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Demoment et al.(10) **Pub. No.: US 2008/0244963 A1**(43) **Pub. Date: Oct. 9, 2008**(54) **LEAD-FREE AVIATION FUEL**(30) **Foreign Application Priority Data**(75) Inventors: **Pascale Demoment**, Le Havre
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Lead-free aviation fuel composition with a MON greater than 100, made up of a major component of a fuel made from Avgas and a minor component of at least two compounds from the group of esters of at least one mono- or poly-carboxylic acid and at least one mono- or polyol, anhydrides of a least one mono- or poly-carboxylic acid, preferably aromatic ethers at a level of at least 5% w/w and ketones at a level of more than 10% w/w.

LEAD-FREE AVIATION FUEL

FIELD OF THE INVENTION

[0001] The present invention relates to a lead-free aviation fuel composition (Avgas), intended for aircraft with piston or reciprocating engines. In particular, a subject of the present invention is a lead-free aviation fuel with a high octane number and having very good combustion characteristics.

TECHNOLOGICAL BACKGROUND

[0002] Aviation fuel is a product which has been developed with care and subjected to strict regulations which go hand in hand with any aeronautical application. Thus, the preparation of aviation fuels in the refinery is carried out with bases which are characterized both by a narrow distillation range and high octane numbers. These bases are generally constituted by alkylates, reformates and isopentane cuts, the latter being used in low concentrations due to their high volatility.

[0003] But before being marketed, aviation fuels must satisfy other precise physico-chemical characteristics, defined by international specifications. Thus, aviation fuels must have a low vapour pressure in order to avoid problems of vaporization (vapour lock) at low pressures encountered at altitude and for obvious safety reasons. The final distillation point must be fairly low in order to limit the formations of deposits and their harmful consequences (power losses, impaired cooling).

[0004] They must also have a fairly high net calorific value (NCV) in order to ensure the best possible autonomy. Moreover, as aviation fuels are used in engines providing good performances and frequently operating with a high load, i.e. under conditions close to knocking, this type of fuel is expected to have a very good resistance to spontaneous combustion. Moreover, for aviation fuel two characteristics are determined which are comparable to octane numbers: one, the MON or motor octane number, relating to operating with a slightly lean mixture (cruising power), the other, the Performance Number or PN, relating to use with a distinctly richer mixture (take-off).

[0005] With the objective of guaranteeing high octane requirements, at the aviation fuel production stage, the refiner generally adds an organic lead compound, and more particularly tetraethyl lead (TEL). As in the case of fuels for land vehicles, administrations are tending to lower the lead content, or even to ban this additive, due to it being harmful to health and the environment. Thus, the elimination of lead from the aviation fuel composition is becoming a long or medium-term objective.

[0006] In order to replace the lead additives, solutions have already been proposed in the literature, such as for example adding other additives or components.

[0007] Patent Application WO 02/22766 describes a lead-free aviation fuel comprising a hydrocarbon compound which can be triptane combined with at least one saturated liquid aliphatic hydrocarbon compound, (4 to 10C) (the base thus obtained is not an AVGAS base) and also comprising an alkyl ether. The problem of preparing lead-free AVGAS-type aviation fuels having very good combustion characteristics was not resolved.

[0008] U.S. Pat. No. 2,398,197 (dated 1943) describes an aviation fuel containing aniline or alkyl aniline in which proportions of between approximately 0.5 and 10% asym-

metric alkyl ketone are incorporated. However the problem of the invention was not solved as AVGAS has been known only since 1950-1960.

[0009] In the patent EP 697 033, an aromatic amine is added to a lead-free aviation fuel constituted by isopentane, alkylate and toluene.

[0010] In the patent EP 910 617, a mixture of an aromatic amine and an alkyl tert-butyl ether, and optionally a manganese compound is added to an alkylate with a wide boiling range constituting the aviation fuel.

[0011] Patent Application EP 609 089 describes alkylate-based lead-free aviation fuels, to which an ether such as ETBE or MTBE is added, as well as 0.4 to 0.5 g/gallon of manganese in the form of cyclopentadienyl manganese tricarbonyl compounds. The problem of the invention was not tackled since the fuel described is not an AVGAS type base: it comprises alkylates, but comprises neither reformates, nor isomerates.

[0012] In other patents such as EP 540 297 and EP 609 089, Methylcyclopentadienyl Manganese Tricarbonyl (MMT) is added to the aviation fuel as a lead substitute. Even if these documents seem to show that these additives lead to an increase in the octane number, this increase remains insufficient. It is not shown whether the characteristics of the aviation fuel thus obtained satisfy the other requirements relating to the calorific value, the vapour pressure and the distillation range. Moreover, the compatibility of these different additives as regards respect for the environment has not been proved.

[0013] Other patents such as EP 948 584, propose to act on the composition of the hydrocarbon bases, and in particular by the addition of triptane to the aviation fuel composition. But the use of such non-petroleum bases, apart from their price, gives rise to storage and logistical technical difficulties of these bases for the refiner, generating costs additional to those generally obtained in order to formulate a standard aviation fuel from a mixture of hydrocarbon bases available in the refinery.

[0014] Moreover, the use of additives for replacing lead compounds in order to improve the octane number is well known for land vehicle gasolines, as in the patents EP 474 342, GB 2 114 596, U.S. Pat. No. 5,032,144 or U.S. Pat. No. 4,647,292. Nevertheless, aviation fuel is subject to much stricter regulations than gasoline for land vehicles, for reasons of reliability and operational safety during the take-off phase and at altitude. It is therefore not straightforward to use these additives for aviation fuel, for which there are much tougher constraints than those required for automobile gasolines.

SUMMARY OF THE INVENTION

[0015] In order to respond to these selection imperatives, the invention therefore relates to a novel lead-free aviation fuel composition, intended for aircraft with piston or reciprocating engines, produced from hydrocarbon bases which are generally available in an oil refinery, having a high octane number, in which the organic lead compounds have been replaced by different additives, in order to increase their octane number. It refers in particular to aviation fuels the NCV (net calorific value), vapour pressure (VP), MON and distillation cut characteristics of which are as close as possible to the specifications adopted for AVGAS 100LL and described in the standard ASTM D910-4, apart from the lead content.

[0016] To this end, a subject of the invention is a lead-free aviation fuel composition, with an MON greater than 100, comprising a major proportion of an AVGAS base type fuel, and a minor proportion of at least two compounds from the group constituted by esters with at least one mono or polycarboxylic acid and at least one alcohol or one polyol; by anhydrides with at least one mono or polycarboxylic acid; by aromatic ethers, with a content greater than 5% by weight and constituted by ketones with a content greater than 10% by weight, as well as their mixtures.

[0017] The lead-free aviation fuel composition which is the subject of the invention has a sufficiently high octane number, at least equal to 100, an NCV extremely close to 43.5 MJ/kg, preferably greater than this value, and a vapour pressure at 37.8° C. varying preferably between 38 and 49 kPa, and is obtained from a mixture of hydrocarbon bases available in sufficient quantities at the refinery and containing additives.

DETAILED DESCRIPTION OF EMBODIMENTS

[0018] By AVGAS base is meant a mixture of refined bases such as the alkylates originating for example from the process of alkylation of isobutane by light olefins, the reformates originating from the reforming of the straight run gasolines and isopentane.

[0019] A minor proportion is for example between 1 and 40% by weight of the composition.

[0020] The advantages of the invention which will be described more precisely hereafter are linked on the one hand to the optimum choice of the mixture of AVGAS type hydrocarbon bases having the highest octane number while satisfying the specifications referred to for the NCV, the vapour pressure and the distillation cut, and the best compromise of the mixture of compounds also having the best MON, the best NCV, the best vapour pressure (VP) and a distillation cut compatible with an AVGAS type base, the addition of the mixture of oxygenated compounds having to degrade the characteristics of the AVGAS base type mixture itself as little as possible.

[0021] With a view to carrying out the invention, the esters are obtained from at least one saturated mono or dicarboxylic acid comprising 1 to 10 carbon atoms, and preferably 1 and 6 carbon atoms with at least one alcohol or one polyol comprising 1 to 10 carbon atoms.

[0022] The anhydrides are obtained from mono or dicarboxylic acids comprising 1 to 10 carbon atoms, which can be cyclic or linear, optionally substituted by alkyl groups in linear, branched or cyclic form.

[0023] The ethers comprise at least one aromatic ring substituted by at least one ether group comprising 1 to 10 carbon atoms.

[0024] The ketones comprise 3 to 10 carbon atoms per linear carbon chain, optionally substituted by alkyl groups in the linear, branched or cyclic form.

[0025] By using these compounds, alone or in mixture, it is possible advantageously to introduce into the aviation fuel composition according to the invention up to 30% by weight of at least two of these compounds.

[0026] Preferably in order to guarantee compliance with the specifications required for the aviation fuel according to the invention, the ester content of the aviation fuel composition varies from 5 to 30% by weight and more preferentially from 10 to 20% by weight in a mixture with another compound.

[0027] Similarly, the anhydride content is chosen to be greater than 5% by weight of the composition, and preferably varies from 5 to 25% by weight.

[0028] Preferably in order to satisfy the characteristics of the composition according to the invention, the aromatic ether content varies from 5 to 30% by weight and more preferentially between 5 and 15% by weight in a mixture with a second compound.

[0029] As regards the addition of ketone to the composition, its concentration is chosen to be greater than 10% by weight of the composition and preferably varying from 10 to 25% by weight.

[0030] In order to carry out the invention and optimize in particular the MON value, at least two compounds different in nature, chosen from the list of the compounds of the invention, are advantageously mixed, preferably 5 to 25% by weight of the composition of a first compound and 25 to 5% by weight of a second compound, these ratios being able to vary upon addition of a third compound.

[0031] In a preferred embodiment of the invention, less than 3.5% by weight of at least one optionally alkyl-substituted aromatic amine, preferably 0.5 to 3% by weight, can be introduced into the fuel composition. Advantageously this aromatic amine comprises at least one amine group bound to at least one aromatic ring, optionally substituted by at least one alkyl with 1 to 10 carbon atoms.

[0032] Among the compositions according to the invention the compositions comprising 25 to 30% by weight of at least one ester, anhydride, ketone or ether type compound in combination with 0.5 to 3% by weight of aromatic amine are preferred.

[0033] More advantageously, in order to produce the combinations of the invention, the nature of the compounds is chosen as described hereafter.

[0034] The esters of the invention are chosen from the alkyl carboxylates the alkyl groups of which include 1 to 6 carbon atoms, preferably from the methyl, ethyl, propyl, butyl, dimethyl, diethyl, isopropyl, isobutyl and tert-butyl acetates, propionates, butyrates, pentanoates and carbonates; with tert-butyl acetate, methyl pivalate and diethyl carbonate being more particularly preferred.

[0035] The anhydrides of the invention are chosen from the acetic, propionic, butyric, valeric acid anhydrides, but also maleic and succinic acid anhydrides; with pivalic anhydride being preferred.

[0036] The aromatic ethers according to the invention are chosen from the group constituted by the alkylaryl ethers such as the alkylphenyl ethers, diaryl ethers, the alkyl groups comprising 1 to 10 carbon atoms in the linear or branched form. The preferred ethers are preferably methylphenyl ether or anisole, ethylphenyl ether or phenetole, propylphenyl ether, butylphenyl ether, isopropylphenyl ether, isobutylphenyl ether; with phenetole being more particularly preferred.

[0037] The ketones according to the invention are chosen from the symmetric or asymmetric alkyl ketones of the group constituted by dimethyl ketone, diethyl ketone, dipropyl ketone, dibutyl ketone, diisobutyl ketone, dipentyl ketone, methylethylketone, methylpropyl ketone, ethylpropyl ketone, methylbutyl ketone, methylisobutyl ketone, ethylbutyl ketone, ethylisobutyl ketone, propylbutyl ketone, propylisobutyl ketone, isopropylbutyl ketone; with methylisobutyl ketone being preferred.

[0038] When, according to various variants, the composition according to the invention contains a substituted aro-

matic alkyl amine, the latter is chosen from the amines comprising 1 to 5 carbon atoms per carbon chain and at least one aromatic ring substituted by at least one alkyl comprising 1 to 5 carbon atoms in the ortho (o), meta (m) or para (p) position in relation to the amine. This aromatic amine is chosen from phenylamine, the o,m,p-tert-butylphenylamines, o,m,p-methylphenylamines, o,m,p-ethylphenylamines, o,m,p-propylphenylamines, o,m,p-isopropylphenylamines, o,m,p-isobutylphenylamines, 3,5-dimethylphenylamine, 3,4-dimethylphenylamine, 3,5-diethylphenylamine, 3,4-diethylphenylamine, 3,5-dipropylphenylamine, 3,4-dipropylphenylamine, 3,5-methylethylphenylamine, 3,4-methylethylphenylamine. The preferred amines are 3,5-dimethylphenylamine, 3,4-dimethylphenylamine, p-methylphenylamine, m-methylphenylamine or m-toluidine, p-ethylphenylamine, m-ethylphenylamine, m-isopropylphenylamine and m-tert-butylphenylamine; with m-toluidine being more particularly preferred.

[0039] Advantageously, the aviation fuel-based composition comprises 25 to 80% by weight of an aviation alkylate, 30 to 5% by weight of aviation reformat and 5 to 25% by weight of isopentane.

[0040] An aviation alkylate comprises at least 95% by weight isoparaffins, ideally at least 98.5% by weight, including at least 65% by weight C8-isoparaffins, ideally at least 70% by weight, containing in particular at least 60% by weight, ideally at least 70% by weight of a mixture of trimethylpentanes, the latter being at least 40% by weight preferably 40 to 65% by weight, ideally at least 52% by weight constituted by 2,2,4 and 2,3,3 trimethylpentane, the respective weight ratio of which can vary depending on the manufacturing process from 2/1 to 8/1.

[0041] An aviation reformat is generally constituted by a hydrocarbon cut containing at least 70% by weight, ideally at least 85% by weight aromatics essentially constituted by toluene (35 to 75% by weight, preferably 45 to 70% by weight), C8 aromatics (15 to 50% by weight ethylbenzene, and ortho, meta, para-xylene) and C9 aromatics (5 to 25% by weight propylbenzene, methylethylbenzenes and trimethylbenzenes), the absolute contents and relative proportions of the different components being able to vary with the cut points, the nature of the feedstock sent for reforming, the type of catalyst used and the reforming operating conditions.

[0042] As already indicated, the scope of the invention would not be exceeded if the quantities of toluene and isooctane necessary in order to adjust the characteristics of the mixture were added to the AVGAS type base mixture, in particular the MON, NCV, vapour pressure (VP) and distillation cut.

[0043] The scope of the invention would not be exceeded if, for certain compositions with or without aromatic amine according to the invention, a lead alkyl derivative was added up to a maximum of 0.14 g of lead, and preferably 0.08 g of lead, per litre of aviation fuel, for example in the form of tetraethyl lead in order to reach in particular the minimum PN (performance number) limit for take-off.

[0044] Lead contents are cited by way of reference to the methods for measuring lead contents, described in the standard ASTM D2392

[0045] Similarly, the scope of the invention would not be exceeded if 5% to 20% mono or dialkyl ethers such as diisopropyl ether, ethyltertbutyl ether, methyltertbutyl ether, dimethyl ether and tertamylmethyl ether were added to the mix-

tures according to the invention. Of course in order to satisfy the other required characteristics, the aviation fuel according to the invention can contain one or more additives which a person skilled in the art could easily choose from the numerous additives used in a standard fashion for aviation fuels. There should be mentioned in particular, but in non-limitative manner, additives such as antioxidants, anti-icing agents, antistatic additives, corrosion inhibitors/agents for improving lubricating power, dyes and their mixtures.

[0046] In the remainder of the present description, examples are given by way of illustration but should not be interpreted as limiting the scope of the present invention.

EXAMPLE

[0047] The present example aims to show that starting with the compounds according to the invention alone, taken two-by-two or in mixture with an aromatic amine, in the concentrations claimed in the present invention, it is possible to produce AVGAS type aviation fuels the specifications of which correspond to those required in the standard ASTM 910-4.

[0048] The operation is carried out with one or two bases B1 and B2 the composition of which is given in Table I below.

TABLE I

Nature of bases	B1	B2
Reformat (% wt)	8.5	20
Alkylate (% wt)	73	62.5
Isopentane (% wt)	18.5	17.5
In each base:		
Toluene (% wt)	4.3	12.2
Iso-octane (% wt)	31.4	39.4
MV15 kg/m ³	699	719.3
VP kPa	50.3	41.2
ASTM D86 (° C.)		
10%	58.3	67.8
40%	95.9	99.1
50%	102.0	102.2
90%	112.1	110.4
MP	143.9	145
MON	92.3	93.2
PN	97.4	
NCV (MJ/kg) - ASTM D4529*	44.0	43.4

VP: vapour pressure of the fuel

PN: performance number of the fuel or Performance Number determined on a CFR engine according to the standard ASTM D909 (F4)

NCV: net calorific value the minimum level of which aimed at for AVGAS 100LL is 43.5 MJ/Kg.

[0049] Several mixtures of compounds were tested on B1 and B2. Each test is referenced Xi in Table II below.

TABLE II

Mixtures	B1			B2			
	X1	X2	X3	X4	X5	X6	X7
Phenetole					10	7	10
Pivalic anhydride		30				5	
Diethyl carbonate			25	15	17	10	8
MIBK				12			10
Methyl pivalate	30						
m-toluidine				3	3		2

TABLE II-continued

Mixtures	B1			B2			
	X1	X2	X3	X4	X5	X6	X7
	Characteristics						
MON ASTM D2700	100.8	101.3	100.5	103	103	100.9	100
NCV (MJ/kg) - ASTM D4529							40.7
VP (kPa) - ASTM D5191	40	42.2	43.6	33.4	33.5	36.9	38.5
ASTM D86							
10%	70.1	66.61	68.6	76.6	74.7	73.5	73.3
50%	99.1	110	105.4	105.4	109	107	109
90%	107.6	189.4	117.7	123.8	155.5	154.3	151.1
Final point	143	192.6	137.5	189.6	187.9	182.8	184.7
Pb (g/l) ASTM D2392	0	0	0.08	0	0	0.08	0
PN	107.4	128.7	126.6	150.7	160.4	121.5	133.8

[0050] It is thus noted that it is possible to obtain lead-free aviation fuels with characteristics similar to the AVGAS 100LL type aviation fuels by adding the oxygenated additives according to the invention to the standard bases.

[0051] In fact, the mixtures which appear to be off specification as regards VP (38-49 kPa) can easily be corrected by optimizing the composition of the base. The PN can reach values greater than 130 and the NCV can approach specification within approximately 10%.

[0052] The results therefore show that it is possible, by acting on the different parameters, to optimize the compositions in order to achieve the intended purpose, which is not evident with respect to the prior art which mentions no PN, NCV or VP value simultaneously.

[0053] Moreover, it is shown that the addition of lead does not always have a positive effect on the performances of the fuels thus obtained.

1. Lead-free aviation fuel composition, with an MON greater than 100, comprising a major proportion of an Avgas base type fuel, and a minor proportion of at least two compounds, of the group constituted by esters of at least one mono or polycarboxylic acid and at least one mono alcohol or one polyol, by anhydrides with at least one mono or polycarboxylic acid, by aromatic ethers, with a content greater than 5% by weight and constituted by ketones with a content greater than 10% by weight, as well as their mixtures.

2. Composition according to claim 1, characterized in that the ester is obtained from saturated mono or dicarboxylic acids comprising 1 to 10 carbon atoms, and preferably 1 to 6 carbon atoms with an alcohol comprising 1 to 10 carbon atoms.

3. Composition according to claim 1, characterized in that the anhydride is obtained from mono or dicarboxylic acids comprising 1 to 10 carbon atoms, which can be cyclic or linear, optionally substituted by alkyl groups in linear, branched or cyclic form.

4. Composition according to claim 1, characterized in that the ether comprises at least one aromatic ring substituted by at least one ether group comprising 1 to 10 carbon atoms.

5. Composition according to claim 1, characterized in that the ketone comprises 3 to 10 carbon atoms per linear carbon chain, optionally substituted by alkyl groups in linear, branched or cyclic form.

6. Composition according to claim 1, characterized in that it contains up to 30% of at least two compounds, in the aviation fuel.

7. Composition according to claim 1, characterized in that the ester content varies from 5 to 30%.

8. Composition according to any one of the preceding claim 1, characterized in that the anhydride content varies from 5 to 25%.

9. Composition according to claim 1, characterized in that the aromatic ether content varies from 5 to 30% by weight, and more preferentially between 5 and 15% by weight in a mixture with at least one second compound.

10. Composition according to claim 1, characterized in that the ketone content varies from 10 to 25% by weight.

11. Composition according to claim 1, characterized in that it comprises 5 to 25% by weight of a first compound and 25 to 5% by weight of a second compound.

12. Composition according to claim 1, characterized in that it contains less than 3.5% of at least one optionally alkyl-substituted aromatic amine, preferably from 0.5 to 3% by weight.

13. Composition according to claim 1, characterized in that the aromatic amine comprises at least one amine group linked to at least one aromatic ring, optionally substituted by at least one alkyl with 1 to 10 carbon atoms.

14. Composition according to claim 1, characterized in that it comprises 25 to 30% by weight of at least two ester, anhydride, ketone or ether type compounds in combination with 0.5 to 3% by weight of aromatic amine.

15. Composition according to claim 1, characterized in that the ester is chosen from the methyl, ethyl, propyl, butyl, dimethyl, diethyl, isopropyl, isobutyl and tertibutyl acetates, propionates, butyrates, pentanoates and carbonates; with tert-butyl acetate, methyl pivalate and diethyl carbonate being preferred.

16. Composition according to claim 1, characterized in that the anhydride is chosen from the acetic, propionic, butyric, valeric acid anhydrides, but also maleic and succinic acid anhydrides; with pivalic anhydride being preferred.

17. Composition according to claim 1, characterized in that the ether is chosen from the group constituted by the diaryl ethers and the alkylphenyl ethers, the alkyl group comprising 1 to 10 carbon atoms in linear or branched form, preferably methylphenyl ether or anisole, ethylphenyl ether or phenetole, propylphenyl ether, butylphenyl ether, isopropylphenyl ether, isobutylphenyl ether; with phenetole being more particularly preferred.

18. Composition according to claim 1, characterized in that the ketone is chosen from the symmetric or asymmetric alkyl ketones, from the group constituted by dimethyl ketone, diethyl ketone, dipropyl ketone, dibutyl ketone, diisobutyl ketone, dipentyl ketone, methylethylketone, methylpropyl ketone, ethylpropyl ketone, methylbutyl ketone, methylisobutyl ketone, ethylbutyl ketone, ethylisobutyl ketone, propylbutyl ketone, propylisobutyl ketone, isopropylbutyl ketone; with methylisobutyl ketone being preferred.

19. Composition according to claim 13, characterized in that the aromatic amine is chosen from the group constituted by the amines comprising 1 to 5 carbon atoms per carbon chain and at least one aromatic ring substituted by at least one alkyl comprising 1 to 5 carbon atoms in ortho (o), meta (m) or para (p) position in relation to the amine.

20. Composition according to claim 19 characterized in that the aromatic amine is chosen from the group constituted

by phenylamine, the o,m,p-tert-butylphenylamines, o,m,p-methylphenylamines, o,m,p-ethylphenylamines, o,m,p-propylphenylamines, o,m,p-isopropylphenylamines, o,m,p-isobutylphenylamines, 3,5-dimethylphenylamine, 3,4-dimethylphenylamine, 3,5-diethylphenylamine, 3,4-diethylphenylamine, 3,5-dipropylphenylamine, 3,4-dipropylphenylamine, 3,5-methylethylphenylamine, 3,4-methylethylphenylamine, 3,5-dimethylphenylamine and 3,4-dimethylphenylamine.

21. Composition according to claim **20** characterized in that the amines chosen are p-methylphenylamine, m-methylphenylamine or m-toluidine, p-ethylphenylamine, m-ethylphenylamine, m-isopropylphenylamine and m-tert-butylphenylamine; with m-toluidine being preferred.

22. Composition according to claim **1**, characterized in that said aviation fuel based fuel comprises 25 to 80% by weight

of an aviation alkylate, 30 to 5% by weight of aviation reformat and 5 to 25% by weight of isopentane.

23. Composition according to claim **1**, characterized in that said aviation fuel based reformat contains more than 35% by weight of toluene preferably between 45 and 70% by weight.

24. Composition according to claim **1**, characterized in that said aviation fuel based alkylate contains more than 40% by weight of 2,2,4 and 2,3,3 trimethylpentanes, preferably between 40 and 65% by weight.

25. Composition according to claim **1**, characterized in that a lead alkyl derivative is added up to a maximum of 0.14 of lead per litre of aviation fuel; preferably up to 0.08 g.

26. Composition according to claim **1**, characterized in that it contains 5% to 20% of mono or dialkyl ethers such as diisopropyl ether, ethyltert-butyl ether, methyltert-butyl ether, dimethyl ether and tertamyl methylether.

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