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# METHOD OF PREVENTING ICE FORMATION AND FILTER PLUGGING IN JET ENGINE FUEL SYSTEMS

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1 Claim. (Cl. 60—35.4)

This invention is concerned with an improved aviation fuel and in particular with a turbo jet-type fuel that will not plug the filters in aircraft fuel systems at relatively low temperatures. In accordance with the present invention, improved jet fuels are secured by utilizing a particular addition agent which is selected from the class of compounds represented by the formula $HO(C_2H_4O)_nH$, wherein $n$ is an integer from 3 to 8, and preferably from 4 to 6. Especially preferred compounds are tetraethylene glycol, pentaethylene glycol, and hexaethylene glycol.

The use of jet-type engines in aircraft has become increasingly widespread in the last few years. The main types of such jet engines are the turbojet, the turboprop, and the pure jet or ram jet type. In all of these engines fuel is burned with air in a set of "combustors." The fuel is introduced into the combustors from a storage tank by means of suitable pumps and connecting lines. One of these pumps, located just before the combustors, is a high pressure pump and is used to inject the fuel into the various combustors at high pressures. To protect the finely machined surfaces of these pumps, micronic-type filters are positioned in the fuel lines to remove any finely divided material that may be present in the fuels employed. A major problem with respect to these micronic filters lies in the fact that they often become plugged at low temperatures with ice particles resulting from the freezing of small amounts of water dissolved or entrained in the fuels. It has now been discovered, however, that this filter plugging problem can be greatly alleviated or entirely prevented by the use of particular polyethylene glycols in the fuels.

The fuels employed in jet engines at the present time are almost entirely derived from and made up of petroleum hydrocarbons. In general, these fuels boil between 100 and 600° F., have gravities of 35 to 55° API, and possess Reid vapor pressures of 0.05 to 7 p. s. i. In this connection, the military interests have established several jet fuel specifications which exemplify very well the types of jet fuels that are being used. These fuels and their more important physical properties are listed in the following table:



TABLE 1

*Comparison of JP–1, JP–3, and JP–4 Turbo-fuel Specifications*

| | | MIL–F–5616 | MIL–F–5624A | |
|---|---|---|---|---|
| | | JP–1 | JP–3 | JP–4 |
| Reid Vapor Pressure | Lim | | 5–7 | 2–3 |
| ASTM Disillation: | | | | |
| 10% Evap. at ° F | Max | 410 | | 250 |
| 90% Evap. at ° F | Lim | <490 | >400 | |
| Final Boiling Pt., ° F | Max | 572 | 600 | 550 |
| Disillation Loss, Vol. Percent | Max | 1.5 | 1.5 | 1.5 |
| Total Sulfur, Wt. Percent | Max | 0.2 | 0.4 | 0.4 |
| Mercaptan Sulfur, Wt. Percent | Lim | | <0.005 | <0.005 |
| Aromatics, Vol. Percent (VV–L–791) | Max | 20 | 25 | 25 |
| Bromine No., eg./gm. (VV–L–791) | Max | 3 | 30 | 30 |
| Freezing Point, ° F | Max | −76 | −76 | −76 |
| Air Jet Residue (VV–L–791): | | | | |
| Bath Temp., ° F | Lim | 390–410 | 390–410 | 390–410 |
| Mgs. Resid. Per 100 ml | Max | 5 | 10 | 10 |
| Corrosion, 3 Hrs. at 212° F | Max | (1) | (1) | (1) |
| 16 Hr. Accel. Gum Test: Gum, mg./100 ml | Max | 8 | 20 | 20 |
| Water Tolerance, ml | Lim | <2 | <1 | <1 |
| Net Heat, B. t. u./lb | Min | | 18,400 | 18,400 |
| Gravity, ° API | Lim | >35 | 45–63 | 40–58 |

[1] None, sl. discoloration only.

It will be noted that each of the specifications listed above calls for fuels having freezing points lower than −76° F. One purpose of this requirement is to combat any fuel filter plugging due to freezing of the fuel itself at the low temperatures existing at the high altitudes where jet aircraft normally operate. This requirement, of course, does not preclude the possibility of filter plugging caused by particles of ice which may be formed by the freezing of water that may be dissolved or entrained in a fuel.

A number of suggestions have been made for overcoming the plugging of jet fuel system filters as occasioned by the formation of ice particles. For example, it has been recommended that small amounts of compounds such as alcohols be incorporated in jet fuels. These materials, however, have been found to have a serious deficiency in that water readily leaches them from the fuel. Inasmuch as water is used on aircraft carriers and at various land installations as a displacing fluid in jet fuel dispensing systems, the importance of this consideration is self-evident. It is in this connection that the present invention is outstanding. Not only do the compounds suggested in this invention overcome the icing problem, but they also are very resistant as regards leaching by water. It should be further pointed out that these compounds are resistant in the latter respect toward both salt water and fresh water.

The specific compounds that have been found to have

the qualities just described are tetra-ethylene glycol, penta-ethylene glycol, and hexa-ethylene glycol. The tetra-ethylene glycol has been found to be especially effective.

Laboratory studies have established the fact that a number of polyethylene glycols are effective in reducing the filter plugging tendencies of hydrocarbon jet fuels. These studies, however, have further established the additional fact that only a limited number of these glycols are resistant to being leached from the fuel by contact with fresh or salt water. In this connection, the present invention may be readily understood by the following example illustrating the same.

EXAMPLE

A water saturated fuel of the JP–4 type described earlier containing 0.005 vol. percent dissolved water was pumped at two different temperatures (—20° F. and —50° F.) through a 10 micron filter and the time which elapsed before filter plugging occurred in each instance was recorded. The time interval at —20° F. was 9 minutes, while the time interval at —50° F. was 4 minutes. This test procedure was repeated with samples of the same water-saturated fuel to which were added 0.05 wt. percent of ethylene glycol or one of its homologs. The time required for filter plugging increased under these conditions, becoming successively longer as the molecular weight of the added polyglycol was increased. Then, to simulate practical conditions more closely, the fuel samples were stored over fresh or salt water for 24 hours and again subjected to the —20° F. filter plugging test. In other words, fuel samples containing the various glycols were run in the filter plugging test first without storing the sample over water and second after storing the same samples over water. The results of these tests are given in the following table.

TABLE 2

*Effect of copolymers of ethylene glycol on the low temperature filter plugging tendencies of water saturated, hydrocarbon jet fuels*

[JP–4 type fuel containing 0.005 vol. percent dissolved water. 0.05 wt. percent of the copolymer added to the fuel. 10 micron fuel filter.]

| *n* value of copolymer of general formula $HO(C_2H_4O)_nH$ | No Additive | 1 | 2 | 3 | 4 | 6 | 9 | No Additive | 3 | 6 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel Temp., ° F | —20 | —20 | —20 | —20 | —20 | —20 | —20 | —50 | —50 | —50 | —50 |
| Time to Filter Plugging, minutes [1]: | | | | | | | | | | | |
| Case 1 | 9 | 13 | 27 | N. P. | N. P. | N. P. | N. P. | 4 | 43 | N. P. | 31 |
| Case 2 | 9 | ------ | ------ | 8 | N. P. | 35 | 8 | ---------- | ------ | ---------- | ------ |

[1] N. P. means no plug in a 50 minute test.
Case 1—Copolymer added directly to fuel before start of run.
Case 2—Fuel containing copolymer stored over water for 24 hours prior to run.

The data in the above table clearly point out that ethylene glycol and copolymers of the same are very effective in reducing the filter plugging tendencies of jet fuels. It is also very apparent that all of the glycols tested with the exception of the tetra- through the hexa-ethylene glycols are readily leached from these fuels by water. These data then established the fact that the tetra-, penta-, and hexa-ethylene glycols are unique in that they not only reduce the filter plugging tendencies of jet fuels, but also are extremely resistant to a leaching action occasioned by contact of such a fuel with water. The reason for the unexpected performance of these particular glycols after storage over water is not readily apparent.

While .05 wt. percent of each polyglycol was added to the various fuel samples tested, it was noted during the tests that some polyglycols were noticeably less soluble than others. The extent to which each polyglycol was soluble in the jet fuel is as follows:

| Polyglycol | Solubility, wt. percent |
|---|---|
| 1. Monoethylene glycol | <0.02 |
| 2. Diethylene glycol | ~0.02 |
| 3. Tetraethylene glycol | >0.05 |
| 4. Hexaethylene glycol | >0.05 |
| 5. Nonaethylene glycol | >0.05 |

These differences in solubility may partially account for the superiority of the tetra- and hexa-ethylene glycols over the mono- and di-ethylene glycols. On this basis, however, it would be expected that the nona-ethylene glycol would be the most effective of all, and such has definitely been shown not to be the case. The experimental filtering data conclusively point to a unique advantage for selected polyethylene glycols.

The value of using the tetra- through hexa-ethylene glycols in jet fuels having been established, it should be pointed out that the amount of additive employed may vary appreciably, but should, in general, be from 0.01 to 1.0% by weight. Preferred concentrations are in the range from 0.02 to 0.5%, and particularly in the range from 0.05 to 0.10%.

These additives may be used to advantage in all types of jet fuels, but are particularly effective in the JP–1, JP–3, and JP–4 grades. They are also applicable to other fuels such as aviation gasoline for reciprocating engines and diesel fuels.

What is claimed:

A method of preventing ice formation and resultant fuel filter plugging within the fuel system of a jet propelled aircraft wherein the fuel consisting of a mixture of hydrocarbons boiling within the range from about 100° F. to 600° F. is subjected to temperatures as low as —50° C. which consists of incorporating from 0.01 wt. percent to 1.0 wt. percent of tetra ethylene glycol within the fuel.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 1,696,642 | Massa | Dec. 25, 1928 |
| 2,499,551 | White | Mar. 7, 1950 |
| 2,563,101 | Colwell et al. | Aug. 7, 1951 |
| 2,563,305 | Britton et al. | Aug. 7, 1951 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 333,200 | Great Britain | Dec. 29, 1930 |

OTHER REFERENCES

Murray: Aircraft Gas-Turbine Fuels, The Oil and Gas Journal (March 29, 1951), pages 218, 219, 271–281. Copy in Scient. Lib.