. In other words, the feasibility for practical application was not confirmed.

c) Sweden

Sweden depends on imported petroleum and has a considerable degree of interest in fuel methanol. So they focused on M15 and the utilization test for car was started on it in 1974. The composition of M15 is gasoline (83%), methanol (15%) and isobutanol (2%).

However, the same result in evaluation was arrived at in West Germany. So the practical application of M15 was denied.

Fig. 8-2-23 M15 Filling Station Network



(Souce) German Field Test Results on Methanol Fuels M100 and M15, API 48th Mid-year Meeting, May 9-12, 982

d) Japan

In Japan too, research for M15 was conducted by several companies in a joint effort with the Japan Automobile Research Institute over a period of three years from 1980. The research was begun in a response to request made by the Agency of Natural Resources and Energy, which was concerned over by the second oil crisis.

The results of the research produced nothing but the same assessment made in European countries. So the plan for practical utilization was placed on the shelf.

iii) High Blend and Neat Methanol

High blend gasoline and neat methanol can contribute significantly in replacing petroleum. They can perform efficiently in terms of the characteristics peculiar to methanol. In short, they are clean fuels of high octane rating. However, conventional car models are not endowed with such advantageous aspects. So remodelling and modification would be necessary. As of yet, practical application has not been promoted.

a) U.S.A.

In the U.S. about 1000 methanol cars including the 300 methanol cars owned by the Bank of America (BOA) for business use and 600 modified cars introduced by California Energy Committee have undergone the fleet test. DOE and the U.S. Army, based on their plan to employ methanol vehicles, started a limited scale of fleet test.

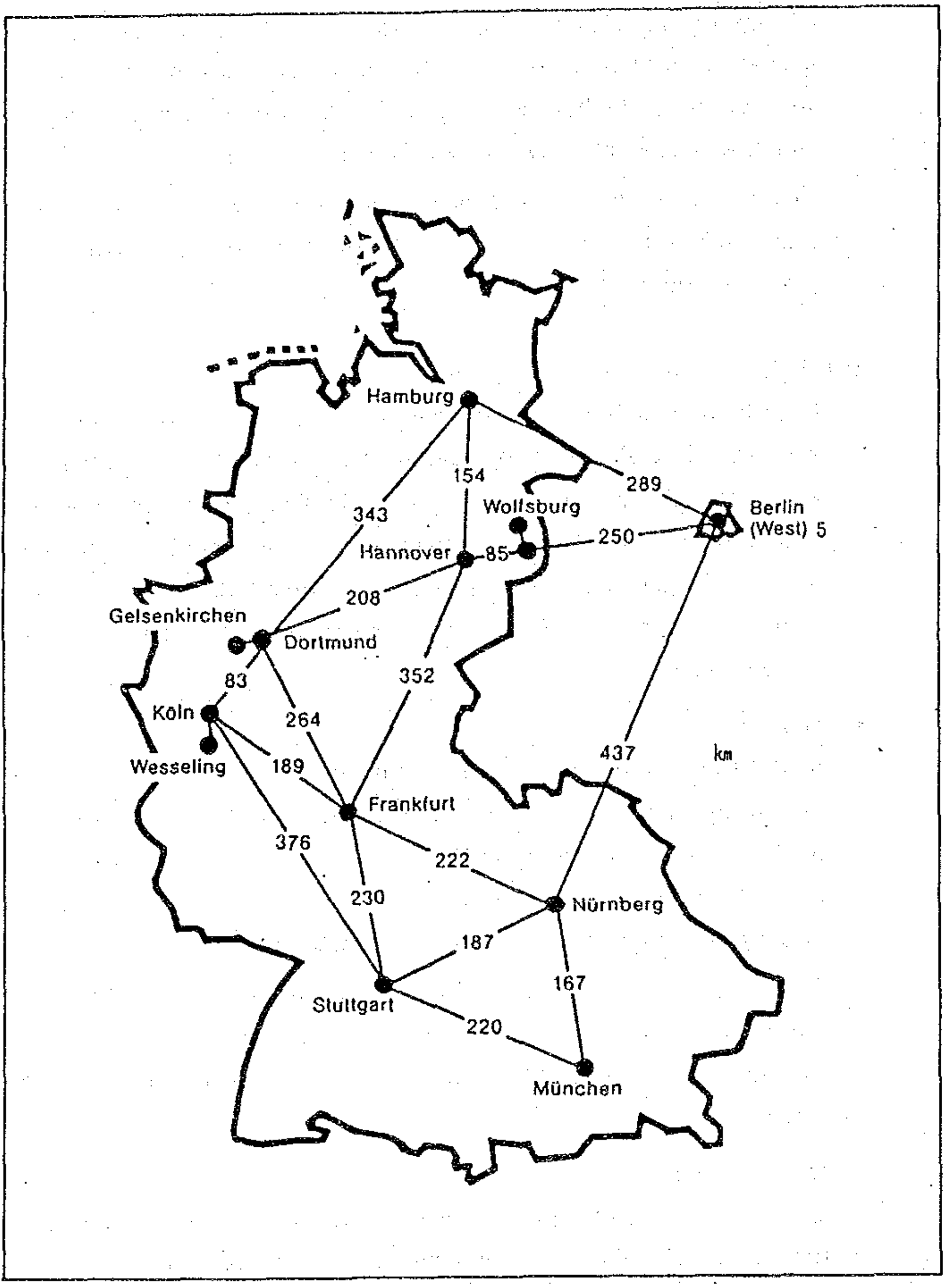
At the beginning of the introduction, the fuel methanol contained 90% methanol along with lead-free gasoline, so it was called M90. However, the rate was changed to 85% and it has been called M85 ever since.

b) West Germany

West Germany, rich in coal, shows a greater interest in the introduction of M100 which is believed to play a satisfactory role as a substitute for petroleum. The R & D of M100 was promoted along with that of M15. M15 has been put aside in the course of the R & D, but M100 will continue to be studied throughout 1988.

About 300 experimental cars specially designed for methanol gasoline are used in the fleet test, and the M100 service stations are located at 17 spots throughout the country as shown in Fig. 8-2-24.

Fig. 8-2-24 M100 Service Station Network



(Source) Same as with Fig. 8-2-23

M100 not composed 100% methanol but 93% methanol and 7% low boiling point hydrocarbon. The mixture of the low boiling point hydrocarbon follows the rates shown below.

Summer:	C5 fraction	6.5%	C4 fraction	90.5%
Winter:	"	4.9%	"	2.1%

c) Japan

In June 1985, the Agency of Resources and Energy, Ministry of International Trade and Industry, worked out a scheme for utilizing new energies to reduce the percentage of petroleum in the fuel used in Japan. To implement the scheme, a Committee of the Study on the Feasibility of High Methanol Blend Fuel was established in September 1985. The following are the items that the Committee intended to implement under a five-year plan:

1. Selection of neat methanol or high methanol blend
2. Establishment of fuel standards
3. Development of an engine specially designed for methanol fuels
4. Analysis of the problems related to distribution of methanol fuels

The Committee consists of five oil companies, the Japan Automobile Researcvh Institute, and two oil-related companies. The subcommittees on the standards of fuel and on storage and distribution of fuel reporting to the Committee conduct research and investigation on their respective issues.

Table 8-2-22 shows the schedule for experiments to be conducted on fuel. The stability in quality and the safety in distribution of fuel methanol will be the themes of immediate experiments. Fuel methanol M80 and M90 produced by the Kashima Refinery will be transported to a service station in Kashima District that has been constructed for experimental use. In the service station, measurements will be made on working environment conditions and corrosion of storage tanks and filling machines using M80 and M90.

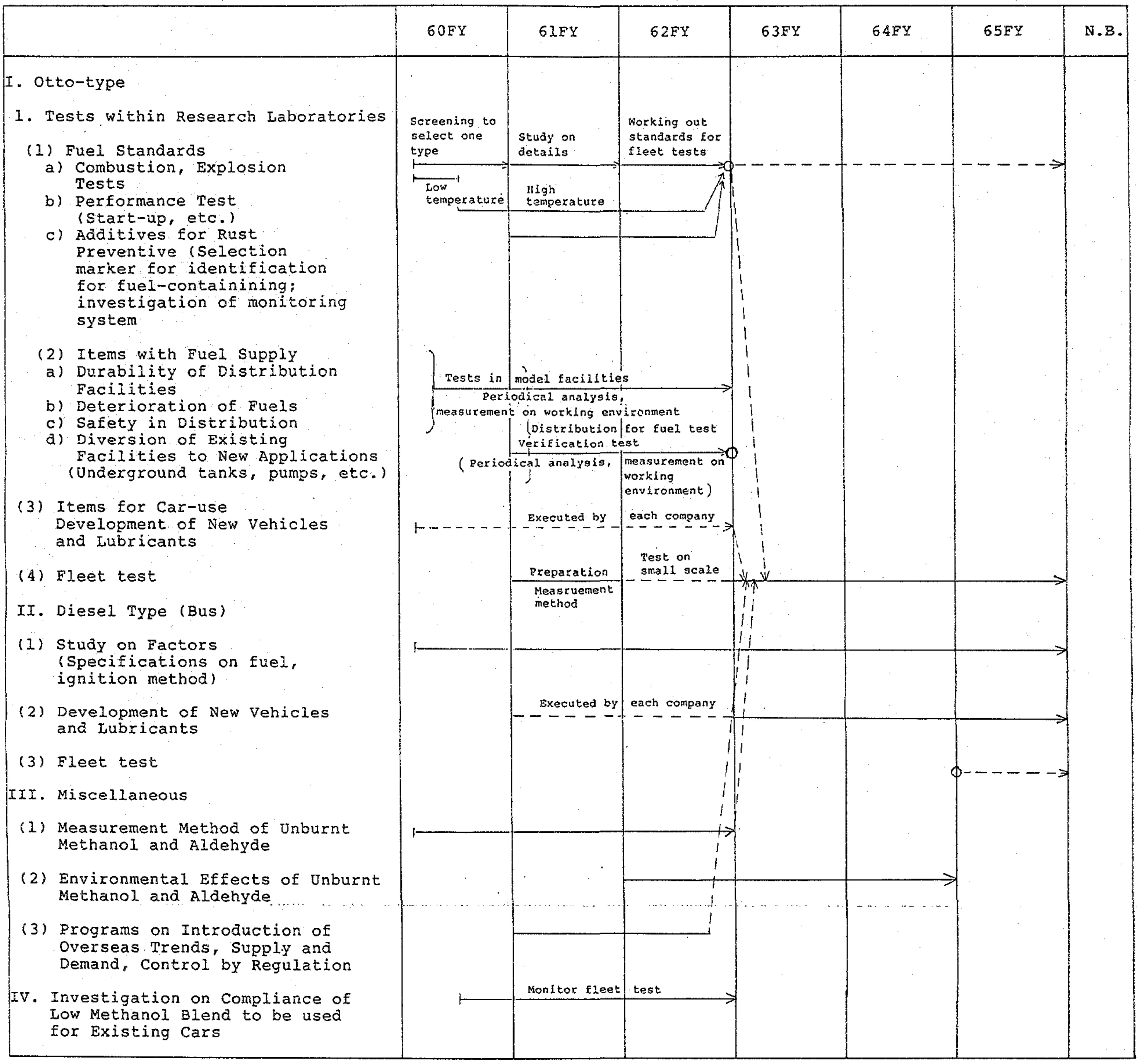
The Ministry of Transportation, which also announced a fleet test project for the promotion of methanol cars in 1984, started such tests in 1986 (Refer to 8-2-1 (4), 5).

2) Methanol for Power Generation

At present fuel methanol is not used for large-scale oil fired power generation because of the cost. Table 8-2-23 shows the assessment of fuel methanol studied in Japan for each power generation method.

According to the assessment, fuel methanol is expected to be used in small-scale reforming gas turbines and fuel cells in the future.

Table 8-2-22 Schedule of Experiments of New Methanol Blend Fuel Oil for Car Use



	60FY	61FY	62FY	63FY	64FY	65FY	N.B.
I. Otto-type							
1. Tests within Research Laboratories							
(1) Fuel Standards a) Combustion, Explosion Tests	Screening to select one type	Study on details	Working out standards for fleet tests				
b) Performance Test (Start-up, etc.)	Low temperature	High temperature					
c) Additives for Rust Preventive (Selection marker for identification for fuel-containining; investigation of monitoring system							
(2) Items with Fuel Supply a) Durability of Distribution Facilities	Tests in	model facilities					
b) Deterioration of Fuels	Periodical analysis, measurement on working environment						
c) Safety in Distribution		Distribution Verification test	for fuel test				
d) Diversion of Existing Facilities to New Applications (Underground tanks, pumps, etc.)	(Periodical analysis,		measurement on working environment)				
(3) Items for Car-use Development of New Vehicles and Lubricants		Executed by	each company				
(4) Fleet test		Preparation Measruement method	Test on small scale				
II. Diesel Type (Bus)							
(1) Study on Factors (Specifications on fuel, ignition method)							
(2) Development of New Vehicles and Lubricants		Executed by	each company				
(3) Fleet test							
III. Miscellaneous							
(1) Measurement Method of Unburnt Methanol and Aldehyde							
(2) Environmental Effects of Unburnt Methanol and Aldehyde							
(3) Programs on Introduction of Overseas Trends, Supply and Demand, Control by Regulation							
IV. Investigation on Compliance of Low Methanol Blend to be used for Existing Cars		Monitor fleet	test				

Tale 8-2-23 Assessment of Fuel Methanol for Each Power Generator Method

Power Generation Method			Assessment		Remarks
			Medium-term (-1995)	Long-term (-2000)	
Steam Power Generation	Modifications on the Present Facility		△	△	A.fuel change is not required but the aging facility may need to be generally replaced.
	New Plant		△	△	Most often new power generation plants using fuel methanol will employ combined cycle power generation system.
Gas Turbine Power Generation	Gas Turbine		△	△	Gas turbine power generation plants are rarely constructed.
	Re-forming	Large-scale (100 thousand kw)	△	○	Promotion of plants may be in accordance with verifications obtained from as element test or with the data obtained from small scale power generation systems.
		Small-scale (10 thousand kw)	○	◎	
Combined Cycle Power Generation			△	△	Methanol price should be reasonably lowered
Fuel Cell	Distribution of Power Source		○	◎	Reducing the cost by phosphoric acid type fuel cells and improving their reliability are crucial before introducing the plant.
	Isolated Island Power Source		○	◎	Same as the above

Assessment level: ◎ : Highly introducible
○ : Introducible
△ : Hardly introducible

Source: Reference 3

3) Other applications

i) For MTBE

MTBE is an excellent octane-rating improver produced by ANIC (a subsidiary of ENI, Italy) in 1973 for the first time in the history. The construction of the MTBE plants has been rapidly promoted since 1980, partly due to the emphasized utilization of lead-free gasoline all over the world. The worldwide operating and planned MTBE capacity is shown in Table 8-2-24. The total U.S. MIBE production capacity, at about 1.2 million metric tons per year, is only 0.5% of the U.S. gasoline consumption. This is obviously well below the 11 vol % maximum allowable by EPA regulations. The limited availability of isobutylene in high concentrations, as is the case with pyrolysis C4 stream (from naphtha and gas oil steam crackers), will force future MTBE producers to use fluid catalytic cracking (FCC) C4 streams containing only 10% to 20% isobutylene.

ii) For Applications in the Kitchen and Illumination

Use of fuel methanol for the purpose of cooking and illuminating may be technically feasible. However, fuel methanol has toxicity nature, and therefore direct use in household sector can not be expected in near future.

iii) For Town Gas

In Japan research and development are being made for a method of manufacturing town gas from fuel methanol as alternative raw materials of town gas in rural area (See 8-2-2 (5)). Fuel methanol is inferior to a competing LPG as raw materials of town gas in terms of cost. It will be hardly possible, therefore, for fuel methanol to replace LPG unless gas utility companies establish a consensus that fuel methanol will become economical and secure themselves against future oil crisis.

Table 8-2-24 Worldwide MTBE Plants

	LOCATION	CAPACITY 10^3 MTPY	START-UP DATE	FEEDSTOCK	LICENSOR
U.S.					
PETRO-TEX	HOUSTON, TX	280	OCT. '79	SC/FCC BY-PRODUCT	SNAM
ARCO	CHANNELVIEW, TX	200	DEC. '79	SC BY-PRODUCT	ARCO
GOOD HOPE REFINING	GOOD HOPE, LA	120	APRIL '80	FCC BY-PRODUCT	HUELS
CHARTER	HOUSTON, TX	60	APRIL '81	FCC BY-PRODUCT	CR&L
CHAMPLIN	CORPUS CHRISTI, TX	70	AUG. '82	SC BY-PRODUCT	HUELS
TEXACO	PORT NEUCHES, TX	270	AUG. '82	SC/FCC BY-PRODUCT	TEXACO
EXXON	BAYTOWN, TX	100	SEPT. '82	SC BY-PRODUCT	HUELS
PHILLIPS	SWEENY, TX	120	DEC. '82	FCC BY-PRODUCT	PHILLIPS
TEXAS PET.	BAYTOWN, TX	30	PLANNED	SC BY-PRODUCT	ARCO
		1,250 (800)			
WESTERN EUROPE					
ANIC	RAVENNE, ITALY	100	1973	SC BY-PRODUCT	SNAM
CWH	MARL, WEST GERMANY	150	MAY '78	SC BY-PRODUCT	HUELS
TEXACO	HEIDE, WEST GERMANY	40	JULY '80	SC BY-PRODUCT	TEXACO
SHELL	PERNIS, THE NETHERLANDS	100	DEC. '80	SC BY-PRODUCT	SHELL
NESTE OY	PORVOO, FINLAND	80	DEC. '80	SC BY-PRODUCT	SNAM
DSM	BEEK, THE NETHERLANDS	80	JUNE '81	SC BY-PRODUCT	SNAM
OMV	SCHWECHAT, AUSTRIA	50	NOV. '83	SC BY-PRODUCT	SNAM
SIBP	ANTWERP, BELGIUM	100	DEC. '83	SC BY-PRODUCT	PHILLIPS
ERDOELCHEMIE	WEST GERMANY	30	1986	SC BY-PRODUCT	LURGI
CO NATIONAL PET.	SINES, PORTUGAL	40	PLANNED	SC BY-PRODUCT	
PETRONOR	SOMORROSTRO, SPAIN	50	PLANNED	UNKNOWN	HUELS
ELF	FRANCE	100	PLANNED	UNKNOWN	
HIGHLANDS HYDROCARBON	NIGGS BAY, SCOTLAND	500	PLANNED	BUTANES	
		1,420 (910)			
EASTERN EUROPE					
CHEMOPETROL	KRALUPY, CSSR	90	1981	SC BY-PRODUCT	SNAM
VEB LEUNAWERKE	LAUNA, EAST GERMANY	50	DEC. '81	SC BY-PRODUCT	HUELS
CHEMOKOMPLEX	LENINVAROS, HUNGARY	30	1984	SC BY-PRODUCT	SNAM
MSK	ZRENJANIN, YUGOSLAVIA	40	1984	BY-PRODUCT	SNAM
KAUCUKA	ZRENJANIN, YUGOSLAVIA	40	1984	BY-PRODUCT	SNAM
NEFTOCHIM	BURGAS, BULGARIA	80	PLANNED	SC BY-PRODUCT	HUELS
TMI	USSR	1,000	PLANNED	BUTANES	
		1,330 (850)			
LATIN AND SOUTH AMERICA					
COPENE	CAMACARI, BRAZIL	50	APRIL '84	SC BY-PRODUCT	PETROFLEX
PETROFLEX	DUQUE DE CAXIAS, BRAZIL	50	PLANNED	SC BY-PRODUCT	PETROFLEX
PEMEX	MORELOS, MEXICO	60	PLANNED	FCC BY-PRODUCT	
EMPRESA	BARRANCABERMEJA, COLUMBIA	120	PLANNED	SC BY-PRODUCT	ECOPETROL
		290 (190)			
FAR EAST					
MITSUI PETROCHEMICAL	CHIBA, JAPAN	10	DEC. '82	SC BY-PRODUCT	HUELS
CHINA SYNTHETIC	CIN YUAN, TAIWAN	100	PLANNED	SC BY-PRODUCT	ARCO
		110 (70)			
MIDDLE EAST					
SABIC	SAUDI ARABIA	500	1988	BUTANES	
KUWAIT PETROCHEMICALS	KUWAIT	UNKNOWN	PLANNED	UNKNOWN	
		500 (320)			
GRAND TOTAL		4,900 (3,140)			

LEGEND

SC = STEAM CRACKER; FCC = FLUID CATALYTIC CRACKER

(   ): methanol required

(2) Fuel Ethanol

The properies and application of ethanol as fuel are almost the same as those of methanol. Ethanol is in wider use compared with methanol because of no toxity, little need for modifications in automobiles, and an appreciation of the agricultural policies in each country.

1) For Automobile Applications

Ethanol has higher compatibility with gasoline than methanol. Middle blend fuel ethanol is used much more often than low blend fuel ethanol. Neat ethanol has also been put into practical use for car fuel.

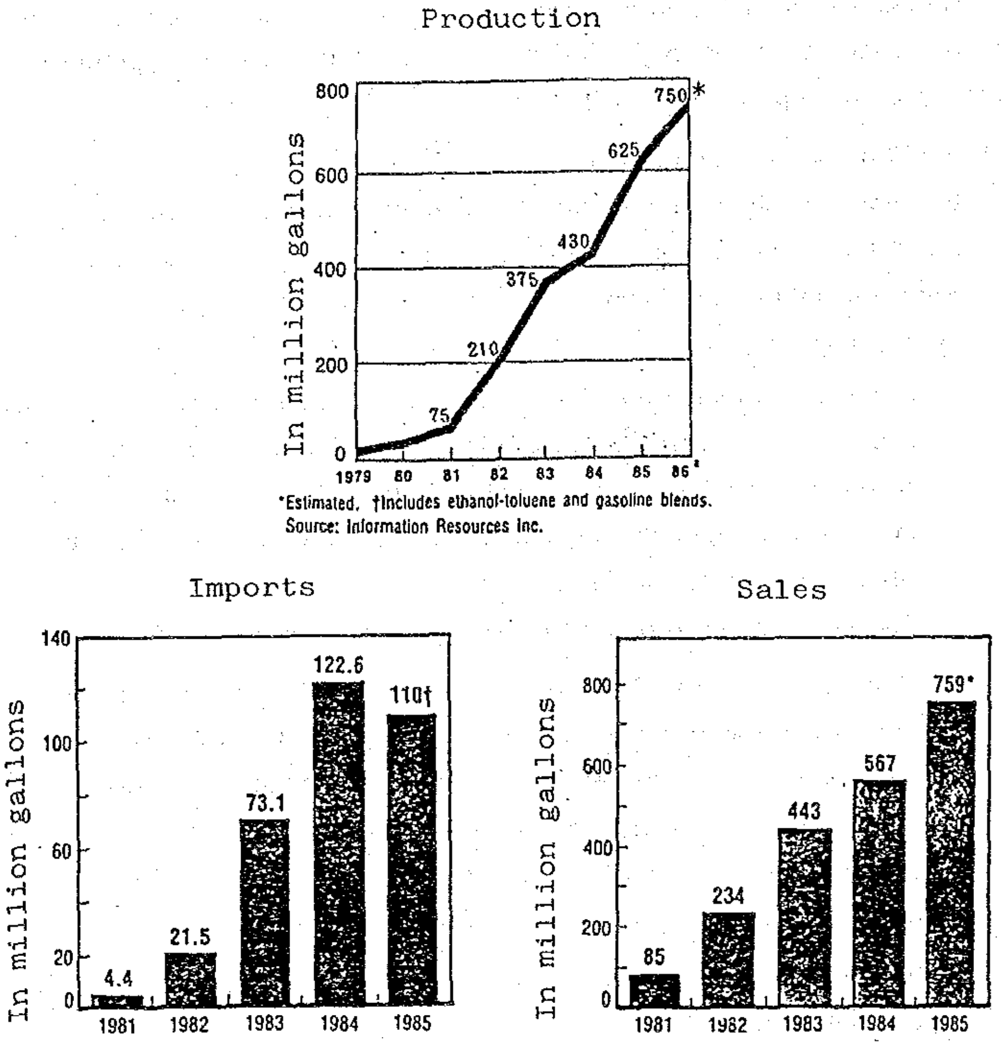
a) The United States

In the U.S. ethanol blend gasoline can contain a maximum 10% ethanol according to the regulation of EPA announced in December, 1978. The gasoline is sold by the name of "Gasohol." This application of fuel ethanol was originally aimed at the effective use of corn the output of which was beyond the demand-supply balance line.
Gasohol is made from Indian corn by ethanol-fermentation.

Since January 1984 a tax reduction of 6¢ had been applied to gasohol per gallon the gasoline tax of which is 9¢. In other words, a tax reduction of 60¢ had been applied to a gallon of ethanol. This triggered the invasion of low-priced Brazilian ethanol. Since September 1984, therefore, a duty of 60¢ is applied to imported ethanol per gallon, in addition to a conventional ad valorem duty of 3%.

Fig. 8-2-25 shows the shifts in the production, imports, and sales of ethanol in the U.S.

Fig. 8-2-25 Shifts of Production, Imports, and Sales of Ethanol



*Estimated. †Includes ethanol-toluene and gasoline blends.
Source: Information Resources Inc.

Fuel ethanol consumption in U.S. was 1.7 million Kl (445 million gallons) in 1983.

At present, gasohol is produced and sold by Texaco, Amoco and Sun. That is 88 octane gasoline produced by adding ethanol into 85 octane lead-free gasoline. After the regulation of EPA for the lead content in gasoline was tightened, Mobil in the State of Illinois started the sales of ethanol added lead-containing gasoline whose lead-content rate was reduced.

Tables 8-2-25 and 8-2-26 show ethanol gasoline market share and alcohol gasoline blend sales respectively.

Table 8-2-25 Ethanol-Gasoline Market Share in Leading States

(in percent)

	1985/86											
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.
Alabama	12.2	11.2	11.2	11.9	11.8	7.8	9.3	11.7	12.6	13.5	13.0	12.9
California	1.1	1.4	3.8	1.2	1.3	1.3	1.1	0.9	0.9	1.2	1.1	1.8
Colorado	10.0	13.6	16.2	17.6	12.6	12.9	10.5	10.1	3.8	2.2	—	1.1
Florida	9.9	9.9	8.9	9.0	8.4	9.0	7.5	7.8	6.9	6.7	—	—
Illinois	29.9	32.7	32.8	38.7	33.1	33.1	37.0	35.6	40.0	38.5	—	—
Indiana	31.4	36.0	32.7	33.1	32.2	30.9	32.7	31.0	21.7	43.0	27.9	23.6
Iowa	42.7	42.8	26.7	31.1	34.6	36.0	36.0	32.1	30.7	29.2	30.5	34.4
Kansas	23.4	22.4	23.5	24.1	30.0	24.0	23.5	22.4	18.8	17.7	19.1	21.9
Kentucky	—	—	—	—	—	29.9	23.7	22.2	37.3	45.8	54.7	24.8
Michigan	15.4	13.0	—	15.4	9.9	9.0	9.4	9.9	9.2	8.5	10.0	8.7
Minnesota	18.2	30.6	35.4	29.1	34.5	32.6	25.1	20.1	17.9	15.6	13.6	12.5
Nebraska	33.5	28.4	34.0	32.6	35.0	34.3	32.1	31.7	28.2	26.8	35.5	24.8
Ohio	15.6	16.0	18.0	17.0	17.8	16.5	—	14.8	18.2	16.7	—	—
Tennessee	12.5	—	—	—	—	12.4	16.5	—	18.1	14.3	16.8	10.7
Texas	5.4	4.7	4.1	4.3	3.3	—	3.3	3.2	—	4.0	—	3.8
Virginia	15.7	16.2	19.7	17.0	19.2	16.2	20.2	18.5	23.5	13.8	16.5	14.5
Average:	18.5	18.9	19.3	19.1	20.3	20.4	19.2	18.1	19.2	18.6	19.0	15.0

Source: Alcohol Week, Nov. 3, 1986

Table 8-2-26 State Alcohol-Gasoline Blend Sales

(in million gallons)

State	Feb.	March	April	May	June	July	Aug.	% change
Alabama	13.11	18.17	21.53	22.94	22.77	23.50	22.43	-4.55
California	8.88	9.75	9.73	11.08	12.43	17.80	20.51	15.22
Colorado	11.23	11.91	9.47	8.40	5.60	3.10	1.36	-56.13
Florida	38.80	39.64	33.98	32.43	28.94	26.55	—	—
Illinois	103.23	99.80	95.30	111.60	104.19	—	—	—
Indiana	50.26	53.38	56.32	62.12	58.00	64.42	63.33	-1.69
Iowa	32.54	36.36	34.49	34.62	29.70	30.55	32.44	6.19
Kansas	20.02	23.39	21.67	20.92	18.83	19.10	19.69	3.09
Kentucky	53.61	46.37	60.69	62.15	62.47	80.65	40.65	-49.60
Michigan	25.28	27.88	31.84	32.86	34.34	35.40	31.64	-10.62
Minnesota	48.22	43.12	35.26	36.70	29.26	21.50	21.67	0.79
Nebraska	16.50	20.44	19.89	19.16	18.43	17.20	16.56	-3.72
Ohio	57.83	58.33	70.50	70.40	64.08	75.02	—	—
Tennessee	19.00	16.48	8.55	24.49	25.87	37.60	20.92	-44.36
Texas	22.13	25.03	24.39	30.94	28.31	32.41	26.83	-17.22
Virginia	37.95	44.17	42.85	44.17	42.49	35.02	30.89	-11.79

Source: Alcohol Week, Nov. 3, 1986

b) Brazil

The Brazilian Alcohol Program "Pro-Alcohol" was established in 1975 to promote the production of ethanol from sugarcane, cassava or any other substrate and was aimed at supplying the needs of domestic and foreign markets and the needs of the automotive fuels policy.

Consequently, in 1985 approximately 11.1 x 10^6 Kl of ethanol were produced by about 400 distilleries, from which about 8.0 x 10^6 Kl were used as fuel for transportation in the domestic market (2.1 x 10^6 Kl of anhydrous ethanol and 5.9 x 10^6 Kl of hydrous ethanol).

By 1986 more than half the gasoline demand had already been met by ethanol fuels, through the use of 22% ethanol (purity 99.3%) - 78% gasoline blends by about 9 million vehicles and the use of hydrous ethanol (containing 4% water) by about 3 million vehicles.

In 1974, before establishment of Pro-Alcohol, the Brazilian economy consumed 94 million toe (tons of oil equivalent) of primary energy. In 1985, energy consumption reached 173 million toe - a 5.7% cumulative annual growth over the 1974-85 period. The crude oil share in primary energy was reduced from 43% in 1974 to 32% in 1985 whereas the sugarcane share increased more than 3 fold over 1974, reaching 13% of total primary energy consumption in the country in 1985. (See Fig. 8-2-26.)

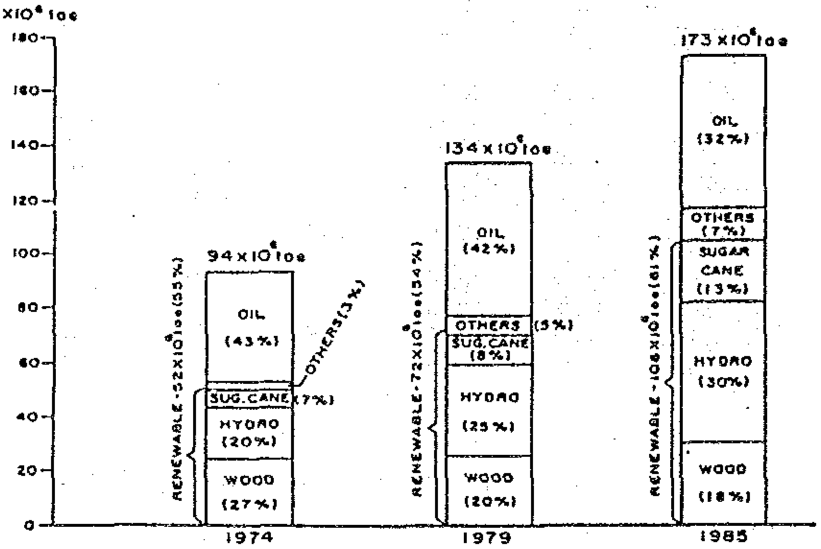


Fig. 8-2-26 Primary Energy Consumption Profile (Brazil)

Source: Reference 14

The largest user of petroleum fuels is the transport sector which consumed 58.0% of all petroleum fuels in 1974 and 56.4% in 1985.

In the transport sector, as shown in Fig. 8-2-27, gasoline was responsible for more than half of the energy supply to the sector in 1974. In that year ethanol had already been blended with gasoline but represented only 0.5% of the sector demand or less than 1% of gasoline consumption. The ethanol share in 1985 was about the same as the gasoline share - around 20% of the total energy consumption of the sector. Total gasoline consumption in 1985 was about half the 1974 figures, while diesel oil consumption increased its share from 35% in 1974 to 45% in 1985 in terms of total energy consumed in the sector including the ethanol contribution.

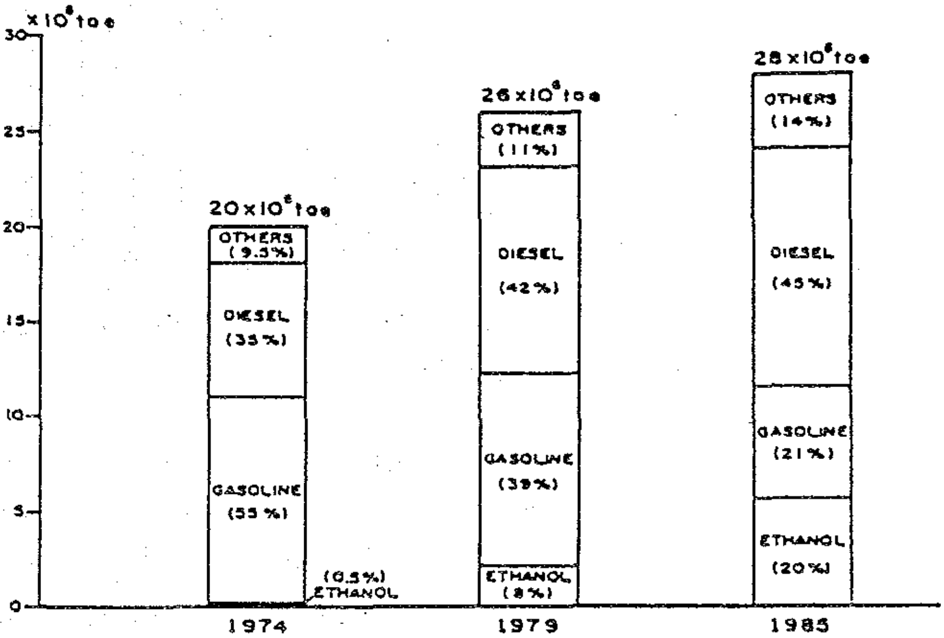


Fig. 8-2-27 Transport Sector Consumption Profile (Brazil)

Source: Reference 14

Several investigations into blends of anhydrous ethanol with gasoline were carried out during the period 1970/1976 by the automotive industries and CTA (Brazilian Aerospace Technical Center).

Based on those experiments the nominal 20% anhydrous ethanol - 80% gasoline blend, requiring no engine modification and bringing on no mileage penalty, was adopted, whenever anhydrous ethanol was added to gasoline. However, the average of 20% was reached nationwide only in 1983. (See Fig. 8-2-28.) Then, in November 1984 the over supply of ethanol led to pressure to increase ethanol content above 20% and a blend 22% ethanol 78% gasoline was adopted.

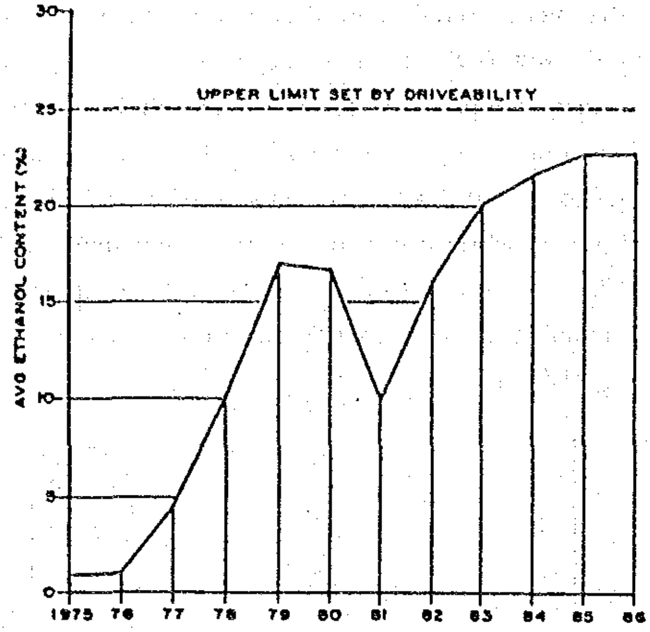


Fig. 8-2-28 Average Rate of Anhydrous Ethanol in Gasoline in Brazil
Source: Reference 14

The research and development of a neat ethanol engine had been started previously and in July 1979 the first vehicle manufactured with a hydrous ethanol engine was marketed directly by the auto industry.

By June 1986 about 2,850,000 vehicles were running on hydrous ethanol in Brazil corresponding to about 25% of the total automotive fleet in the country. Hydrous ethanol vehicle sales in the first half of 1986 corresponded to 93.3% of total light passenger vehicle sales or 82.2% of total sales of the auto industry in the domestic market as shown in Total 8-2-27.

Table 8-2-27 Vehicle Sales in the Domestic Market 1st Semester 1986

Type of Vehicle	Total Sales			Hydrous Ethanol Vehicle Sales			Hydrous Ethanol Vehicle Share (%)	
	Jan/June 85	Jan/June 86	% Increase	Jan/June 85	Jan/June 86	% Increase	1985	1986
Light passenger vehicle	243,514	359,727	47.7	233,172	335,907	44.9	95.7	93.3
Light commercial	35,903	59,835	66.6	25,056	41,383	65.1	69.7	69.1
Heavy commercial	23,195	40,335	73.8	723	820	13.4	3.1	2,0
TOTAL	302,612	459,897	51.9	258,951	378,110	46.0	85.5	82.2

Source: Reference 14

Automotive fuel consumption in the Jan.-June 1986 period showed a substantial increase over the same period of 1985, as shown in Table 8-2-28 about 40% increase for hydrous ethanol, 14% for ethanol-gasoline blend and 10% for diesel oil.

Table 8-2-28 Automotive Fuels Consumption (thousand m^3)
1st semester 1986

Fuel	Period Jan/June 85	 Jan/June 86	% increase
Hydrous ethanol	2,603	3,642	39.9
Ethanol-gasoline blend (containing 22% ethanol by vol.)	4,506	5,151	14.3
Diesel oil	8,920	9,840	10.3

Source: Reference 14

Table 8-2-29 shows the shifts in consumption of ethanol as a fuel for vehicles in Brazil. It is found that in the 1st semester of 1986 about 50% of gasoline demand has already been met by ethanol fuels (both anhydrous and hydrous).

The utilization of ethanol fuels to displace diesel oil have not shown such a good performance, due to technical and economic barriers. Actually only heavy vehicles are allowed to consume diesel oil in Brazil.

Tabe 8-2-29 Consumption of Ethanol as Fuel for Vehicles in Brazil (thousand m^3)

Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986(1)
Hydrous ethanol	-	-	-	4.8	16.3	429.2	1,391.7	1,674.3	2,950.2	4,468.2	5,932.0	3,642.0
Anhydrous ethanol	162.2	171.6	639.3	1,504.1	2,219.1	2,253.1	1,146.1	2,020.9	2,196.7	2,082.0	2,121.0	1,152.0
Anhydrous ethanol content in the blend (%)	1.14	1.19	4.79	11.06	16.66	16.47	9.48	16.27	20.17	21.20	22.20	22.00
% gasoline displaced (2)	1.14	1.19	4.79	11.08	16.74	18.53	17.17	24.48	34.48	42.35	48.16	50.0

Notes: (1) until June 1986
(2) assuming equivalence of 1.24 liters of hydrous ethanol to 1.0 liter of gasoline

Source: Reference 14

1) Others

The Philippine Government established the Philippine Ntional Alcohol Committee (PNAC) to introduce ethanol blend gasoline for automotive fuel in 1979.

Blend gasoline containing 20% ethanol has been put into practical use, and the output of fuel ethanol in 1988 is expected to be approximately 930 thousand Kl.

Other countries such as Cuba, Ireland and South America have also introduce fuel ethanol as transportation energy.

2) For Power Generation

Fuel ethanol can be applied as fuel for power generation as in the case of fuel methanol. However, fuel ethanol is more expensive than fuel methanol, thus is not economical to feed the boiler with fuel ethanol as a heat source. So it must be true that the introduction of ethanol as a heat source should be limited to such a special case yielded by the stagnant market in conventional use. Besides, ethanol is more difficult to be reformed than methanol. So methanol is superior to ethanol when applied to gas turbines or fuel cells. For these reasons, the fuel ethanl will not be put into practical use within short or medium-range periods of time.

3) Other Applications (For the Applications in the Kitchen and Illumination)

It is not at all technically difficult to use fuel ethanol for the purpose of cooking and illuminating. Ethanol does not have any toxicity unlike methanol, so the use by an ordinary housewife does not pose any danger, either. So if only an effective price control measure for fuel ethanol is applied, chances are that fuel ethanol will be utilized practically to a certain degree, especially for replacing kerosine used in cooking and illumination.

In fact, fuel ethanol is more cost-effective for car-use. Unless peculiar circumstances arise, therefore, it will not be used in household sector.

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8-3 Potential Demand for Fuel Alcohol in Indonesia

8-3-1 Demand for Petroleum Products

(1) Supply and Demand for Energy

1) Past trend of primary energy demand

In 1969 Indonesia initiated the first five year plan (REPELITA-I) and in 1984 the country finished REPELITA-III. In the 70's the Indonesian economy expanded and its average growth rate per annum reached 7.6%.

In accordance with this rapid economic growth, energy consumption in the country sharply increased. Commercial energy consumption, in particular, has increased five times in the last 16 years, admittedly though it started from a low base. During the 1974-84 period average energy growth was 11.6%. This remarkable energy growth was not only caused by the population growth (2.34% p.a.), but could also be traced to growing demand from Industry, transportation, and the wider distribution of electricity in the country.

Table 8-3-1 shows commercial energy supply by energy sources for the last 10 years. The share of oil decreased to 72 percent in 1984 from 91 percent in 1975 but is still dominant, leading natural gas which has been expanding its share very rapidly. And also, the very high growth rate of hydro to as high as coal is remarkable.

The growth rate of total energy supply decreased very much from 11%/yr (1984/75) to 3%/yr. (1984/81), to which a rapid decrease in oil demand contributes substantially.

Table 8-3-2 shows the primary energy supply at the end of Repelita II, III and IV. The share of oil will be reduced to 66% by the end of Repelita IV (1988/89). Natural gas, hydro and coal will make up the gap.

2) Energy demand by sectors

Table 8-3-3 shows energy consumption by consuming sectors.

In 1984, the industrial, transportation, power generation and household sectors had 38.5%, 24.7%, 16.4% and 20.4% respectively. The transportation and husehold sectors are losing their shares and the industrial and power geneation sectors are gaining.

However, the household sector also consumes much non-commercial energy such as wood and agricultural waste and therefore, consumed more than 60% of total energy in 1985.

(2) Long-term Supply and Demand Prospects for Energy

Repelita IV is a formal energy supply and demand projection, which began in 1984. (See Table 8-3-2.)

Table 8-3-4 shows partial data on each share of consuming sectors in total commercial energy.

Table 8-3-5 shows the shares of commercial-and non-commercial energy at the end of Repelita IV and their future trend. Total energy consumption including commercial-and non-commercial energy is projected to increase by about 3% p.a. or more. Of this, non-commercial energy is to grow by less than 2% p.a. and commercial energy by 4-5% p.a. As a result, the share of commercial energy is to increase to 67% by the year 2000 from 60% projected at the end of Repelita IV.

As to this projected share, the growth rate in the share of commercial energy is not expected to grow as rapidly as those in Table 8-3-4.

(3) Demand of Petroleum Products

Table 8-3-6 shows BBM consumption from 1975 to 1985.

In the last 10 years, fuel oil recorded high growth rate of 10% p.a. and ADO and IDO show a growth rate of a 8-9% p.a. Kerosene consumption, which occupied 27% of total BBM demand in 1985, shows a relatively low growth rate of 3.5% p.a.

The above tendency was further strengthened between 1981 and 1985. BBM consumption almost leveled off and ADO and IDO was forced to grow by such a limited rate as 0.2% p.a. and 1.6% p.a. respectively. Kerosene recorded a minus growth rate of 5% p.a. On the other hand, fuel oil had a very high growth rate of 9% p.a. And also, mogas recorded a slightly minus growth rate.

Such factors as decreased growth of the economy and price effect of reducing the subsidy for petroleum products (esp. kerosene) aided this tendency.

As to decreasing demand for kerosene, such structural changes as rural electrification and substitution by LPG in urban areas seemed to contribute to this trend.

As a result, there seems to exist much uncertainty even in Indonesia about the future demand for petroleum products.

Table 8-3-7 shows oil products consumption by such consuming sectors as transportation, industry, power generation and households from 1975 to 1985. In the four years from 1981 to 1985, kerosene in the household and industrial sectors recorded minus growth of 4.4% p.a. and 3.7% p.a. respectively. The power generation sector recorded as high a growth rate as 9% p.a. and the transportation sector recorded only 1.2% p.a.

Tabe 8-3-8 shows each share of oil consumption by each consuming sector from 1979 to 1985. Both the transportation and power generation sectors (including only PLN) showed an expanding trend of 35.4% and 13.6% respectively as of 1985. On the other hand, household and industrial sectors show almost a levelling-off or slightly decreasing trend.

Table 8-3-9 shows the sales volume of each oil product by supply region of Pertamina in 1985.

Tables 8-3-10, 8-3-11 show oil products demand by each region for 1995 based upon actual data as of 1985. In this study, we assumed the Repelita IV-based case as a high demand case, where the growth rate of each BBM in Repelita IV was adopted to estimate demand for 1995. And also Ascope figures were adopted as a low demand case. For the study on "Prospects of Long-term Demand for Fuel Alcohol (See Section 8-3-2(1)), we employed Ascope estimates as a "more likely" case based upon interviews in Jakarta in 1986. (See Table 8-3-12.)

Table 8-3-1 COMMERCIAL ENERGY SUPPLY BY SOURCES
1975 - 1984

UNIT 10^6 BOE

	Natural Gas	Coal	Hydropower	Geothermal	Oil	Total
1975	6.658	816	1.095	—	81.300	89.869
	7.4	0.9	1.2		90.5	(100)
1976	7.754	778	1.117	—	91.916	101.565
	7.6	0.8	1.1		90.5	(100)
1977	11.556	888	1.093	—	108.134	121.671
	9.5	0.7	0.9		88.9	(100)
1978	20.410	818	1.497	—	123.553	146.278
	14.0	0.6	1.0		84.5	(100)
1979	25.729	746	5.793	—	139.088	171.356
	15.0	0.4	3.4		81.2	(100)
1980	30.283	951	5.552	—	149.425	186.211
	16.3	0.5	3.0		80.2	(100)
1981	36.682	1.041	6.176	—	163.566	207.465
	17.7	0.5	3.0		78.8	(100)
1982	35.523	.995	6.859	.063	166.469	209.909
	16.9	0.5	3.3	0.03	79.3	(100)
1983	39.850	1.060	10.139	.384	163.721	215.154
	18.5	0.5	4.7	0.2	76.1	(100)
1984	45.672	1.816	14.712	.447	164.144	226.791
	20.1	0.8	6.5	0.2	72.4	(100)

Source; MIGAS

Growth Rate (%/yr.)

1975 - 1984	23.9	9.3	33.5		8.1	10.8
1981 - 1984	7.6	20.4	33.4		0.1	3.0

Table 8-3-2 Commercial Energy Supply at the End of Pelita II, III and IV

Unit; 10^6 BOE

SOURCES	End of PELITA II (1978/197)	End of PELITA III (1983/1984)	End of REPE-PELITA IV (1988/1999, projection)
Natural Gas	24.5 (15.3%)	43.41 (17.7%)	55.2 (19.6%)
Coal	0.65 (0.4%)	1.14 (0.5%)	14.7 (5.2%)
Hydro	3.85 (2.4%)	11.64 (3.7%)	24.3 (8.6%)
Geo-thermal	-	0.42 (0.2%)	1.96 (0.7%)
Oil			186.0 (65.9%)
Total	160.0 (100.0%)	223.61 (100.0%)	282.2 (100.0%)
Growth Rate (per cent/Y)		6.92	4.76

Table 8-3-3

Consumption of Commercial energy by Demand Sector

(In Million BBL Oil Equivalent)

	INDUSTRY		TRANSPORTATION		ELECTRICITY		HOUSHOLD		TOTAL	
YEAR	MBOE	%	MBOE	%	MBOE	%	MBOE	%	MBOE	%
1968	15.25	35.2	11.90	27.4	2.45	5.7	13.76	31.7	43.35	100
1969	12.91	28.9	13.28	29.8	2.22	5.0	16.21	36.3	44.62	100
1970	14.00	29.9	13.74	29.4	2.61	5.6	16.40	35.1	46.75	100
1971	18.41	34.9	14.56	27.6	2.85	5.4	16.92	32.1	52.72	100
1972	13.85	25.8	16.60	30.9	3.38	6.3	19.88	37.0	53.71	100
1973	21.94	32.3	20.06	29.5	3.79	5.6	22.15	32.6	67.95	100
1974	22.05	29.3	23.30	31.0	4.15	5.5	25.66	34.1	75.16	100
1975	26.18	27.7	28.61	30.2	7.95	8.4	31.91	33.7	94.65	100
1976	28.78	27.3	32.68	31.0	9.17	8.7	34.72	33.0	105.35	100
1977	36.56	30.1	36.04	29.7	10.50	8.6	38.45	31.6	121.55	100
1978	51.97	35.2	40.09	27.1	12.52	8.5	43.10	29.2	147.68	100
1979	59.29	35.5	44.75	26.8	15.82	9.5	47.30	28.3	167.16	100
1980	64.92	35.6	49.19	27.0	17.37	9.5	50.76	27.9	182.24	100
1981	74.65	36.8	52.53	25.9	21.56	10.6	54.27	26.7	203.01	100
1982	73.36	35.4	55.64	26.8	24.41	11.8	53.95	26.0	207.36	100
1983	82.11	38.2	53.71	25.0	30.65	14.2	48.69	22.6	215.16	100
1984	86.58	38.5	55.47	24.7	36.79	16.4	45.95	20.4	224.79	100

Source: From 1968 to 1974: Dept. of Mines & Energy (P.T.E.)
From 1975 to 1984: MIGAS

Table 8-3-4 Projection of Energy Share By Sector

	1990	1995	2000	2005
Industry, Agriculture Construction, Mining	45.7	48.1	50.5	52.7
Transportation	27.3	26.5	26.0	25.6
Household/Service	27.0	25.4	23.5	21.7

Source: Paper presented at the Second Meeting, Indonesia - Japan Joint Energy Committee (January 86, Tokyo)

Table 8-3-5-(1) Projection of Total Energy Consumption at the End of REPELITA IV (1988/1989) and future trends

Unit: 10^6 BOE

	REPELITA IV (1988/89)	1995	2000	2005
Commercial Energy	282.2 (60%)	366.5	462.9	572.0
Non-Commercial Energy	183.3 (40%)	208.6	226.3	245.7
合　計	465.5 (100%)	575.1	689.1	817.7

Table 8-3-5-(2) Growth Rate of Energy Consumption (%/yr)

	95/88	2000/95	2005/2000
Commercial Energy	3.8	4.8	4.3
Non-Commercial Energy	1.9	1.6	1.7
Total	3.1	3.7	3.5

Table 8-3-6 BBM Consumption in Indonesia

(10^3kl/yr.)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Growth Rate 85/75	Growth Rate 85/81
Avgas	20.1	19.9	17.8	20.5	20.4	18.8	16.7	15.0	12.7	11.4	10.4	△6.4	△11.2
Avtur	287.4	322.1	347.9	401.2	500.6	540.7	606.4	618.2	587.9	608.3	622.9	8.0	0.7
Mogas	2409.8	2630.0	2909.9	3290.0	3729.6	3856.4	4216.0	4077.1	3954.4	4114.2	4157.6	5.6	△0.3
Kerosene	4885.0	5301.0	5875.8	6999.1	7349.0	7891.0	8436.7	8027.3	7597.6	7212.5	6914.8	3.5	△4.9
ADO	3043.0	3817.0	4457.0	5204.0	5869.8	6768.4	7510.1	7999.8	8096.3	7920.4	7576.5	9.6	0.2
IDO	758.0	893.0	1024.0	1261.0	1310.6	1319.4	1580.8	1498.4	1715.0	1709.8	1686.0	8.3	1.6
Fuel oil	1828.0	1853.0	2130.0	2693.0	3066.6	3152.8	3399.5	3699.4	4607.2	4821.4	4832.7	10.2	9.2
Total	13231.3	14836.0	16762.4	19868.8	21846.6	23547.5	25766.3	25935.2	26571.1	26398.1	25800.9	6.9	0.03

Source: MIGAS

Table 8-3-7

Oil products Consumption by Sectors

(Unit: 10^3BBL)

YEAR	Transportation							Industry				Power Generation				Household
	Avgas	Avtur	Gas.	ADO	IDO	F.O.	Total	ADO	IDO	F.O.	Total	ADO	IDO	F.O.	Total	Kerosene
1975	126.1	1807.2	15155.3	8249.0	710.3	2509.5	28557.4	9034.4	3653.9	7448.4	20136.7	1854.8	401.1	1537.5	3793.4	30723.2
1976	125.1	2025.7	16540.3	11050.1	1001.9	1892.0	32635.1	9811.5	4309.7	7839.9	21961.1	3142.1	307.4	1924.4	5373.9	33337.7
1977	111.9	2187.9	18300.2	12161.4	1040.2	2177.8	35985.3	11713.6	5121.3	9138.9	25973.7	4154.5	279.0	2081.2	6514.7	36952.8
1978	128.7	2523.2	20691.1	13699.1	1070.7	1932.8	40045.5	13844.1	5712.9	12169.5	31726.5	5187.2	1144.1	2832.6	9163.9	41501.8
1979	126.9	2999.8	22963.2	15654.6	1030.5	1929.9	44704.8	15857.5	6602.0	12335.0	34794.5	4484.1	605.0	4820.6	9909.7	45564.1
1980	126.7	3266.3	24029.6	18330.7	1139.5	2239.5	49131.7	18427.6	6797.0	11030.1	36254.8	4876.0	169.8	6477.3	11523.1	49054.0
1981	103.8	3725.7	26235.2	20229.4	1099.5	1053.1	52446.7	19892.9	8331.3	10767.7	38991.9	5712.7	270.9	8897.0	14880.5	52584.3
1982	98.1	3888.7	26075.6	23098.9	1079.9	1333.9	55575.0	20312.0	8236.0	10608.8	39516.8	6609.8	207.3	10589.5	17406.6	51892.3
1983	83.6	3686.0	24694.5	23017.0	1010.0	1168.8	53660.7	20997.0	8924.0	12067.1	41988.0	6712.5	272.9	12917.6	19903.0	48169.8
1984	72.0	3629.6	25472.1	22965.9	1460.3	1653.7	55453.7	20561.6	8924.3	13672.8	43158.7	5863.2	290.5	14121.0	20274.8	45256.5
1985	65.1	3893.4	25877.8	22695.9	1265.0	1205.9	55003.1	18666.4	8653.1	6256.2	33575.7	5757.4	222.7	14682.8	20662.9	43923.5
Growth Rate (%/Yr.)																
85/75	△6.4	8.0	5.50	10.7	5.94	△7.1	6.8	7.53	9.0	△1.73	5.23	12.0	△5.71	25.3	18.5	3.64
85/81	△11.0	1.1	△0.3	2.9	3.6	3.4	1.2	△1.6	1.0	△12.7	△3.7	0.2	△4.8	13.3	8.6	△4.4

Source: MIGAS

Table 8-3-8 Share of Oil Consumption by Sector

	Transportation	Industry	Electricity	Household	Total
1979	32.4	23.4	7.6	36.6	100
1980	32.7	23.7	8.3	35.3	100
1981	32.8	23.3	9.7	34.2	100
1982	33.7	22.5	11.0	32.8	100
1983	32.5	24.0	12.7	30.7	100
1984	34.1	23.4	13.1	29.4	100
1985	35.4	22.2	13.6	28.8	100

Source: MIGAS (“Oil and Gas Industry of Indonesia”)

Table 8-3-9 Domestic Sales Volume of Oil Products 1985年 (C.Y.)

Oil Products	Sales Volume 10^3 KL	Pertamina Supply Region								
		I	II	III	IV	V	VI	VII	VIII	
Avgas	103.4 [100]	0.988 [9.6]	0.099 [1.0]	3.944 [38.1]	0.180 [1.7]	3.812 [36.9]	0.148 [1.4]	0.233 [2.3]	0.939 [9.1]	
Avtur	619.0 [100]	61.515 [9.9]	21.637 [3.5]	204.048 [33.0]	21.055 [3.4]	206.359 [33.3]	56.851 [9.2]	23.669 [3.8]	23.870 [3.9]	
Premium Gas	116.9 [100]	3.654 [3.1]	0.217 [0.2]	89.397 [76.4]	10.368 [8.9]	13.279 [11.4]	0.023 [0.02]	-	-	
Regular Gas	3997.3 [100]	447.89 [11.2]	292.302 [7.3]	1551.898 [38.8]	478.127 [12.0]	898.207 [22.5]	182.649 [4.6]	114.939 [2.9]	31.304 [0.8]	
Kerosene	6983.3 [100]	774.378 [11.1]	439.209 [6.3]	2538.363 [36.3]	1002.824 [14.4]	1738.017 [24.9]	256.350 [3.7]	201.906 [2.9]	32.250 [0.5]	
ADO	7491.5 [100]	1171.905 [15.6]	897.560 [12.0]	2416.445 [32.3]	836.783 [11.2]	1565.744 [20.9]	299.072 [4.0]	216.314 [2.9]	87.629 [1.2]	
IDO	1612.3 [100]	54.418 [3.4]	131.296 [8.1]	960.336 [59.6]	140.696 [8.7]	308.725 [19.1]	16.782 [1.0]	-	-	
Fuel Oil	3361.8 [100]	159.218 [4.7]	39.694 [1.2]	1512.146 [45.0]	425.104 [12.6]	1053.966 [31.4]	171.653 [5.1]	-	-	
BBM Total	24192.4 [100]	2673.966 [11.1]	1822.014 [7.5]	9276.577 [38.3]	2915.137 [12.0]	5788.109 [23.9]	983.528 [4.1]	557.061 [2.3]	175.992 [0.7]	

(Note): Regions
I : Medan
II : Palembang
III : Jakarta
IV : Semarang
V : Surabaya
VI : U. Pandang
VII : Menado
VIII : Jayapura

T a b l e 8-3-10 Domestic Sales Volume of Oil Products 1995(C.Y.)

[Ascope case]

Oil Products	Sales Volume 10³ KL	Pertamina Supply Region								
		I	II	III	IV	V	VI	VII	VIII	
Avgas	147.9	14.2	1.5	56.3	2.5	54.6	2.1	3.4	13.5	
Avtur	620.5	61.4	21.7	204.8	21.1	206.6	57.1	23.6	24.2	
Premium Gas	167.8	5.2	0.3	128.2	14.9	19.1	0.03	-	-	
Regular Gas	5720.3	640.7	417.6	2219.5	686.4	1287.1	263.1	165.9	45.8	
Kerosene	7040.1	781.5	443.5	2555.6	1013.8	1753.0	260.5	204.2	35.2	
ADO	7163.3	1117.5	859.6	2313.7	802.3	1497.1	286.5	207.7	86.0	
IDO	1541.7	52.4	124.9	918.9	134.1	294.5	15.4	-	-	
Fuel Oil	3250	152.8	39.0	1462.5	409.5	1020.5	165.8	-	-	
BBM Total	25651.5	2847.3	1923.9	9824.5	3078.2	6130.7	1051.7			

(Note): Regions

I : Medan
II : Palembang
III : Jakarta
IV : Semarang
V : Surabaya
VI : U. Pandang
VII : Menado
VIII : Jayapura

Demand figures are taken from ASCOPE document (Dec. 1985).
Sales volumes in each supply region were calculated based upon shares in 1985 (C.Y.)

Table 8-3-11 Domestic Sales Volume of Oil Products 1995(C.Y.) [Pelita IV Based Case]

Oil Products	Sales Volume 10^3 KL	Pertamina Supply Region								
		I	II	III	IV	V	VI	VII	VIII	
Avgas	123.0	11.81	1.23	46.86	2.09	45.39	1.72	2.83	11.19	
Avtur	604.7	59.87	21.16	199.55	20.56	201.37	55.63	22.98	23.58	
Premium Gas	139.6	4.33	0.28	106.65	12.42	15.91	0.028	-	-	
Regular Gas	4757.7	532.86	347.31	1845.99	570.92	1070.48	218.85	137.97	38.06	
Kerosene	11751.5	1304.4	740.34	4625.79	1692.22	2926.12	434.81	340.79	58.76	
ADO	11824.1	1844.56	1418.89	3819.18	1324.30	2471.24	472.96	342.90	141.89	
IDO	1968.5	66.93	159.45	1173.23	171.26	375.98	19.69	-	-	
Fuel Oil	5489.5	258.01	65.87	2470.28	691.68	1723.70	279.96	-	-	
BBM Total	36658.6	4069.40	2749.40	14040.24	4399.03	8761.41	1503.00	843.15	256.61	

(Note): Regions I : Medan V : Surabaya
II : Palembang VI : U. Pandang
III : Jakarta VII : Menado
IV : Semarang VIII : Jayapura
Demand figures are calculated based upon the growth rate in Pelita IV.
Sales volumes in each supply region were calculated based upon shares in 1985 (C.Y.)

Table 8-3-12 Estimates of Oil Products Demand in 1995

10^3 kL/yr

	Sales Volume		Actual Data 1985
	Pelita IV Base	ASCOPE	
Avgas	123.0 〔0.3〕	147.6 〔0.6〕	103.4 〔0.4〕
Avtur	604.7 〔1.6〕	620.5 〔2.4〕	619.0 〔2.6〕
Premium Gas	139.6 〔0.4〕	167.8 〔0.7〕	116.9 〔0.5〕
Regular Gas	4757.7 〔13.0〕	5720.3 〔22.3〕	3997.3 〔16.5〕
Kerosene	11751.5 〔32.1〕	7040.1 〔27.4〕	6983.3 〔28.9〕
ADO	11824.1 〔32.3〕	7163.3 〔27.9〕	7491.5 〔31.0〕
IDO	1968.5 〔5.4〕	1541.7 〔6.0〕	1612.3 〔6.7〕
Fuel Oil	5489.5 〔15.0〕	3250.0 〔12.7〕	3361.8 〔13.9〕
BBM Total	36658.6 〔100〕	25651.5 〔100〕	24192.4 〔100〕

NOTE: Ascope figures are taken from the document in the 3rd Conference of ASCOPE, Dec. 1985, the title of which is "Long Range Outlook of Petroleum Product Supply and Demand and Utilization of Refining Capacity in the ASEAN Region"

8-3-2 Potential Demand for Fuel Alcohol

8-3-2-(1) Prospect of Long-term Demand for Fuel Alcohol in Indonesia (Economic Requirements for Fuel Alcohol Introduction and Demand Prospect)

1. Object of Survey

This survey is aimed at quantitative evaluating and analysing, in the "Effective Utilization of Banko Coal," the impacts by introducing fuel alcohol into Indonesia as a substitute fuel for various oil products, namely, the production costs of methanol, oil prices and introduceable quantity of fuel methanol, on the basis of oil refining capacities in the country, crude oil costs, export prices of oil and prospect of demands for various oil products.

In the survey, a LP model (linear programming model), which represents the crude oil and oil-product flows in Indonesia, has been prepared and used.

The presence or absence of economic benefits obtained by introducing fuel alcohol into Indonesia may be determined by the difference in magnitude between the cost for introduction (namely, alcohol price) and the increase in profits obtainable from the increase in the export of crude oil and oil products, etc.

Therefore, it has been decided in the present survey to obtain the critical conditions where the increased cost by alcohol introduction becomes equal to the increased profits obtained by the decrease in consumption (namely, increase in export) of crude oil and oil products as well as the increase in profits due to a decrease in the production cost in the oil refining sector. Then the economic requirements for fuel alcohol introduction, namely, the equilibrium between the alcoho price and the crude oil price, are calculated.

2. Construction of LP Model

2.1 Outline

The LP model used in the present survey consists of matrices comprising about 2,000 equations and about 3,500 variables. Table 8-3-13 shows the main matrices; Fig. 8-3-1 and 8-3-2 show the entire flow charts.

Matrices are composed of such parts as crude oil production, oil refining, demand location and alcohol production.

Object functions are defined as profit functions, and optimization has been performed to maximize the profits.

Table 8-3-13

Main Matrix of LP Model

Structural Variables / Equation	Crude Oil			Refineries						Products Transportation	Domestic Demand	Fuel Alcohol Transportation	Fuel Alcohol Production	(Type)
	Production	Export	Domestic Transportation	Crude Oil Input	Refining Unit	Refining Unit	Blending	Oil Products	Oil Products Export					
Objective function(Profit)	— Production Cost	+ Export Price	— Transportation Cost		— Refining Cost	— Refining Cost			+ Export Price	— Transportation Cost	+ Sales Price	— Transportation Cost	— Production Cost	= MAX
<Crude Oil Volume Balance>														
Crude Oil Volume	+	—	—											= 0
<Material Balance in Refineries>														
Material Balance 1				+	—									= 0
Material Balance 2					+	—								= 0
Unfinished Products						+	—							= 0
Oil Product Production							+	—						= 0
Oil Product Delivered								+	—	—				= 0
<Refining Unit>														
Processed Volume					+	+								<Capa.
Own Use					—	—								= 0
<Product Spesification>														
MAX							+	—						< 0
MIN							+	—						> 0
<Balance of Transported Volume>														
Crude Oil			+	—										= 0
Oil Products										+	—			= 0
Fuel Alcohol											—	+		= 0
<Balance of Alcohol>														
Alcohol Production												—	+	= 0
Constraint Conditions	Production Level	Exports Level			Processing Capacity	Processing Capacity		Product Specification			Demand Level		Production Level	

Fig. 8-3-1 Flow of LP Model in Indonesia (existing capacity case)

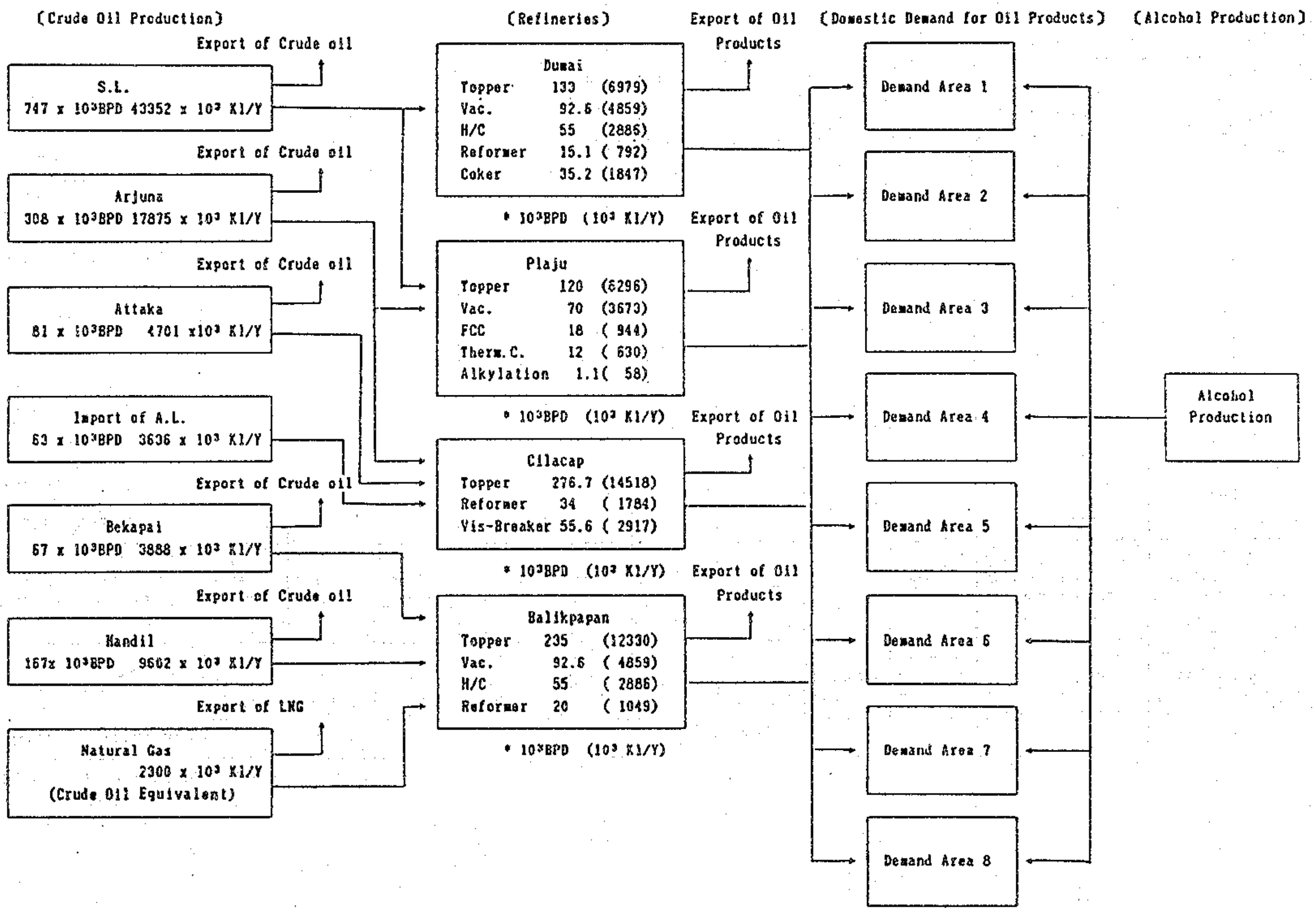
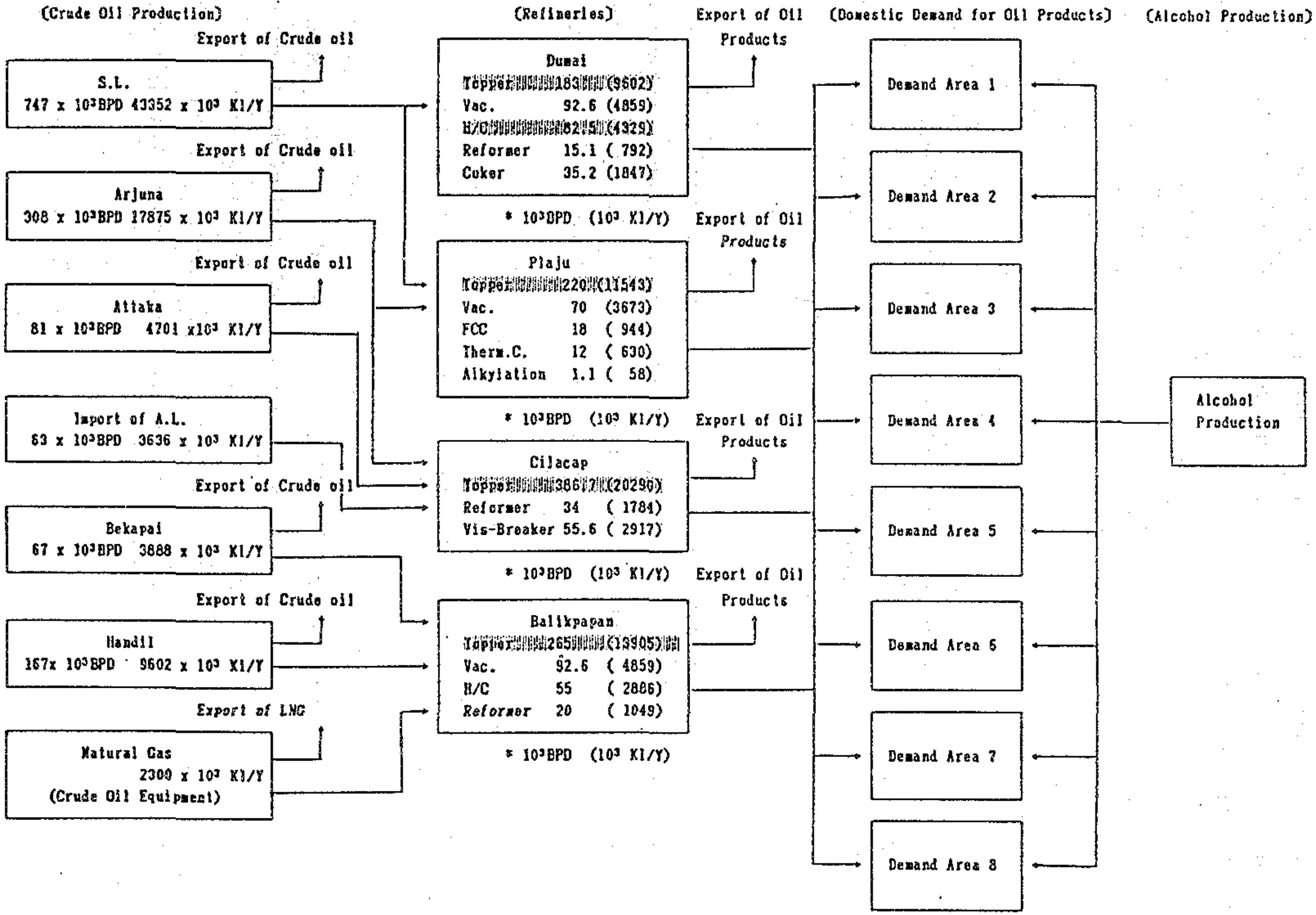


Fig. 8-3-2 Flow of LP Model in Indonesia (expanded capacity case)



NOTE: Refining capacity were expanded in dotted part (▨).

2.2 Crude Oil

For the crude oil produced, the following six kinds of oil have been set up, and other crude oils have been included into the six crude oils according to their respective production areas:

Sumatra Light	(SL)
Arjuna	(AJ)
Attaka	(AT)
Bekapai	(BP)
Handil	(HD)
Arun Condensate	(AC)

The contents of inputs for the respective crude oil are as follows:
Upper limit of production
Production cost per kl ($/kl)
Transportation cost to one of four refineries ($/kl)
Export price (FOB: $/kl)

Since the object functions are profit functions, the sign for the object function is minus in respect to the cost. Namely, production and transportation (domestic use) of crude oil decrease profits. Conversely, the sign of the export price for the object function is plus, and the export of crude oil and oil products will earn profit.

A quantitative balance shall be obtained by the following:

Crude oil production - crude oil export - Domestic transportation of crude oil (Domestic consumption) = 0

Part of the crude oil production is transported to a domestic refinery, and the remainder is exported. Provided that it has been assumed that the total production of the Arun Condensate will be exported, and the upper limit of this export has been set up. Natural gas also has a set-up upper limit for export, and is used at the Balikpapan refinery for manufacturing hydrogen. For producing lubricants, it has been assumed that Arabian Light (AL) will be imported and processed at Cilacap.

2.3 Refineries

At present, there are nie refineries in Indonesia, but in the model, refineries which are in adjacent areas are grouped, and all Indonesian refineries are represented by the following four refineries:

P. Brandan Dumai S. Pakning	Dumai
Plaju S. Gerong	Plaju
Cilacap Wonokromo Cepu	Cilacap
Balikpapan	Balikpapan

"Refining capacity" is the total capacity of the respective grouped refineries.

The topper yield of crude oil and yields of respective refinery facilities, unit consumptions, etc., have been set up on the basis of data obtained by the site survey, and the validity of these data has been confirmed by comparing them with the actual data of oil refining in 1985.

For each refinery facility, the following data have been inputted.

Processing capacity (1,000 kl/yr)
Material balance
Home-use fuel consumption
Hydrogen balance
Steam consumption
Electric power consumption
Catalysts and chemical costs

Of the above items, home-use fuel, hydrogen, steam and electric power are all provided by the refinery, and catalysts and chemicals will be purchased.

For product blending, the following restrictions have been posed.

Gasoline	
Research octane number (RON)	84 (clear) or above
50% dist. temp.	88°C or above
Reid vapor pressure (R.V.P.)	9 psi or above
Gas oil	
Kinetic viscosity (100°F)	1.6 cSt or above
10% carbon residue	0.1% or above
Cetane index	48 or above
Heavy oil	
Kinetic viscosity (100°F)	1.250 sec or below (Redwood)
Carbon residue	10% or below

Quantity balances at the refinery are as follows:

Domestic crude oil transported - Topper crude-runs = 0

Finished-product production - Domestic product transporation - Product export = 0

Blending stock and unfinished product balance in the refinery

It has been assumed that the finished products are transported to domestic demand regions and the remaider is exported.

The domestic transportation cost of products has been set up on the basis of the marine transportation distance from the refinery to the demand region concerned. Land transportation costs have been omitted, because they do not affect variation in profits among the various cases.

2.4 Domestic Demand

Domestic demand has been divided into eight regions according to the sales units of PERTAMINA.

Demand Region 1	Acheh, Riau, North Sumatra, West Sumatra and their sorrounding areas
Demand Region 2	Jambi, South Sumatra, West Sumatra and their surrounding areas
Demand Region 3	Jakarta, West Java and their surrounding area
Demand Region 4	Central Java, Jogyakarta and their surrounding areas

Demand Region 5	East Java, Bali, Madura and their surrounding area
Denand Region 6	South Sulawesi, Cental Sulawesi and their surrounding area
Demand Region 7	North Sulawesi, Central Sulawesi and their surrounding area
Demand Region 8	Irian Jaya and its surroundig areas

For each product at each demand region, the following data are inputted:

Demand quantity
Sales price
The quantitative balance is as follows:

Domestic transportation of products from 4 refineries - demand at demand area concerned = 0

Thus products transported from the refinery are sold at the demand region and earn profits.

3. Setup of Assumptions

3.1 Setup of Cases on Economic Requirements for Introducing Fuel Methanol

As a result of the trial calculation on the economical benefits of methanol introduction at a methanol price of \$139/kl, when the crude oil prices is \$30/BBL (\$189/kl) on the basis of the results obtained by the preliminary survey of fiscal 1985 on the methanol production cost, it has been found that the introduction of fuel methanol at a price of \$139/kl is economically disadvantageous.

Therefore, an examination has been made by a method in which either the crude oil price or methanol price is fixed firmly and the other critical price is calculated for introducing the total quantity of methanol.

For the domestic demand for oil products, two kinds have been set up; and in the case based on Pelita IV, in which the total products cannot be produced by the current refining capacities, two cases have been set up to cope with this situation, that is, the case of expanded refining capacities and the case of importing kerosene.

Incidentally, the lower critical value (IRR = interest = 8,0%/yr) of the cost for producing methanol from Banko coal is \$102/kl.

3.2 Setup of Survey Cases on Economic Requirements for Introducing Ethanol

Ethanol is mainly considered as a gasoline substitute; therefore, the examination has been made only in respect of ASCOPE, where gasoline demand is great, to obtain the prospects of ethanol demand.

3.3 Assumptions

(1) Crude Oil

a. Production ceiling

SL	747×10^3 BPD	$43,352 \times 10^3$ kl
AJ	308×10^3 BPD	$17,875 \times 10^3$ kl
AT	81×10^3 BPD	$4,701 \times 10^3$ kl
BP	67×10^3 BPD	$3,888 \times 10^3$ kl
HD	167×10^3 BPD	$9,692 \times 10^3$ kl
AC	130×10^3 BPD	$7,545 \times 10^3$ kl
Total	$1,500 \times 10^3$ BPD	$87,053 \times 10^3$ kl

Total crude oil volum of $1,500 \times 10^3$ was divided into each crude oil based on crude oil production by each well OGJ.

b. Production cost

SL	$1.86/BBL	$11.7/kl
AJ	$9.01/BBL	$56.7/kl
AT	$10.49/BBL	$66.0/kl
BP	$4.73/BBL	$29.7/kl
HD	$4.50/BBL	$28.3/kl
AC	$1.86/BBL	$11.7/kl

c. Transportation cost

Wt. Av. in total Indonesia: $3.05/kl ($0.06/km.kl)

	Dumai	Plaju	Cilacap	Balikpapan
SL	0.0	4.32		
AJ		4.50	4.50	
AT			9.72	
BP				0.0
HD				0.0
AC				
AL			8.00	

The number of $0.006/km.kl was calculated based upon wt.av. transportation cost of $3.05/kl.

c. Export volume

Production volume - processing volume

d. Export price

(Ave. crude oil price in OPEC + 0.5)$/BBL

e. Import volume of AL

3636 x 10^3 kl (400 x 10^3 of Lub demand and 11% of its yield were assumed.)

f. Import price of AL

The price was assumed to be the same of Ave. Price of OPEC crude oil.

(2) Oil Refining

a. Processing capacity by refineries 10^3 kl/yr.

	Dumai	Plaju	Cilacap	Balikpapan
Topper	6,979	6,000	14,518	12,330
Vacuum	4,859	3,673	0	4,859
Reformer	792	0	1,784	1,049
FCC	0	944	0	0
Alkylation	0	58	0	0
H/C	2,886	0	0	2,886
Coker	1,847	0	0	0
Visbreaker	0	0	2,917	0

The following capacities were assumed as added refining capacities.

10^3 kl/yr.

	Dumai	Plaju	Cilacap	Baikpapan
Topper	9,602	11,543	20,290	13,905
Vacuum	4,859	3,673	0	4,859
Reformer	792	0	1,784	1,049
FCC	0	944	0	0
Alkylation	0	58	0	0
H/C	4,329	0	0	2,886
Coker	1,847	0	0	0
Visbreaker	0	0	2,917	0

b. Crude oil processed in each refinery 10^3 kl/yr.

	Dumai	Plaju	Cilacap	Balikpapan
SL	o	o		
AJ		o	o	
AT			o	
BP				o
HD				o
AC				
AL			o	

(3) Demand for Petroleum Product

a. Petroleum products demand by regions

Please refer to 8-3-1-(3).

b. Domestic sales price of petroleum products sales price are assumed to be as follows.
(Av. Price of OPEC crude oil x 1.05 + 6.95) $/kl
(5% is refining cost + 6.95 of ave. transportation cost)

c. Transportation cost of petroleum products of crude oil price

$6.95/kl($0.014/km.kl)

	Dumai	Plaju	Cilacap	Balikpapan
Demand Region 1	5.60	15.40	32.20	
Demand Region 2	10.50	0.00	17.50	25.90
Demand Region 3	18.90	7.70	0.00	21.00
Demand Region 4	21.00	11.62	0.00	16.10
Demand Region 5	25.20	15.40	0.00	12.60
Demand Region 6	30.10	32.90	21.00	7.84
Demand Region 7			37.10	13.58
Demand Region 8				35.00

The number of $0.014/km.kl was calculated based on wt. av. transportation cost of $6.95/kl.

d. Export price of products

Export prices are assumed from market prices of 1985 in Singapore.

Propane : Ave. Crude Oil Price of OPEC x 1.0
Butane : Ave. Crude Oil Price of OPEC x 1.0
Naphtha : Ave. Ceude Oil Price of OPEC x 1.0
Kerosene : Ave. Crude Oil Price of OPEC x 1.2
Gas Oil : Ave. Crude Oil Price of OPEC x 1.2
Reformate : Ave. Crude Oil Price of OPEC x 1.3
Fuel Oil : Ave. Crude Oil Price of OPEC x 0.9

(4) Cases for Introducing Methanol

a. Production area

South Sumatra

b. Production volume

1,600 x 10^3t or 2,010 x 10^3 kl (Gr. 0.796)

c. Plant gate price of methanol

$139/l (35 yen/kg) (exchange rate; 200 yen/$)

d. Introducing area

One half of kerosene demand of each region was assumed to be max. for methanol demand.

As to introduction of methanol for gasoline, market and diesel oil, demand region 3 and 5 are selected because of their bigger shares in total. (without ceiling of intoducing volume)

e. Substituting volume of petroleum products by methanol

Gasoline	: 0.52 kl/1 kl of methanol
Kerosene	: 0.49
ADO	: 0.47
IDO	: 0.46

(calorific equivalent base)

f. Transportation cost

The same cost in the case of petroleum product (cost per/unit volume) was assumed for this.

g. Cases for introducing ethanol

South Sumatra, Kalimantan : Cassava
Java : Molasses

b. Production volume

South Sumatra, Kalimantan: 395×10^3 kl/each area
Java : 160×10^3 kl

c. Plant gate price of ethanol

Ethanol from cassava : $1,326/kl
Ethanl from molasses : $ 659/kl

d. Introducing area

As to kerosene market, ethanol was assumed to be introduced in each demand region. (with no volume restriction) As to gasoline market, demand region 3 and 5 are selected. (With no volume restriction)

e. Substituting volume of petroleum products

Gasoline : 0.70 kl/1 kl of ethanol
Kerosene : 0.66
(Calorific equivalent base)

f. Transportation cost

The same transportation cost in the case of petroleum product ($/kl) was assumed for ethanol.

Table 8-3-14 Cases for Methanol Introduction

Case	Crude Oil Price	Methanol Price	Domestic Oil Demand	Remarks
[Case A]				
A	30$/BBL	No Introduction of Methanol	ASCOPE	Reference case (No introduction of Methanol)
A C	30$/BBL →	? $/kL	ASCOPE	Maximum price of methanol for introducing full volume of 1.6 million T/Y
A M	? $/BBL ←	139$/kl	ASCOPE	Minimum price of crude oil for introducing full volume of 1.6 million T/Y
AM20-AM37		139$/kl	ASCOPE	Methanol volume of introduction in relation to crude oil price (20$/BBL~38$/BBL) with fixed methanol price of 139$/kl

NOTE: 1.6 million T/Y of Methanol is assumed to be produced in South Sumatra and to be introduced in domestic oil products market.

Methanol introduction depends upon both crude oil price and methanol price. Here boundary condition of each price was calculated with fixed price of the other.

As to domestic oil demand, two cases were assumed. For Pelita IV - based case, both added refining capacity case and kesosene import case were set to respond to bigger kerosene demand.

Table 8-3-15 Cases for Ethanol Introduction

Case	Crude Oil Price	Ethanol Price	Domestic Oil Demand	Remarks
A	30$/BBL	No Introduction of Ethanol	ASCOPE	Reference case (No introduction of ethanol)
A-C-1	30$/BBL →	? $/Kl	ASCOPE	· Ethanol production of 790 x 10^3 KL from S. Sumatra and Kalimanian (from Cassava) Maximum price of ethanol for introduction in full volume
A-C-2	30$/BBL →	? $/Kl	ASCOPE	· Ethanol production of 395 x 10^3 KL from S. Sumatra (from Cassava) Maximum price of ethanol for introduction in full volume
A-C-3	30$/BBL →	? $/Kl	ASCOPE	· Ethanol production of 160 x 10^3 KL in Java (from Molasses) Maximum price of ethanol for introduction in full volume
A-E-1	? $/BBL ←	1326$/kl	ASCOPE	· Ethanol production of 790 x 10^3 KL from S. Sumatra and Kalimanian (from Cassava) Minimum crude oil price for ethanol introduction in full volume
A-E-2	? $/BBL ←	1326$/kl	ASCOPE	· Ethanol production of 395 x 10^3 KL from S. Sumatra (from Cassava) Minimum crude oil price for ethanol introduction in full volume
A-E-3	? $/BBL ←	659$/kl	ASCOPE	· Ethanol production of 160 x 10^3 KL from Java (from Molasses) Minimum crude oil price for ethanol introduction in full volume

NOTE: As to the introduction of ethanol, studies were done in the case for bigger gasoline demand i.e. ASCOPE demand

As to rough estimation of ethanol production cost in Indonesia, please refer 8-5-2.

4. Results of LP Model Study concerning Fuel Methanol

4.1 Equilibrium between Methanol Price and Crude Oil Price

The results are shown in Case A-C and Case A-M of Table 8-3-16.

(1) Case A

This case is a reference for comparison with other cases, and presupposes no methanol introduction for the prospects of oil product demands. The case shows a refining pattern based on ASCOPE demand as a reference for a more likely case. Since gasoline demand is great, according to the above demand prospect, the refining pattern has become the "maximum gasoline yield." As a result, a shortage of naphtha, which is the fuel and feedstock of hydrogen for hydrocrackers, has occurred in Dumai and Balikpapan refineries. In spite of achieving a higher degree of hydrocracker operations, which can obtain higher profits, in actuality, the hydrocrackers have such a relatively low rate of operation (Dumai 69%; Balikpapan 66%).

(2) Case A-C

This case is aimed at examining the necessary conditions for introducing a total quantity of 1.6 million tons of methanol, with respect to Case A. If the crude oil price is fixed at $30/BBL, the equilibrium price (the maximum allowable price) of methanol introduction will be $111/kl. In such a case, methanol of 810 x 10^3 kl and 222 x 10^3 kl (oil product equivalent) will be introduced as substitutes for gasoline and kerosene, respectively. The impact to the refining pattern in this case is that hydrocrackers can be put to more effective use, resulting in a decrease in unprofitable fuel oil exports of about 2.1 million kl and, conversely, in an increase of about 2.6 million kl in export of highly value added products mainly consisting of kerosene and reformate. On the other hand, although the maximum allowable price of methanol, $111/kl, in this case is higher than the lower limit value of $102/kl (price corresponding to IRR : 8.0%) of the cost for producing methanol from Banko coal, this case is not necessarily profitable, considering the risk of investment in methanol production facilities.

(3) A-M Case

In this case, the equilibrium crude-oil price for introducing methanol is calculated, when the methanol price is fixed at $139/kl (which corresponds to IRR

13.5% in the methanol production project). The crude oil price, which permits the introduction of the total 1.6 million tons of methanol at a price of \$139/kl, is \$38/BBL. In this case, as in the A-C Case, methanol has been introduced as gasoline and kerosene substitutes. The impact to the refining pattern has resulted in increases in kerosene and reformate exports through a higher rate of operation of hydrocrackers.

4.2 Relation between Crude Oil Price and Introduceable Quantity of Methanol

When the methanol price was fixed at \$139/kl (price corresponding to IRR: 13.5%), the crude oil price for allowing the introduction of the total methanol amount of 1.6 million tons per year was \$38/BBL (A-M Case). Here, the methanol price is fixed at \$139/kl regardless of the introduced quantity of methanol, and changes in the amount of the introduced quantity of methanol are obtained, when the crude oil price is changed from \$30 to \$38/BBL. Results are shown in Table 8-3-16 and Fig. 8-3-3.

Changes in the introduceable quantity of methanol, when the crude oil price is fixed at \$30/BBL and the methanol price is changed from \$111 to \$139/kl, have not been investigated at this time, owing to restrictions in time. This investigation must be conducted in the future.

(1) Case A-M30

At a crude oil price of \$30/BBL, methanol of 119 x 10^3 kl is introduced as a gasoline substitute. As a result, the shortage in naphtha in Case A is filled up, and hydrocrackers operate at a higher rate. The resultant increase in export of the middle distillate is to make up for the methanol introduction cost.

(2) Case A-M31

As the crude oil price is increased to \$31/BBL, methanol of 252 x 10^3 kl is introduced as a gasoline substitute (gasoline equivalent of 131,000 kl). As a result, gasoline production facilities, i.e., reformers, experience a lower operation rate, and this appears, in the overall balance, mainly as an increase in the kerosene export. Incidentally, in the Case A-M30, the swing portion amounting to 84 x 10^3 kl between naphtha and kerosene was directed to naphtha, namely gasoline production, whereas in Case A-M31, the swing portion is directed to kerosene production due to the difference in the export price between kerosene and gasoline.

(3) Case A-M34

As the crude oil price is increased to \$34/BBL, methanol of 656 x 10^3 kl (gasoline equivalent of 341 x 10^3 kl) is introduced as a gasoline substitute. Since excess naphtha is now put to reformers, reformate, which is the blending stock for gasoline, is increased in production for export.

(4) Case A-M35

The gasoline substitute by methanol rises to 671 x 10^3 kl (gasoline equivalent of 349 x 10^3 kl), resulting in an increased production of reformate and in an increased rate of operation by hydrocrackers (for the same reasons as in Case A-M30).

(5) Case A-M37

When the crude oil price reaches \$37/kl, methanol is introduced to the amount of 671 x 10^3 kl as a gasoline substitute (gasoline equivalent of 349 x 10^3 kl and to the amount of 453 x 10^3 substitute (kerosene equivalent of 222 x 10^3 kl). The refining pattern is the same as in Case A-M35, resulting in a further increase in kerosene export.

(6) Case A-M38 (= Case A-M)

Only when the crude oil price rises to \$38/BBL, the introduction volume of methanol rises for the first time to 1.6 million tons (2.01 million kl).

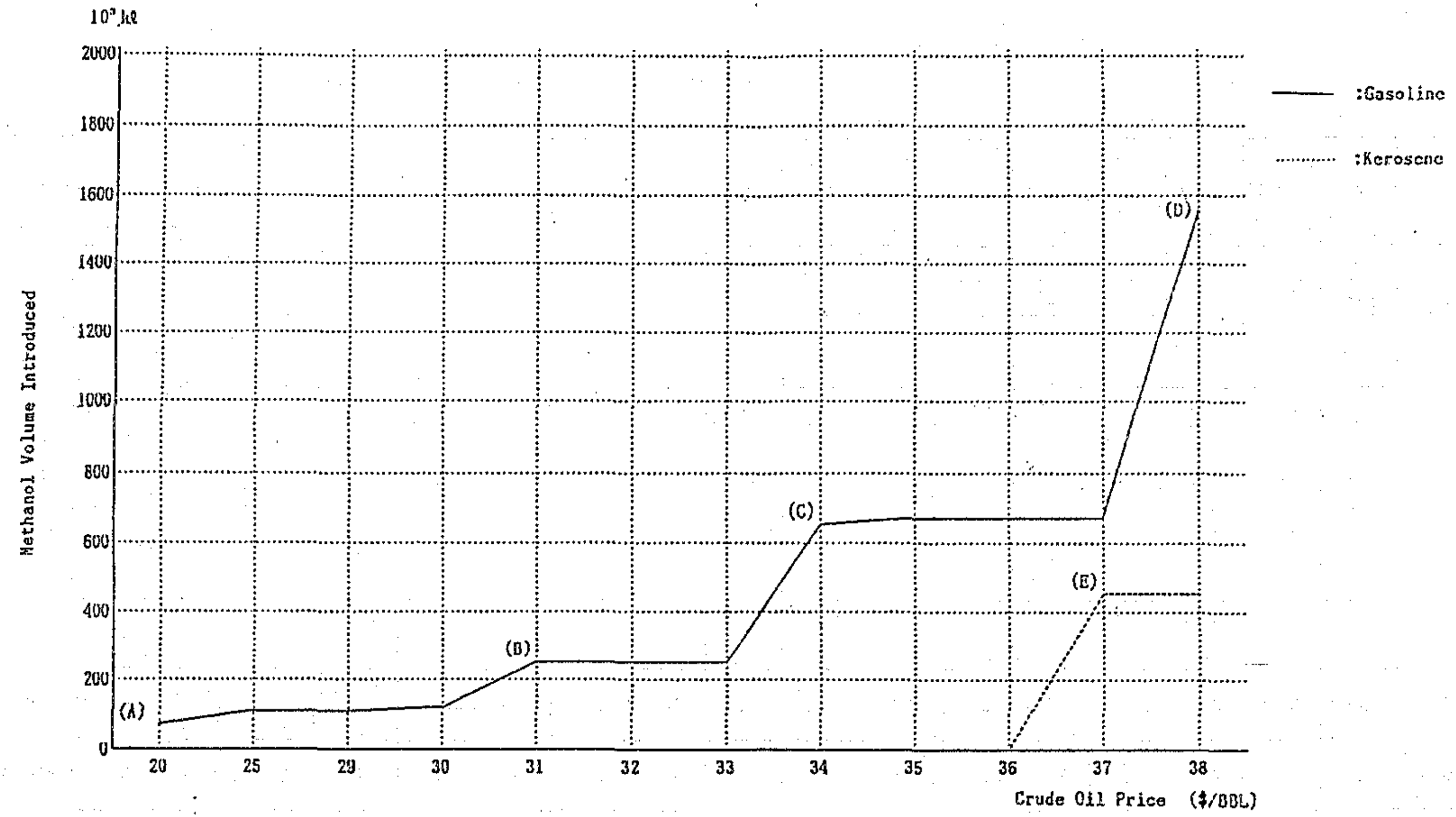
Table 8-3-16

Results of Cases for Methanol Introduction

Cases / Items	A	A－C	A－M	A-M20	A-M25	A-M26	A-M27	A-M28	A-M29	A-M30	A-M31	A-M32	A-M33	A-M34	A-M35	A-M36	A-M37
(1) Crude oil Price($/BBL)	30	30 ↓	38 ↑	20	25	26	27	28	29	30	31	32	33	34	35	36	37
Methanol Price($/kℓ)		111	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139
(2) Methanol volume																	
To Demand Area 2																	
Kerosene market(10^3kℓ)		453	453														453
To Demand Area 3																	
Gas. market (10^3kℓ)		1557	1557	74	110	110	110	110	110	119	252	252	252	656	671	671	671
Kerosene market(10^3kℓ)																	
Total (10^3kℓ)		2010	2010	74	110	110	110	110	110	119	252	252	252	656	671	671	1124
(3) Oil Products Replaced																	
Gas. (10^3kℓ)		810	810	38	57	57	57	57	57	62	131	131	131	341	349	349	349
Kerosene (10^3kℓ)		222	222														222
(4)Relative relation between Methanol price and Crude oil price		1.18	1.16	2.21	1.77	1.70	1.64	1.58	1.52	1.47	1.43	1.38	1.34	1.30	1.26	1.23	1.19

Note: Case A is the reference case with no introduction of fuel methanol.

Fig. 8-3-3 Methanol Volume Introduced (v.s. Crude Oil Price)



Note: 1 Assumptions; Methanol Price 139$/kℓ
Domestic Oil Product Demand ASCOPE Case

2 Through methanol introduction, gasoline delivery for demand area 3 from Cilacap is reduced at such points as (A)(B)(C)(D).

At points (A)(B)(C), gasoline delivery for demand area 4 from Cilacap is increased and that from Dumai is decreased, leaving gasoline production in Dumai reduced.

At point(C), reformate export from Dumai is to start. At point(D), gasoline delivery for Area 5 from Cilacap is increased and gasoline production in Balikpapan is decreased, starting reformate export from that refinery.

At point(E), kerosene delivery for Area 2 from Plaju is to be replaced by methanol. This causes delivery for Area 3 from Plaju increased, that for Area 3 from Cilacap decreased, that for Area 4 from Cilacap increased and finally, that for Area 4 from Balikpapan decreased.

And as a result, kerosene production from Balikpapan is to be decreased.

5. LP Model Study concerning Fuel Ethanol

5.1 Equilibrium between Ethanol Price and Crude Oil Price

Since ethanol is considered mainly as a gasoline substitute, the prospect of ethanol demand has been examined in respect of ASCOPE, which has a bigger demand for gasoline. The results are shown in Table 8-3-17.

Taking as a premise the ethanol production cost from cassava of \$1,326/kl and that from molasses of \$659/kl, all the cases shown below have no economic benefit, if ethanol is simply taken as a substitutive energy.

The pros and cons of fuel-ethanol introduction may be governed by how the merits, other than the economic factors enumerated below, are evaluated.

i) Effectiveness of a smooth execution of the transmigration policy due to ethanol production at the location of transmigration.

ii) Environment-improving effect due to the use of lead-free gasoline (an economic comparison between this effect and that of the octane-number-improving policy by increased installation of reformers should be separately executed).

iii) Effects of preserving domestic oil resources and saving cost of oil resource development due to a reduction of gasoline consumption.

(1) Case A

This case is the same as the reference case used in the methanol introduction. Since the refining pattern is "maximum gasoline yield," naphtha, which is the fuel and feedstock of hydrogen for hydrocrackers, becomes short in supply, and the operation rate of hydrocrackers drops.

(2) Case A-C-1

In this case, ethanol is produced from cassave in South Sumatra and Kalimantan. Production has been set to 395×10^3 kl each, 790×10^3 kl in total. It has also been assumed that ethanol, as a substitute product for oil, will be used as a gasoline substitute in Demand Region 3 and 5 and as a kerosene substitute throughout Indonesia.

At a crude oil price of \$30/BBL, the equilibrium price, which permits the total volume of ethanol produced in both South Sumatra and Kalimantan to be introduced into the market, is \$148/kl.

(3) Case A-C-2

In this case, an equilibrium price has been obtained only for ethanol prodduced from South Sumatra. The result if $168/kl, which is a price $20/kl higher than in Case A-C-1, but still there will be no possibility of an economical introduction of ethanol.

(4) Case A-C-3

In this case, it is assumed that ethanol of 160 x 10^3 kl/year is produced from molasses in Java. At a crude oil price of $30/BBL, the equilibrium price of ethanol produced in Java is $193/kl The reason for the equilibrium at this higher price than the prices in Case A-C-1 and A-C-2 is that because the ethanol is produced on the island of Java, land transportation cost is minimal. In this case also, purely economical ethanol introduction is inconceivable.

Table 8-3-17

Results of Cases for Ethanol Introduction

Cases / Items	A	A-C-1	A-C-2	A-C-3
(1) Crude oil Price($/BBL)	30	30 ↓	30 ↓	30 ↓
Ethanol Price ($/kℓ)		148	168	193
(2) Ethanol volume				
To Demand Area 3 Gas. market $(10^3 k\ell)$		395	395	160
To Demand Area 5 Gas. market $(10^3 k\ell)$		305		
Total $(10^3 k\ell)$		790	395	160
(3) Oil Products Replaced				
Gas. $(10^3 k\ell)$		553	277	112
(4) Relative relation between Methanol price and Crude oil price		1.12	1.27	1.46

6. Prospects of Long-term Demand for Fuel Alcohol

6.1 Fuel Methanol

From the study results of the LP model, the long-term demand for fuel alcohol is projected as follows from the relation between the crude oil price and production cost of methanol:

i) At a crude oil price of \$30/BBL, the economic merit of fuel methanol introduction cannot be expected. Fuel methanol introduction is governed by how to evaluate the effects other than economic factors such as preservation of oil resources, increase in employment opportunities due to industrialization, etc.

   Therefore, it is considered in the present study that no long-term demand for fuel methanol will occur, if the crude oil price is below \$30/BBL.

ii) At a crude oil price of \$30/BBL, a long-term demand of 1.6 million t/yr for fuel methanol exists, if it is supplied at a cost of \$111/kl or below. When methanol is to be produced from Banko coal, a methanol supply at \$111/BBL has only a low economic benefit (IRR: about 9.5%) in view of the investment risk, and thus the present project will not become an attractive one.

iii) Changes in the introduceable quantity of methanol, when the crude oil price is fixed at \$30/BBL and the methanol price is changed from \$111/kl (when IRR is about 9.5% in case of Banko coal) to \$139/kl (IRR: about 13.5%), have not been investigated in the present survey due to time restrictions. After executing an additional study in the future, the long-term demand for methanol (methanol supply capacity viewed from economic benefit) at a crude oil price of \$30/BBL should be judged.

6.2 Fuel Ethanol

i) According to ordinary economic evaluation in a free economic society, no economic values can be found in the introduction of fuel ethanol.

ii) If factors other than pure economic merits are considered, for example, the contribution to the transmigration policy, gasoline octane-number-improving effect, and coal resource preservation effect, there is sufficient room for introducing fuel ethanol. In such a case, the long-term demand for ethanol is 950 x 10^3 kl/yr (160 x 10^3 kl of ethanol from molasses and 790 x 10^3 kl of ethanol from cassave).

8-3-2-(2) Potential Demand by Sectors

1) Transportation Sector

i) Fuel ethanol

While neat ethanol (100% ethanol) is employed as a motor fuel in Brazil, 10-20% ethanol is generally blended with gasoline and widely used around the world, including the United States, the Philippines, Cuba, Ireland and South America.

Ethanol is harmless to the human body. When up to 20% is blended with gasoline, anhydrous alsohol can serve as a motor fuel without requiring any modifications of a gasoline engine. For these reasons, ethanol can easily be introduced as an alternative energy to oil, which forms the first characteristic. Ethanol is also effective as an octane booster. In the United States, some states have already designated ethanol as an octane booster, 10% of which is blended with gasoline. In other words, with ethanol employed as an octane booster, replacing conventional harmful 4-ethyl lead (T.E.L.), favorable effects can be expected in improving the environment.

The octane number of ethanol stands at 106 (RON) and 89 (MON). Study results show that by blending reguar gasoline of low octane number with ethanol of high octane number, the octane number of the resultant motor fuel is enhanced in the research and motor processes alike. By blending 25% ethanol with regular gasoline, the resultant octane number is comparable to that of premium gasoline in both the research and motor processes and the viability of ethanol as a substitute for 4-ethyl lead (T.E.L.) has been fully demonstrated in the United States, where 10% ethanol is blended with regular gasoline.

In the Republic of Indonesia currently in use as an octane booster of gasoline is 4-ethyl lead (T.E.L.). Although environmental problems have not yet become so serious nationwide, Jakarta, the Indonesian capital, seems to have been undergoing a markedly worsening environment due to exhaust gases emitted from autos in the morning and evening rush hours, and may surface as an environmental problem in the near future.

Such being the situation, it would be good to introduce it first in Jakarta and its environs, where autos are concentrated, and endeavor to improve the environment (particularly to eliminate lead-borne pollution) by banning the use of 4-ethyl lead (T.E.L.) as an octane enhancer, which can be substituted for by blending around 10% ethanol with regular gasoline.

The 1985 edition of the Statistical Yearbook of Indonesia states that the number of passenger cars registered in 1984 totalled 925,335 throughout Indonesia.

Of them, 321,837 were registered in Jakarta and its environs, meaning that about one third were in use in and around Jakarta. Hence, as gasoline consumption is assumed to be 4,758 x 10^3 kl in 1995 based on the growth rate planned in Repelita IV, demand for fuel ethanol, if blended with gasoline, would be 160 x 10^3kl/y.

The ultimate demand for fuel ethanol is estimated to total 950 x 10^3 kl a year on the assumption that some 20% of the nation's gasoline needs in 1995 would be covered by ethanol blending.

To sum up, fuel ethanol demand in the transport sector is estimated to total:

160 x 10^3 kl/y at the penetration stage
950 x 10^3 kl/y at the ultimate stage

ii) Fuel methanol

a) Low level methanol blending in gasoline

In the future, this use may be the most important demand for increasing methanol use. However, the uncertainties of substituting methanol for gasoline are substantial. Implementing the widespread use of neat methanol in the transportation sector means the rapid expansion of the down-stream distribution system before the car manufacturer is willing to produce and sell neat methanol-fueled cars. The existing distribution network is not compatible with methanol use. And installing an additional parallel distribution system would mean significant investment costs. For car manufactureers at present, there is no significant impetus to large-scale production of large quantities of methanol-fueled cars.

For that reason low level methanol blending seems to be the preferred solution to introducing methanol in the medium term. The use of methanol as a direct blending component in transportation fuels has been limited to a max. 3% of gasoline mixture. If one assumes methanol will be blended in gasoline consumed in Indonesia, the demand could amount to somewhere around 140 x 10^3 kl/yr.

If one assume that supply of low level methanol blend will be started in major cities, the methanol demand could amount to 48 x 10^3 kl/yr. in the Jakarta area and 28 x 10^3 kl/yr. in the Surabaya area.

b) Neat methanol for gasoline substitution

Introducing neat methanol (M100) to replace gasoline hits on quite severe infrastructure obstacles which have to be solved among car producers, methanol producers and consumers themselves as discussed earlier.

The frequent evaluations of recent years on the potential use of M100 in the gasoline sector are now considered to have ben too optimistic. They do not appear to be realistic during this century. This situation could change radically in the case of interruptions in the supply of crude oil. It must be considered that 99% of transportation fuel is produced from oil, and also the R/P - ratio in Indonesia was 18 at the end of 1985.

Natural gas and coal must be substituted for gasoline to avoid a decrease of oil exports.

c) Neat methanol for diesel oil substitution

Introducing neat methanol to replace diesel oil does not also appear realistic for the time being in Indonesia. However, diesel oil substitution must be done over the long term for the same reasons mentioned above. The consumption of diesel oil in 1995 in Indonesia is estiamted to be 11.8 x 10^6 kl/yr. During the penetration stage, the demand for neat methanol as a diesel oil substitute will be in major cities for use by city buses and trucks and will improve the environment. If one assumes that 10% of diese oil consumption in the year 2000, and 30% in the year 2020 are substituted by neat methanol (100%), then the potential demand for fuel methanol in this sector is expected to be 1360 x 10^3 kl/yr. in 2000 and 4080 x 10^3 kl/yr. in 2020.

d) Total potential methanol in transportation sector

Above estimated demands are summarized as follows:

(10^3 kl/yr.)

	Penetration stage	Year 2000	Ultimate stage
*Low level blend	48 - 76	140	140
*Gasoline substitution	-	240	1430
*Diesel oil substitution	-	1360	4080
Total	48 - 76	1740	5650

2) Power Genertion Sector

Methanol can be applied for large power stations of steam and gas turbines, or 1 - 5 MW class diesel engines or 100 KW - 1000 KW class small and medium diesel engines.

Although the interconnection of the electric grid has been extended, there are still many isolated small power stations of 100 KW class needed in Indonesia. The total number of unelectrified villages was over 53,000 at the end of 84/85. As for rural areas such as PLN region X, V and IX, the electrification rate is a low 2.7%, 2.7% and 5.8% respectively. The rate in Jakarta Raya and Tangerang is the highest, 54%.

Package type generator sets of 100 KW class diesel type alcohol engine seem to have a big potential for using fuel methanol. Assuming the fuel consumpton rate is 0.27 - 0.28 l of ADO.IDO/kWh or 0.6 l of methanol/Kwh in about 10% of total unelectrified villages, total monthly methanol consumption is 180 x 10^3 kl/month.* However, this demand for fuel methanol (2200 x 10^3 kl./yr.) has only max. potential for rural electrification.

Note: 5000 units x 0.5 x 100 kW x 24 hrs. x 30 days x 0.6 = 180 Ml/month

load factor l/Kwh

A long term potential demand study using the LP model mentioned in Section 8-3-2-(1) shows that the consumpton of kerosene will be substituted by fuel methanol in a specific demand pattern and assumed prices of oil and methanol.

This means kerosene used in the household sector can be decreased by electricity use in the household sector and methanol consumption will be increased in the power generation sector.

In Indonesia, typical boiler type power generators are not expected to have a bigger market share for fuel methanol because natural gas and coal are produced in Indonesia and the economics for power generation use in a boiler is superior than that of fuel methanol.

However, the result of the LP model study is reasonable if one assumes that some percentage of increased electricity consumption will be generated through gasturbine power generators and diesel engine power generators using fuel methanol.

Table 8-3-18 shows the power generating capacity of PLN gas turbine power generators were around 950 MW total and that of diesel type was around 650 Mw in 1985/86. The diesel type will be increased to 1280 - 1725 MW but gas turbines will be decreased to 267 - 627 MW in 1993/94.

However, if fuel methanol through a reforming system is applied for gas turbine power generators by making modifications, existing gas turbine power generators will be kept operating because the modification cost is expected to be cheaper than other new power generators and thermal efficiency will be greatly improved. Diesel type power generators will also be the fuel methanol reformer type.

To show potential methanol demand in the power generation sector, it was assumed that existing gas turbine capacity will not be scrapped but modified to fuel methanol use through a reformer.

The fuel consumption (HSD/IDO) of gas turbine power generators in 1985/86 was estimated around 450 x 10^3 kl/yr. If one assumes that all gas turbines will be modified to consume fuel methanol through a reformer in the long term, the potential demand for fuel methanol could amount to

around 870 x 10^3 kl/yr. ($478 \times \frac{9100}{3800} \times \frac{0.28}{0.37} = 868$)

If 20% of new additional diesel type power generation is fuel methanol type through a reformer, the potential demand for fuel methanol will be around 76 x 10^3 kl/yr.

3) Industrial Sector

Diesel oil consumption (ADO, IDO) in industry in 1995 is estimated to be 13800 x 10^3 kl/yr. Detailed usage and volume of ADO and IDO in industry is not clear but is estimated to be for power generation by diesel or gas turbines and for process heating purposes.

Therefore, in this study, the potential demand in industry is estimated based on the following assumptions:

a) 30% of ADO and IDO is power generation use and 30% of consumption could be converted to fuel methanol if the price of metanaol is competitive.

b) 70% of ADO and IDO is process heating and other use and cannot be converted to fuel methanol because of technical reasons.

Then, the potential demand in industry is estimated to be 1400 x 10^3 kl/yr.

4) Household Sector

Fuel methanol is toxic and therefore direct use in households cannot be expected. The long-term prospects using the LP model shows that the kerosene consumed in households will be substituted by fuel methanol through power generation.

Therefore, in this study, the potential demand in the household sector was estimated to be negligibly small.

5) Summary of Potential Demand

(10^3 kl/y.)

	Penetration stage	Ultimate stage
Fuel Ethanol	160	950
Fuel Methanol	48 - 76	8150

Table 8-3-18-(1) Power Generating Capacity in PLN (up to 93/94) (MW)

(1) JAVA

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94
Hydro-P	535	535	885	1235	1241	1770	1884	2064	2564	2564	2739
		–	–	–	(1235)	(1824)	(1946)	–	–	–	(2564)
Oil	1506	1506	1506	1506	1456	1856	1806	1806	1806	1806	1806
		–	–	–	–	–	–	–	–	–	–
Coal	0	400	800	800	800	1200	1600	2000	2400	2800	3200
		–	–	–	–	–	–	(1600)	(1600)	(2400)	(2800)
Geotherm	30	30	30	30	140	140	140	140	250	470	470
		–	–	–	–	–	–	–	–	–	–
Gas T.	645	645	645	645	645	645	645	570	520	100	100
		–	–	–	–	–	–	(520)	(480)	(480)	(460)
Total	2716	3116	3866	4216	4282	5611	6075	6580	7540	7740	8315
		–	–	–	(4276)	(5665)	(6137)	(6130)	(6700)	(7720)	(8100)

Table 8-3-18 (2)

(2) Outside JAVA

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94
Hydro-P	129	179	179	185	202	219	260	386	437	579	734
		–	–	–	–	(203)	–	–	(385)	(385)	(525)
Oil	50	115	180	180	180	180	310	310	310	310	310
		–	–	–	–	–	–	–	–	–	–
Coal				130	130	130	130	180	230	280	430
				(0)	–	–	–	(130)	(180)	(230)	(330)
Diesel	518	567	647	950	1181	1279	1266	1264	1266	1303	1280
		(631)	(740)	(1139)	(1444)	(1570)	(1500)	(1655)	(1667)	(1722)	(1725)
Gas T.	217	280	300	300	300	300	300	300	285	221	167
		–	–	–	–	–	–	–	–	–	–
Total	914	1140	1305	1744	1992	2107	2266	2440	2528	2693	2921
		(1205)	(1399)	(1804)	(2256)	(2383)	(2588)	(2781)	(2827)	(2868)	(3057)

Note: Figures are from the document of PLN' as of June 30,'85.
Figures in parentheses are from the document of PLN as of April, 1986.

Table 8-3-18-(3) Total Fuel Consumption (Unit: 10^3 kl)

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94
1. Diesel P. (HSD/IDO)	492	487	550	636	697	740	748	709	815	829	760
2. Gas.T.P (HSD/IDO)	501	691	478	435	431	433	392	304	240	37	37
3. Oil (MFO)	2403	2690	1883	2038	2675	3004	2833	3034	2953	2996	3350

8-4 Programs for Introducing Fuel Alcohol in Indonesia

8-4-1 Fuel Methanol

(1) Markets and steps for introduction

Long-term demand evaluations based on the LP model show that fuel methanol is paticularly advantageous in economic terms when it is substituted for gasoline and kerosene among the various petroleum products. (See Sec. 8-3-2-(1).) Because the market is big, fuel methanol can be introduced by taking the following steps.

1) Penetration stage

i) Introduction to the gasoline market

To permit the use of the existing gasoline distribution mechanism as well as gasoline-fueled equipment, like autos, without any modifications, blended gasoline to be introduced must feature a methanol concentration as low as 3%. During the penetration stage, it is recommended from the supply system aspect to start marketing blended gasoline primarily in big cities, like Jakarta and Surabaya, where there is huge gasoline demand. At this stage, it can be proposed to utilize the surplus production capacity of the Bunyu methanol plant as a fuel methanol supply source. Methanol can be blended with gasoline at refineries or oil depots close to consuming areas.

ii) Introduction to kerosene market

All kerosene in Indonesia is used for cooking and lighting in the residential sector. LP-model study results support the good economics of fuel methanol as a kerosene substitute. As discussed before, one of the most viable methods of introducing fuel methanol is methanol-fueled power generation/distribution by gas turbines or diesel-type power generators with a town, a village or a group of towns and villages as a unit. However, because this requires technology establishment, including construction/improvement of generating systems (ex. methanol-fueled diesel generators, small reformed-type gas turbine generators, fuel cells), a few model cases alone can be expected during the penetration stage. Accordingly, demand for fuel methanol should also be limited.

2) Ultimate stage

i) Gasoline market

At the ultimate stage, demand for fuel methanol could grow as a result of commercialization of the engines fueled by high methanol-blended gasoline or neat methanol. Assuming methanol supply from Banko brown coal (1,600 x 10^3 t/y, or 2,010 x 10^3 kl/y), 60-80% of the assumed amount (600-800 x 10^3 kl/y gasoline equivalent) would be destined for the gasoline market with Java as the centerpiece. (See AC and KC cases.)

ii) Kerosene market

The most viable method of using methanol is the same as at the penetration stage, while the market would become larger as a result of the establishment of generating systems. Assuming methanol supply from Banko brown coal, 20-40% of available methanol (200-400 x 10^3 kl/y kerosene equivalent) would be destined for the kerosene market. However, where kerosene demand holds a relatively large share in total product demand, resulting in tight supply, the greater part of lignite-derived methanol would be used as a kerosene substitute.

(2) Production Program

The Bunyu methanol plant, completed in 1986 in Indonesia, has a designed capacity of 330,000 t/y, of which some 100,000 t/y is currently excess due to limited demand for methanol from the domestic chemical industry. Also, amid a worldwide oversupply, the export environment is extremely severe, permitting little hope for exports at economically reasonable prices.

Such being the situation, it is recommended to make the best use of some 100,000 t/y of excess capacity at the Bunyu methanol plant in developing markets at the penetration stage.

Because of the current slack supply and demand situation, there are no plans to construct new methanol plants in addition to the Bunyu plant. Accordingly, in parallel with the preparation of plans for using fuel methanol, such as low-concentration blends and neat methanol, it will be necessary to make some plans to supply fuel methanol from natural gas or coal. Meanwhile, methanol production requires a long lead time because it takes as long as 10 years to complete construction of supply equipment from the start of planning.

Also, because metanol production is capital intensive, it is desirable that a methanol plant be operated at as high operating rate as possible from the first day of operation to push fixed costs down. To this end, fuel methanol demand should be expanded by the time an additional methanol plant is put on stream.

(3) Distribution systems and relevant facilities

Methanol is generally characterized by a large production scale at a plant and is produced from natural gas or coal in large quantities. In the Republic of Indonesia, an already established distribution system originates from the Bunyu methanol plant. If an additional large methanol plant is constructed to manufacture methanol from Banko coal, etc., its distribution system is likely to become virtually similar to the existing one. Therefore, while referring to the distribution system from the Bunyu plant, representative distribution systems and relevant facilities are presented below.

1) Upstream distribution system

Methanol produced at the Bunyu plant is sent by pipeline to coastal shipping tanks, from which it is transported by barge, having a capacity of 500-1,000 kl, to depots in Kuang, Merak, Semarang, Surabaya, Samarinda, Banjarmasin, Pangkalanbuun and Ambon. Also, it is planned to forward methanol by barge from these depots to secondary depots. The sites scheduled for construction of such secondary depots include Langsa, Medan, Jambi, Palembang and Pontianak.

Fig. 8-4-1 shows an upstream distribution system, which illustrates transport systems from a methanol plant to depots. Though the transport system will be the same as the existing one, transportation of fuel methanol is likely to require introduction of larger barges, expansion of primary depots, diversification of secondary depots and others because the amount of fuel methanol transported should become larger.

2) Downstream distribution system

Methanol transported by barge to a depot is stored in a tank. Outlined below are methanol transport systems from the tank to end users.

o To factory users:

Methanol is transported by tank truck directly from a tank at the depot to factory users.

o To ordinary users:

For ordianry users whose requirements are large enough, methanol is transported also by tank truck directly from a tank at the depot to the users' tanks.

For ordinary users whose requrements are limited, methanol is shipped by tank truck to distributors, who put methanol into small drums or cans, which are delivered by truck to individual small ordinary users.

Because the amount of fuel methanol transported is larger, it is likely that methanol will be pipelined from a tank at the primary depot to a storage tank at a processing plant (run by PERTAMINA). Also for particular users whose requirements are large enough, such as power stations (PLN), direct transportation of methanol to their own tanks by barge is likely. (See Fig. 8-4-1.)

Fig. 8-4-1 Upstream Distribution System (Bunyu - Depot)

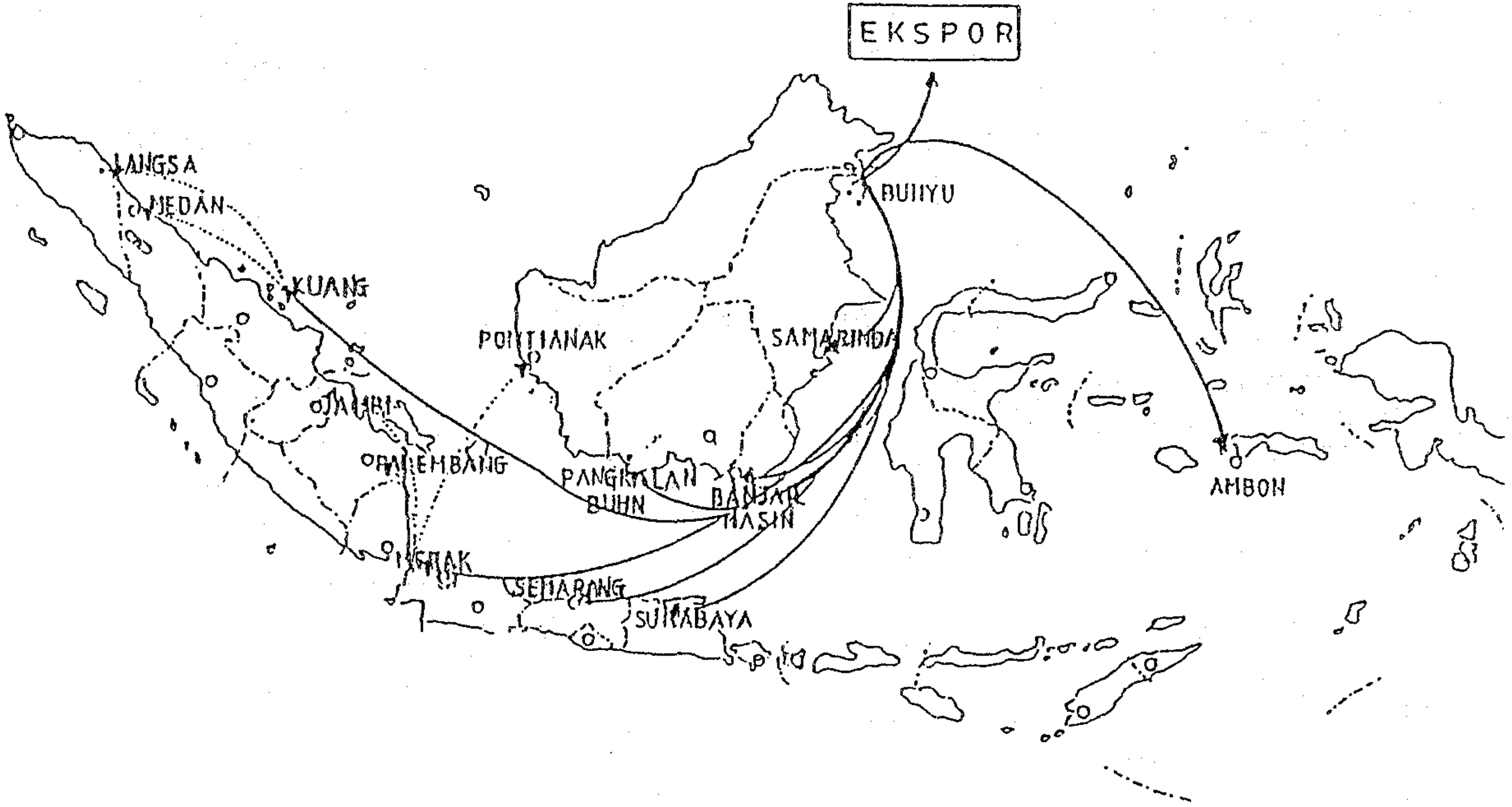


Fig. 8-4-2-(1) Downstream Distribution System

- Chemical Use -

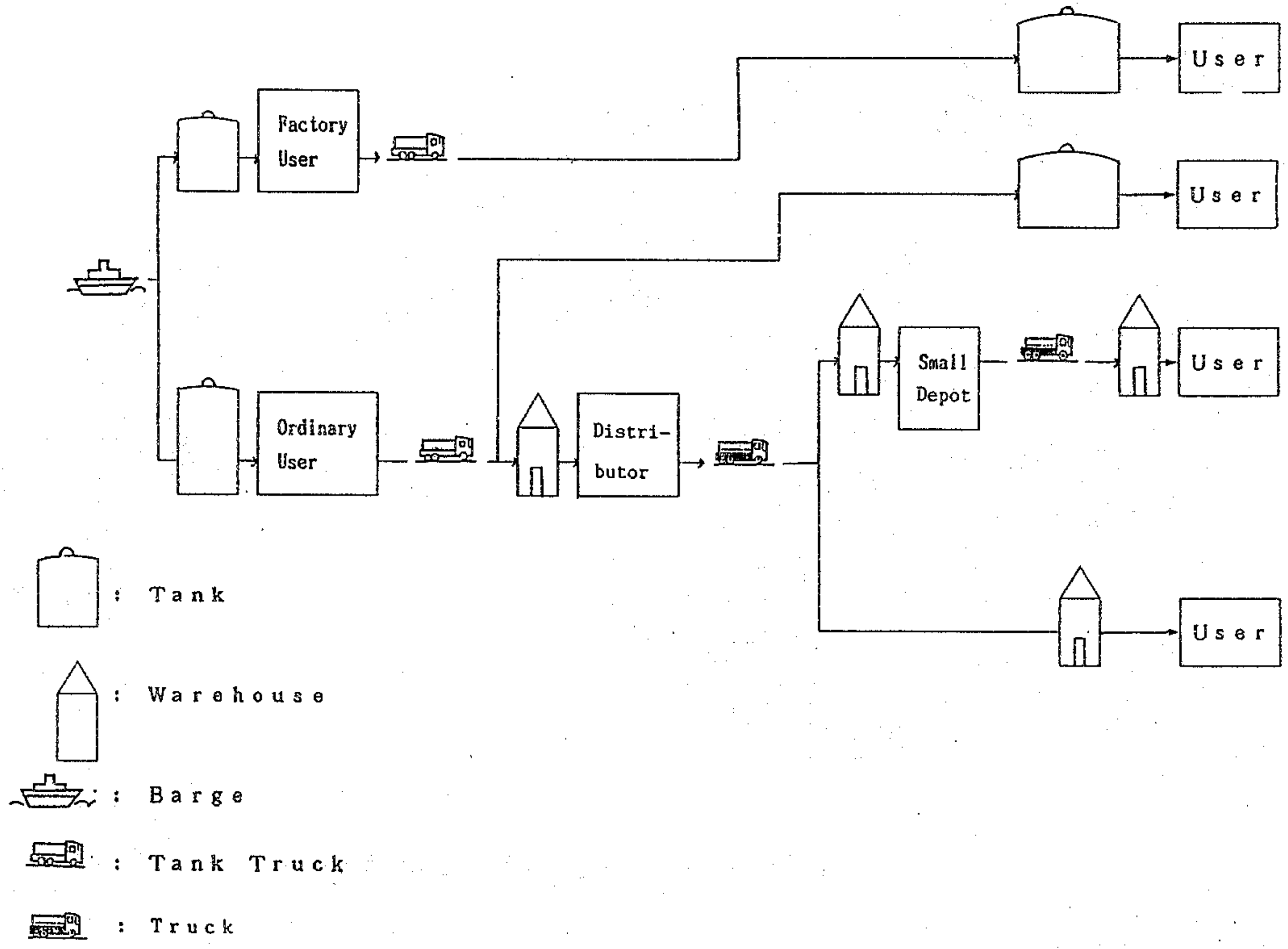


Fig. 8-4-2-(2) Downstream Distribution System - Power generation & Transportation use -