

COOPERATIVE DETERMINATION OF OCTANE REQUIREMENT FOR CAR POPULATIONS IN ASEAN COUNTRIES

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ABSTRACT

The supply of motor gasoline at the correct octane level is of utmost importance to every country since it bears economic and technical consequences in the cost of energy supply and in the maintenance and replacement costs of engines. The determination of the actual octane requirement of the existing car population, on the other hand, is a tedious and costly activity. Better results and less cost could be incurred through a cooperative approach by several countries.

The paper describes the significance of octane requirement, its method of measurement, and presents the results for Indonesia. Based on this experience a strong recommendation is made for a cooperative determination of octane requirement in the ASEAN region.

I. INTRODUCTION

The gasoline markets in most countries are generally supplied with several grades of motor gasolines, such as regular, premium, super, special gasolines, etc. These names are but labels used commercially to indicate the quality of the gasolines, particularly their antiknock quality as shown by the octane number.

An earlier survey on gasoline specifications in ASEAN countries indicated that, with the exception of Malaysia, two grades are available in each country, i.e. regular grade and premium grade, although the names may be different from one country to another. In Indonesia, the low grade gasoline is called premium

and the higher grade, super. Malaysia, however, has four grades ranging in octane number from 85 to 100. The complete tabulation of grades, names, and colour of gasoline in five ASEAN countries is reproduced in Table 1 [4].

Normally, the octane number of the regular grade and the premium grade of gasoline should be made to fit the octane requirement of the car population in each country. And this can only be done by actual measurement of octane requirement level in the car population in the respective country. It is not known whether this is done by all ASEAN countries. In Indonesia, LEMIGAS RD Center for Oil and Gas Technology has carried out this activity since 1975 [5]. In most developed countries this is done on an annual

Table 1
Grades, Names, and Colour of Gasoline in ASEAN Countries [4]

RON	81	83	85	87	91	92	93	95	97	98	100
Indonesia				Premium						Super	
Malaysia			Grade 85		Grade 91				Grade 97		Grade 100
Philippines	Regular						Premium				
Singapore						RMG(S)			PMG(S)		
Thailand		Regular						Super			
Colour	Orange	Red	Orange	Yellow	Blue	Orange	Red	ASTM 0.5-1.0	Red	Red	Green

basis.

The present paper describes the method of determination of octane requirement level of the car population that can be done in ASEAN countries and the results so far for Indonesia. This is presented with the view of developing a cooperative approach for this determination. Such approach may give better results, reduce cost, permit the sharing of the technology and experience, and fulfill the cooperative spirit upon which ASEAN (Association of South East Asian Nations) was founded. Such study could be carried out by organization such as ASCOPE (ASEAN Council on Petroleum) which is an official ASEAN instrument on oil and gas matters.

II. THEORETICAL BACKGROUND

A. Octane Level of Gasoline and Energy Conservation

The supply of correct octane level of gasoline, as actually required by the existing car population is very important from the point of view of energy conservation. It is a well known fact that the supply of gasoline at a higher octane level than required by the car population is wasteful, since every octane number in the gasoline higher than that existing in the crude requires an additional amount of crude oil for its production. The values of incremental oil usage in the production of unleaded gasoline at various octane numbers as illustrated in Figure 1 is based on the data published by Dartnell [1]. It can be seen that to increase the octane number from 89 ON in the straight run naphtha to 96 ON in the finished gasoline, for example, over 3% more crude oil is required; to make it 98 ON, nearly 9% more crude oil is used.

On the other hand, if the octane of gasoline supplied is lower than that required by the car population a waste in gasoline consumption in the car will be observed. The figures of 1 to 1.4% with the average of 1.3% are often quoted as the incremental effect to the gasoline consumption of the vehicle of every octane number lower than that required by the engine [3,9].

Therefore, the correct matching of the octane level of the gasolines supplied in the market with the

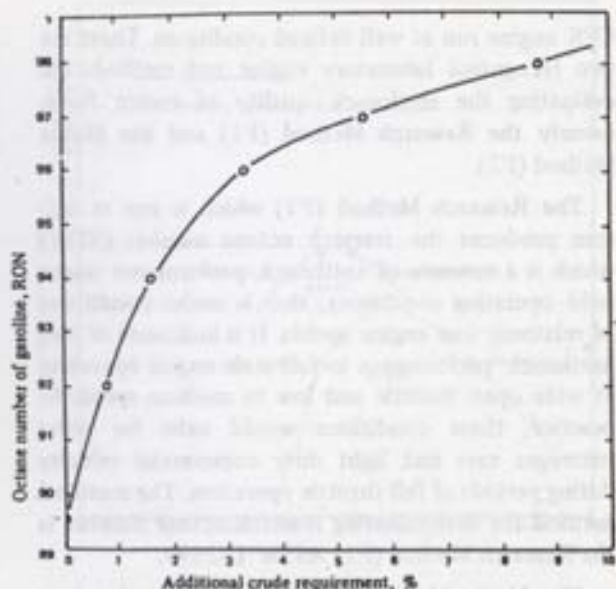


Figure 1. Additional crude oil required to produce higher Octane number than originally present in the crude (89.5 RON)

actual requirement of the car population is of very great importance from the energy conservation point of view.

B. Factors Affecting Octane Number of a Fuel

Octane number is a quality of gasoline which relates to its combustion properties. Gasoline of higher octane number has less tendency to produce knocking, which is a form of abnormal combustion, compared to that of lower octane number. Hence the octane numbers of a gasoline is the measure of the antiknock quality of the fuel.

Knocking which manifests itself by a characteristic metallic noise and has detrimental consequences, such as loss of power, strong vibrations with local over-pressure on mechanical parts, and engine overheating which may have an adverse effect in terms of power loss and possible damage to engine.

The octane number of a fuel is defined as the percentage by volume, to the nearest tenth, of ASTM isooctane (equal to 100.0) in a blend with n-heptane (equal to 0.0) that exactly matches the knock intensity of the unknown sample when compared according to standard methods.

The standard method to measure the octane number of a fuel is by the use of a standard single cylinder

CFR engine run at well defined conditions. There are two recognized laboratory engine test methods for evaluating the antiknock quality of motor fuels, namely the Research Method (F1) and the Motor Method (F2).

The Research Method (F1) which is run at 600 rpm produces the research octane number (RON) which is a measure of antiknock performance under mild operating conditions, that is under conditions of relatively low engine speeds. It is indicative of fuel antiknock performance in full scale engine operating at wide open throttle and low to medium speed. In practice, these conditions would exist for most passenger cars and light duty commercial vehicles during periods of full throttle operation. The standard method for determining research octane number is the Research Method (F1) ASTM D-2699.

The Motor Method (F2), on the other hand, is run at 900 rpm and measures the motor octane number (MON) or the antiknock performance of a gasoline under more severe operating conditions, that is under conditions of relatively high inlet mixture temperature and a relatively high engine speeds. It is indicative of fuel antiknock performance for full scale engine operating at wide open throttle and high engine speeds. In practice, these conditions would exist for many passenger cars and light duty commercial vehicles during the periods of power acceleration or climbing on hills. It would apply to many commercial heavy duty vehicles during any period of high power output. The motor octane number is determined by the standard Motor Method (F2) ASTM D-2700.

As a property of the fuel, the octane number depends to a great extent on the chemical nature of the hydrocarbon fuel itself and the use of additives or components to increase the octane number.

Most gasoline presently used are hydrocarbon fuels produced in petroleum refineries. It is composed of several types of hydrocarbon such as normal paraffines, isoparaffines, olefines, aromatics, and naphthenes. Each of the hydrocarbon type has different antiknock properties, and they further vary with their respective boiling points. The actual compositions of gasolines vary from one to another, depending on the crude oils used and their refining methods, as well as the components which go into the gasoline blend. The actual octane number of the gasoline depends on the

composition and the interaction between the components.

Certain products derived from other sources than petroleum such as alcohols, ketones, amines, etc., may have good antiknock qualities and can be used to increase the octane number of the fuel, but the chemicals mostly used as antiknock additives are tetraethyl-lead (TEL) and tetra-methyl-lead (TML), usually in association of ethylene dichloride and ethylene dibromide as scavenger. The amount used is generally small, and lately, unleaded gasolines are promoted on account of the pollution effects of lead compounds. The lead content of gasolines sold in ASEAN countries vary from a low 0.4 g/L in Singapore and Malaysia to 1.16 g/L in the Philippines [4]. But Singapore has lately reduced its gasoline lead content to 0.15 g/l. Other countries in the region might follow soon.

The use of octane boosting oxygenated compounds such as methanol and higher alcohol, and MTBE (methyl tra-butyl ether) has lately entered into gasoline manufacture, mainly as a replacement of lead compounds which have been known to cause detrimental air pollution. Countries such as the Philippines has, at various times, experimented with alcogas, while Malaysia has plan for the construction of an MTBE plant. Indonesia is conducting a number of research activities for finding the most suitable lead substitute for the country.

C. Octane Requirement of a Car and a Car Population

While octane number is a quality of a fuel, the octane requirement is characteristic of the engine. The octane requirement of a car indicates the octane number of a fuel which would not produce knocking when used in that particular car. If a car is run with a fuel having octane number less than its octane requirement, abnormal combustion will occur as evident from knocking sounds, with the subsequent detrimental effects to the engine and power output as described above. The loss of power will result in increase in fuel consumption.

If a higher octane number of fuel is used compared to the octane requirement of the car, no adverse effect may be observed, except that the production of high octane gasoline may involve higher consumption of crude oil and higher cost. Therefore, from the

economic point of view and in the interest of energy conservation, it is very important that the octane number of the gasoline supplied matches correctly with the octane requirement of the car.

The octane requirement of a car is determined by actual measurement on the road. The most commonly used method is the CRC-E-15-62 method by the Coordinating Research Council in the USA. This method was also adopted by the CORC (Cooperative Octane Requirement Committee) in Europe and has been applied in Indonesia by LEMIGAS. This method consists of the determination during acceleration of the speed where knocking appears and disappears when using reference fuel mixtures having octane number between 80 to 100, with one unit increment.

This measurement is made with the vehicle to be tested has been adjusted so that spark advance is set at manufacturer's recommendation, and the engine must be first allowed to reach its thermal equilibrium. Observations are then plotted on a graph such as Figure 2, where in the abscissa engine rotation speeds are recorded, and in the ordinate, the octane number of the reference fuel mixture are recorded. The maximum value of the curve obtained is called the octane requirement of the car that is being tested. In the CORC method the observations are made for engine speeds between 1000–3500 rpm at highest gear. This corresponds to the speed of 20–80 km/hour, which seem suitable for ASEAN driving, where highway driving does not currently predominate.

In practice, it is important to know the octane requirement of the car when using commercial gasoline. In this case, the measurement is carried out by using blends of gasolines made of commercial gasoline components having research octane number between, say 80–100 RON. This commercial reference fuel should have a chemical composition, specific gravity, and distillation curve similar to the commercially available gasoline in the country. Similar curve relating the octane number and engine speed is produced, and the octane requirement of the car based on average commercial gasoline is determined from the maximum value of this curve.

The knowledge of the octane requirement of a car allows its manufacturer to match its octane requirement with the octane level of the fuels available in the country in which the car will operate. Inversely, to determine the octane level of fuels so as to satisfy

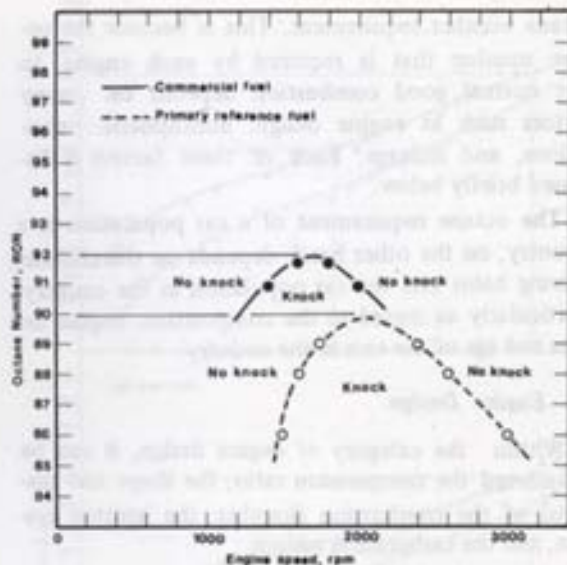


Figure 2. Curve for determination of octane requirement of a car

the users of a given country or region, it is necessary to measure the octane requirement of the car population in the country or region considered.

This consists of studying the octane requirement of a large number of cars as to be representative of the population considered. For example for cars population of 1 000 000 vehicles, for example, a sample of 100–500 cars may be required to determine the level of octane number to be supplied in the market. In Indonesia, samples of 50 cars were used. These samples were taken from cars up to 5 years old which represent the car population of the country [5,6].

The octane requirement curves, for primary reference fuel, allow the refinery or the government to determine the desired level of octane number to be incorporated in the gasoline to the market. Generally, regular grade is made to satisfy 50% of car population, and premium grade to satisfy 90% of the car population. However, this is subject to many economic and non-technical factors, and is largely a policy matter.

D. Factors Affecting Octane Requirement

Not all engines have the same octane number requirement that would give normal combustion. Each engine under each operating condition has different

octane number requirement. This is because the octane number that is required by each engine to give normal good combustion depends on many factors such as engine design, atmospheric conditions, and mileage. Each of these factors is discussed briefly below.

The octane requirement of a car population in a country, on the other hand, depends on the climate, driving habit and the car population in the country, particularly as regard to the composition, engine design and age of the cars in the country.

a) Engine Design

Within the category of engine design, it can be considered the compression ratio, the shape and material of the combustion chamber, the ignition system, and the carburation system.

Compression ratio, i.e. the ratio of the volume of air and fuel when the piston is at the lower end of the cylinder, to the volume when the mixture is compressed and the piston is in the topmost position, is the most important factor which affects the combustion qualities of fuel. In general, the higher the compression ratio the higher the tendency of the engine to knock, and the higher the octane number of the gasoline that should be used. In some cases, octane number requirement increases from 75 to 95 as the compression ratio of an engine is increased from 6.0 to 9.0 [10]. A European study indicates an increase in octane requirement in the range of 4.3 to 6.3 ON per unit increase of compression ratio [3]; while the British Technical Council (BTC) concluded that an average figure of 5.6 increase in octane number requirement/unit increase in compression ratio applies generally to the current engine designs [8]. The reduction of compression ratio, on the other hand, affects the fuel consumption. The British Technical Council found that fuel consumption increased by 7.6% for each drop in compression ratio, and the Committee of Common Market Automobile Constructors (CCMC) came up with the figure of 5.6%. Both these figures refer to smaller European engine. For pre-1973 American cars, the figure was 5.9% [2].

The shape and design of the combustion chamber bears an effect on the octane requirement of the engine. Engines with similar compression ratio, but with different design of combustion chambers may require different octane numbers of gasoline to produce no-

knock combustion. The material of construction of the combustion chamber also affects the octane requirement of the engine. This is due to better heat transfer that may occur through certain light alloys.

With regards to the ignition system, spark advance and spark plug types and gaps are known to affect the octane requirement of an engine. One degree variation in spark advance may cause about one point difference in octane requirement [10].

The richness of the fuel/air mixture in the carburation system has also a marked effect on the octane requirement. This variation in octane requirement as caused by variation on the carburetted mixture can be as high as 1-5 ON points [10].

b) Atmospheric Condition

Temperature, pressure and humidity all may affect the octane requirement of a car. Octane requirement of a car in one country may not be the same in another country with different climate.

Increase in temperature may cause increase in octane requirement. One test showed that the average octane requirement increase is about 0.05 points per °C in crease in ambient temperature [10].

The atmospheric pressure directly affect the octane requirement of an engine. The variation follows a certain empirical formula, but on average the octane requirement of a car decreases about 4.4 points as one mounted from sea level to about 1000m altitude [10].

Humidity has been reported to reduce the octane requirement of a car which may decrease as far as 3-4 points during rainfall [10].

c) Mileage of Car

The mileage of the car may cause variation on octane number requirement. Generally, the octane requirement of a car increase up to 4-10 from the running-in period to about 10-20,000 km, where it reaches stability and flattened down [10]. Therefore the age of the car in car population in a country have also bearing on the octane requirement level.

III. METHOD OF MEASUREMENT

The study of octane requirement of car population consists of the following main steps :

1) Study of car population

The statistics on car population in the country is first collected to know number, and types of the cars in the population. These statistics must be of such details as to indicate the brand, type, year of make, etc., of the cars in the population.

2) Determination of the number composition of car sample

The sample cars to be tested is representative of the actual composition of the car population. If 1983 Toyota Corolla DX, for example, represents 2% of the actual car population in the country, this should also comprise 2% of the sample. If the number of cars in the sample to be tested is decided to be 100, for example, then two 1983 Toyota Corolla DX should be tested.

3) Measurement the octane requirement of each car in the samples

For each car in the sample, octane number requirement measurements are made on primary reference fuel and commercial reference fuels. The measurements are carried out following the method described in part II.C of this paper.

4) Plotting and evaluation the results of all the measurements in an octane requirement curve

The results of the measurements are plotted in a curve of octane requirement for the particular car population, where the octane requirement is plotted on the ordinates; and on the abscissa, the percentage of the car population satisfied by each octane value. Two curves should be obtained, one for each type of reference fuel, respectively.

IV. RESULTS FOR INDONESIA

The results of octane requirement determinations for Indonesia are presented in Figure 3(a), (b), and (c) for the car population of 1969-1974, 1972-1976, and 1978-1982, respectively. Two curves are presented for each period of car population, one being for primary reference fuel, and another for the actual commercial fuel.

The results for Indonesia as shown above show the evolution of the octane requirement of the car population as signified by the octane requirement for 50 percent and 90 percent satisfaction. As indicated

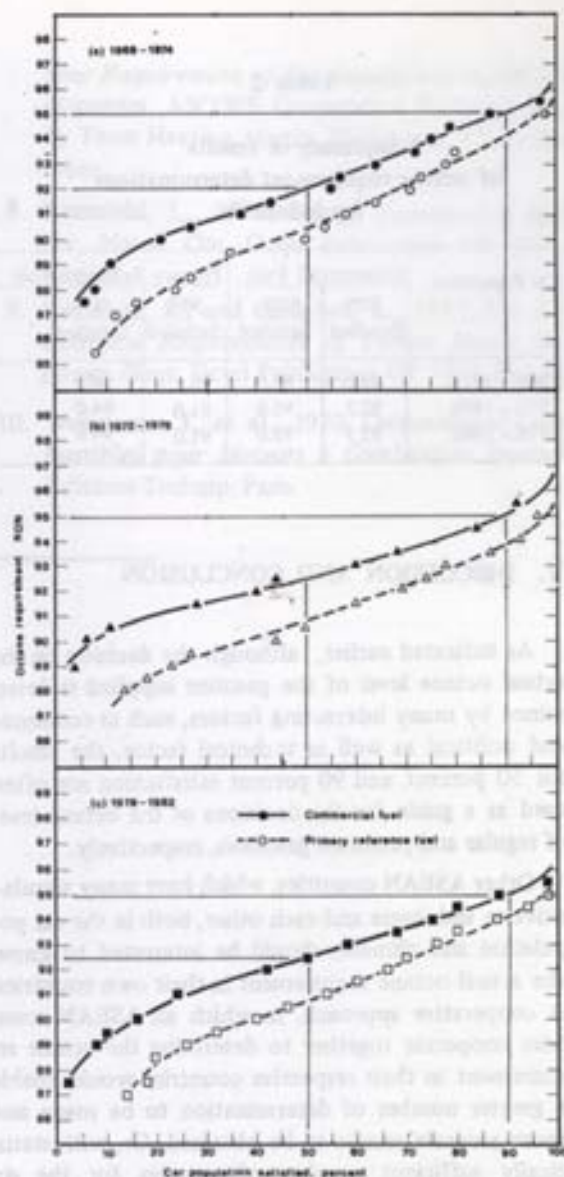


Figure 3. Octane requirement curves for Indonesian car populations

in Table 2, although the shapes of the curves change somewhat, the 50% satisfaction levels and the 90% satisfaction level do not change greatly during the periods. The 50% satisfaction level is 92.0 RON for 1969-1974 population and changes to 92.5 for 1972-1976 and 1978-1982 populations. The 90% satisfaction remains from 95.0 during the three periods. The finding is interesting when one compares the figures to the level of octane supplied in Indonesia and other ASEAN countries as shown in Table 3.

Table 2

Summary of results
of octane requirement determinations
for Indonesia

Car Population	Commercial Fuel		Primary Reference Fuel	
	50% Satisfied	90% Satisfied	50% Satisfied	90% Satisfied
1969 - 1974	92.0	95.0	90.5	94.0
1972 - 1976	92.5	95.0	91.0	94.0
1978 - 1982	92.5	95.0	91.0	94.0

V. DISCUSSION AND CONCLUSION

As indicated earlier, although the decision on the actual octane level of the gasoline supplied is determined by many interacting factors, such as economic and political as well as technical factor, the results for 50 percent and 90 percent satisfaction are often used as a guide for the decisions of the octane level of regular and premium gasolines, respectively.

Other ASEAN countries, which have many similarities to Indonesia and each other, both in the car population and climate, should be interested to know the actual octane requirement in their own countries. A cooperative approach, in which all ASEAN countries cooperate together to determine the octane requirement in their respective countries would enable a greater number of determination to be made and more accurate results to be obtained. Or, with statistically sufficient number of samples for the six ASEAN countries (Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, and Thailand) the cost would be significantly reduced.

In the United States, such study is coordinated by the ASTM (American Society for Testing and Materials) and the CRC (Coordinating Research Council Inc.). In Japan, the cooperative effort is made by Japanese oil companies, so that each company is responsible to test only 6-7 cars. In Europe, this study is carried out cooperatively by CORC (Cooperative Octane Requirement Committee), a committee comprising some oil companies in Europe.

Table 3

Comparison of Indonesian results
with actual octane levels in ASEAN countries

	"Regular" Level RON	"Premium" Level RON
Average measurement in Indonesia	92	95
Actual level in Indonesia	87	98
Malaysia	91	97
Philippines	81	93
Singapore	92	97
Thailand	83	95

Similar approach could be effected in ASEAN, capitalizing on the Indonesian experience and the predominant spirit of cooperation among ASEAN countries. ASEAN instrument for oil and gas cooperation such as ASCOPE could take an active role in this regard.

The cooperative approach in the ASEAN countries has the following advantages:

- (1) it permits exchange of information and mutual assistance by members especially to those who have not had the relevant experience,
- (2) it permits the sharing of the results and therefore improve the accuracy and general quality of the determination,
- (3) it permits, in the future, to develop a system to distributes the responsibility of determination, and thus reduce the number of test each member country must make, with the subsequent reduction of cost and expenditure.

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