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Microbiological Spoilage of Aviation Turbine Fuel: Part II—Evaluation of a Suitable Biocide

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ABSTRACT

Addition of ethylene glycol monoethyl ether, an anti-icing fuel additive, supports microbial growth when added to aviation turbine fuel in low dosages. However, increase in its concentration to certain limits effectively prevents bioactivity in the fuel. The optimum dosage of this biocide for prevention of bioactivity in aviation turbine fuel has been studied by the specified qualitative performance tests after 18 months storage of the inhibited fuel under accelerated conditions of temperature and humidity.

1. INTRODUCTION

Microorganisms are known to cause serious flight hazards by their metabolic activity in the aviation fuels and systems throughout the world[1-6]. Like other living beings, microorganisms have major nutritional requirement of carbon, nitrogen, phosphorous and sulphur along with other elements and these are obtained from the fuel and its additives. In India, the climatic conditions being more suited to microbial activity, the microflora involved is much varied and quite persistent type. Presence of a strain of *Desulphovibrio desulfuricans* was detected in aviation gasoline storage tanks in the early sixties by this laboratory[7] Subsequent change over to different types of aircraft by the Services resulted in the change of fuels also. This led to the studies of JP-4 and JP-5 types of fuels[8], both of which supported microbial growth. These fuels were also replaced by the currently used, aviation turbine fuel (ATF). Several strains of fuel consuming microbes were isolated from a clogged filter of a Service aircraft in the Eastern Sector[9]. Studies of growth conditions in the ATF resulting in the clogging of fuel filters were conducted and reported[9].

Due to the universality of this grave problem, the search for a suitable biocide for aviation fuels was initiated in many laboratories of the world[10-13] and thousands of chemicals were screened in the process. In India, the work was carried out at DMSRDE, Kanpur and a number of inhibitors, for oil phase as well as water phase, in the storage tanks were investigated. An anti-icing fuel additive, ethylene glycol monoethyl ether (EGME), was found to provide excellent protection to ATF against microbial growth when added to it in a particular dose. This paper describes the work carried out to arrive at the effective concentration of the chemical in ATF and its compatibility to the fuel.

2. MATERIALS AND METHODS

2 Aviation Turbine Fuel

ATF used in the studies was obtained from the Indian Oil Corporation Depot at IAF Station, Kanpur. The aircraft fuel filters of different types were obtained from the Base Repair Depot of the IAF and Hindustan Aeronautics Ltd, Kanpur.

Twelve biocidal chemicals both for oil phase and water phase were obtained from the trade: (i) mersolite-19 (phenyl mercury salicylate), (ii) dimethyl glycol, (iii) ortho-cresol, (iv) meta-cresol, (v) pentachlorophenol laurate, (vi) para-cresol, (vii) salicylnaphthalide,

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(viii) thymol, (ix) phenyl mercury borate, (x) ethylene glycol monoethyl ether (EGME), (xi) cetramide (ICI), UK, and (xii) hibatane (ICI), UK. They were evaluated as additives in varying concentrations of use for their effectiveness as compatible inhibitors on long term basis.

2.2 Determination of Effective Concentration

Out of the above chemicals, EGME was found to be the most effective biocide at a reasonably low concentration. Being an accepted anti-icing additive, its compatibility with ATF did not present any problem. The only factor which needed investigation was the determination of an effective concentration for a prolonged period. Another factor was the compatibility of the increased doses of the additive for the performance properties of the fuel.

The concentrations of 0·25 and 0·5 per cent v/v in the fuel were evaluated for a period of 12 months under accelerated conditions of the test in the laboratory tropical chamber maintained at a cyclic temperature of 29 °C (18 hr) and 25 °C (6 hr) with a relative humidity of 90 and 95 per cent respectively. Each of the replicates including those of the control were inoculated with a mixed microbial suspension of the isolated organisms[9] prepared in 5 ml of sterile distilled water to serve as source of infection and moisture, essential for the growth. The observations were recorded after one year of storage (Table 1).

All the chemicals used were of laboratory grade. Standard microbiological techniques,viz microscopy and plate counts were adopted since these provide a fool-proof indication of viability or otherwise of the biomass. Spectrophotometric studies were not carried out since the tests were carried out as per the IS:1571-1967.

2.3 Compatibility Determination

Although the inhibitor was found to be quite effective at 0·5 per cent concentration, it was found

Table 1. Effectiveness of the inhibitor concentration in ATF during an exposure of one year

Period of observation	Degree of microbial growth (based on average of 3 replicates)				Remarks
	Control ATF (without inhibitor)	ATF with 0.25% inhibitor	ATF with 0.5% inhibitor	ATF with 1.0% inhibitor	
1 Month					No fungus growth was observed in any replicate, only bacterial growth indicated by thin pellicle formation or slight turbidity was noticed.
2 Months	b				
3 Months	b				
4 Months	b				
5 Months	b				
6 Months	b				
7 Months	b				
8 Months	b				
9 Months					
10 Months					
11 Months	b				
12 Months	b				

Legend: a : very slight grov b : slight growth : no growth desirable to evaluate its suitability at a higher concentration of 1·0 per cent v/v to meet all types of unseen exigencies during prolonged periods of storage. Initially a comparative evaluation of ATF samples with the requisite concentration of EGME and without it (control) was carried out. Both the samples were put to test as per the IS:1571-1967 for quality control of ATF. The data is presented in Table 2.

In order tô ensure that there are no adverse effects of the inhibitor dosage on the fuel properties after

Table 2. Comparative data for ATF with and without inhibitor

Sl. No.	Parameter	Sample with 0·5% inhibitor	Sample without inhibitor (control)
	Sp. gravity at 60 °F/ density at 15 °C	0·813	0·881
2.	Colour (lovibond/say bolt)	Colourless (very slight yellow)	Colourless (very slight yellow
3.	Appearance	Clear	Clear
4.	Visible impurities/water	Nil	Nil
5.	Inorganic acidity	Nil	Nil
6.	Corrosion CS 2 hr at the rate of 212 °F/100 °C ASTM Corrosion Standard	Passes 1(a)	Passes 1(a)
7.	Distillation IBP (°C)	140·0	145·0
	% recovered at 200 °C	57·0	55·0
	20% recovered at (°C)	174·0	178·0
	50% recovered at (°C)	195·0	198·0
	90% recovered at (°C)	232·0	233·0
8.	FBP (°C)	262·0	264·0
	% recovery	98·0	98·0
	% residue	1·0	1·0
	% loss	0·5	0·5
9.	Aromatic (% by volume)	14.4	15·0
10.	Bromine number/olefin contents (% by volume)	1·4	1·7
11.	Total sulphur (% by weight)	0·02	0·02
12.	Water reaction		
	Change in volume	Less than 0·5	Less than 0·5
	Numerical rating	1(b) (sharp separation)	1(b) (sharp separation)
	Calorific value (net)/product of API gravity and aniline point (in °F)	5950	5950
	Flash point (Abels) °C	Above 38	Above 38
15.	Mercaptan sulphur	Negative	Negative
	Doctor test	Negative	Negative
	O_2 by weight	Negative	Negative
16.	Residue on evaporation (steam/jet)	1	
	Accelerated gum (mg/100 ml)	3	3
18.	Freezing point/cold test temp (°C)	Below −50	Below −50
19.	Silver strip corrosion	No tarnish *Cl'O'*	No tarnish *Cl'O'*

prolonged storage of the inhibited fuel, two sets of ATF containing 0·5 and 1·0 per cent EGME respectively, along with a control without inhibitor were put for one and a half year storage under tropical conditions as mentioned earlier. After the storage, the samples were subjected to tests as per the Indian Specification mentioned above. The data obtained is given in Table 3. Storage period of one set of the inhibited ATF was extended upto 30 months to judge the effective period of the inhibitor.

Table 3. Data on tests carried out after 18 months storage at a cyclic temperature and humidity (25 to 29 °C and 90 to 95%RH)

Sl. No.		ATF with 0·5 % inhibitor	ATF with 1·0 % inhibitor	ATF without inhibitor
	Sample identification mark for visual examination	A	B	
	a) Colour	Yellowish	Yellowish	Yellowish
	b) Appearance	Clear	Clear	Clear
2.	Visible impurities	Nil	Nil	Nil
3.	Inorganic acidity	Nil	Nil	Nil
4.	Corrosion CS 2 hr at the rate of 212 °F/100 °C ASTM Corrosion Standard	Passes 1(a)	Passes 1(a)	Passes 1(a)
	Water reaction			
	a) Change in volume	Less than 0·5	Less than 0·5	Less than 0·5
	b) Numerical rating	Sharp separation 1(b)	Sharp separation 1(b)	Sharp separation 1(b)
6.	Flash point (Abels) °C	Above 38	Above 38	Above 38
7.	Mercaptan sulphur	Negative	Negative	Negative
8.	Residue in evaporation mg/100 ml (by air jet)	7	8	8
9.	Silver strip corrosion test	No tarnish ASTM *Cl* (O)	No tarnish ASTM *Cl* (O)	No tarnish ASTM *Cl* (O)

N.B. As samples were not sufficient for full specimen tests, only important tests have been done

2.4 Compatibility with Filter Components

For compatibility studies, fuel filters from the different types of aircraft, viz Hunters (Patent Nos. 33uu BA6 9550 and FG-2437), SU-7 and MIG-21 (Patent No. 340079A), and HS-748 (Patent No. 3901616) were used.

After superficial cleaning of these filters they were kept immersed in the ATF containing 0·5 per cent EGME for 90 days. Later, the filters were stripped open and the various components viz felt, metal, mesh and PVC rings etc were examined for corrosion and other damages, if any. Since nothing adverse could be detected by visual examination, the filters were re-assembled and returned to their units for performance tests. The units reported that the filters were in absolute serviceable condition. No adverse effect on their performance could be detected.

3. RESULTS AND DISCUSSION

Besides nutrients, microbes need some moisture for growth on any substrate including ATF. Studies at DMSRDE, Kanpur have shown that ATF developed microbial growth even at a low moisture content[14] of 100 ppm. The organisms involved accept their food in aqueous solutions and hence are primarily associated with the aqueous phase or the fuel water interface[7,10]. Most of the earlier work was therefore, directed to the addition of water soluble[10,15] preservatives. This no doubt prevented the microbial proliferation in the water phase or at the interface, but could not prevent the flow of resistant strain spores to oil phase. These spores germinated and formed colonies on attaining favourable conditions.

It is well known that to deliver completely dry aviation fuel to the user is inpracticable. Use of bulk storage tanks and common fuel pipelines at the refineries and storage depots, and deposition of atmospheric condensate in the aircraft tanks cannot be controlled.

In view of these difficulties, it was necessary to develop a biocide for the oil phase as a fuel additive. In early sixties a formulation (PFA-55-MB) by the Phillips Petroleum Co, Bartlesville, USA, proved to be quite effective at 0·1 per cent level[16]. Another formulation prepared by mixing parahydroxybenzoate with an anti-icing-agent in low concentration was reported to be quite effective[17]. Use of EGME based formulations to reduce time for attaining fuel sterility were also reported[10]. A few fuel soluble biocides, viz benzimidazole fungicide, an organo boron, a pyridinethion and two isothiazolone products were evaluated against *Cladosporium resinae*. These fungicides exhibited marked differences in antifungal activity[18] but none of these workers investigated the possibility of increasing the EGME concentration beyond a level needed for its anti-icing properties in the fuel. Moreover, these additives were not very effective in the case of resistant strains of Indian isolates. Out of the seven isolates from the ATF found by Tewari, *et al*[9] one strain of *C. resinae* (DMSRDE No. 1008) was found to be most resistant. This fungus is reported to utilise ATF as a direct carbon source[19]. Due to this particular character it exhibits a competitive advantage over other microbes in the environment. It grows fast and forms a thick, tough and blackish mat at the fuel water interface.

The accepted use of EGME as a fuel additive and the knowledge of its being a mild bactericide prompted us to investigate its biocidal properties against isolates from the ATF. However, initial experiments in the laboratory indicated that at lower concentrations (below 0·05 per cent v/v) EGME supports microbial growth rather than inhibiting it. This finding is confirmed by some other workers also[10]. Gradual increase in the concentration of EGME indicated decrease in the degree of growth and increase in the time of initiation of growth in fuel under storage. The possibility of using EGME in higher doses to serve as effective biocide for ATF was therefore investigated. The suitability of the higher doses was determined by the subsequent experiments. The optimum dosage of 0·5 per cent EGME in fuel is double the normal dosage of 0·25 per cent but without any ill effects on the performance quality of the fuel. To be safer, the inhibitor concentration upto 1·0 per cent was evaluated after 18 months of storage and no significant change of any type could be noticed (Table 3).

It may be worthwhile to point here that the comparative data obtained for samples with 0·5 per cent inhibitor and samples without the inhibitor (control) after 12 months storage (Table 2) in respect to specific gravity, distillation temperatures and bromine number are slightly higher for samples without the inhibitor (control). But since these figures are much below the specified acceptable limits, these slight variations are insignificant and need not cause any concern. The most important factor is that the inhibitor is fully combustible with no ash and will not have any deleterious effect on the engines, or sealants, etc. This advantage far outgrows minor deviations of the data like changes in colour, specific gravity (slight), bromine number and distillation temperature, etc.

4. CONCLUSION

Ethylene glycol monoethyl ether, an anti-icing additive of the ATF, can be used as a biocide when added to it in 0·5 per cent concentration (v/v). It is a very safe, long term preventive and compatible biocide. It does not impart any ill effects on the components or performance of the fuel/aircraft.

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