Tikrit Journal of Eng. Sciences/Vol.17/No.2/June 2010, (22-35)

Selective Additives for Improvement of Gasoline Octane Number

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Abstract

High octane blend base gasoline stocks are reformulated from 30% LSRN, 45% Reformate and 25% Powerformate on volume basis. ASTM standard and IROX 2000 analysis are performed to test blend stocks sample. Different additive types are used to improve octane number. These additives are tetraethyl lead, methylcyclopentadienyl manganese tricarbonyl; methyl alcohol, ethyl alcohol, iso-propanol, n-butanol, sec-butanol, tertiary butyl alcohol, tert-amyl alcohol, active amyl alcohol, iso-pentyl alcohol, isobutyl carbinol, benzol ,telone, xylene, amino benzene, N-N-dimethyl aniline, dimethyl ketone, and ethyl methyl ketone.

Comparison is made between significant individual RON gains measured by standard CFR test-engine. The results indicated that the combined iso-propanol, oxinol (50/50 blend of methanol and TBA), aniline, and xylene with hydrocarbons fraction content in the gasoline base pool is better to ensure high RON. The results showed that a mixture of 20/54/10/16 of blend aniline/ iso-propanol/ oxinol/ xylene respectively, led to an increase in RON of gasoline blend pool from 84.5 to 96 RON, or 11.5% RON gain.

Keywords: Gasoline additives, Octane Rating, Reformulated Gasoline, RON

زيادة الرقم الاوكتاني لبنزين المحركات باستخدام اضافات كيمياوية منتقاة

الخلاصة

الغرض من هذا البحث دراسة زيادة الرقم الاوكتاني لبنزين المحركات والذي تم خلطه مختبريا من القطفات البترولية المنتجة في مصفى الدورة بالنسب الحجمية التالية 30% نفثا خفيفة، 45% ريفورميت، و 25% باورفورميت. لقد تم تحليل الخواص الكيمياوية و الفيزياوية للكازولين المستخدم باستخدام الطريقة القياسية ASTM وجهاز التحليل الطيفي IROX2000، وكما تم قياس الرقم الاوكتاني باستخدام ماكنة الاحتراق الداخلي القياسية CFR. لقد شملت الدراسة استخدام العديد من الاضافات الكيمياوية المنتقاة من خمسة مجاميع مختلفة. المجموعة الاولى وتمثل اضافات معدنية عضوية مثل رابع اثيلات الرصاص و مثيل سايكلو بنتادايين تترا كاربونيل المنغنيز و المجموعة الثانية وتضم الكحولات مثل الميثانول، الايثانول ،ايزوبروبانول، نورمال بيوتانول، ثنائي بيوتانول، البيوتانول الثالثي ، الاميل الثلاثي ،كحول الاميلي الفعال، الايزوبيوتيل، و ايزوبيوتيل كاربينول . المجموعة الثالثة من الكيتونات مثل الاسيتون و مثيل اثيل كيتون .المجموعة الرابعة وتمثل الاضافات الاروماتية مثل البنزول و التلوين و الزايلين.و اخيرا المجموعة الخامسة من الاضافات الاروماتية الامينية مثل الانيلين و داي مثيل الانيلين. لقد بينت النتائج العملية ان خليط الاضافات المكون من 20% انيلين، 54% ايزوبروبانول، 10% الاوكسينول (ويمثل خليط من 50% ميثانول و 50% بيوتانول ثالثي) و 16% زايلين هو الافضل في زيادة الرقم الاوكتاني لبنزين المحركات الخالي من الرصاص من 84.5 الى 96 وقد بلغت نسبة الزيادة حوالي 11.5%.

الكلمات الدالة: مضافات الكازولين، تحسين الرقم الاوكتاني.

Introduction

The typical octane number has increased since 1920s in order to meet performance needs of modern engines; it

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is an important measure of gasoline's quality [1], and to allow higher compression ratios without pre-ignition of fuel and the resultant engine knock. Octane number is a measure of a fuels tendency to knock in a test engine when compared to other fuels [2]. Knocking occurs when the fuel-air mixture explodes on the compression stroke of the engine cycle, i.e. before the application of the spark. This creates a loud knocking noise within the engine and can lead to engine damage.

The strategy of motor gasoline production has been forced to meet property limit, which comply with performance specification and environmental regulations. As a result, there are different kinds of gasoline that are sold across the world and can be primarily divided between regular and premium and in many countries in different types according to the octane number.

Many of gasoline grade types are obtained in modern manufacturing processes by proper blending of component with minimum losses of hydrocarbon feedstock, obtained through primary distillation, thermal cracking and reforming, coking, hydrocracking, alkylation, polymerization, isomerization, and other high octane blend stocks.

Domestic gasoline manufacturing technology differs significantly from modern technology, because they have a low fraction of catalytic naphtha cuts and insignificant alkylate, isomerizate, and oxygenate content. However, it required a large capital investment for converting technology to produce high octane gasoline with a significant alkylate and isomerizate content. For this reason, currently most widely economical approach in improving the antiknock properties of gasoline is the use antiknock agents to increase the production of high octane gasoline.

Obviously the materials in widespread use as antiknock agent are organometallic compounds such as tetraethyl lead (TEL) and methylcyclopentadienyl manganese tricarbonyl (MMT), in which carbon atoms are bonded directly to the metals. These substances are assumed to have an attractive to both refineries and to fuel marketers because it provide a good octane boost as well as anti valve seat recession properties [3].

Even through the gasoline with these agents are most serious source of environmental pollution due to the toxicity[4], the present world fuel and energy situation does not offer any intermediate hope of curtailing the output of oragnometallic gasoline or any significant reduction of the content in gasoline.

One of the greatest advantages of these components over other octane boosters or the use of high octane blend stocks is the very low concentrations needed. Also because organometallic gasoline have higher energy content and the storage quality eventually, led to a universal switch to other fuel.

Comparison between physical properties of TEL and MMT are shown in Table (1).

This is well known for lead alkyl compounds which have been extensively studied[5]. These compounds are relatively thermally unstable and easily produce low energy free radicals with a low propensity to form free radical chains but will act as free radical scavengers. Free radical quenches and traps are very efficacious and are used in very small amounts. Lead oxide, either as solid particles or in the gas phase, reacts with HO_2 and removes it from the available radical gasoline pool. Thereby deactivating the major chain branching reaction sequence that results in

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undesirable, easily-autoignitable hydrocarbons [6,7]. TEL remains the most effective additive because its ability to increase the fuel's octane rating and prevent detonation [8]. For example reduction of lead content from 0.6 to 0.15 g/lit will increase amounts of gasoline from 1.73, 2.36, and 4.03% with RON of 94, 96, and 98 respectively [9].

MMT is a liquid octane enhancer for unleaded and lead replacement gasoline. While MMT is superior antiknock and is capable of improving the octane number, it has the disadvantage of high cost. The MMT are quit compatible with TEL and thus can be used either with TEL or alone. The response of gasoline octane to MMT is affected by many factors depending on the nature of hydrocarbon composition of gasoline [10,11].

Oxygenates decreases the toxicity of exhaust gases in several ways; reduces exhaust emissions of hydrocarbons and CO in old as well as new motor vehicles [12],using oxygenates can result in the reformulation of the hydrocarbon portion of the fuel. Typically, aromatics may be reduced when oxygenate is added. The addition of oxygenates has a beneficial effect on the gasoline distillation properties and reduces olefins, sulfur and aromatics at least by dilution [13].

Additions of small amounts of alcohols to gasoline have several advantages: improves fuel blend water tolerance, material compatibility, and volatility characteristics and improve the blends' knock resistance. [14-19]. In addition, branched-chain alcohols have higher octane numbers compared with their straight-chain counterparts [20].

Acetones and MEK are chemicals, and because their higher octane number makes them accepted blending components to gasoline pool.

Aromatics which are often referred to as BTX are also assumed another way to increase octane in gasoline. BTX have a RON octane rating larger than 100. Complete combustion of BTX yields CO_2 and H_2O. This fact ensures that the entire emission control system such as the catalyst and oxygen sensor of car is unaffected. There are no metallic compounds such as lead, magnesium etc, no nitro compounds and no oxygen atoms in BTX, and it's made up of exactly the same ingredients as ordinary gasoline. In fact it is one of the main ingredients of gasoline.

Experimental Work

Formulation Base Gasoline

In Doura refinery, Gasoline is manufactured according to the specification that includes physical properties ranges and limits necessary to ensure good performance in vehicles.

Different base gasoline streams are produced, and can be blended in proportions necessary to satisfy the specification.

The base gasoline pool was reformulated experimentally from a high octane blend stocks produced from refining processes namely: Light Straight Run Naphtha (LSRN), Heavy Straight Run Naphtha (HSRN), Reformate (from Reforming mixture of 30% LSRN and 70% HSRN) and Power Formate (From Reforming HSRN). The reformulated base gasoline appears in Table (2), and represented in Figure (1).

All blend stocks are tested using ASTM standard methods and IROX 2000 Portable Gasoline Analysis. The results are listed on Table (3).

Octane Enhancing Additives:

The additives subject to this research are summarized in Table (4). Selective additives were used to improve octane number of unleaded gasoline are selected from various group such as organometallic components (as TEL, MMT), alcohols, aromatics, aromatic amines, and ketons in base gasoline formulation. The octane quality of gasoline fuel was determined using Cooperative Fuel Research Engines (CFR).

Comparisons of the physical properties of selected octane enhancing additives are shown in Table (5).

Results & Discussion

First Stage

Orgnometallic Additives:

Three kinds of organo-metallic additives are used in this study; TEL, MMT and a mixture of MMT and TEL in a ratio of 75:25. The results for these additives are shown in Table (6) and represented in Figure (2). From the results it is indicated that increasing of lead content of gasoline base pool from 5-25 g/lit will increase gasoline gain 3.3-11.4 respectively. While, MMT octane boost has a slight positive impact on RON improvement compared with TEL. Also the results show that by using mixture of MMT and TEL in ratio of 75:25 gives 2.7-9.9 RON boosts with same values of concentration 5-25 gm/lit.

It might be expected from the above results that the effectiveness of the octane booster is depends on the base gasoline composition and the quantity of organometallic component used.

Alcohol Components:

Different kinds of alcohols are used; normal and branched-chain alcohols with carbon numbers ranging from C_1 to C_5; namely; methanol, ethanol, iso-propanol, 1-butanol, 2-butanol, tert butanol, 2-methyl-2-butanol, and 3-methyl-1-butanol, are individually blended with unleaded gasoline base pool.

The results shown in Figures (3-7), indicated that variation occurs at all selected concentration levels between 2.9-100% vol. relative to gasoline base pool.

The change in specific gravity of used alcohols with gasoline base pool blends are shown in Figure (3). The results indicate that increasing alcohol concentration will increase gasoline blend's specific gravity. Fuel blends with higher alcohols as tert butanol, 2-methyl-2-butanol, and 3-methyl-1-butanol are slightly denser than those with lower alcohols as methanol, ethanol, iso-propanol for a given percentage volume concentration.

Alcohol volume percentage in alcohol-gasoline blends with matched oxygen content are shown in Figure(4). The higher the alcohol blend, the higher the oxygen content in the fuel. The results show linear relationship between oxygen content and alcohol concentration. This indicates that when higher alcohols are blended individually with gasoline, larger amounts are needed in the blend in order to match the oxygen content of lower alcohols blends.

The energy-mass density for each blend is predicted by summing up the mass weighted heating values of the neat components [21]. For comparison alcohol, with higher oxygen content in the gasoline blend will have the lower energy mass-density value, as shown in Figure (5). The energy-volume density for each blend is computed by multiplying its energy-mass density and its specific gravity. Blends with higher alcohols have larger energy-volume densities, when compared to those with lower alcohols, as shown in Figure (6). Generally, for the same operating conditions, engines burning a stoichiometric mixture need to consume more alcohol-gasoline blend than neat gasoline, as shown in Figure (7).

As it is can be seen from Figure (8), even the addition of low concentrations of alcohol to the unleaded base fuel has a significant effect on the octane number of the resulting gasoline-alcohol blend. The results indicate that iso-propanol, ethanol, and 2-butanol are the best in increasing RON gain compared with methanol, tert-butanol, 1-butanol, 2-methyl-2-butanol, and 3-methyl-1-butanol in the alcohol content 2.9-10.7% vol in gasoline base pool. For example, the addition of 10.7l % of iso-propanol, the RON gain is 7.5 points.

Ketones

RON gain of gasoline with increasing ketones content-gasoline pool base fuel are shown in Figure (9). Because of the higher octane number of ketons, (same as alcohols), makes them accepted as blending components to gasoline pool. The results show that increasing of MEK content between 2.9-10.7% will increase gasoline gain 0.5-4.6., while Acetone has a slight positive impact on RON improvement compared with MEK for the equivalent concentrations.

Aromatics And Aromatics Amines Components

The effect of increasing aromatics and aromatic amines components content from 2.9-10.7% (benzene, toluene, xylene, aniline, and N-N-Dimethyl aniline) in gasoline pool base fuel on RON gain are shown in Figure (10). The results indicated that benzene, toluene and xylene have effect for increasing octane value of blended unleaded gasoline pool, while aniline and because of its good sensitivity in gasoline combustion will offer higher RON gain [22]. For example at aniline concentration up to 2.9 vol% allow increasing the octane number by 11.2 points, while RON gain reach 32 at 10.7%.

Reformulated of Blending Agents (Second Stage)

The concentrations of alternative antiknock compounds in gasoline are limited for different reasons. For this reason, the possible increase in the octane number in use of some type of additive is also limited. Thus reformulated of the blending agents is subjected with the composition of gasoline base pool in order to determine its efficiency of octane boosting composition.

Because of many possible variants of composite antiknock compounds, eleven blending agents in different combinations were selected as shown in Table (7). This approach will allows summing the antiknock effect of the additives and obtaining a synergistic effect of different types of additives and their quantities in gasoline base pool. The results of blended RON with 10.7%vol in gasoline base pool are represented in Figure (11)

The results of the tests confirmed that the additives of a combined iso-propanol, oxinol (50/50 blend of methanol and TBA), aniline, and xylene with hydrocarbon fraction content in the gasoline base pool, ensure high RON. As it can be seen from Figure (11), the RON was increased with the addition of 10.7% of all selected components. However, the best of these blending agents is E10, a mixture of 20/54/10/16 of aniline/ isopropanol/ oxinol/ xylene respectively, due to its higher effect on octane blend. E10 was recorded an increase in RON of gasoline blend pool from 84.5 to 96 RON, or 11.5 RON gain.

Summarized testing for gasoline base pool with and without E10 are shown in Table (8). The results show that 10.7% of E10 is a sufficient quantity to achieve 96 RON and 93 MON. RON and MON gain increase by about 11.5, 7.9 respectively.

Conclusions

All selected additives act positively to improve octane number of reformulated gasoline pool:

- Mixture of MMT and TEL in ratio of 75:25 gives RON boosts higher than MMT alone and lower than TEL alone at of same concentration.
- Iso-propanol alcohol gives the higher RON gain compared with other used materials of oxygenated group.
- The octane booster of this project was aniline, which gives the largest RON.
- Blending agents in different combination improve RON gain in various degrees for example a mixture of 20/54/10/16 of blend aniline/ iso-propanol/ oxinol/ xylene, respectively led to increases in 11.5% RON.

Acknowledgments

The Iraqi Oil Ministry through its Office of Research and Development in Al-Doura Refinery funded and managed the project research described here. The authors gratefully acknowledge the contributions of special thanks expressed to Mr. Dathar Al Khashab, Mr. Lateef Wahab, Mr Kerim Thamer, Mr. Tarik Talib, Mrs. Inaam Mahmood, Mr. Yosif Tawfeek, Mr. Sabah Abd Alzahra, and Al Doura Refinery Laboratory Staff for their assistance in providing the required equipments and materials to complete this work.

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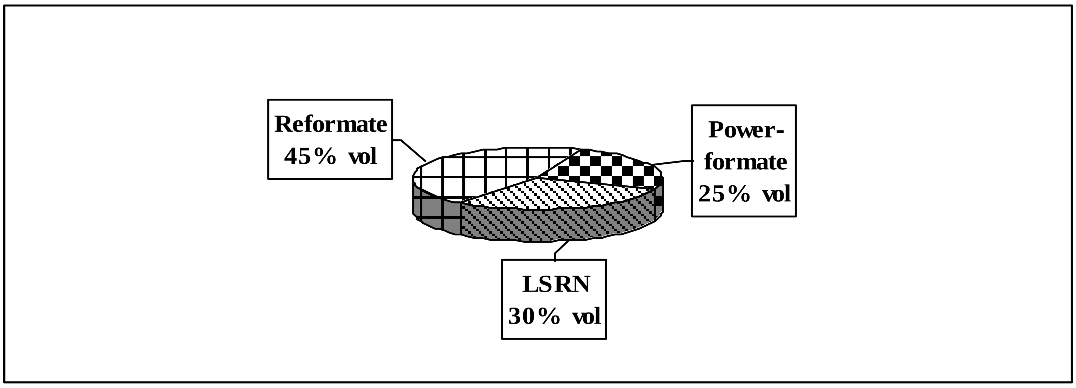


Figure (1): Base Gasoline Formulations

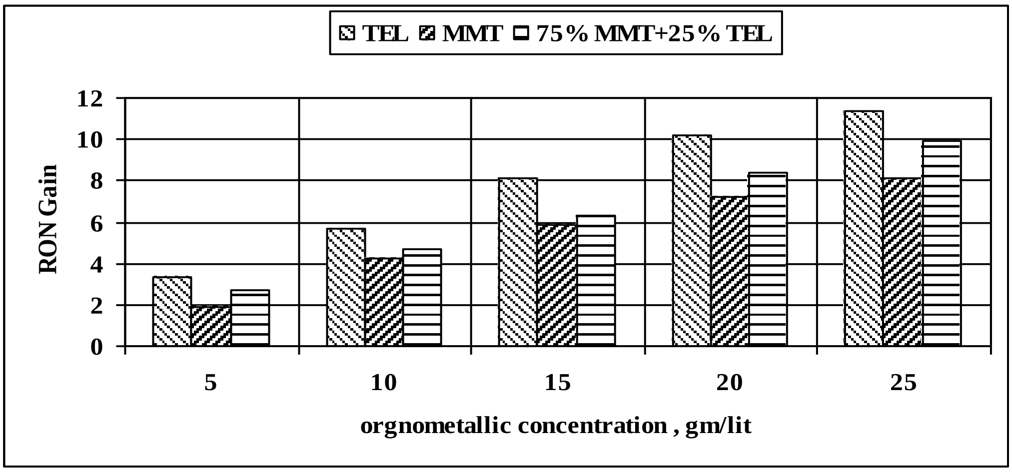


Figure (2): RON Gain of gasoline with increasing TEL, MMT content - Gasoline Pool Base Fuel

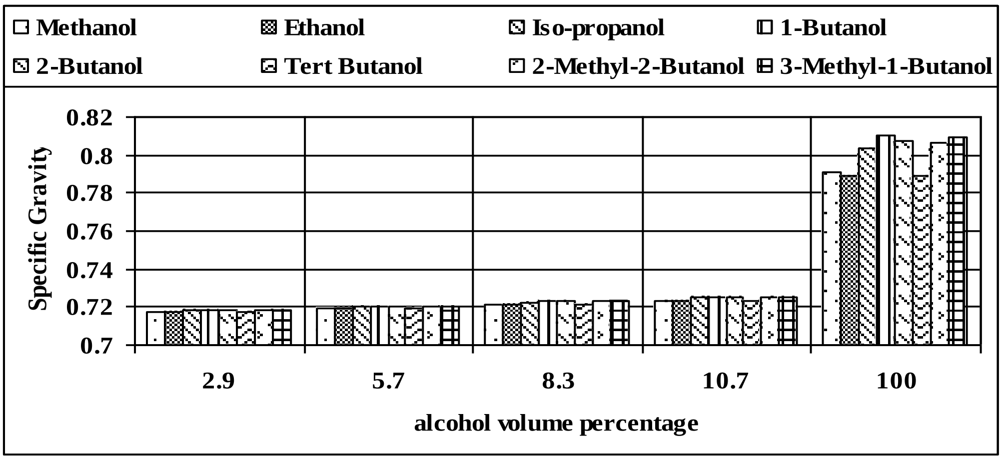


Figure (3): The Change in Specific Gravity of Used Alcohol – Gasoline Base Pool Blends

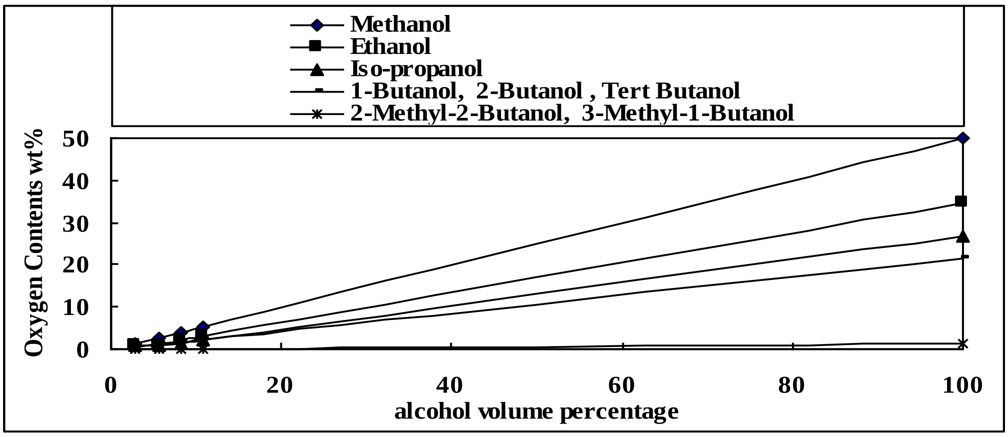


Figure (4): Alcohol Volume Percentage in Alcohol-Gasoline Blends with Matched Oxygen Content.

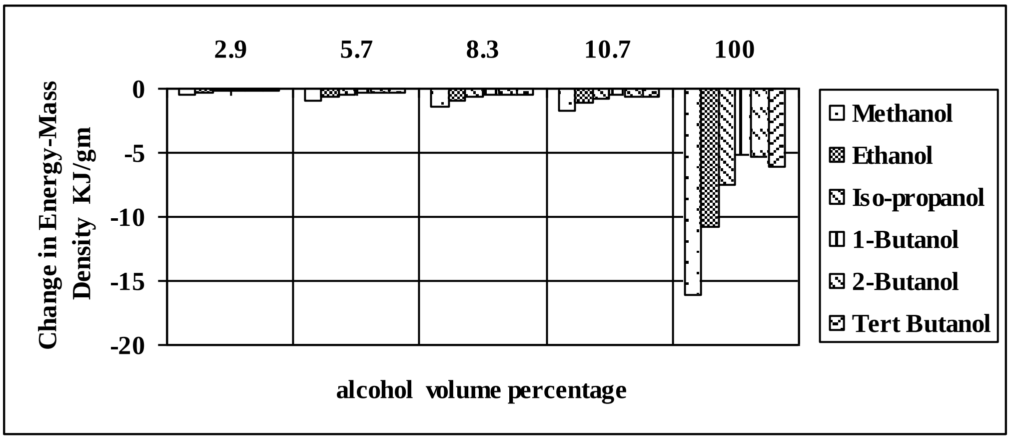


Figure (5): The Change in Energy- Mass Density of Selected Alcohols- Gasoline Blends Relative to Gasoline Base Pool.

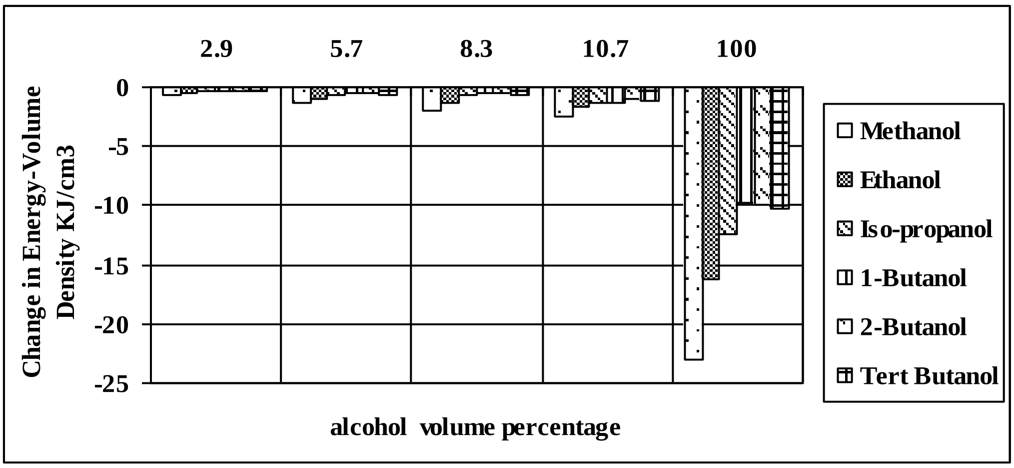


Figure (6): The Change in Energy-Volume Density of Selected Alcohol-Gasoline Blend Relative to Gasoline Base Pool.

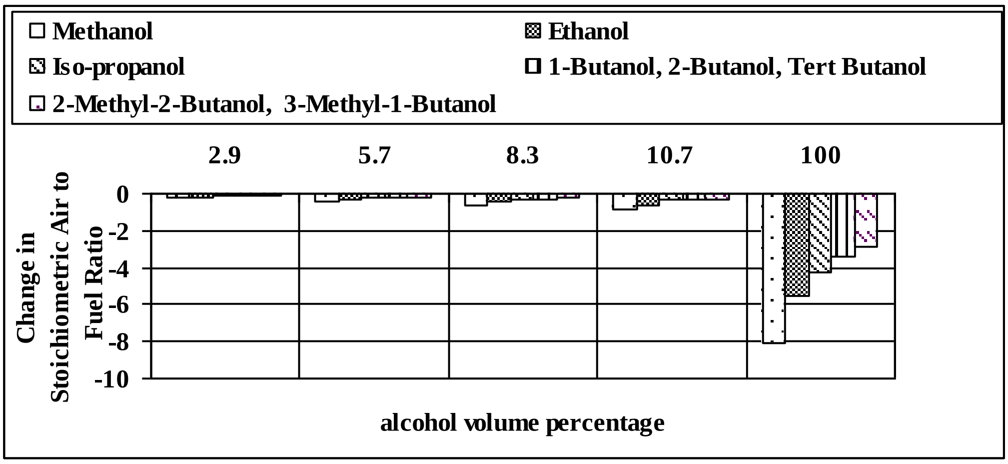


Figure (7): The Change in Stoichiometric Air to Fuel Ratio of Selected Alcohols –Gasoline Blends Relative to Gasoline Base Pool

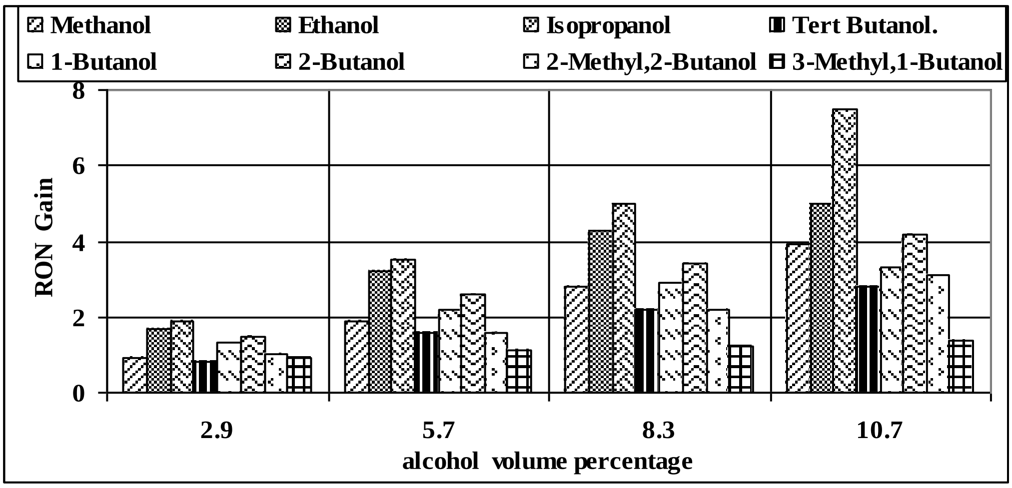


Figure (8): RON Gain of Gasoline with Increasing Alcohol Content - Gasoline Pool Base Fuel

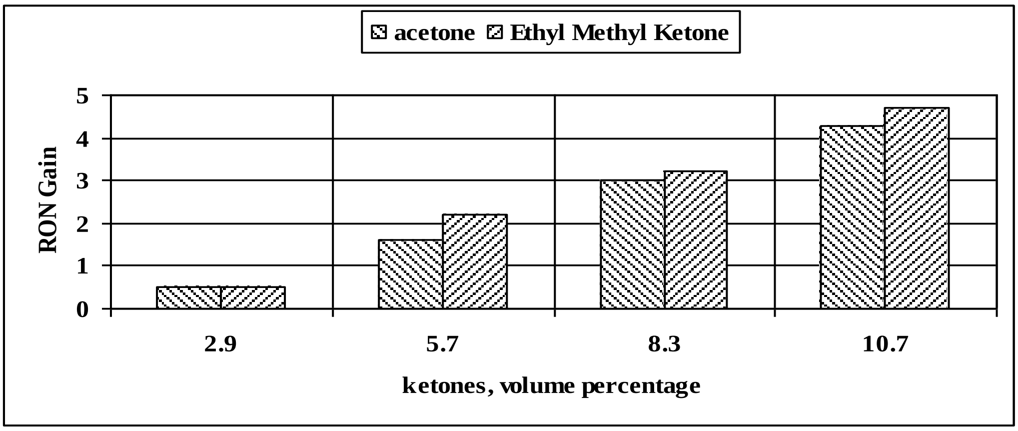


Figure (9): RON Gain of Gasoline with Increasing Ketone Content – Gasoline Pool Base Fuel

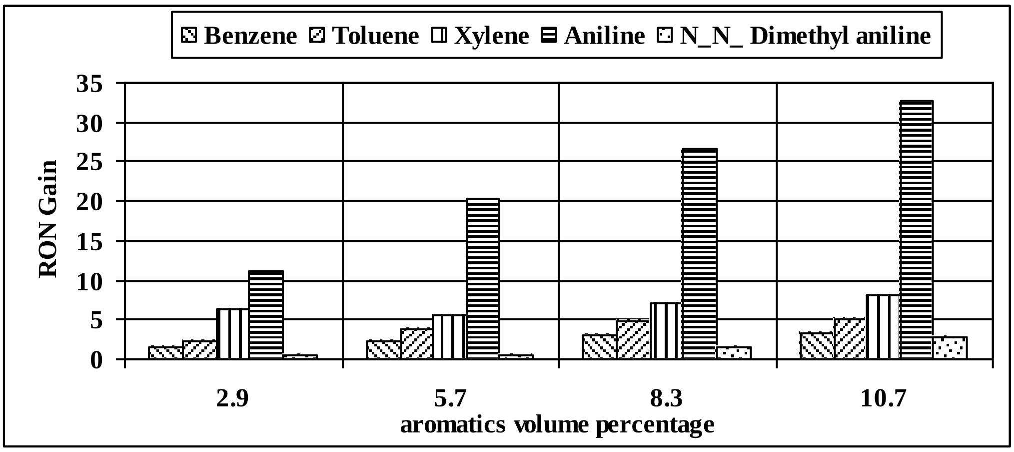


Figure (10): RON Gain of Gasoline with Increasing Aromatic Content - Gasoline Pool Base Fuel

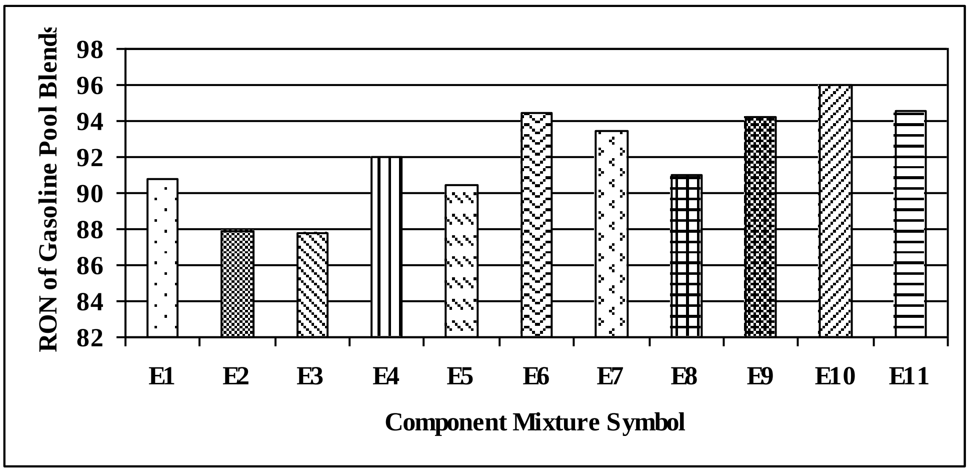


Figure (11): Comparison between RON of Preparation Gasoline Pool Blends with 10.7%vol Preparation Component Mixtures

Table (1) Comparison Between Physical Properties of TEL and MMT [11]

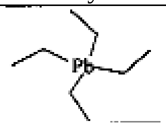
	TEL	MMT
Chemical Name	Tetraethyl Lead	Methylcyclopentadienyl Manganese Tricarbonyl
Chemical Structure		
Manufacturer Location	Associate Octel UK	Ethyl Corp. USA
Concentration	112 g Pb/liter	4 g Mn/liter
Carrier	Toluene/Heptane	Toluene
Typical Level	250 mg/liter	30 mg/liter
Molecular weight	323.44	218.09
Density gm/cm^3	1.653	1.38
Boiling point ^oC	85	233
Melting point ^oC	-136	-1

Table (2): Base Gasoline Formulation

Component	RON	Vol%	Expected RON
LSRN	69.2	30	20.8
Reformate	90.5	45	40.7
Powerformate	89.3	25	23.3
Total Blend		100	84.8

Table (3): Summarized Laboratories Testing Properties of Gasoline Blend Stocks

Properties Items	Test Methods	LSRN	HSRN	Blend of 30%LSRN+ 70%HSRN	Reformate	Power Formate	Base Gasoline Pool
Specific gravity.	IROX test	0.659	0.733	0.71	0.755	0.757	0.715
RVP bar	ASTM D323	0.94	0.4	0.56	0.38	0.37	0.6
Distillation Temp.^oC	ASTM D86						
IBP		32	62	45	43	40	36
10%		43	75	66	68	58	54
20%		52	89	80	82	77	64
30%		58	105	88	98	95	72
40%		63	122	97	110	117	82
50%		68	141	106	121	135	92
60%		74	155	113	134	152	102
70%		80	169	120	146	168	115
80%		86	178	127	161	186	129
90%		97	188	134	182	198	148
EBP		115	203	174	215	219	187
T.D.ml		98	98.5	98	98	98.5	98.5
Max. S content ppm	ASTM D4294	74.90	32.00	45	91.40	34.80	43.8
Water content ppm	ASTM D4928	35.60	43.00	40	67.22	42.00	131.95
Existent gum mgm/100ml	ASTM D381	0.60	Nill	Nill	Nill	Nill	1.2
Calorific value kcal/kgm		11488	11272	11341	11203	11197	11326
MON	ASTM D2700	64.60	51.20	55.71	86.00	84.80	80
RON	ASTM D2699	69.20	56.50	60.31	90.50	89.30	84.5
Aromatics vol%	IROX test	4.30	10.80	8.85	41.66	39.23	24.25
Olefins vol%	IROX test	0.00	2.70	1.89	0.00	0.00	0
Paraffins & Naphthenes vol%	IROX test	95.70	86.50	89.26	58.34	60.77	75.75

Calorific value (Cp) kcal/kg.m=12400-2100(sp.gr)^2

Table (4): Octane Enhancing Additives

Group	Short Chemical Name	Full Chemical Name
Organometallics	TEL MMT	Tetra ethyl lead Methylcyclopentadienyl manganese tricarbonyl
Alcohols	Methanol Ethanol IPA 1-Butanol 2-Butanol Tert Butanol 2-Methyl-2-Butanol 3-Methyl-1-Butanol	Methyl alcohol Ethyl alcohol Iso-propanol n- Butanol Sec-Butanol Tertiary butyl alcohol Tert-Amyl alcohol Active Amyl alcohol, Isopentyl Alcohol, Isobutyl Carbinol
Ketones	Acetone EMK	Dimethyl ketone Ethyl methyl ketone
Aromatics	Benzene Toluene Xylene	benzol Methyl benzene Dimethyl benzene
Aromatic amines	Aniline DAE	Amino benzene N-N- Dimethyl aniline

Table (5): Physical and Chemical Properties of Selected Octane Enhancing Additives

Octane Enhancing Additives		Chemical Structure	Molecular Weight	Specific Gravity	Boiling Point °C	Flash Point °C	Oxygen Content wt%	Latent Heat of Vaporization (KJ/kg)	Energy-Mass Density (KJ/gm)	Energy-Volume Density (KJ/cm^3)	Stoichiometric Air/Fuel Ratio	RVP, (kPa)	RON	MON
Alcohols	Methanol	CH_3OH	32.04	0.791	65	6.5	49.9	1101.1	19.93	15.76	6.43	30	122	93
	Ethanol	C_2H_5OH	46.07	0.789	78.5	12	34.7	841.5	26.75	21.11	8.94	9	121	97
	Iso-propanol	C_3H_7OH	60.11	0.804	97.4	13	26.63	663.1	30.45	24.36	10.28	4.12	117	95
	1-Butanol	$C_4H_9(OH)$	74.12	0.810	117.2	24	21.59	581.8	33.08	26.79	11.12	0.58	96	78
	2-Butanol	$C_4H_9(OH)$	74.12	0.807	99.5	24	21.59	550.7	32.96	26.6	11.12	1.7	108	91
	Tert Butanol	$(CH_3)_3COH$	74.12	0.789	82.3	11	21.59	527.0	32.59	25.71	11.12	4.51	107	94
	2-Methyl-2-Butanol	$C_5H_{12}O$	88.15	0.806	102	25	1.13	460.7	NA	NA	11.68	1.60	97	
	3-Methyl-1-Butanol	$C_5H_{12}O$	88.15	0.809	128.5	42	1.13	500.6	NA	NA	11.68	0.40	113	
Ketones	Acetone	C_3H_6O	58.08	0.790	56.2	-17	1.72	501.7	28.59	22.59	9.45	30	110	
	Ethyl Methyl Ketone	$(CH_3)_2CH_2O$	72.12	0.805	79.6	-6	1.39	342.5	33.80	27.21	8.57	10.40	118	
Aromatics	Benzene	C_6H_6	78.12	0.877	80.1	12	---				0.00	14	101	93
	Toluene	$C_6H_5CH_3$	92.15	0.867	110.6	40	----				0.00	5.4	114	103
	Xylene	$C_6H_4(CH_3)_2$	106.17	0.861	138.3	63	----				0.00	0	117	100
Aromatic Amines	Aniline	$C_6H_5NH_2$	93.13	1.022	184	70	----	478.2	36.48	37.28	0.00	0.5	310	290
	N,N-dimethyl Aniline	$C_2H_{11}N$	121.18	0.956	194.8	62	----				0.00	0.067	95	84

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Table (6): Typical Octane Number Response Data of Gasoline Base Pool with TEL, MMT

Orgnometallic Additives	5 gm / lit		10 gm / lit		15 gm / lit		20 gm / lit		25 gm / lit	
	Pool RON	RON Gain	Pool RON	RON Gain	Pool RON	RON Gain	Pool RON	RON Gain	Pool RON	RON Gain
TEL	86.3	3.3	88.7	5.7	91.1	8.1	93.2	10.2	94.4	11.4
MMT	84.9	1.9	87.2	4.2	88.9	5.9	90.2	7.2	91.1	8.1
75%/25% MMT/TEL	85.7	2.7	87.7	4.7	89.3	6.3	91.4	8.4	92.9	9.9

Table (7): Composition of Blending Additives.

Additive Symbol	Composition vol%
E1	33.3%ethanol+33.3%methanol+33.3%aceton
E2	30.8% xylene + 69.2% benzene
E3	33.3%xylene + 33.3%benzene + 33.3%toluene
E4	10%Aniline +75%isopropanol +15% oxinol
E5	5%Aniline +75%isopropanol +10%oxinol + 10%xylene
E6	10%Aniline + 70% isopropanol +10% oxinol +10%xylene
E7	10%Aniline +60%isopropanol +10% oxinol +20%xylene
E8	10%Aniline +60%isopropanol +30%xylene
E9	15%Aniline +75%isopropanol +5% oxinol +5%xylene
E10	20%Aniline +54%isopropanol +10% oxinol +16%xylene
E11	20%Aniline +25% oxinol +55%xylene

Table (8): Summarized Lab. Testing for Gasoline Base Pool with and without E10

Properties Items	Gasoline Base Pool	Gasoline Base Pool + 10.7%E10
Specific gravity	0.733	0.754
RVP bar	0.44	0.49
Distillation Temp ^oC IBP	49	46
10%	63	57
20%	67	67
30%	79	78
40%	89	90
50%	99	104
60%	113	116
70%	126	131
80%	138	140
90%	152	154
EBP	179	183
T.D.ml	98	99
Max. S content ppm	44.5	34.5
Water content ppm	45.4	58.7
Existent gum mgm/100ml	Nill	Nill
Calorific value kcal/kgm	11272	11250
MON	85.1	93
RON	84.5	96
Aromatics vol%	32.99	34.63
Olefins vol%	0	0
Paraffins and Naphthenes vol%	67.01	66.5