

SHORT COMMUNICATION

The Effect of Polymeric Additives on Fire Spread Across Turbine Fuel

THOR I. EKLUND *Fire Safety Branch, National Aviation Facilities Experimental Center, Atlantic City, New Jersey 08405*

(Received April 6, 1977)

The potential effects of polymeric additives on fire spread across fuel pools have been known for some time (Glassman *et al.*, 1969). The convective liquid phase heat transfer ahead of the fire front can be decreased by increasing the liquid viscosity. A number of theoretical efforts have treated the relation of a surface tension driving force to a viscosity dominated retarding force (Sirignano and Glassman, 1970; Torrance and Mahajan, 1975). Experimental work has been done in the past 10 years to elucidate the controlling parameters (Akita, 1973; Mackinven *et al.*, 1970).

One area of application of these basic researches is the attempt to modify aviation turbine fuels to minimize postcrash fires. The first generation fuel additives consisted of various gels and emulsions, and testing for the most part preceded the developments in basic research. Flame spreading rates were typically tested in some sort of angle-iron trough (Kuchta *et al.*, 1969). Although these early tests could differentiate between additives, no consideration was given to possible radiative effects or effects of container geometry and size.

Currently, investigated fuel additives consist of high molecular weight polymers which are mixed with the fuel to weight percentages of 0.2 to 0.7 percent. Scant attention has been focused on liquid fuel fire spread. Instead, the efforts have been directed at eliminating postcrash spray fires (Zinn *et al.*, 1976) and at evaluating compatibility potential with existing aircraft fuel systems (Walsh *et al.*, 1975). This compatibility requirement has been a major criterion for determining the acceptability of any given additive candidate (Russell and Salmon, 1972).

To provide a more complete background for comparative evaluation of these so-called antimisting additives, some simple fire spreading tests were performed. The test apparatus was dimensioned

from the results presented by Mackinven *et al.* The fuel tray measured 20 cm in width, 91 cm in length and 5 cm in depth. The whole fuel tray was set in a water bath 41 cm in width, 137 cm in length, and 20 cm in depth. The temperature of the bath was controlled by addition of ice for lower temperatures and by application of heating rods for higher temperatures. No attempt was made to control the ambient air temperature. For all tests, a 2000 cc fuel sample was added to the tray and allowed to equilibrate with the bath. Because of unfavorable interaction between some of these additives and water, a water substrate could not be employed for true leveling.

The modified fuels were ignited by application of a propane torch behind a hand-held metal strip at the end of the fuel tray. Neat Jet A was ignited by priming the end of the tray with a small amount of alcohol. A 30 cm length was allowed for the flame to reach a steady velocity, and the propagation rate was clocked by stopwatch over the next 51 cm.

The additives employed were polymers of a proprietary composition. Table 1 shows the additives, their nominal weight in the fuel, the modified

TABLE 1
Properties of modified fuels

Fuel	Additive mass fraction	Flash point (°C)	Viscosity (cSt)/Temperature (°C)
Jet A	0.000	48	1.9(22)
Jet A/XD8132.01 ^a	0.007	50	11.7(24)
Jet A/FM-4 ^b	0.004	47	5.6(24)
Jet A/AM-1 ^c	0.002	48	6.7(24)

^a Dow Chemical

^b Imperial Chemical Industries

^c Continental Oil

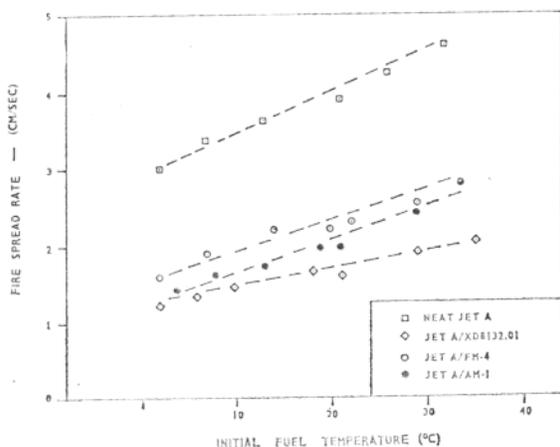


FIGURE 1 Fire spread rates.

fuel flash point, and the measured viscosity. The Tag Closed Tester was used to measure flashpoint. Since the same batch of Jet A was used in all sample preparations, differences in flashpoint are likely related to effects of the flashpoint tester rather than changes in the equilibrium vapor pressure curve. The viscosity measurements were made with a Ubbelohde tube (ASTM designation 1C). Figure 1 shows the data for fire spreading rates as a function of initial fuel temperature. The slope changes at 20°C are probably caused by second order gas phase buoyancy effects when the ambient air temperature differs from the fuel temperature. The fire spread rate decreases monotonically with increased viscosity for these additives even though their rheological properties are known to be quite different (Mannheimer, 1977).

REFERENCES

- Akita, K. (1973). Some problems of flame spread along a liquid surface. *Fourteenth Symposium (International) on Combustion*, The Combustion Institute, Pittsburgh, p. 1075.
- Glassman, I., Hansel, J. G., and Eklund, T. (1969). Hydrodynamic effects in the flame spreading, ignitability, and steady burning of liquid fuels. *Combustion and Flame*, **13**, 99.
- Kuchta, J. M., Furno, A. L., Martindill, G. H., and Imhof, A. C. (1969). Crash fire hazard rating system for controlled flammability fuels. Federal Aviation Administration, Report NA-69-17.
- Mackinven, R., Hansel, J. G., and Glassman, I. (1970). Influence of laboratory parameters on flame spread across liquid fuels. *Combustion Science and Technology*, **1**, 293.
- Mannheimer, R. J. (1977). Rheology study of antimist fuels. Federal Aviation Administration, Report FAA-RD-77-10.
- Russell, R. A., and Salmon, R. F. (1972). Development of crash-safe turbine fuels. Gas Turbine Fluids Engineering Conference, San Francisco. ASME Paper 72-GT-28.
- Sirignano, W. A., and Glassman, I. (1970). Flame spreading above liquid fuels: Surface-tension driven flows. *Combustion Science and Technology*, **1**, 307.
- Torrance, K. E., and Mahajan, R. L. (1975). Fire spread over liquid fuels: Liquid phase parameters. *Fifteenth Symposium (International) on Combustion*, The Combustion Institute, Pittsburgh, p. 281.
- Walsh, R. H., Timby, E. A., and Robinson, D. J. R. (1975). Systems problems associated with the use of safety fuels. AGARD/NATO Forty-fifth Meeting, Aircraft Fire Safety, Rome.
- Zinn, S. V., Eklund, T. I., and Neese, W. E. (1976). Photographic investigation of modified fuel breakup and ignition. Federal Aviation Administration, Report FAA-RD-76-109.