THE INFLUENCE OF GASOLINE'S AROMATIC CONTENT ON ENGINE COMBUSTION CHAMBER DEPOSIT FORMING

by
Djainuddin Semar and **Nur Ahadiat**

ABSTRACT

*Aromatic content in gasoline fuels should be limited due to its influencies to the cleaness of engine combustion chamber and emission of carbon monoxide, carbon dioxide and hidrocarbon. Ussually the highest aromatic content mean more higher its benzene content and it will couse increase of air pullotion. According to specification of gasoline 91(*SK No. 3674 k/24/DJM/2006*), maximum aromatic content is 50 % volume. Those specification conform to catagory 1 of World Wide Fuel Charter (WWFC). However, aromatic and benzene content test on domestic gasoline in Indonesia obviously fulfil maximum limit for gasoline catagory 2 of WWCF. Effect of several volume variaties of aromatic content in gasoline 91 againts deposit development and cleaness (rating) of engine combution chamber will be discuss in this paper.*

Key words: aromatic content, deposit, performance.

1. INTRODUCTION

A. *Background*

Gradually decrease of of tetra ethyl lead in domestic gasoline untill now became domestic unleaded gasoline through out Indonesia bring about acceleration of using high octane mogas component (HOMC) as octane booster for domestic gasoline. The reason of highest aromatic content in gasoline because of the height aromatic content in HOMC. Due to aromatic content in gasoline influence the build up of deposit in engine combustion chamber, where benzena increase vechicle exhaust emission. The thing to be judge in making gasoline specification it happend that of the advancce of automotive engineering, environment standard improvement, the ability of domestic refineries and buying power of domestic consumer.

Specification of domestic gasoline standard decided by Directorate General MIGAS on behalf of Indonesian goverment in their SK No. 3674 K/24/DJM/2006 dated March 17, 2006, which limited aromatic content in gasoline 91 and gasoline 95 not more than 50 % volume. The purpose of this paper, is to reevaluated and reduced aromatic and benzene content in gasoline, so it will decrease its influence in developing deposite in engine combustion chamber and exhaust gas emission.

B. *Purpose*

The course of this paper is to examine the influence of aromatic content in gasoline againts deposite development in engine combustion chamber and its exhaust gas emission by analizing gasoline characteristic tests and conducting engine performance test on multicylinders test bench Mercedes Benz M 111. Data collected from this research hopefully for beneficial of goverment policy in reevaluation of aromatic content in future gasoline specification.

C. *Scope of Work*

Scope of this research including; literature study, survey, physical and chemical of gasoline laboratory test, gasoline formulation, performance test using multicylinders bench test and report.

II. STUDY PREPARATION

A. *Data Engine Bench Test*

Gasoline performance test conducted on multi cylinders test bench acording to European Coordination Council (ECC) Standard test method using

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 35 - 42

Mercedes Benz M 111 engine that require fuel with 91 RON. Details data of engine M 111 can be seen in Table 1.

Table 1
Technical Data Marcedes Benz M111 Engine

Merk	Mercedes Benz M111 Engine
Type/CEC code	Coordinating European Council CEC F – 20 – A – 98
Test Method	Deposit forming tendency on intake valve and in combustion chambers of gasoline engines
Engine	Daimler Chrysler M 111
Status	Approved (IVDs) ; Tentative (TCDs)
Cylinder	4
Compression ratio	12,5
Speed (Idle)	750 ± 50 rpm
Lube oil capacity	6 litre

1. Engine Power

The defination of engine power is the amount of works done (Nm) per unit time (second). By measuring torque and distance course in revolution per minute, will come up with works produce. Generally engine power calculate with the following formula;

$$P = \frac{T.2.\Pi.2.n}{60.10^3} \quad \text{..... (1)}$$

By using Mercedes Benz M 111 test bench that has certain legth of dynamometer brake, will simplyfy the above become formula 2 as follow;

$$P = \frac{T.n}{9543,3} \quad \text{..... (2)}$$

Where T = Engine torque (Nm); P = Engine power (kW);
N = Engine speed (rpm).

(*Source*: Internal Combustion Engines and Air Pollution, Edward F. Obert).

2. Fuel Consumption

Testing fuel consumption conducted by measuring combustion time to burn 50 gram fuels completly at the finite torque, speed and certain load. Fuel consumption in an hour calculated by using formula 3 as follow:

$$B = \frac{3600.G}{t}\ (gr/hour) \quad \text{..... (3)}$$

Specific fuel consumption (Sfc) which fuel consume in gram or kilogram per kW per hour, calculate by formula 4 as follow:

$$Sfc = \frac{3600.G}{t.P}\ (gr/kW.hour) \quad \text{..... (4)}$$

Where G = Fuel weight (gram)
T = time elapsed to completely burn a certain amount of fuel (second).

B. *Hydrocarbon Content*

HOMC constribute to increase gasoline octane number due to its hydrocarbon compound which has higher octane number. Composition of hydrocarbon compound consist of aromatic, benzene and olefin. The effect of hydrogen compound in fuel to engine performance shall be describe as follow;

- Aromatic affected againts deposit development in engine combustion chamber and exhaust gas emission; CO and NOx,
- Olefin influence againts deposit development in engine intake valve,
- Benzene, affected againts exhaust gas emission.

III. EXPERIMENTAL

A. *Materials Used*

Materials used in this research consisted of HOMC, Base Gasoline, ex-Pertamina, Gasoline 88 from SPBU (Gas Station), and Gasoline 91 (Pertamax) as fuel reference ex- Pertamina Gas Station.

B. *Gasoline Formulation*

Before conducting engine performance test, several fuels with diferent fomulation should be prepared with minimum RON 91, those fuels will be tested in engine test bench. Gasoline RON 91 formulated in such a manner so its aromatic content (volume %) in gasoline have several variation.

Final formula blended for this engine performance test as follow;

1. Formula F-0 it is gasoline 88 with minimum RON 88.
2. Formula F – 1 it is gasoline with minimum RON91
3. Formula F – 2 are 60 - 75 % vol. PRX + 5 - 15 % F-0 + 20 % ART
4. Formula F – 3 are 40 - 65 % vol. PRX + 5 - 10 % F-0 + 40 % ART

Where: F-0 = Gasoline wirth minimum RON 88
PRX = Gasoline wirth minimum RON 91
ART = Aromatic Compound.

C. *Characteristic Test*

Characteristic test conducted in two kind samples gasoline RON 91 those are; gasoline formulated and gasoline ex- Pertamina Gas Station

1. Formulated gasoline included reference gasoline (F-1) and gasoline modification (F-2 & F-3) againts MIGAS specification for gasoline RON 91 (Pertamax).
2. Gasoline RON 91 ex-SPBU (Pertamax Pertamina) and Pertamax produced by private companies picked it up from several provicies through out Indonesia.
3. The result of those gasoline sample test againts its aromatic and benzene content in gasoline RON 91 tabulated in Table 3.

D. *Performance Test*

Performance test on Multicylinders Mercedes Benz M 111, using three kinds of gasoline such as F-1, F -2, and F-3 with test procedure as follow;

1. Firstly, engine will run with gasoline F-1, with load at ½ throattle, ¾ throattle and full throattle at last. The limeted performance test conducted for 60 hours.
2. Secondly, with the same arrangement and sequence, engine will run using gasoline fuel F-2.
3. Thirdly, with the same arrangement and sequence, engine will run using gasoline fuel F-3

Table 2
Test result for Sample F-0 compared with standard specification of Gasoline 88

No.	Characteristics	Test Result F-0	Limit *)		Test Method ASTM
			Min.	Max.	
1	Research Octane Number	88,5	88,0	-	D 2699 – 86
2	Oxidation stability, sec.	> 480	480	-	D 525 – 99a
3	Distillation:				D 86 – 99a
	o 10% vol. evaporation, °C	55,5	-	74	
	o 50% vol. evaporation, °C	95,0	88	125	
	o 90% vol. evaporation, °C	160,5	-	180	
	o End Point, °C	197,5	-	215	
	o Residue, volume %	1,0	-	2,0	
4	Reid vapour presssure, kPa	58,5	45	62	D 5191-99 or D 323
5	Density at 15°C, kg/m^3	725,0	-	-	D 4052-96 or D 1298
6	Copperstrip corrosion, merit	1a	Class 1		D 130 – 94
7	Doctor test	Negative	Negative		IP 30
8	Appearance	Yellow	Red		Visual
9	Colour	Yellow	Red		Visual

Remarks;
- *) Specification of domestic gasoline standard decided by Directorate General MIGAS on behalf of Indonesian goverment in their SK No. 3674 k/24/DJM/2006 dated March 17, 2006
- *) PRM: 100% Gasoline 88

Table 3
Test result for Gasoline F-1, F-2, F-3 compared with standard specification of Gasoline 91

No.	Characteristics	Test Result			Limit *)		Test Method
		F-1	F-2	F-3	Min.	Max.	ASTM
1	Research Octane Number	92,3	92,6	93,4	91,0	-	D 2699 – 86
2	Oxidation stability, sec.	> 480	> 480	> 480	480	-	D 525 – 99a
3	Olefin content, volume %	25,01	13,52	10,46	-	**)	D 1319 – 99
4	Aromatic content, volume %	25,0	35,6	40,8	-	50,0	D 1319 – 99
5	Benzene content, volume%	0,19	2,74	1,97	-	5,0	D 4420 – 94
6	Distillation:						D 86 – 99a
	o 10% vol. evaporation, ^{o}C	50,5	55,5	61,0	-	70	
	o 50% vol. evaporation, ^{o}C	88,5	100,0	105,5	77	110	
	o 90% vol. evaporation, ^{o}C	170,5	167,0	160,0	130	180	
	o End Point, ^{o}C	192,5	195,0	195,0	-	215	
	o Residue, % vol.	1,0	1,0	1,0	-	2,0	
7	Reid vapour pressure, kPa	59,3	52,4	46,2	45	62	D 5191-99 or D 323
8	Density at 15^{o}C, kg/m^{3}	735,3	751	762	715	770	D 4052-96 or D 1298
9	Existent gum, mg/100 ml	0,22	2,75	4,62		5	D 381-99
10	Copperstrip corrosion, merit	1a	1a	1a	class 1		D 130 – 94
11	Doctor test	negative	negative	negative	negative		IP 30
12	Appearance	clear	clear	clear	clear	clear	
13	Colour	blue	blue	blue	blue	blue	

Keterangan:

- *) Specification of domestic gasoline standard decided by Directorate General MIGAS on behalf of Indonesian goverment in their SK No. 3674 k/24/DJM/2006 dated March 17, 2006
- **) If olefin content up to 20%, test result of oxidation stability minimum 1000 second.

IV. RESULT AND DISCUSSION

A. *The Result of Physicals and Chemical Test*

Comparing the test result of sample gasoline 88 (F-0) againts MIGAS specification for Gasoline 88, tabulated at Table 2. Evaluation of physical-chemical test result on sample gasoline 88, it happened that all physical-chemical characteristic conform with MIGAS unleaded gasoline 88 specification.

On Table 3 please find the result test of modification gasoline sample (F-1, F-2, F-3) each againts MIGAS specification of gasoline 91.

B. *An Influence of Gasoline Characteristic*

Aromatic content test result for gasoline sample F-1, F-2 and F-3 all sort of 25 % volume, 35.6 % volume and 40.8 % volume. From the result test of F-2 and F-3 due to physical-chemical characteristic, it shown that the increased of aromatic content in gasoline will sligthly raised density, RON, and gum content. But those changes still conform with MIGAS specification for Gasoline RON 91, such as tabulated in Table 3.

C. *The Result of Performence Test*

1. Engine Power

a. Using gasoline F-2. Over all, comparing power evaluation of engine run by gasoline F-2 againts engine run by gasoline F-1, shown average decrease power of 3.42 %.

b. Using gasoline F-3. Overall, comparing power evaluation of engine run by gasoline F-3 againts engine run by gasoline F-1, shown average decrease power of 5.05 %.

c. The tendency of engine power decrease againts aromatic content increase in gasoline presented in Figure 1a and Figure 1b.

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 35 - 42

2. Specific Fuel Consumption

a. Using fuel F-2. Overall, comparing specific fuel consumption of gasoline F-2 againts gasoline F-1, shown average increase of specific fuel consumption of 4,49 %.

b. Using fuel F-3. Overall, comparing specific fuel consumption of gasoline F-3 againts gasoline F-1, shown average increase of specific fuel consumption of 6,35 %.

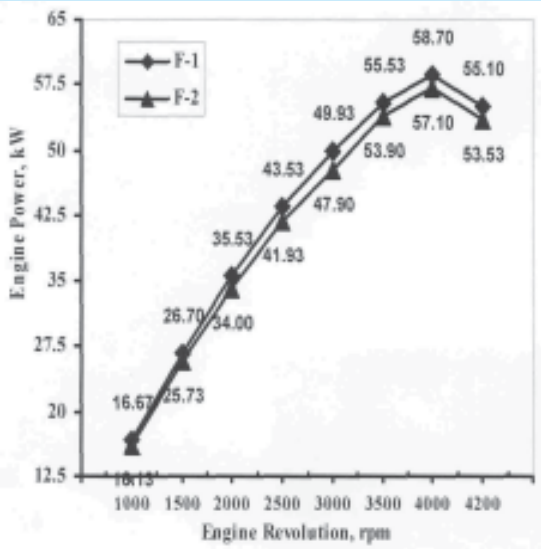

Figure 1a
Engine power vs engine revolution gasoline fuel Sample F-2 compare with Sample F-1

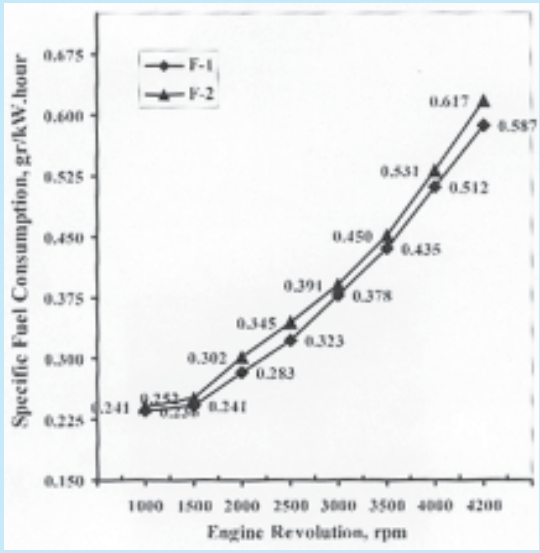

Figure 2a
Specific fuel consumption vs engine revolution gasoline fuel Sample F-2 compare Sample F-1

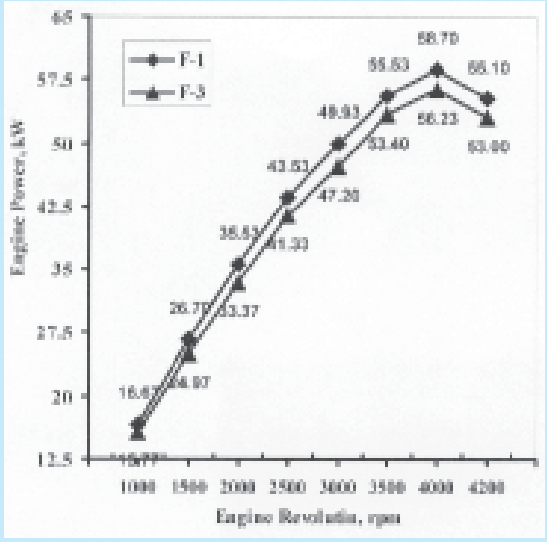

Figure 1b
Engine power vs engine revolution gasoline fuel Sample F-3 compare Sample F-1

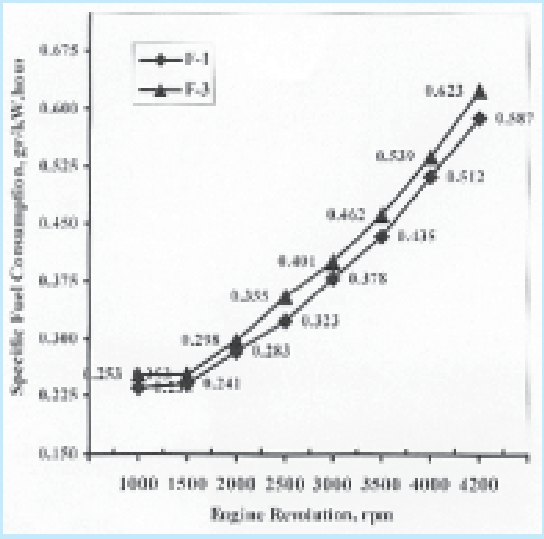

Figure 2b
Specific fuel consumption vs engine revolution gasoline fuel Sample F-3 compare Sample F-1

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 35 - 42

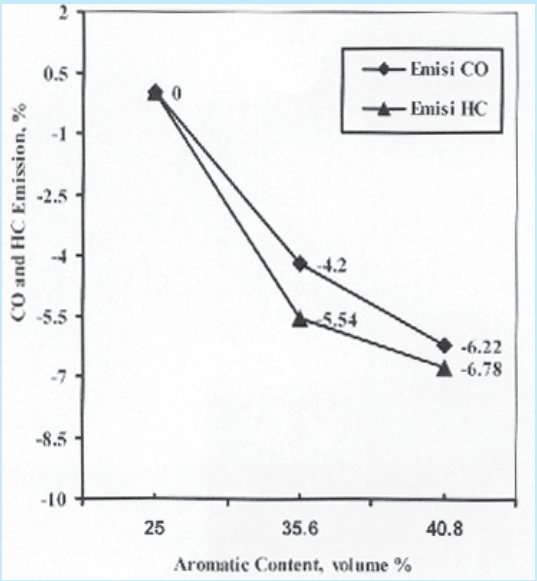

Figure 3
The tendency of increasing aromatic content gasoline on F-2 and F-3 againts CO and HC emission of gasoline F-1

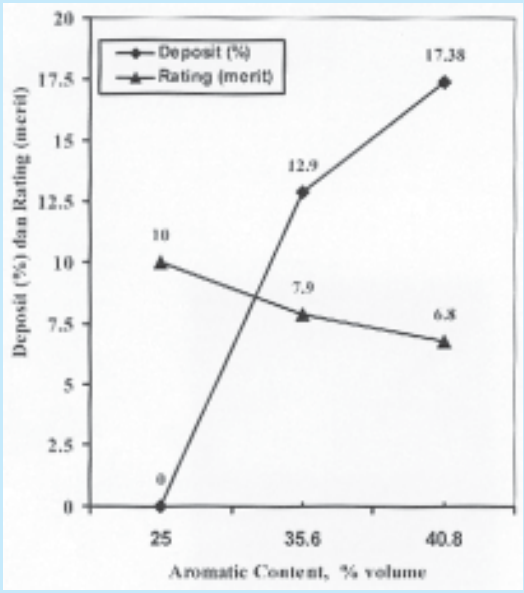

Figure 4
The Tendency of alteration of deposit amount and rating deposit using gasoline F-2 and F-3 compare to gasoline F-1

c. The tendency of specific fuel consumption of gasoline F-2 and F-3 againts spesific fuel consumption of gasoline F-1, presented in Figure 2a and Figure 2b.

3. Carbon Monoxide Emission

a. Using gasoline F-2. Overall, comparing carbon monoxide emission from gasoline F-2 againts COx emission from gasoline F-1, indicate everage increase of 5.07 % COx emission .

b. Using gasoline F-3. Overall, comparing carbon monoxide emission from gasoline F-3 againts COx emission from gasoline F-1, indicate everage increase of 6.14 % COx emission.

4. Hydrocarbon Emission

a. Using gasoline F-2. Overall, comparing CO and HC emission from gasoline F-2 againts CO and HC emission from gasoline F-1, indicate everage increase of 5.87 % CO and HC emission .

b. Using gasoline F-3. overall, comparing CO and HC emission from gasoline F-3 againts CO and HC emission from gasoline F-1, indicate everage increase of 7.98 % CO and HC emission .

c. The tendency of increasing CO and HC emission gasoline F-2 and F-3 against CO and HC emission of gasoline F-1, presented in Figure 3

D. *Engine Combustion Chamber Deposit*

Result of deposit rating and cleaness of engine combustion chamber evaluation of engine bench test Mercedes Benz M111 will be describe bellow;

1. Comparing Gasoline F-2 against Gasoline F-1

a. Result analyzed of engine combustion chamber deposit by using gasoline F-2 compared against using gasoline F-1 presented in Figure 3. Comparing deposit weight, indicate that combustion chamber deposit using F-2 more filthy than combustion chamber deposit using F-1

b. From deposit rating point of view, using gasoline F-2 compare to gasoline F-1, indicate deposit rating 7.9.

2. Comparing Gasoline F-3 against Gasoline F-1

a. Result analyzed of engine combustion chamber deposit by using gasoline F-3 compared against using gasoline F-1 presented in Figure 3. Comparing deposit weight, indicate that combustion chamber deposit using F-3 more filthy than combustion chamber deposit using F-1

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 1, MAY 2007 : 35 - 42

b. From deposit rating point of view, using gasoline F-3 compare to gasoline F-1, indicate deposit rating 6.8.

c. The tendency of alteration of deposit amount and rating deposit on engine bench test Mercedes Benz M 111 using gasoline F-2 and F-3 compare to those of gasoline F-1, presented in Figure 4.

V. CONCLUSION AND RECOMENDATION

A. *Conclusion*

From above discussion of physical-chemicals characteristics test result and fuel performance test, several conclusion can be drawn as follow;

1. Physical/Chemical Characteristics

The result test of gasoline F-1 (with 25 % aromatic content volume), gasoline F-2 (with 35.6 % aromatic content volume) and gasoline F-3 (with 40.8 % aromatic content volume), indicate that overall samples confirm to MIGAS specification of gasoline 91.

2. Fuels Performance

Multicylinders bench test Mercedes Benz M 111 using gasoline F-2 and F-3, indicate that engine power, specific fuel cosumption, engine combustion chamber deposit and exhaust gas emission, compared to fuel performance of gasoline F-1 can be discribed as follow;

a. The engine power decrease in order of 3.42 % and 5.05 %.

b. The specific fuel consumption raise cosecutively by 4.49 % and 6.35 %

c. The engine combustion chamber deposit increase in order of 12.9 % and 17.38 %.

d. The deposit merit rating, each one indicate 7.9 and 6.8

e. The CO emission increase in order of 5.07 % and 6.14 %.

f. The HC emission increase consecutively by 5.87 % and 7.98 %.

B. *Recommendation*

The test result of domestic gasoline 91 (see Table 4) indicate that; aromatic content around 21.29% - 28.64% by volume and benzene content between 0.22% - 1.42 % by volume.

The test result of gasoline F-2 (with aromatic content 35.6% by volume) and gasoline F-3 (with aromatic content 40.8% by volume) compare againts deposit rating of each fuel, consecutively by 7.9 % and 6.8 %

The test result of aromatic content and benzene content in gasoline 91 ex-Gas Station where deposit amount test and deposit rating in engine combustion chamber of engine Mercedes Benz M 111 that mention above, consequently since aromatic content (21.29% - 28.64% by volume) and benzene content (0.22% - 1.42% by volume) of domestic gasoline 91 (Table 4) bellow the requirement standard of World Wide Fuel Charter (WWFC) catagory 2 where are aromatic content maximum 40 % by volume and benzene content maximum 5 % by volume. So the

Table 4
Test result of aromatic content Gasoline 91
ex- Pertamina Gas Station and ex- Private Gas Station
at several provincies in Indonesia

No.	Sample From	Hydrocarbon Content (volume %)		Remark
		Aromatic	Benzene	
1	Medan (Sumatera Utara)	22,23	1,42	
2	Pekanbaru (Riau)	23,45	0,22	
3	Palembang (Sumatera Selatan)	21,29	0,57	
4	Lampung (Lampung)	23,23	0,48	
5	Bekasi (Jawa Barat)	24,36	0,75	
6	Bandung (Jawa Barat)	28,64	1,33	
7	Jakarta (DKI Jakarta)	24,28	0,76	
8	Jakarta (DKI Jakarta)	26,81	1,14	Excluded Pertamina
9	Serang (Banten)	23,34	0,72	
10	Yogyakarta (DI Yogyakarta)	23,68	0,64	
11	Semarang (Jawa Tengah)	23,51	0,62	
12	Denpasar (Bali)	23,96	0,64	

domestic Gasoline 91 can be propose to become fuel WWFC catagory 2.

REFERENCES

1. EMA, ACEA, JAMA, 2002 "World Wide Fuel Charter".
2. Specification of domestic gasoline standard decided by Directorate General MIGAS on behalf of Indonesian goverment in their SK No. 3674 k/24/DJM/2006 dated March 17, 2006
3. Jasjfi E., Nasution A.S., The Progress Tower Cleaner Transportation Fuels in ASEAN", *LEMIGAS Scientific Contribution* 2, 1997/1998.
4. Keith Owen, Trevor Coley, 1995. "Automatic Fuels Reference Book", SAE, Inc. Warrentale.
5. UOP, 1997 "The Challenge of Reformulated Gasoline. The 1990 Clean Air Act Amendments" Des Plaines Illinois.
6. US EPA, 1999 "Implementers Guide to Phasing Out Lead in Gasoline", Environmental Pollution Prevention Project Hagler Badly Services, Inc. Alexandria.´