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(54) UNLEADED AVIATION GASOLINE

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(57) **ABSTRACT**

The present invention relates to an aviation gasoline formed by blending (i) an unleaded base fuel having a base MON of at least 94, with (ii) at least one aromatic amine effective to provide the base fuel with a final MON of at least 100.

FIGURE 1

Knock Limited Brake Horse Power (BHP) of Unleaded Octane Rating Fuels

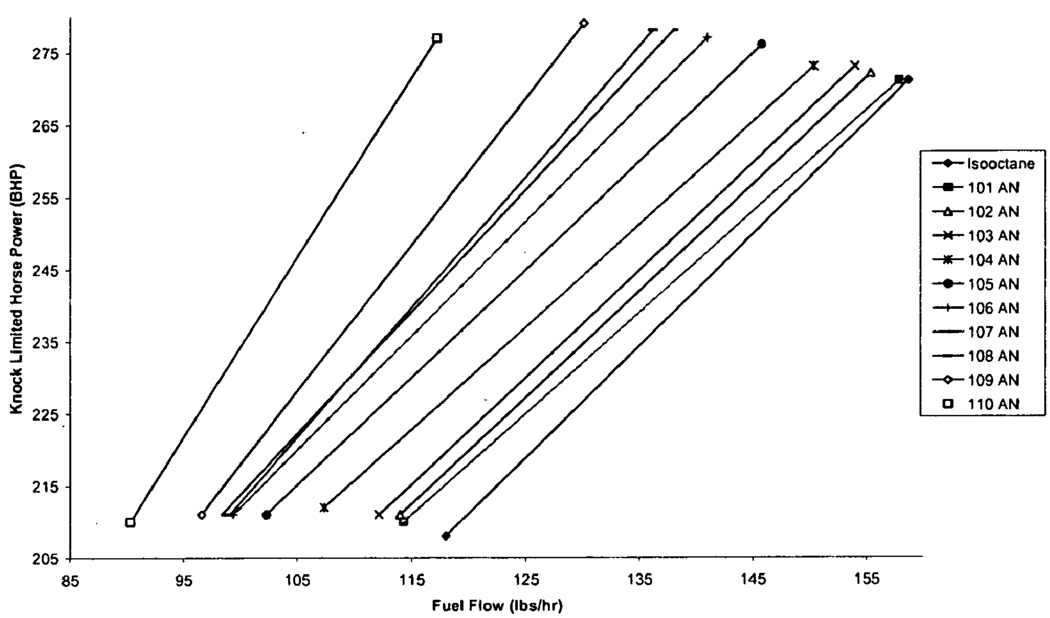


FIGURE 2

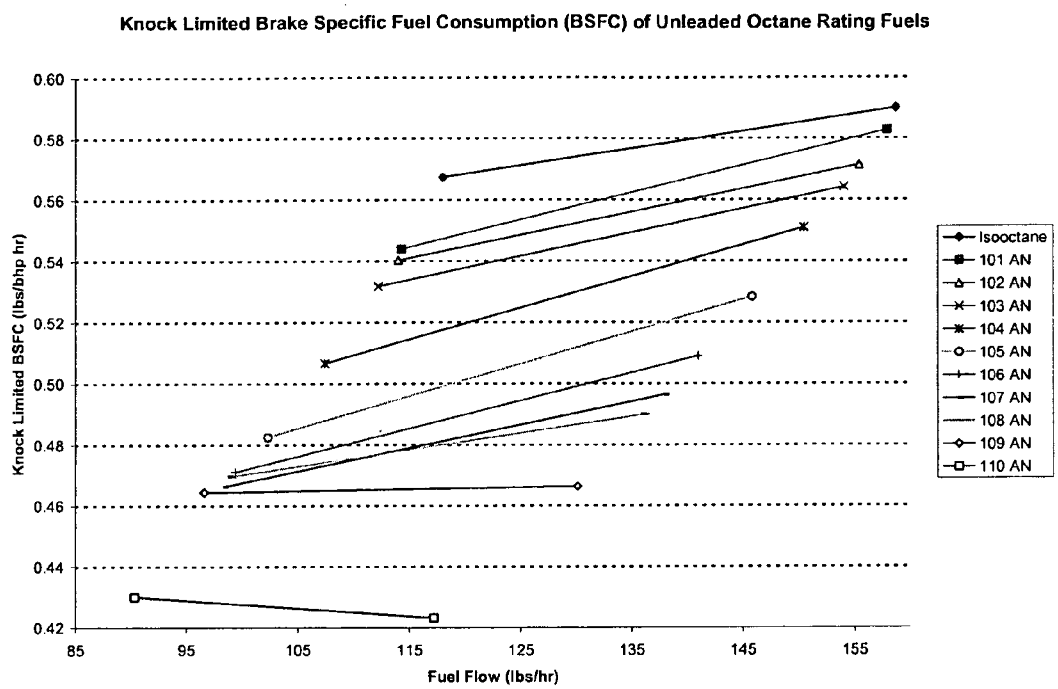

Knock Limited Brake Specific Fuel Consumption (BSFC) of Unleaded Octane Rating Fuels
Knock Limited BSFC (lbs/bhp hr)
0.60
0.58
0.56
0.54
0.52
0.50
0.48
0.46
0.44
0.42
85
95
105
115
125
135
145
155
Fuel Flow (lbs/hr)
Isooctane
101 AN
102 AN
103 AN
104 AN
105 AN
106 AN
107 AN
108 AN
109 AN
110 AN

FIGURE 3

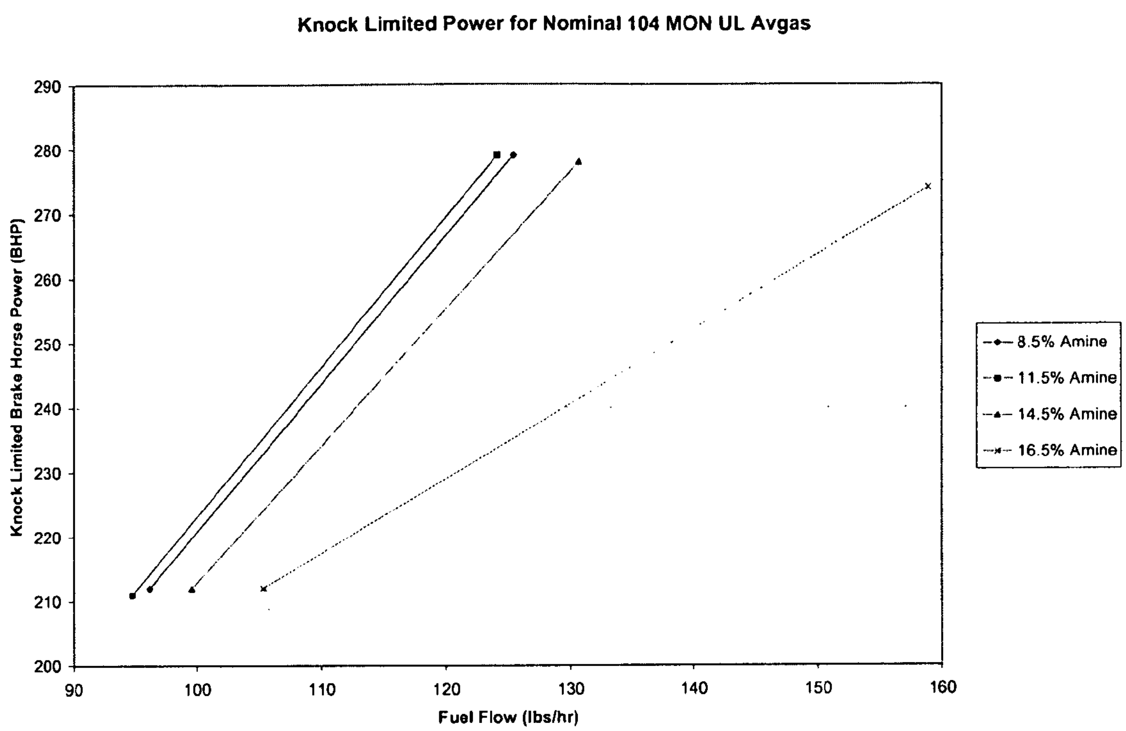
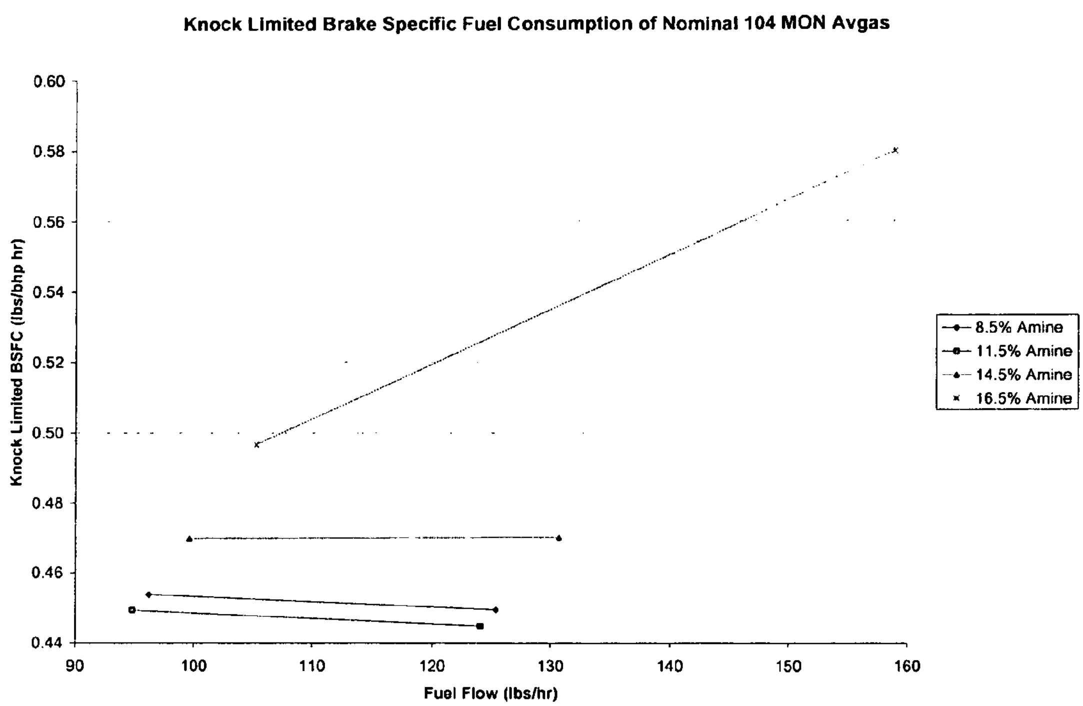

Knock Limited Power for Nominal 104 MON UL Avgas
Knock Limited Brake Horse Power (BHP)
290
280
270
260
250
240
230
220
210
200
90
100
110
120
130
140
150
160
Fuel Flow (lbs/hr)
8.5% Amine
11.5% Amine
14.5% Amine
16.5% Amine

FIGURE 4


Knock Limited Brake Specific Fuel Consumption of Nominal 104 MON Avgas
0.60
0.58
0.56
0.54
0.52
0.50
0.48
0.46
0.44
Knock Limited BSFC (lbs/bhp hr)
90
100
110
120
130
140
150
160
Fuel Flow (lbs/hr)
8.5% Amine
11.5% Amine
14.5% Amine
16.5% Amine

UNLEADED AVIATION GASOLINE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This Application claims the benefit of U.S. Provisional Application 61/212,397 filed Apr. 10, 2009.

[0002] This Application claims the benefit of U.S. Provisional Application filed Apr. 10, 2009.

FIELD OF THE INVENTION

[0003] The present invention relates to an unleaded aviation gasoline.

BACKGROUND OF THE INVENTION

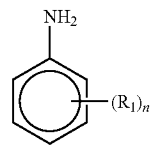
[0004] High octane requirements for aviation gasoline for use in piston driven aircraft which operate under severe requirements, e.g., aircraft containing turbo-charged piston engines, require that commercial aviation fuels contain a high performance octane booster. Organic octane boosters for automobile gasolines ("Mogas"), such as benzene, toluene, xylene, methyl tertiary butyl ether, ethanol, and the like, are not capable by themselves of boosting the MON to the ≧100 MON levels required for aviation gasolines ("Avgas"). To boost the MON to a level≧100 MON, tetraethyl lead (TEL) has been employed in aviation gasolines.

[0005] Compositionally, Avgas is different from Mogas. Avgas, because of higher octane and stability requirements, is typically a blend of isopentane, alkylate, toluene and tetraethyl lead. A typical Avgas base fuel without octane booster such as tetraethyl lead has a MON of 88 or higher, usually 88 to 97. Mogas, which has lower octane requirements, is a blend of many components such as butane, virgin and rerun naphtha, light, intermediate and heavy cat naphthas, reformate, isomerate, hydrocrackate, alkylate and ethers, or alcohols. Octane requirements of Mogas are based on the average of research and motor octane numbers (RON+MON/2). For a given fuel, the RON is on average 10 octane numbers higher than its corresponding MON. Thus, the average premium Mogas possesses a MON of 86 to 88, whereas current Avgas must have a MON of 99.5. MON, not the average of RON+MON, is the accepted measure of octane for Avgas and is measured using ASTM D2700-07b.

[0006] Conventional octane boosters for Mogas, such as benzene, toluene, xylene, methyl tertiary butyl ether and ethanol are capable of boosting the MON of unleaded Avgas to the 92 to 95 MON range if added to Avgas in high enough concentrations. As noted previously, this is insufficient to meet the needs of 98 MON high octane Avgas.

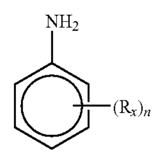
[0007] High performance aircraft engines are certified to operate safely on minimum 100/130 octane normal lead or 100 octane low lead (100LL) aviation gasolines. However, governmental requirements are quickly moving toward requiring that Avgas be lead-free or unleaded. When lead is removed and an unleaded fuel is blended to the same (100 MON) leaded octane performance, high performance engines remain unsatisfied and cannot be operated safely. Specifically, high performance engines certified on 100LL, operated at or near their certified limits, knock when fueled by unleaded fuels of the same octane (i.e., 100 MON). To satisfy high performance engines with an unleaded fuel, we have found that an octane rating of greater than 100 is required. We have further found that an MON of at least 104 is preferred. With the phasing out of tetra-ethyl lead as an octane booster resort must be made to other means for boosting octane.

[0008] U.S. Pat. No. 5,470,358 teaches a high octane unleaded aviation gasoline comprising unleaded aviation gasoline base fuel and an amount of at least one aromatic amine effective to increase the motor octane number of the base fuel to at least about 98, the aromatic amine having the formula



wherein R_1 is C_1-C_{10} alkyl, n is an integer of from zero to 3 with the proviso that R_1 cannot occupy the 2- or 6-position on the aromatic rings. When R_1 is alkyl, it occupies the -3, -4, or -5 (meta- or para-) positions on the phenyl ring. Alkyl groups in the 2- or 6-position result in aromatic amines which cannot boost octane to a MON value of 98. Examples of preferred aromatic amines for octane improvement include phenylamine, 3-methylphenylamine, 3-ethylphenylamine, 4-methylphenylamine, 3,5-dimethylphenylamine, 3,4-dimethylphenylamine, 4-isopropylphenylamine, 2-fluorophenylamine, 3-fluorophenylamine, 4-fluorophenylamine, 2-chlorophenylamine, 3-chlorophenylamine and 4-chlorophenylamine. Especially preferred are 3,5-dimethylphenylamine, 3,4-dimethylphenylamine, 2-fluorophenylamine, 4-fluorophenylamine, 3-methylphenylamine, 3-ethylphenylamine, 4-ethylphenylamine, 4-isopropylphenylamine, 4-t-butylphenylamine and 4-t-amylphenylamine. Preferred halogens are described as being Cl or F.

[0009] U.S. Patent Application 2006-0123696 describes an unleaded aminated aviation gasoline which contains a deposit control additive and comprises a blend of a base aviation gasoline having a base Motor Octane Number (MON) of less than 98 and an effective amount of at least one aromatic amine effective to increase the MON of the base fuel to at least 98, the aromatic amine having the formula [I]



[I]

wherein R_x is C_1-C_{10} alkyl, halogen or a mixture thereof, n is an integer of from 0 to 3 provided that when n is 1, 2, or 3 and R_x is an alkyl group it occupies the meta and/or para position on the phenyl ring. When R_x is alkyl, it occupies the -3, -4, or -5 (meta- or para-) positions on the phenyl ring. Alkyl groups in the 2- or 6-position result in aromatic amines which cannot boost octane to a MON value of 98. Examples of preferred aromatic amines for octane improvement include phenylamine, 3-methylphenylamine, 3-ethylphenylamine, 4-methylphenylamine, 3,5-dimethylphenylamine, 3,4-dimethylphenylamine, 4-isopropylphenylamine, 2-fluorophenylamine, 3-fluorophenylamine, 4-fluorophenylamine, 2-chlorophenylamine, 3-chlorophenylamine and 4-chlorophenylamine.

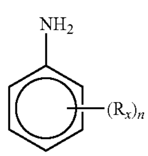
Especially preferred are 3,5-dimethylphenylamine, 3,4-dimethylphenylamine, 2-fluorophenylamine, 4-fluorophenylamine, 3-methylphenylamine, 3-ethylphenylamine, 4-ethylphenylamine, 4-isopropylphenylamine, 4-t-butylphenylamine and 4-t-amylphenylamine. Preferred halogens are described as being Cl or F.

[0010] U.S. Pat. No. 5,851,241 and U.S. Pat. No. 6,258,134 are directed to aviation fuel compositions which contain a combination of an alkyl tertiary butyl ether, an aromatic amine and optionally a manganese component such as methyl cyclopentadienyl manganese tricarbonyl (MMT). The base fuel to which the additive combination may be added may be a wide boiling range alkylate base fuel. According to these patents, the combination of the alkyl tertiary butyl ether, the aromatic amine and, optionally, the manganese component results in a synergistic combination which boosts the MON of the fuel to a degree greater than that seen when each additive is used individually in the base fuel.

[0011] Inevitably, lead production will continue to decline and, at some point, governmental requirements will severely curtail or eliminate its use in aviation gasolines. Replacing lead with amine octane boosters has progressed over the years, however, satisfying high performance engines has been very difficult. Unleaded fuels produced that meet the minimum octane performance specification listed in D 910 (100 MON) have failed to satisfy high performance engines. Thus, the need remains to produce an unleaded aviation gasoline that, at a minimum, satisfies the octane requirements of a majority of high performance aircraft engines.

SUMMARY OF THE INVENTION

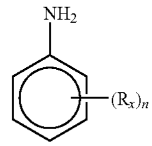
[0012] The present invention is an unleaded aviation gasoline formed by blending an unleaded fuel having a Motor Octane Number (MON) of at least 94 and an effective amount of at least one aromatic amine effective to increase the MON of the base fuel to at least 100. The aromatic amine has the following formula [I]:



[I]

wherein R_x is C_1-C_{10} alkyl, halogen or a mixture thereof, n is an integer of from 0 to 3 provided that when n is 1 or 2 and R_x is an alkyl group it occupies the meta and/or para position on the phenyl ring.

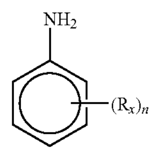
[0013] The present invention is an unleaded aviation gasoline which comprises a blend of an unleaded base fuel having a Motor Octane Number (MON) of at least 94 and an effective amount of at least one aromatic amine effective to increase the MON of the base fuel to at least 100. The aromatic amine has the following formula [I]:



[I]

wherein R_x is C_1-C_{10} alkyl, halogen or a mixture thereof, n is an integer of from 0 to 3 provided that when n is 1 or 2 and R_x is an alkyl group it occupies the meta and/or para position on the phenyl ring.

[0014] The present invention is also a method for fuelling an aircraft comprising providing to the aircraft an aviation gasoline comprising an unleaded fuel having a Motor Octane Number (MON) of at least 94 and a sufficient aromatic amine to provide the unleaded fuel with a final MON of at least 100. The aromatic amine has the following formula [I]:



[I]

wherein R_x is C_1-C_{10} alkyl, halogen or a mixture thereof, n is an integer of from 0 to 3 provided that when n is 1 or 2 and R_x is an alkyl group it occupies the meta and/or para position on the phenyl ring.

[0015] These and other advantages of the present invention shall become apparent from the following detailed description of the invention, and the appended figures and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** shows a plot of Knock Limited Brake Horse Power versus Fuel Flow.

[0017] FIG. **2** shows a plot of Knock Limited Brake Specific Fuel Consumption versus Fuel Flow.

[0018] FIG. **3** shows a plot of Knock Limited Brake Horse Power versus Fuel Flow for Nominal 104 MON Unleaded Aviation Gasoline.

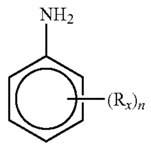
[0019] FIG. **4** shows a plot of Knock Limited Brake Specific Fuel Consumption versus Fuel Flow for Nominal 104 MON Aviation Gasoline.

DETAILED DESCRIPTION OF THE INVENTION

[0020] This invention describes an unleaded Avgas composition that satisfies the octane requirements of a majority of high performance aircraft engines. Engine satisfaction is achieved through the use of a high octane base-fuel in combination with an optimum concentration of select aromatic amines. An engine remains satisfied, with regard to octane, when it can be run knock free within its entire certified operating envelope. The base fuel is composed of hydrocarbons selected from C_4 to C_9 hydrocarbons. With this unique combination of high octane base fuel and select aromatic amines, satisfying high performance aircraft engines with an unleaded aviation gasoline is now possible.

[0021] The unleaded aviation gasoline of the present invention contains a blend of an unleaded base fuel having a base Motor Octane Number (MON) of at least 94 and an effective amount of at least one aromatic amine effective to increase the MON of the base fuel to at least 100. The aromatic amine has the following formula [I]:

[I]



wherein R_x is C_1-C_{10} alkyl, halogen or a mixture thereof, n is an integer of from 0 to 3 provided that when n is 1 or 2 and R_x is an alkyl group it occupies the meta and/or para position on the phenyl ring.

[0022] With reference to formula [1], when R_x is alkyl, it occupies the -3, -4, or -5 (meta or para) positions on the phenyl ring. Alkyl groups at the 2- or 6-position result in aromatic amines which cannot increase octane to a MON over 98. When R_x includes a halogen, useful halogens are Cl or F. Examples of useful aromatic amines in the present invention include phenylamine, 3-methylphenylamine, 3-ethylphenylamine, 4-methylphenylamine, 3,5-dimethylphenylamine, 3,4-dimethylphenylamine, 4-isopropylphenylamine, 2-fluorophenylamine, 3-fluorophenylamine, 4-fluorophenylamine, 2-chlorophenylamine, 3-chlorophenylamine and 4-chlorophenylamine. Especially useful are 3,5-dimethylphenylamine, 3,4-dimethylphenylamine, 2-fluorophenylamine, 4-fluorophenylamine, 3-methylphenylamine, 3-ethylphenylamine, 4-ethylphenylamine, 4-isopropylphenylamine, 4-isoamylphenylamine 4-t-butylphenylamine and 4-t-amylphenylamine,.

[0023] The unleaded base fuel contained in the aviation gasoline of the present invention is desirably unleaded and has an MON of at least 94.

[0024] However, the MON may be, at least either 95, 96, 97, 98, 99, 100, 101, 102 or greater. The unleaded base fuel is composed of an alkylate comprising, or selected from a group consisting of, at least one or any combination of C_4 to C_{12} hydrocarbons. The unleaded base fuel may also be composed of an alkylate comprising, or selected from a group consisting of, at least one or any combination of the following hydrocarbons: C_4H_{10}, C_5H_{12}, C_6H_{14}, C_7H_{16}, C_8-C_{18}, C_9H_{20}, $C_{10}H_{22}$, $C_{11}H_{24}$ and $C_{12}H_{26}$. The unleaded base fuel may also be composed of an alkylate comprising, or selected from the group consisting of, at least one or any combination of the following: n-butane; 2-methylbutane(isobutane); n-pentane; 2-methylpropane(isopentane); 2,2-dimethylpropane(neopentane); n-hexane; 2-methylpentane; 3-methylpentane; 2,2-dimethylbutane(neohexane); 2,3-dimethylbutane(diisopropyl); n-heptane; 2-methylhexane; 3-methylhexane; 3-ethylpentane; 2,2-dimethylpentane, 2,3-dimethylpentane; 2,4-dimethylpentane; 3,3-dimethylpentane; 2,2,3-trimethylbutane(triptane); n-octane; 2-methylheptane; 3-methylheptane; 4-methylheptane; 3-ethylhexane; 2,2-dimethylhexane; 2,3-dimethylhexane; 2,4-dimethylhexane; 2,5-dimethylhexane(diisobutyl); 3,3-dimethylhexane; 3,4-dimethylhexane; 2-methyl-3-ethylpentane; 3-methyl-3-ethylpentane; 2,2,3-trimethylpentane; 2,2,4-trimethylpentane("isooctane"); 2,3,3-trimethylpentane; 2,3,4-trimethylpentane; 2,2,3,3-tetramethylbutane; n-nonane; 2-methyloctane; 3-methyloctane; 4-methyloctane; 3-ethylheptane; 2,2-dimethylheptane; 2,6-dimethylheptane; 2,2,4-trimethylhexane; 2,2,5-trimethylhexane; 2,3,3-trimethylhexane; 2,3,5-trimethylhexane; 2,4,4-trimethylhexane; 3,3,4-trimethylhexane; 3,3-diethylpentane; 2,2-dimethyl-3-ethylpentane; 2,4-dimethyl-3-ethylpentane; 2,2,3,3-tetramethylpentane; 2,2,3,4-tetramethylpentane; 2,2,4,4-tetramethylpentane; and 2,3,3,4-tetramethylpentane.

[0025] The aviation gasoline of the present invention includes from about 8.5 weight percent to about 14.5 weight percent of the aromatic amine described above. However, the aviation gasoline may include from about 9.5 weight percent to about 13.5 weight percent of the aromatic amine; or may include from about 10.5 weight percent to about 12.5 weight percent of the aromatic amine; or may include from about 11 weight percent to about 12 weight percent of the aromatic amine.

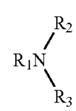
[0026] It has been found that aromatic amine concentrations greater than about 14.5 weight percent lose their octane increasing efficacy at higher concentrations.

[0027] The aviation gasoline of the present invention has a final MON of at least 100. However, the final MON may also be at least 100, at least 101, at least 102, at least 103, at least 104, at least 105, at least 106, at least 107, at least 108, or at least 109.

[0028] The aviation gasoline of the present invention may also include a deposit control additive which is added in an amount up to about 1000 ppm, or up to about 500 ppm, or up to about 250 ppm, or up to about 100 ppm, active ingredient of the deposit control additive. The deposit control additive may be selected from the group consisting of carrier oil, high molecular weight hydrocarbyl amine, high molecular weight hydrocarbyl succinimides, high molecular weight hydrocarbyl substituted Mannich bases, and combinations and mixtures thereof.

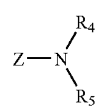
[0029] High molecular weight hydrocarbyl amines are generally represented by the formula [II]

[II]



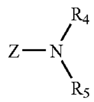
wherein R_1 is the high molecular weight hydrocarbyl group containing about 30 to about 200 carbons and having a weight average molecular weight (Mw) of about 400 to 2800, or about 500 to about 2000, or about 500 to 1500, or about 1000 to 1200, and are usually homo- or copolymer of low molecular weight C_2 to C_6 olefins, e.g., polyisobutylene, R_2 and R_3 are the same or different and are selected from hydrogen, C_2 to C_{10} alkyl,

[III]



wherein Z is a C_1-C_{10} alkylene, R_4 and R_5 are the same or different and are selected from hydrogen, C_1-C_{10} alkyl, C_1-C_{10}—OH, or R_2 and R_3 are hydrogen, C_2-C_4 alkyl,

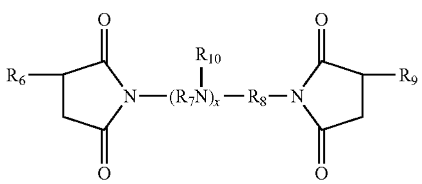
[IV]



[0030] wherein Z is a C_1-C_{10} alkylene, R_4 and R_5 are hydrogen, C_1-C_4 alkyl, C_1-C_4—OH, or R_1 is 1000-1200 Mw polyisobutylene, R_2 and R_3 are the same or different and selected from hydrogen, C_2H_4—NH_2, $C_2H_4N(H)C_2H_4$—OH, $C_3H_6N(CH_3)_2$, or R_2 and R_3 are hydrogen or one of R_2 and R_3 is $C_2H_4NH_2$, $C_2H_4N(H)C_2H_4$—OH or $C_3H_2N(CH_3)_2$.

[0031] High molecular weight succinimides are generally represented by the formula

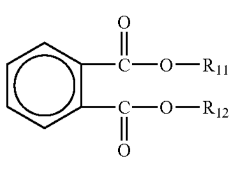
[V]



wherein R_6 and R_9 are the same or different high molecular weight hydrocarbyl group containing about 30 to 200 carbons and having a weight average molecular weight (Mw) of about 400 to 2800, or about 500 to about 2000, or about 500 to 1500, or about 1000 to 1200, or 1000-1200 Mw polyisobutylene, R_7 and R_8 are the same or different and are selected from C_1 to C_{40} alkylene, or C_1-C_4 alkylene, or C_2-C_4 alkylene and R_{10} is hydrogen or C_1-C_{10} alkyl.

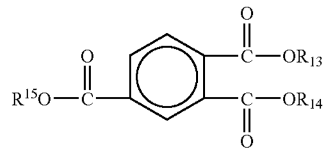
[0032] Carrier oils can be added as such or as components or reaction diluents used in the manufacture of any other additive that may be added. Carrier oils include mineral oils, polyalkylenes, polyalphaolefins, polyalkylene oxides, polyethers, esters, and mixtures thereof, preferably 500-900 SUS mineral oils, 500-1000 Mw polyisobutylene, 500 to 1000 Mw polypropylene, about 1000 Mw polypropylene oxide, about 1000 Mw polybutylene oxide, phthalates, trimellitate, adipates such as exemplified by the formula:

[VI]



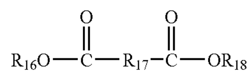
wherein R_{11} and R_{12} are the same or different and selected from C_8-C_{15} alkyl, preferably C_{10}-C_{13} alkyl,

[VII]



wherein R_{13}, R_{14} and R_{15} are the same or different and are selected from C_6-C_{12} alkyl, preferably C_8-C_{10} alkyl, and

[VIII]



wherein R_{16} and R_{18} are the same or different and are selected from C_6-C_{15} alkyl, preferably C_6 to C_{10} alkyl and R_{17} is a C_1-C_{10} alkylene group.

[0033] Mannich bases, such as those described in U.S. Pat. No. 4,767,551, are made from the reaction of alkylphenols, formaldehyde or alkylaldehydes and amines. Process aids and catalysts, such as oleic acid and sulfonic acids, can also be part of the reaction mixture. Molecular weights of useful alkylphenols range from 800 to 2,500. Representative examples are shown in U.S. Pat. Nos. 3,697,574; 3,703,536; 3,704,308; 3,751,365; 3,756,953; 3,798,165; and 3,803,039, which are incorporated herein in their entirety by reference, for the purposes of United States patent practice and those regions which also allow incorporation by reference.

[0034] Typical Mannich base condensation products useful in this invention can be prepared from high molecular weight hydrocarbyl substituted hydroxy-aromatics, primary or secondary amines and formaldehyde, paraformaldehyde, or alkylaldehydes, or alkylaldehyde or formaldehyde precursors.

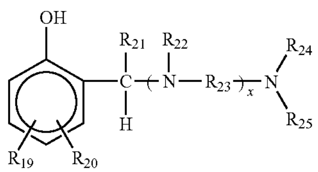
[0035] Examples of high molecular weight hydrocarbyl substituted hydroxyaromatic compounds are polypropylphenol, polybutylphenol, and other polyalkylphenols. These polyalkylphenols can be obtained by the alkylation, in the presence of an alkylating catalyst, such as BF_3, of phenol with high molecular weight polypropylene, polybutylene, polyisobutylene and other polyalkylene compounds to give alkyl substituents on the phenyl ring of the phenol having a weight average molecular weight (Mw) of about 400 to 2800, or about 500 to about 2000, or about 500 to 1500, or about 1000 to 1200, or 1000-1200 Mw polyisobutylene or polypropylene.

[0036] Examples of reactants are alkylene polyamines, principally polyethylene polyamines, primary or secondary amine. Other representative organic compounds suitable for use in the preparation of Mannich condensation products are well known and include the mono- and di-amino alkanes and their substituted analogs, e.g., ethylamine and diethanol amine; aromatic diamines, e.g., phenylene diamine, diamino naphthalenes; heterocyclic amines, e.g., morpholine, pyrrole, pyrrolidine, imidazole, imidazolidine, and piperidine; melamine and their substituted analogs.

[0037] Amines having nitrogen contents corresponding to the alkylene polyamines in the formula H_2N—(Z—NH—)$_n$H, wherein Z is a divalent alkylene of C_2-C_6, and n is 1 to 10 are useful herein. Examples of alkylene polyamine reactants include ethylenediamine, diethylene triamine, triethylene tetraamine, tetraethylene pentaamine, pentaethylene hexamine, hexaethylene heptaamine, heptaethylene octaamine, octaethylene nonaamine, nonaethylene decamine, and decaethylene undecamine and mixture of such amines. Corresponding propylene polyamines such as propylene diamine and di-, tri-, tetra-, penta-propylene tri-, tetra-, penta- and hexaamines and mixtures thereof are also suitable reactants. The alkylene polyamines are usually obtained by the reaction of ammonia and dihalo alkanes, such as dichloro alkanes. Thus the alkylene polyamines obtained from the reaction of 2 to 11 moles of ammonia with 1 to 10 moles of dichloro alkanes having 2 to 6 carbon atoms and the chlorines on different carbons are suitable alkylene polyamine reactants.

[0038] Aldehyde reactants useful in the preparation of the high molecular products useful in this invention include the aliphatic aldehydes such as formaldehyde (also as paraformaldehyde and formalin), acetaldehyde and aldol (b-hydroxybutyraldehyde). Formaldehyde or a formaldehyde-yielding reactant is preferred. Mannich bases can be represented by the following non-limiting formula:

[IX]



wherein

[0039] R_{19} is the same or different and each is selected from a high molecular weight hydrocarbyl group containing about 30 to 200 carbons and having a weight average molecular weigh (Mw) of about 400 to 2800, preferably about 500 to 2000, more preferably about 500 to 1500, still more preferably about 1000-1200, most preferably 1000-1200 Mw polyisobutylene or polypropylene;

[0040] R_{20} is the same or different and selected from hydrogen or C_1-C_{10} alkyl, preferably hydrogen or C_1-C_4 alkyl more preferably hydrogen or methyl;

[0041] R_{21} is the same or different and selected from hydrogen or C_1-C_4 alkyl, preferably hydrogen or methyl, more preferably hydrogen;

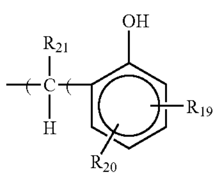
[0042] R_{22} is hydrogen or C_1-C_4 alkyl, preferably hydrogen or methyl, more preferably hydrogen;

[0043] R_{23} is C_1-C_{10} alkylene, C_6-C_{10} arylene, preferably C_1-C_4 alkylene, most preferably C_2-C_3 alkylene;

[0044] R_{24} is hydrogen or C_1-C_4 alkyl, preferably hydrogen or methyl, more preferably hydrogen;

[0045] R_{25} is hydrogen, C_1-C_4 alkyl or

[X]



[0046] provided that both R_{24} and R_{25} are not hydrogen;

[0047] x is 1 to 10, preferably 1 to 4.

[0048] Typical detergents such as polyether amines which are identified in the literature as effective detergents in automotive gasoline have been discovered to be unsatisfactory for controlling deposits caused by the combustion of aminated unleaded aviation gasoline, while, quite unexpectedly, materials selected from carrier oils high molecular weight hydrocarbyl substituted amines, high molecular weight hydrocarbyl substituted succinimides, high molecular weight hydrocarbyl substituted Mannich bases and mixture thereof have been found useful in controlling insoluble deposits formed by aviation gasoline.

[0049] Further, even among those deposit control additives which have been found to control deposits derived from aminated fuels, it was expected that they would exhibit poor water separation properties. Unexpectedly, it has been discovered that a number of the deposit control additives not only effectively control toluene insoluble deposits but also enable the fuels to exhibit satisfactory water separation properties. Aviation fuels operate in environment characterized by wide temperature swings. Fuels cooled from 75° F. down to 32° F. can drop out 12 ml of water per 100 gallons. Water in fuels at low temperature can cause undesirable operational problems that can potentially impact fuel flow in carburetors, fuel lines and injectors. Therefore, it is important to minimize a given fuel's water content.

[0050] Useful deposit control additives have both the ability to control deposits and exhibit good water separation and are the high molecular weight hydrocarbyl amines, the high molecular weight hydrocarbyl substituted Mannich bases, the carrier oils and mixtures thereof.

[0051] Generally the aviation gasoline of the present invention contains anywhere from zero to up to about 25 wt % toluene, but usually is of low toluene content, e.g., zero to 6 wt % toluene, or zero to 2 wt % toluene, or zero to <1 wt % toluene.

[0052] When toluene is used or present in limited quantity when amines are used, fouling and formation of toluene insoluble deposits can still occur. To control the toluene insoluble deposits it has been found necessary to utilize at least one of the deposit control additives described herein.

[0053] The aviation gasoline of the present invention may also contain at least one additional additive. This additional additive can be selected from the group consisting of octane boosters, antioxidants, toluene, metal deactivators, dyes and mixtures and combinations thereof. Co-solvents include low molecular weight aromatics, alcohols, nitrates, esters, ethers, halogenated hydrocarbons and the like. With the phase out of TEL, octane boosters may be employed. Such conventional octane boosters include ethers, alcohols, and non-lead metals, including, e.g., ethyl tertiary butyl ether, methyl cyclopentadienyl manganese tricarbonyl, iron pentacarbonyl. Antioxidants such as 2,6-di-t-butyl hydroxy toluene (BHT) can be present in an amount up to 200 mg/liter of fuel, or up to 100 mg/liter of fuel, or up to 50 mg/liter of fuel, or up to 24 mg/liter of fuel. Metal deactivators such as N,N-disalicylidene-1,2-propane diamine can be present in an amount up to 50 ppm, or up to 25 ppm, or up to about 10 ppm. ASTM D-910 lists Avgas approved additives which may be employed in the Avgas of this invention.

[0054] Antioxidants and metal deactivators, such as BHT and N,N-disalicylidene1,2-propane diamine, may inhibit the reactions that cause deposit formation. The deposit control additives do not necessarily inhibit the reactions which cause the initial deposit formation, but can be effective over a greater range of conditions, including temperature and concentration fluctuations and in addressing pre-existing deposits.

[0055] The present invention is also directed to a method for fuelling an aircraft. The method comprises providing the aviation gasoline described herein to an aircraft. The method may also include the additional step of filtering the fuel prior to providing the aviation gasoline described herein to the aircraft. Useful filters and methods of filtration are known to those of skill in the art.

[0056] This invention allows high performance aircraft engines to operate knock free using unleaded Avgas, making the transition from leaded to unleaded fuels essentially transparent. To date, high performance aircraft engines have not been satisfied by unleaded aviation fuels meeting the minimum octane requirement for the 100/130 or 100LL ("low lead") specification listed in ASTM D 910. It has been found that two unleaded fuels possessing essentially the same ultra high octane number, as measured by D 2700, may not provide the same level of engine satisfaction (measured via ASTM D 6424). Moreover, an optimum amine concentration ensures maximum engine satisfaction is achieved with a given octane number fuel.

[0057] Engine tests have shown that the majority of aircraft engines are satisfied with a 104 MON unleaded amine based fuel. FIGS. **1** and **2** show the octane requirement of a Lycoming IO-540 K high performance aircraft engine based on knock limited power and knock limited break specific fuel consumption (BSFC) using standard unleaded octane rating fuels. In both cases 100 MON and 101 -110AN (amine number) unleaded primary reference fuels were used. FIG. **1** shows that achievable horsepower at a given fuel flow increases directly as octane level increases. FIG. **2** shows that as octane increases so does the Brake Specific Fuel Consumption (BSFC).

[0058] It was discovered that a variety of unleaded Avgas fuels that rate at a nominal 104 MON by ASTM D 2700, do not provide the same level of engine satisfaction, as determined by ASTM D 6424. Specifically, high performance engines, like the Lycoming IO-540 K, are best satisfied when the base fuel possesses a MON of 95 and the amine concentration of about 11.5 weight percent.

[0059] Table 1 lists the base fuel MONs and percent amine added to obtain a nominal 104 MON Ultra High Octane finished fuel.

TABLE 1

Base Fuel MON	% amine (wt %)	Finished Fuel MON
90.0	16.5	102.9
93.0	14.5	103.3
95.0	11.5	104.0
97.0	8.5	103.4

[0060] FIG. **3** shows that about 11.5 weight percent amine in a base fuel that produces a finished Avgas possessing a nominal MON of 104 provides maximum octane satisfaction for the Lycoming IO-540 K high performance engine. FIG. **4** supports this contention showing knock limited BSFC.

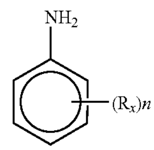
[0061] In the present description, one of skill in the art will appreciate that any end point in the aforementioned ranges can be combined with any other end point to form another suitable range.

[0062] Persons of ordinary skill in the art will recognize that many modifications may be made to the present invention without departing from the spirit and scope of the present invention. The embodiments described herein are meant to be illustrative only and should not be taken as limiting the invention, which is defined by the appended claims.

What is claimed is:

1. An aviation gasoline formed by blending (i) an unleaded fuel having a MON of at least 94, with (ii) at least one aromatic amine effective to provide the unleaded fuel with a final MON of at least 100, the aromatic amine having the formula

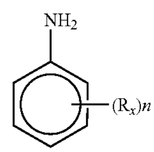
[I]



wherein R_x is C_1-C_{10} alkyl, a halogen or a mixture thereof, n is an integer from zero to 3 and wherein when n is 1, 2 or 3 and R_x is an alkyl group, the alkyl group occupies the meta and/or para position on the phenyl ring.

2. An aviation gasoline comprising an unleaded fuel having a MON of at least 94 and an effective amount of at least one aromatic amine to provide the unleaded fuel with a final MON of at least 100, the aromatic amine having the formula

[I]



wherein R_x is C_1-C_{10} alkyl, halogen or a mixture thereof, n is an integer of from zero to 3 provided that when n is 1, 2 or 3 and R_x is alkyl it is in the meta and/or para position on the phenyl ring.

3. The aviation gasoline of claim **1** or claim **2** further including up to about 1000 ppm of a deposit control additive selected from the group consisting of high molecular weight hydrocarbyl amine, carrier oil, high molecular weight succinimide, high molecular weight hydrocarbyl substituted Mannich bases, and mixtures thereof.

4. The aviation gasoline of claim **3** wherein the deposit control additive is present in an amount up to about 500 ppm active ingredient.

5. The aviation gasoline of any of the previous claims wherein the unleaded fuel has a MON of at least 95.

6. The aviation gasoline of any of the previous claims wherein the unleaded fuel has a MON of at least 96.

7. The aviation gasoline of any of the previous claims wherein the unleaded fuel has a MON of at least 97.

8. The aviation gasoline of any of the previous claims wherein the unleaded fuel has a MON of at least 98.

9. The aviation gasoline of any of the previous claims wherein the unleaded fuel has a MON of at least 99.

10. The aviation gasoline of any of the previous claims wherein the unleaded fuel has a MON of at least 100.

11. The aviation gasoline of any of the previous claims wherein the unleaded fuel has a MON of at least 101.

12. The aviation gasoline of any of the previous claims wherein the unleaded fuel has a MON of at least 102.

13. The aviation gasoline of any of claims **1** to **4**, wherein the aviation gasoline contains from about 8.5 weight percent to about 14.5 weight percent of the aromatic amine.

14. The aviation gasoline of any of claims **1** to **4**, wherein the aviation gasoline contains from about 9.5 weight percent to about 13.5 weight percent of the aromatic amine.

15. The aviation gasoline of any of claims **1** to **4**, wherein the aviation gasoline contains from about 10.5 weight percent to about 12.5 weight percent of the aromatic amine.

16. The aviation gasoline of any of claims **1** to **4**, wherein the aviation gasoline contains from about 11 weight percent to about 12 weight percent of the aromatic amine.

17. The aviation gasoline of any of claims **1** to **4** wherein the final MON is at least 101.

18. The aviation gasoline of any of claims **1** to **4** wherein the final MON is at least 102.

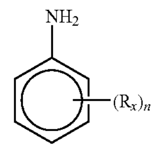
19. The aviation gasoline of any of claims **1** to **4** wherein the final MON is at least 103.

20. The aviation gasoline of any of claims **1** to **4** wherein the final MON is at least 104.

21. The aviation gasoline of any of the preceding claims further comprising at least one additional additive selected from the group consisting of octane boosters, antioxidants, co-solvents, toluene, metal deactivators, dyes, and combinations and mixtures thereof.

22. A method for fuelling an aircraft comprising providing to the aircraft an aviation gasoline comprising an unleaded fuel having a MON of at least 94 and sufficient aromatic amine of the formula:

[I]



wherein R_x is selected from the group consisting of C_1-C_{10} alkyl, halogen or a mixture thereof, n is an integer of from zero to 3 provided that when n is 1, 2 or 3 and R_x is alkyl, it is in the meta- and/or para position on the phenyl ring to provide the base fuel with a final MON of at least 100.

23. The method of claim **22** wherein the aviation gasoline further includes a deposit control additive selected from the group consisting of high molecular weight hydrocarbyl amine, high molecule weight hydrocarbyl succinimide, high molecular weight hydrocarbyl substituted Mannich base, carrier oil, and mixtures thereof, wherein the high molecular weight hydrocarbyl substituent has a weight average molecular weight of about 400 to 2800 Mw.

24. The method of claim **22** wherein the unleaded fuel has a MON of at least 95.

25. The method of claim **24** wherein the aviation gasoline contains from about 11 weight percent to about 12 weight percent of the aromatic amine.

26. The method of claim **25** wherein the unleaded base fuel has a final MON of at least 104.

27. The method of any of claims **22** to **26** wherein the aviation gasoline further comprises at least one additional additive selected from the group consisting of octane boosters, antioxidants, co-solvents, toluene, metal deactivators, dyes, and combinations and mixtures thereof.

28. The method of any of claims **22** to **27** further including the step of filtering the fuel.

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