THE EFFECTS OF FUSEL OIL BLENDING ON GASOLINE FUEL CHARACTERISTICS

by

E. Jasjfi

ABSTRACT

Fusel oil, which comprises a mixture of higher alcohols, has prospective potentialities for use as a cosolvent in gasoline-methanol blends since it can improve their water tolerance. This has been demonstrated in an earlier work by the author.

The present paper presents the results of a series of tests made to investigate the effects of fusel oil addition to the actual gasoline fuel characteristics. The results indicated that such additions could result in improving the gasoline properties as can be examined through comparison with the established specifications.

I. INTRODUCTION

Fusel oil is a volatile, oily mixture of alcohols produced as a by-product in alcoholic fermentation of starches, grains, or fruits to produce ethyl alcohol. In Indonesia, this product is mainly available from sugar cane refining. A sample of fusel oil from a sugar mill in West Java was analysed to contain 41.71% ethanol by weight, 0.93% propanol-1, 3.04% isobutanol and 54.31% isoamyl alcohol on the water-free basis; or 35.54% ethanol, 0.79% propanol-1, 2.59% isobutanol, 46.26% isoamyl alcohol and 14.82% water on as received basis (Jasjfi, 1986).

A study by the author (op. cit.) demonstrated the positive effects of fusel oil in improving the water tolerance of gasoline-methanol blend. As fusel oil consists of a mixture of alcohols one would expect that it would increase the octane number of gasoline. But, as it contains oxygenated compounds, with 25.29% by weight of oxygen on the dry basis or 34.14% on the as received basis, it is expected to affect adversely the gum properties of gasoline. Furthermore, there would be a significant change in the distilation curve and vapour pressure of the gasoline. The present paper presents the results of a study which investigates, in the quantitative manner, the effects of addition of fusel oil to gasoline on the latter's characteristics as motor fuel.

II. GASOLINE AS MOTOR FUEL

Gasoline is the hydrocarbon fuel designed for spark ignition engines. Its application involves transfering of the fuel by pump from the car fuel storage tank into the carburettor where it mixes with air. The mixture is then distributed into the engine cylinders where it is compressed and iginited by electric sparks from the spark plug. The combustion energy thus released is transmitted to the power train which ends up in turning the wheels and making the vehicle to move. The combustion gases are then exhausted to the atmosphere as waste gases (Fig. 1 a).

The basic operations, thus, involve storage and transportation of the fuel through the fuel line, preparation of good and uniform air-fuel mixture, and combustion reaction in the cylinders (Fig. 1 b). The properties of gasoline are therefore designed to properly fulfill these functions, and these can be classified into combustion qualities, volatility, and cleanliness and stability characteristics (Fig. 1 c).

Each class of qualities is controlled by specific tests of fuel characteristics. Octane number is used as the measure for combustion quality; distillation and RVP (Reid Vapour Pressure) for volatility; and gum, corrosion, and sulfur content for cleanliness stability and corrosion properties (Fig. 1 d).

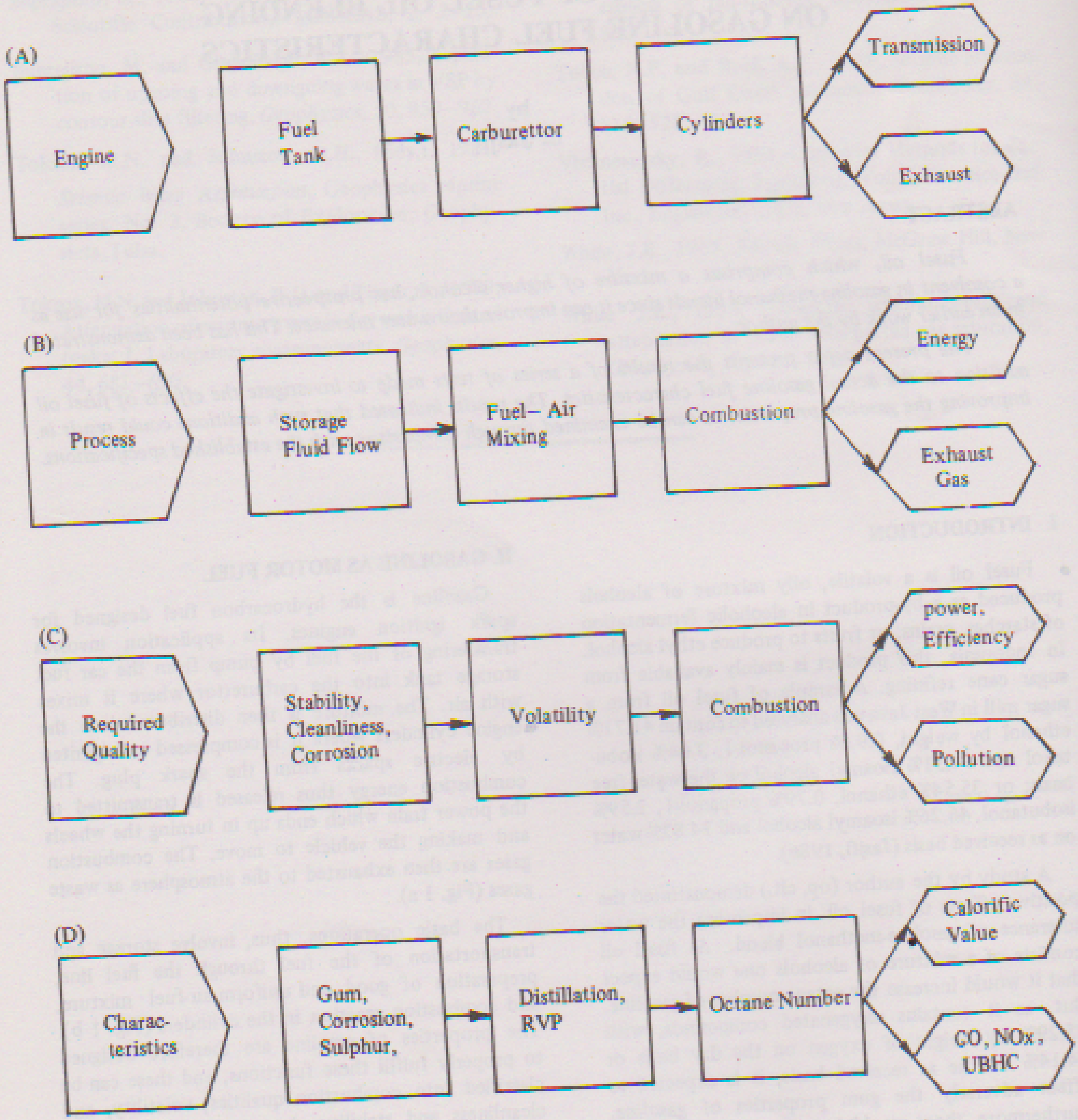

Figure 1 – A Schematic Model for Fuel System in Gasoline Engines

TABLE I

Characteristics of Indonesian Premium Gasoline and its Blends with Fusel Oil

Characteristics	ASTM Test Method	Spec. Limit	Premium Gasoline Sample (0% Fusel Oil)	Blends of Premium Gasoline and Fusel Oil (% vol. Fusel Oil) 5%	10%	15%	20%
Combustion quality							
Research Octane Number (F – 1)	D–2699	87 min	87.1	88.2	89.3	90.3	91.9
Volatility							
Distillation Temp. (°C) at	D–86						
10% evap.		74 max	58.9	53.9	52.8	51.0	48.9
50% evap.		88 min 125 max	102.5	101.7	99.4	98.3	96.0
90% evap.		180 max	147.2	144.4	141.7	140.0	138.0
20% – 10% evap.		8 min	9.9	10.0	10.0	10.8	11.1
Residu % (vol)		2.0 max	1.4	1.4	1.4	1.4	1.4
Reid Vapour Pressure at 100°F (psi)	D–323	9.0 max	6.10	6.77	6.96	7.01	7.16
Cleanliness and Stability							
Gum							
Existent (mg/100 ml)	D–381	4.0 max	0.22	0.36	0.46	0.52	0.64
Stability (induction period, minutes)	D–525	240 min	> 300	> 300	> 300	> 300	> 300
Sulfur/Corrosion							
Sulfur content (% wt)	D–1266	0.20 max	0.042	0.046	0.061	0.074	0.093
Mercaptan (% wt)	D–1219	0.015 max					
(ppm)			0.99	0.95	0.92	0.89	0.85
Doctor test	D–484	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Copperstrip test	D–130	No.1 max	No.1	No.1	No. 1	No.1	No.1
TEL content (mg/AG)	D–526	2.5 max	1.024				
Dye content (g/100 AG)		0.5 max					
Colour		Yellow					
Odour		Marketable					
Specific gravity 60/60°F	D–1298	–	0.7450	0.7469	0.7499	0.7527	0.7567

TABLE I

Characteristics of Indonesian Premium Gasoline and its Blends with Fusel Oil

Characteristics	ASTM Test Method	Spec. Limit	Premium Gasoline Sample (0% Fusel Oil)	Blends of Premium Gasoline and Fusel Oil (% vol. Fusel Oil)			
				5%	10%	15%	20%
Combustion quality							
Research Octane Number (F – 1)	D–2699	87 min	87.1	88.2	89.3	90.3	91.9
Volatility							
Distillation Temp. (°C) at	D–86						
10% evap.		74 max	58.9	53.9	52.8	51.0	48.9
50% evap.		88 min 125 max	102.5	101.7	99.4	98.3	96.0
90% evap.		180 max	147.2	144.4	141.7	140.0	138.0
20% – 10% evap.		8 min	9.9	10.0	10.0	10.8	11.1
Residu % (vol)		2.0 max	1.4	1.4	1.4	1.4	1.4
Reid Vapour Pressure at 100°F (psi)	D–323	9.0 max	6.10	6.77	6.96	7.01	7.16
Cleanliness and Stability							
Gum							
Existent (mg/100 ml)	D–381	4.0 max	0.22	0.36	0.46	0.52	0.64
Stability (induction period, minutes)	D–525	240 min	> 300	>300	>300	> 300	> 300
Sulfur/Corrosion							
Sulfur content (% wt)	D–1266	0.20 max	0.042	0.046	0.061	0.074	0.093
Mercaptan (% wt)	D–1219	0.015 max					
(ppm)			0.99	0.95	0.92	0.89	0.85
Doctor test	D–484	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Copperstrip test	D–130	No.1 max	No.1	No.1	No. 1	No.1	No.1
TEL content (mg/AG)	D–526	2.5 max	1.024				
Dye content (g/100 AG)		0.5 max					
Colour		Yellow					
Odour		Marketable					
Specific gravity 60/60°F	D–1298	–	0.7450	0.7469	0.7499	0.7527	0.7567

The values of each characteristics are specified in the product specification, which refers to the formal stipulation and determines the minimum quality of a product which may be transacted between suppliers and consumers. The product specification is applied for the purpose of protecting the users against damage to the equipment in which the fuel is utilized, and to the people handling it.

The specification limits for gasoline marketed in Indonesia is listed in Table 1.

III. EXPERIMENTAL

The objective of the experiment is to study the effects of fusel oil blending into gasoline to the characteristics of gasoline. A series of mixtures of premium gasoline and fusel oil were prepared, each blend was tested and the results were compared with the current standard specification. These would reveal the maximum amount of fusel oil which may be blended into gasoline before the specification limits are reached.

Gasoline and fusel oil blends containing 0%, 5%, 10%, 15%, and 20% fusel oil by volume were prepared. The gasoline sample used was a typical Indonesian premium gasoline as obtainable from Pertamina's public refuelling station. (It is to be noted that Pertamina is the state enterprise responsible as the sole supplier and dispenser of petroleum fuels in Indonesia). The characteristics of the gasoline sample were as shown in Table 1.

The fusel oil sample which was used as the blending agent was a product of a sugar-cane refinery in West Java, Indonesia. It is a colourless liquid with a sweet odour, and a specific gravity of 0.8524. Its composition and distillation curve have been reported earlier (Jasjfi, op. cit.).

The blends were tested for their characteristics according to the parameters specified in the Indonesian specification for premium gasoline, using the standard test methods stipulated in the specification. Care was taken in maintaining the blends in their original compositions during the test by keeping the samples in clean and sealed coloured glass containers in refrigerated storage during the period of the experiment.

For octane number, the F-1 (research method) procedure was used according to ASTM D-2699 test method. The test employed the standard CFR (Cooperative Fuel Research) test engine of Lemigas Engine Laboratory, operated at 600 rpm test condition. The test comprises comparison of the knocking tendency of the test sample with blends of n-heptane and iso-octane, where the n-heptane is assigned an octane number of 0 and iso-octane and octane number of 100. The octane number of the

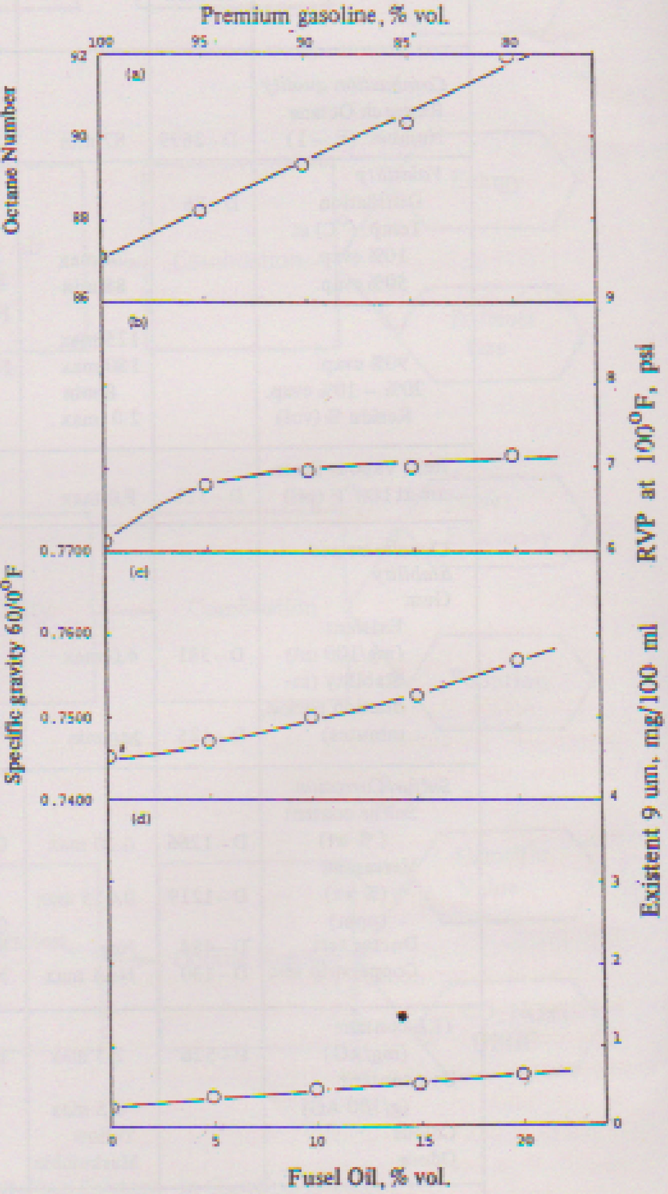

Figure 2 – Effects of fusel oil additon on gasoline fuel characteristics

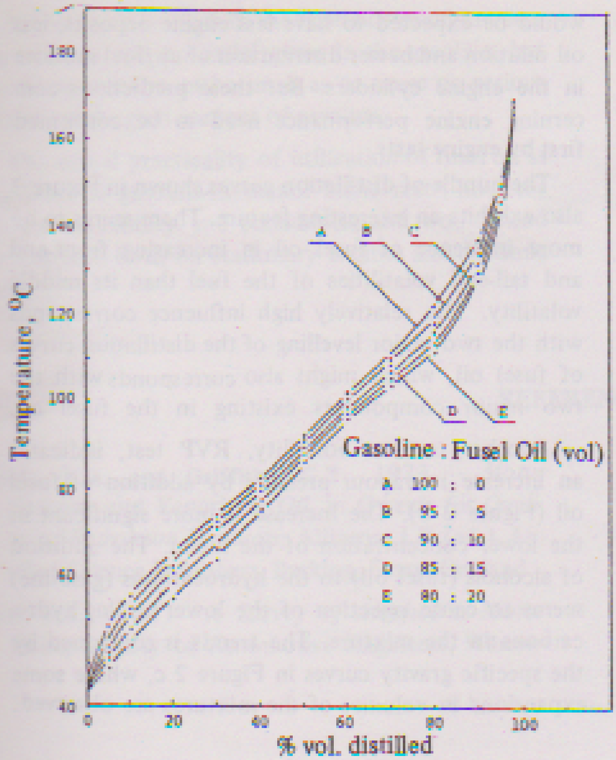

Figure 3 – ASTM distillation curves of gasoline-fusel oil blends

test sample is equal to the percentage of iso-octane in the standard sample which gives the same knock intensity as the test sample.

The ASTM D–86 test method for distillation of petroleum products using the ASTM prescribed standard distillation apparatus and procedure was used for distillation test. The vapour pressure test was conducted in accordance with the Reid method (ASTM D–323) using the Reid vapour pressure apparatus. This test measures the vapour pressure at 110°F.

Existent gum was determined by jet evaporation according to ASTM D–381 method that utilizes a measured and heated stream of air to assist vaporisation. This test indicates the amount of gum at the time of the test. Test on gum stability (induction period) involved heating the gasoline at 212°F in a bomb at a pressure of 100 psi in an atmosphere of oxygen (ASTM D–525).

A number of methods are available in the ASTM procedure for sulphur determination in the petroleum products, among these are lamp method, x-ray fluorescence method, oxygen bomb method, x-ray spectrography, etc., but the suitable method employed in the this study was the ASTM D–1266, lamp method, as stipulated in the gasoline specification of Indonesia. In this test method sulphur is burnt in a closed system, using a standardized lamp, and the oxides of sulphur thus generated are converted by hydrogen peroxide into sulphuric acid. This is then titrated with barium chloride.

Mercaptans comprise a class of odoriferous sulphur compounds which are undesirable in petroleum products due to their corrosiveness and unpleasant odour. It was tested in a quantitative manner according to ASTM D–1219 methods. Qualitatively, their presence was determined by "doctor test" (ASTM D–484).

The corrosion tendency of the sulphur compounds in gasoline was tested qualitatively by the copper strip test (ASTM D–130). This consists of immersing a polished copper strip in gasoline contained in a test tube, and heating it at 112°F for 3 hours. The strip is then washed and dried and inspected for tarnish by comparing it with a set of standard colours.

The lead content, which had been introduced to the gasoline through the additon of tetraethyl lead (TEL) as antiknock improver additive was tested following the ASTM D–526. The test consists of transforming the lead compounds into lead chloride and extracting the gasoline with hydrochloric acid. The extract was evaporated, the organic residues were oxidized by nitric acid and the lead was then determined as lead chromate. Since fusel oil used in this experiment by no means contains any lead compound, this test was applied only to the original gasoline and not to the blends.

IV. RESULTS AND DISCUSSION

The test results for the test blends, namely premium gasoline containing 0%, 5%, 10%, 15%, and 20% fusel oil by volume are presented in Table 1 back-to back with specification limits for Indonesian premium gasoline. A cursory view of the figures as a whole immediately indicates that the addition of up to 20% fuel oil would not make the gasoline off-specification. However, the effects of fusel oil on each of the specification parameters deserve some comments.

A. Combustion Characteristics

Addition of fusel oil improves the combustion characteristics of gasoline as evident from the increase in octane number almost linearly from 87.1 to 91.9 at 20% vol. fusel oil (Figure 2a). The positive effect of fusel oil on octane number is only to be expected, since alcohols seem to have relatively high octane number as exemplified by methanol which has a Research Octane Number of 112 (Dartnell, 1978) and ethanol which has 106 RON, (Bolt, 1980). If the linear trend as shown from the graph continues, one would expect the Research Octane Number of fusel oil to be approximately 111. The actual figure, however, could only be determined by direct measurement.

The increase of octane number in the blend is accompanied by an additional benefit, namely a decrease in TEL content. A gasoline blend designed to have 87 Research Octane Number would then require less TEL and emits cleaner exhaust which contains less lead to the air.

B. Vaporization Quality

The ASTM distillation curves for the blends are presented in Figure 3. Fusel oil seems to lower the boiling curves of the fuel, and this is of advantage in the case of 10% and 90% evaporation temperatures where maximum limits are specified. In the case of the 50% evaporation temperature which has upper and lower limits, the blending of fusel oil appears to push the distillation curves nearer to the lower limit, although the margin is still relatively large. It seems, from the inspection of the curves, that the limit would only be touched by the addition of approximately 40% by volume of fusel oil.

Considering that the 10% distillation point controls the the ease of starting, the engine would be easier started with the blends, although, on the other hand, the vapour lock tendency would also increase. The 50% distillation point has influence in the warm-up, acceleration and pick-up, and the engine would be expected to have better performance in these regards. With the better tail-end volatility, as indicated by the lowering of 90% distillation temperature, the engine would be expected to have less engine deposits, less oil dilution and better distribution of air/fuel mixture in the engine cylinders. But these predictions concerning engine performance need to be confirmed first by engine tests.

The bundle of distillation curves shown in Figure 3 also exhibits an interesting feature. There seems to be more influence of fusel oil in increasing front-end and tail-end volatilities of the fuel than its middle volatility. The relatively high influence corresponds with the two major levelling of the distillation curves of fusel oil, which might also corresponds with the two major components existing in the fusel oil.

Another test on volatility, RVP test, indicates an increase in vapour pressure by addition of fusel oil (Figure 2 b). The increase is more significant in the lower concentration of the blend. The addition of alcohols (fusel oil) to the hydrocarbons (gasoline) seems to cause rejection of the lower boiling hydrocarbons in the mixture. The trends is confirmed by the specific gravity curves in Figure 2 c, where some expansions in volumes of the mixtures are observed.

C. Cleanlines and Stability

The addition of fusel oil increases the existent gum in the fuel, (Figure 2c) and it is expected that the stability would be reduced, although this cannot be observed in the induction test period. The tests were terminated at 300 minutes as specified in the standard procedure. Very probably, the induction period would be lower at higher concentrations of fusel oil, as it is believed that addition of oxygenated compound would favour the formation of gum.

Addition of fusel oil seems to introduce trace amounts of sulphur, as the manufacture of fusel oil involves treatment of molasses with sulphuric acid. But the sulphur contents are very small, far below the specification limit of 0.20% by weight for gasoline. Similar observations were also made on mercaptan sulphur, doctor test, and copperstrip corrosion test.

V. CONCLUSIONS

Addition of fusel oil into gasoline results in positive effects on the fuel properties of gasoline. This would enhanced the advantage of using fusel oil as the cosolvent in the gasoline-methanol blend.

The oxygen content in the fusel oil would increase the existent and potential gums in the gasoline, but the increase seems ot be small as to cause no serious effects on the gum content of gasoline.

The actual practicality of utilization of fusel oil as cosolvent in gasoline-methanol blend rests, however, on its availability and economics, and would need further tests both on stationary engines and dynamic ones.

Acknowledgement

The author wishes to express his thanks to the management and staff of LEMIGAS Laboratories for support in the laboratory facilities and to Miss Arfiyanti of Andalas University for assisting in the experiments.

REFERENCES

Boldt, K.A. and Griffiths, G.T., 1973 – *Motor Gasoline and Vaporizing Oil*, in *Criteria for Quality of Petroleum Products*, Allinson, J.P. (ed.), Applied Science Publishers, Barking, Essex, England.

Bolt, J.A., 1980 – *A Survey of Alcohol as Motor Fules*, Society of Automotive Engineers, Warrendale, P:A.

Dartnell, P.L., 1978 – *Future Fuels and Engines*, Octel Publications, Op 78/1.

Jasjfi, E., 1986 – *Fuel Oil and Its Potential as a Cosolvent in Gasoline-Methanol Blends*, LEMIGAS Scientific Contributions, No. 2/86.