# GASOLINE SPECIFICATIONS IN THE ASEAN COUNTRIES

by
E. Jasjfi

**ABSTRACT**

*Gasoline is one of the most important petroleum products which is directly used by a large section of the general public. Countries of the Southeast Asia have been cooperating closely in many fields, including the petroleum industry.*

*In view of the facts, it would be of prime interest to examine and compare the gasoline specifications in the ASEAN countries.*

*This paper presents the results of the study, based on the official standard specifications in force in five ASEAN countries. Their similarities and differences are emphasized, as well as their significance.*

## I. INTRODUCTION

ASEAN (Association of South East Asian Nations) is a regional cooperation which comprises six countries of the Southeast Asia, namely Brunei, Indonesia, Malaysia, the Philippines, Singapore and Thailand. With the exception of Brunei which joined ASEAN quite recently, national oil companies in these countries established also an organization as a special instrument for regional cooperation in the field of oil and gas. It is known as ASCOPE (ASEAN Council on Petroleum) and is aimed at promoting active collaboration and mutual assistance among its members in the development of petroleum resources in the region.

In view of the close cooperation existing among these countries, and the fact that the climate and many other conditions are quite similar, it would be of considerable interest to analyse and compare the specifications of petroleum products in the region. Such information would provide better views concerning the interchangability of the products between the countries; such situation might become necessary in light of the firmness of the spirit of mutual assistance upon which the association was based. The information revealed from this study might also throw additional light to any country in the region in the event of considering of making adjustment to its standard specification.

The present paper is limited to the specifications of gasoline in the five original ASEAN countries. The data used in this study were extracted from the standard specifications decreed by the Directorate General of Oil and Gas in Indonesia, the Malaysian Standard MS 118:1973 (updated for lead content), Philippine National Standard PNS 19:1984, Singapore standard specification of January, 1985, and the fuel specification of the Thai Ministry of Commerce and Thai Industrial Standards Institute.

## II. GENERALITIES

The specification of a product is a formal stipulation which determines the minimum quality of a product which may be transacted between different parties. The nationally applied specification is usually decreed by an authority or official agency in the country. Its purpose is to protect all parties involved in the transaction and to provide a basis for reference in the event of any legal or commercial problem.

The specification of a product in a country is necessarily a compromise between four contradicting factors existing in the country. These are the technical requirement of the users of the product or the equipment using it, the economic capability of the producer to produce such quality, and the safety and protection of the public in general who might be involved in or affected by the product. On top of these three factors there is the history in each country which provides an inertia against any dynamic changes of specifications. Those are some of the reasons which may have resulted in the difference of product specifications in the various countries.

Today, most countries in the ASEAN countries provide two grades of gasoline, with the exception of Malaysia which appears to offer a wider choice for their motorists with four grades of gasolines allowed in the country's standard specifications.

The role of history seemed also to express itself further in the nomenclature used for the same product in the five countries. Generally the product of major consumption is called regular, being intended to satisfy 50 - 60 per cent of car population and the higher grade, intended to satisfy the 30 - 40 per cent of the population is called premium gasoline.

In Indonesia the majority of consumption is on the lower grade, but this is called premium gasoline, and the higher grade comprising only about 2 to 4 per cent of total consumption is called super grade. In the Philippines the higher grade, 93 RON, is the more important product, consumption wise, and is called premium, while the lower grade, called regular, is the minority. Thailand similarly calls its lower grade regular, but the higher grade is called super. Malaysia seems to denote their gasolines by the octane number.

## III. GASOLINE AS MOTOR FUEL

Gasoline is a petroleum product designed for its primary use in reciprocating, spark ignition, internal combustion engine. As such it comprises a mixture of hydrocarbons having low boiling range of between about 30$^{o}$ to 210$^{o}$C, complemented with various additives and chemicals to improve or adjust its properties. Its use involves mixing it with air in the carburettor, compressing the mixture in the cylinder, and igniting the compressed mixture with a spark. The combustion energy thus released is used in the power stroke which ends up in turning the wheels and moving the vehicle. The combustion gases are then exhausted to the atmosphere as waste gases. The properties of gasoline are thus designed to promote those actions.

There are three classes of properties which are required in gasolines. The first are the combustion qualities to ensure smooth running of the engine; the second are the physico-chemical properties to provide correct mixture of air and fuel from the carburettor; and thirdly, other chemical properties related to the stability of the gasoline under storage and other conditions and the safety of its use. All these properties must be taken into account when formulating the specification of the product.

## IV. COMBUSTION QUALITY

Good combustion quality is demonstrated in the smooth running of the engine without any abnormal combustion, in the ease of the starting of cold engine and restarting when hot, and the quick response of the engine on running at various driving conditions.

The most useful measure of combustion quality is the octane number. This indicates the tendency of the fuel to withstand abnormal combustion at high compression. Fuel of high octane number can be used in high compression engine without knocking or detonation which results from abnormal condition.

The gasoline used in an engine must therefore be those which satisfy its minimum octane requirement. The octane requirement of an engine depends on the design of the engine, the atmospheric conditions and the age and history of the engine. The parameters related to the engine design are the compression ratio, the shape and the materials used in the combustion chamber, the ignition timing, and the richness of the carburettor mixture.

Atmospheric conditions which bear influence to the octane requirement include the ambient temperature, atmospheric pressure and the humidity of the air. The factors related to the condition and history of the engine which may influence the octane requirement of an engine are the presence of combustion deposits in the combustion chamber as well as the deposits originated from the cooling water outside the chamber, which affects the heat exchange from the chamber.

Thus there are a multitude of factors which together define the octane requirement of an engine, so that it is best determined by actual experimental measurement. But, the gasoline provided in a country must be designed to satisfy the octane requirement of the whole car population in the country.

The octane requirement of the car population in a country is usually determined through experimental measurement of a statistically determined number of selected cars to represent the whole car population in the country. The octane number of gasoline grades established in a country are usually designed to satisfy 50 - 60 per cent of car population by the lower grade gasoline and 80 - 90 per cent of the car population by the higher grade.

However, of all countries in the Southeast Asia, only Indonesia is known to determine the octane requirement of their car population regularly. The results of its last measurement[2], made in 1983, indicate that 50 per cent of the car population would be satisfied by the Research Octane Number (RON) of 92 and 90 per cent by RON of 95. The results surprisingly fit the gasoline provided for the motorists in most ASEAN countries except Indonesia itself. As indicated in Table 1, Malaysia, Philippines, Singapore and Thailand have gasoline within the octane range of 91 to 95, while Indonesia has only 87 RON and 98 RON gasolines.

The octane number used in the specifications are usually the Research Octane Number, determined by the laboratory CFR engine running mild operating condition at 600 rpm in accordance with ASTM D-2699 test method. This is believed to reflect the relatively low engine loading such as experienced in passenger cars and light duty commercial vehicles.

The motor method (ASTM D-2700) with CFR engine running at 900 rpm and representing a more severe operating conditions, i.e. high inlet mixture temperature and high engine loading such as would be experienced during full throttle operation at high speed is generally not specified in the gasoline specification in all ASEAN countries. The exception is Singapore which requires it to be measured and reported upon request.

Table 1

**Grades, names, and Colour of Gasoline in ASEAN Countries**

| 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 |

Singapore which appears to define the most complete of tests among the five ASEAN countries insists also on the measurement of RON 100°C, which indicates the research octane number of the lower boiling fraction (up to 100°C). The minimum value which has to be met is 77.0 minimum for the regular and 86.0 for premium gasoline.

## V. VOLATILITY

The main characteristics of a motor fuel which relates to the formation of correct carburetted mixture of fuel and air is its volatility. The volatility of the motor fuel affects the performance of the engine in a number of ways, the chief of which are the ease of starting, the rate of warm-up, vapour lock, and crankcase dilution. In temperate countries, another problem may appears as a result of the fuel volatility, namely, carburettor icing.

The fuel must be sufficiently volatile to give easy starting, rapid warm-up, and adequate vaporization for proper distribution between cylinders. On the other hand it must not be too volatile that the vapour losses from the fuel tank is excessive or that vapour may be formed within the fuel line, thus impeding the flow of fuel to the carburettor by vapour lock. This is achieved by using the correct proportion of components in making the blend for the gasoline pool in the refineries.

The volatility characteristic of fuel is measured by means of two standard test methods, i.e. ASTM Distillation method (ASTM D-86) and the measurement of Reid Vapour Pressure (RVP) by ASTM D-323. Both these tests are empirical.

The ASTM distillation allows a distillation curve to be constructed through a simple standardised laboratory batch distillation. Three points are identified in the curve, namely the temperatures at 10, 50, and 90 per cent evaporated in addition to the end point. The first three points mentioned above describe roughly what is known as the front-end volatility, middle volatility and tail-end volatility, respectively, of the gasoline.

The front-end volatility has a great influence on the ease of cold starting, but also on the tendency of vapour lock. The maximum value noted in the specification is usually made as a compromise between these two contradicting factors. In temperate countries the value is adjusted with variation according to the season, with a higher value specified for summer. In the ASEAN countries, where the ambient temperature is almost constant all year long (except in the northern part of Thailand, perhaps), one volatility specification for motor gasoline is generally enough to fulfill the needs. The value for 10 per cent distilled is 74°C maximum in Indonesia, Malaysia and Singapore, and 75°C in the other two countries.

The middle volatility, 50 per cent distilled, has a great influence is warm-up, acceleration and pick-up, and some influence on vapour lock. Too low a temperature for 50 per cent point would lead to vapour lock and poor hot idling, while too high a value leads to poor acceleration and difficulties during warm-up period.

A relatively low minimum of 75°C is specified in Thailand, while in Singapore is 85°C and 88°C in Indonesia and the Philippines. Malaysia does not specify the lower limit for this test. The maximum value is 125°C in most countries, except it is 120°C in Singapore and Malaysia.

The heavy fraction, the tail-end volatility, shown by the 90 per cent distillation point have significant influence on engine deposites, oil dilution, air/fuel mixture distribution among the cylinders as well as on engine wear. For all these factors the lowest possible 90 per cent distillation point is best. But, on the other hand, the specific fuel consumption expressed in terms of kilometer per liter will suffer if the 90 per cent point is too low. In ASEAN countries the maximum value specify in the specifications is 180°C in Indonesia and Malaysia, 185°C in the Philippines and 190°C in Singapore and Thailand.

The end point varies from a low 205°C in Indonesia to a high 225°C in Singapore. Thailand has it at 215°C, Malaysia 220°C and the Philippines 221°C.

The use of heavy fraction is often necessary when catalytic reformates having a relatively high octane number is used. The tendency now, however, is for a reduction in the use of the heavy fraction in gasolines. It seems that the relatively low cutting point applied in Indonesia has something to do with the need to maximize kerosene fraction in the country; but, on the other hand, it is consistent with the general trends.

The distillation specifications of gasoline in ASEAN countries are summarized in Table 2. As can be noted from the table, of all countries, Indonesia use an additional distillation specification, namely 20% - 10% evaporation of 8°C minimum. Its purpose is not clear, except perhaps to give a nice balance between warm-up and cold starting capability.

**Table 2**

**Distillation specifications of gasolines in ASEAN countries (ASTM D-86)**

| | | Indonesia | Malaysia | Philippines | Singapore | Thailand |
|---|---|---|---|---|---|---|
| Distillation | | | | | | |
| 10% evap. | C max | 74 | 74 | 75 | 74 | 75 |
| 50% evap. | C min | 88 | – | 88 | 85 | 75 |
| | C max | 125 | 120 | 125 | 120 | 125 |
| 90% evap. | C max | 180 | 180 | 185 | 190 | 190 |
| End point | C min | 205 | 220 | 221 | 225 | 215 |
| 20% - 10% | C min | 8 | – | – | – | – |
| Residue | % vol. | 2 | 2 | 2 | 2 | 2 |

Another measure of volatility is the Reid Vapour Pressure (RVP), measured by ASTM D-323 test method. The test is performed with the Reid Vapour Pressure bomb which consist of two chambers : an air chamber in the upper section and a gasoline chamber below. The gasoline chamber is filled up with the chilled sample and connected to the air chamber. The apparatus is immersed in a constant temperature bath at 100°F and is shaken periodically until an equilibrium is reached. The manometer reading corresponding to the pressure, read on the gauge attached to the apparatus is the RVP of the sample.

The RVP is closely related to the tendency of the gasoline towards vapour locking and loss in storage. The gasoline vapour pressure depends critically on its butane content, and the refinery final adjustment of vapour pressure of gasoline to meet the specification is often made by butane injection. The values specified in ASEAN countries vary from a low 9.0 psi (62 kPa) maximum in Indonesia and Thailand to a rather high 12 psi (83 kPa) in the Philippines (see Table 3).

**Table 3**

**RVP of gasolines in ASEAN countries**

| | Specification (ASTM D-323) | | Comparative value | |
|---|---|---|---|---|
| | Value | Unit | psi @ 100°F | kPa @ 37.8°C |
| Indonesia | 9.0 | psi | 9.0 | 62 |
| Malaysia | 9.5 | psi | 9.5 | 65.5 |
| Philippines | 83 | kPa | 12.0 | 83 |
| Singapore | 70 | kPa | 10.2 | 70 |
| Thailand | 62 | kPa | 9.0 | 62 |

However, due to the complicated make up of gasoline blend, RVP has proved inadequate as criterion of vapour locking tendencies, and various other control methods have been suggested. One of these is to measure the volume of vapour (V), and to express the vapour locking tendencies as the value of V/L at a suitably specified temperature. Of all ASEAN countries under study, only Singapore applies this test as a specification, where the V/L ratio of 20 must be achieved at 57°C minimum.

## VI. OXIDATION STABILITY

Hydrocarbon components of gasoline undergo slow oxidation upon contact with oxygen or air. The tendency is more pronounced in the unsaturated olefines or diolefines present in gasolines, especially those using cracked components and reformates. The rate on oxidation is slow, but it is accelerated by intimate contact with oxygen and at a high temperature. The oxidation products form a conglomeration of compounds, which can not as yet be accurately defined, but which has the from of gum or resins. These gums are deposited in various parts of the engines and adversely affect the flow of fuel and the smooth running of the engine. Evaporation from the carburettor may deposit gum at the carburettor float valve and cause the float to stick. Evaporation the carburettor nozzle may deposit gum in the venturi area where it may build up to an extent that cause difficulty. Gum may deposit around the throttle and interfere with its proper functioning.

Gum formation is more serious in hot climate such as the southeast Asia. There are two tests which are commonly used to assess the tendency of fuel to form gum and deposits in various parts of the engine. The first is the existent gum test (ASTM D-381), which shows the quantity of gum actually present in the gasoline at the time of test, or when it is used immediately. The sample is evaporated in a glass beaker at a temperature of 325°F by means of controlled hot air jet at the same temperature. The residual gum is weighed and reported as milligrams per hundred milliliters of gasoline.

The existent gum, although it may indicate tendency towards inlet system if the gasoline is used immediately, is not quite realistic since in some cases it may take several months between the time of production of the gasoline and its use. A more relevant test to assess the possibility of gum formation during storage, or the gum stability of the gasoline is the induction period test (ASTM D-525). In this test the gasoline sample is placed in a pressure vessel, allowed in contact with oxygen at 100 psi initial pressure, and heated at 100°F for some time, until the oxygen pressure began to fall due to the oxidation of the sample and the formation of gum in the gasoline. The "induction period" needed before the oxidation reaction began to accelerate indicates the time during which the gasoline can be stored safety without excessive oxidation. Guthrie[3] claimed that an induction period of 4 hours is equivalent to about two years of ordinary storage, while Nelson[4] quite conservatively approximated the induction period in hours to equal to the months that the gasoline can be stored under conditions of commerce.

Generally, as indicated in Table 4, most ASEAN countries specify a minimum of 240 minutes of induction period and 4 mg/100 ml, maximum, for existent gum. The exception is Philippines which does not specify the induction period, and Thailand which specifies 5 mg/100 ml of existent gum and no requirement for induction period.

**Table 4**

**Gum content and oxidation stability requirement of gasolines in ASEAN**

| | Existent gum ASTM D-381 mg/100 ml max | Induction Period ASTM D-525 minutes min |
|---|---|---|
| Indonesia | 4 | 240 |
| Malaysia | 4 | 240 |
| Philippines | 4 | 240 |
| Singapore | 4 | 240 |
| Thailand | 5 | 240 |

## VII. CORROSIVENESS

One of the chemical quality which relates to the save use of a product is that it must not cause corrosion or other damages to the equipment using it. Gasoline, therefore must be substantially free from corrosive compounds both before and after combustion. The corrosiveness in gasolines is caused by the presence of free sulphur, hydrogen sulphide and other sulphur compounds which, during combustion, may burn to form sulphur dioxide. This combines with water vapour formed by the combustion of the hydrocarbon fuel to produce sulphurous acid. This acid may further oxidize to slight extent to form sulphuric acid. Both these acids are corrosive towards the metallic parts of the engine. It would attact the cooler parts of the engine's exhaust system and its cylinders as they cool off after the engine is shut down.

The presence of sulphur in gasoline components is also harmful to the susceptibility or responsiveness of the gasoline to tetraethyllead (TEL), which, in the past, has been a major additive used to improve the antiknock quality of gasoline. It has also a negative effect in the increase in the quantity of deposits in the combustion chamber, which hampers the heat exchange, and may even causes abnormal combustion in the engine. The sulphur content of gasoline has also been related to the abnormal wear of the engine.

There are various method used to determine the total sulphur content of gasoline. The most common, and the one used in all ASEAN countries is the lamp method (ASTM D-1266) in which the gasoline is burned in a small wick-fed lamp in an artificial atmosphere of carbon dioxide and oxygen. The oxides of sulphur are converted to sulphuric acid, which is then determined volumetrically or gravimetrically. A limit of 0.2 per cent by weight of sulphur applies throughout ASEAN, with the exception of the Philippines which waives this requirement (see Table 5). The action of sulphur on copper parts is evaluated by means of copper strip corrosion test (ASTM D-130), which consists of immersing a polished copper strip in the gasoline, contained in a test tube, and heating at 122° F for 3 hours. The strip is washed and dried and inspected for tarnish by comparing it with a set of standard. The presence of not more that a very slight tarnish, comparable to No. 1 standard strip, means that the gasoline is free from copper-corrosive tendencies and is safe to use. The copper strip corrosion standard of No. 1 is specified throughout all ASEAN countries.

**Table 5**
**Corrosiveness limits in gasoline specifications in ASEAN countries**

| | Sulphur content (ASTM D-1266) % wt. max. | Copperstrip corrosion (ASTM D-130) 3 hrs/50 C max. | Mercaptan sulphur (ASTM D-1219) % wt. max. | Doctor test (ASTM D-484) max. |
|---|---|---|---|---|
| Indonesia | 0.20 | No. 1 | 0.0015 | neg. |
| Malaysia | 0.20 | No. 1 | – | – |
| Philippines | – | No. 1 | – | – |
| Singapore | 0.20 | – | 0.0015 | neg. |
| Thailand | 0.20 | No. 1 | – | – |

Hydrogen sulphide and mercaptan sulphur are most undesirable contaminants because, apart from their corrosive nature, they possess extremely unpleasant odour. Mercaptan sulphur content is estimated by means of ASTM D-1219 test method, and their content is limited to 0.0015 per cent by weight. This is applied in Singapore and Indonesia. In Indonesia it is required as an alternative to another test, the "doctor test" (ASTM D-484) which determines the presence of mercaptans in gasoline as detected by the change of colour of gasoline upon reaction with sodium plombite solution. There should be no change of colour, or "negative" results from the test. This test is specified also in Singapore.

## VIII. LEAD CONTENT

Another chemical quality related to the safe use of gasoline, this time towards human being, and not merely to equipment, is its lead content. Lead compounds especially tetraethyllead (TEL) and tetramethyllead (TML) are use to improve the antiknock quality of gasoline. Therefore they are commonly used as additive to increase the octane number of a blend of gasoline components in order to meet the knock rating specification.

On the other hand lead, being a heavy metal, is harmful to human being. With the rapid increase of vehicles and traffic the lead content in the atmosphere in some places has become alarmingly high, and there are definite trends in many countries to reduce the lead content of gasoline to allow value or even to use lead free gasoline.

The tests for lead content consist of transformation of the lead compounds into lead chlorides and extracting the gasoline with hydrochloric acid. The extract is evaporated, the organic residues are oxidized by nitric acid and the lead is determined as lead chromate. Other methods used polarography, X-ray, atomic absorption spectrophotometry for determination of lead content.

The limits of lead content in gasoline are variably expressed as gram per liter, milliliter of TEL per American gallon. Their limiting values vary from a low 0.4 g/liter in Malaysia and Singapore to a relatively high 0.84 g/liter in Indonesian super grade.

**Table 6**
**Lead content of gasolines in ASEAN countries**

| | Specification | | | | Equivalent Pb g/L |
|---|---|---|---|---|---|
| | TEL or Pb | Limit max | Unit | Method ASTM | |
| Indonesia | TEL | 3.0 (S) | ml/AG | D-526 | 0.84 |
| | TEL | 2.5 (P) | ml/AG | D-526 | 0.70 |
| Malaysia | Pb | 0.4 | g/L | D-526 | 0.4 |
| Philippines | TEL | 1.1 | ml/L | D-2547 | 1.16 |
| | Pb | 1.16 | g/L | D-3227 | 1.16 |
| Singapore | Pb | 0.4 | g/L | D-3341 | 0.4 |
| Thailand | Pb | 0.45 | g/L | D-3341 | 0.45 |

## IX. CONCLUSION

We have examined and compared above the gasoline specifications in the five original ASEAN countries and discussed their significance. It seems quite clear now that there exist a wide variation of products used in the five countries. Consider, for example, the octane number of gasoline grades. No two countries in the association has the same octane rating in their gasoline. The sole exception is Malaysian Grade 97 and Singapore PMG(S); but these two countries have been especially close, many oil companies are operating in both countries, and the traffic and transportation communication between the two countries have been remarkably fluid.

Apart from the history and inertia against changes, the specification of gasoline in each country seems to relate to the country's economic situation, particularly those connected with the availability of oil in the country. Countries like Singapore and Malaysia seem to be able to afford to offer the best products for their consumers, while the Philippines having have to depend on its oil needs from import responds to the situation by stipulating a minimum number of requirement in its gasoline specification. And, to a lesser extent, so is Thailand. Indonesia, having to maximize its kerosene a middle distillate to meet the domestic demand, cuts its gasoline fraction at a relatively low end point of 205°C.

Decisions such as those are necessary and must be taken. But they preferably be based upon careful study and research in order to give them a solid basis. In view of the fact that close cooperation already exists among the countries, it would be beneficial for those countries to cooperate together in join studies and research to investigate practical problems connected to their product specifications. For example, what would be the effect of lowering the 10 per cent distillation point from 75°C now in force in Thailand and the Philippines to the level of 74°C such as in Indonesia, Malaysia, and Singapore? Or, what would be the effect of increasing the RVP from 9.0 psi in Indonesia and Thailand to 12.0 psi such as now used in the Philippines? Do cars in the Philippines experience more vapour lock problems than those in the countries with lower RVP specification, considering that the climate in all those countries are quite similar?

It would also be reasonable if the octane rating in the specification is based on the actual measurement of the octane requirement of the car population in the countries, considering again that the climate, car population, and probably driving habit and temperament of the people in the region are quite in common. We believe that a lot of benefits could be reaped, and probably better specification of gasoline in the countries, which suits better to each country's economic needs might result from such studies.

## REFERENCES


1. Allison, J.P., 1973 – *Criteria for Quality of Petroleum Products*, Applied Science Publisher, England.

2. Batti, F. and W. Kaslan, 1983 – *A Study on Octane Requirement for Motor Vehicles in Indonesia*, Proceeding, Second International Pacific Conference on Automotive Engineering, Tokyo, November 7 - 10.

3. **Guthrie, V.B., (ed.)**, 1960 – *Petroleum Products Handbook*, McGraw-Hill Book Company, New York, p. 4 - 32.

4. **Nelson, W.L.**, 1969 – *Petroleum Refinery Engineering*, McGraw-Hill Book Company, New York, p. 35.

5. **Weissmann, J. et at.**, 1970 – *Carburants et combustibles pour moteur a combustion interne*, p. 409, Editions Technip, Paris.

6. **ASTM Standards**, *National Standards of Indonesia, Malaysia, the Philippines, Singapore, and Thailand.*