Data Report No. 127

Fire Protection Branch, ANA-420

Project 181-520-050

DRAFT

FLAMMABILITY TESTING OF FM-9 MODIFIED FUEL

Prepared by: Samuel V. Zinn, Jr.
Thor I. Eklund

October 1976

Federal Aviation Administration
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

Purpose

This work was part of an overall program to evaluate modified turbine fuels for their resistance to burning when air sheared. Some recent results of these investigations are stated in Final Report No. FAA-RD-76-109. As a sequal to those findings, this report contains an evaluation of the Imperial Chemical Industries (ICI) FM-9 modified fuel.

Discussion

The tests reported here were accomplished over the period June through August 1976. Participating in these tests were William Neese, Aerospace Technician; Louis Brown and Irwin Block of Drexel University; Joseph Cox and James Valleley of the Photographic Section; and Maurice Dungan of ANA-410. The work included determination of flash point and viscosity and photographic evaluation of fuel breakup using the NAFEC Air Gun and Airflow Facilities.

Fuel Properties

The flash point of the FM-9 fuel as taken with the Tag Closed Tester was 111°F. The viscosity at 74°F was 2.0 centistokes as measured with a Ubbelohde tube (ASTM designation 1C). Figure 1 is a plot of the torque versus rotational speed as found with the Brookfield LVT viscometer with a UL adapter. The FM-9 fuel was supplied by the Royal Aircraft Establishment (RAE) as a .3 percent blend of the additive in Avtur.

Along with FM-9, data taken for Jet A is plotted in figure 1. Although the FM-9 data were taken at 74°F while the Jet A was at 73°F and although Avtur was the base fuel for FM-9, the viscometer data points are almost identical.

Airflow Facility Test Method

The operational procedures used in the Airflow Facility are detailed in Report No. FAA-RD-76-109. Figure 2 shows the calibration curve for flow of FM-9 fuel through the supply line to the fuel nozzle. Figures 3, 4, 5, 6, and 7 show spark photographs of the FM-9 fuel at distances 1, 6, 26, 46, and 66 inches, respectively, from the nozzle. The fuel particles demonstrated similarity to the XD8132.01 particles previously photographed. In these FM-9 fuel tests, the nominal air velocity was 110 knots.

In ignition attempts with a propane torch, no burning downstream of the torch was observed until the fuel flow reached 14 pounds per minutes. At lower fuel flow rates, some lengthening of the propane flame was noted. At equivalent fuel flow rates, the XD8132.01 fuel behaved

similarly to the FM-9 fuel in the presence of the torch. However, rheological properties constrained the delivery rate of XD8132.01 to less than 6 pounds per minute.

The pictures in figures 3 through 7 are all at 6.25 magnification. The ambient air temperature was 71°F so the wind tunnel air temperature would be 68°F corresponding to 110 knots.

Air Gun Test Method

Report No. FAA-RD-71-49 describes the history of emulsified and gelled fuels. This report also describes the use of the air gun in testing these fuels. Hence, the facility description in this data report will be brief.

The facility layout is pictured in figures 8 and 9. The grid on the panel in the background is composed of 1-foot squares and can be used for dimensional reference. The two vertical cylindrical torches on stands nearest the grid are fueled with propane, and the other three burning pots are fueled with Jet A.

Figures 10 and 11 illustrate the flammability characteristics of FM-4 versus FM-9 with projectile velocity of 104 knots (120 mph), air temperature 84°F, and fuel temperature 95°F. Figures 12 and 13 are photographs of FM-4 and FM-9 with projectile velocity of 104 knots, air temperature 68°F, and fuel temperature 78°F. The projectile velocity is the calibrated speed of the fuel container as it leaves the air gun. Complete visual coverage of all tests is recorded on 35-mm and 70-mm film along with video TV sound tape and are on file at NAFEC.

Table 1 gives complete data on the air gun tests. From these data, it can be observed that the size of the fireball increases with velocity and temperature. FM-9 fuel was inferior to FM-4 fuel for minimizing the fireball. The FM-4 was mixed at NAFEC with Jet A and had a flash point of 117°F.

The FM-9 was mixed by the RAE in Avtur in April 1976 and received by NAFEC in June.

Analysis

A review of cumulative motion pictures of the Airflow Facility tests indicates that FM-9 fuel atomizes in a manner similar to the XD8132.01, and that FM-9 flammability is similar to that evidenced both by FM-4 and XD8132.01 fuels in past testing. The air gun tests in contrast show FM-9 fuel to be highly flammable in comparison to FM-4. FAA Report No. DS-67-7 shows the flash point differing from the lean limit of the equilibrium flammability envelope between 19°F and 27°F for aviation kerosene. Since many of the air gun tests were performed during high summer temperatures,

a possibility exists that the vapor space between the FM-9 particles was flammable. To clarify this effect, either the tests should be rerun on samples mixed with the same base fuel, or the tests should be rerun when the ambient temperature is low enough to minimize differences in vapor pressures of the fuels.

In addition to vapor pressure effect, aging effects may have affected the air gun test results. The time-dependent degradation of FM-9 fuel has been discussed in a letter dated August 12, 1976, from Dr. Miller of the RAE. This characteristic of the additive was confirmed by discussion with H. Brooks of ICI in discussion at China Lake, California, during the week of October 11, 1976. The maximum shelf life of the blend appears to be 4 months.

Summary

Although there is discrepancy between the air gun and wind tunnel tests of flammability, improved flow characteristics of FM-9 fuel over those of previously tested modified fuels are evident. In the wind tunnel, the FM-9 demonstrated flammability behavior similar to FM-4 and XD8132.01. In the air gun tests, FM-9 showed significantly greater flammability than FM-4 at equivalent velocities and temperatures. Due to the discrepancies, no definitive statement about FM-9 relative flammability can be made at this time.

TABLE 1. AIR GUN TEST FACILITY

Test No.	Date	Fuel	Temp °F	Temp °F	Projectile Vel. MPH (knots)	Air Press PSI	
1	8-3-76	FM-9	95	74	100 (.87)	26	Fireball - 70 mm camera failed
2	"	"	"	"	120 (104)	34	Larger fire than #1
3	"	"	"	"	140 (122)	36	" " " #2
4	"	"	"	"	160 (139)	39	" " " #3
5	"	"	"	"	180 (157)	41	" " " #4
6	8-10-76	Jet A	"	76	100 (.87)	26	Very large fireball
7	"	FM-4	"	"	"	26	No fire
8	"	"	"	"	120 (104)	34	" "
9	"	"	"	"	140 (122)	36	" "
10	8-12-76	"	"	84	100 (.87)	26	" "
11	"	"	"	"	120 (104)	34	Small fire
12	"	FM-9	"	"	"	34	Fireball larger than #11
13	8-17-76	Jet A	90	71	140 (122)	36	Very large fireball
14	"	FM-4	92	"	160 (139)	39	No fire
15	"	"	"	"	180 (157)	41	Very small fire
16	"	Jet A	90	"	160 (139)	39	Very large hot burn mushroom-shape cloud of black smoke
17	8-19-76	FM-9	78	68	100 (.87)	26	Small fire
18	"	FM-4	"	"	120 (104)	34	No fire
19	"	FM-9	"	"	120 (104)	34	Small fire

FIG. 1 — DYNAMIC VISCOMETER MEASUREMENTS

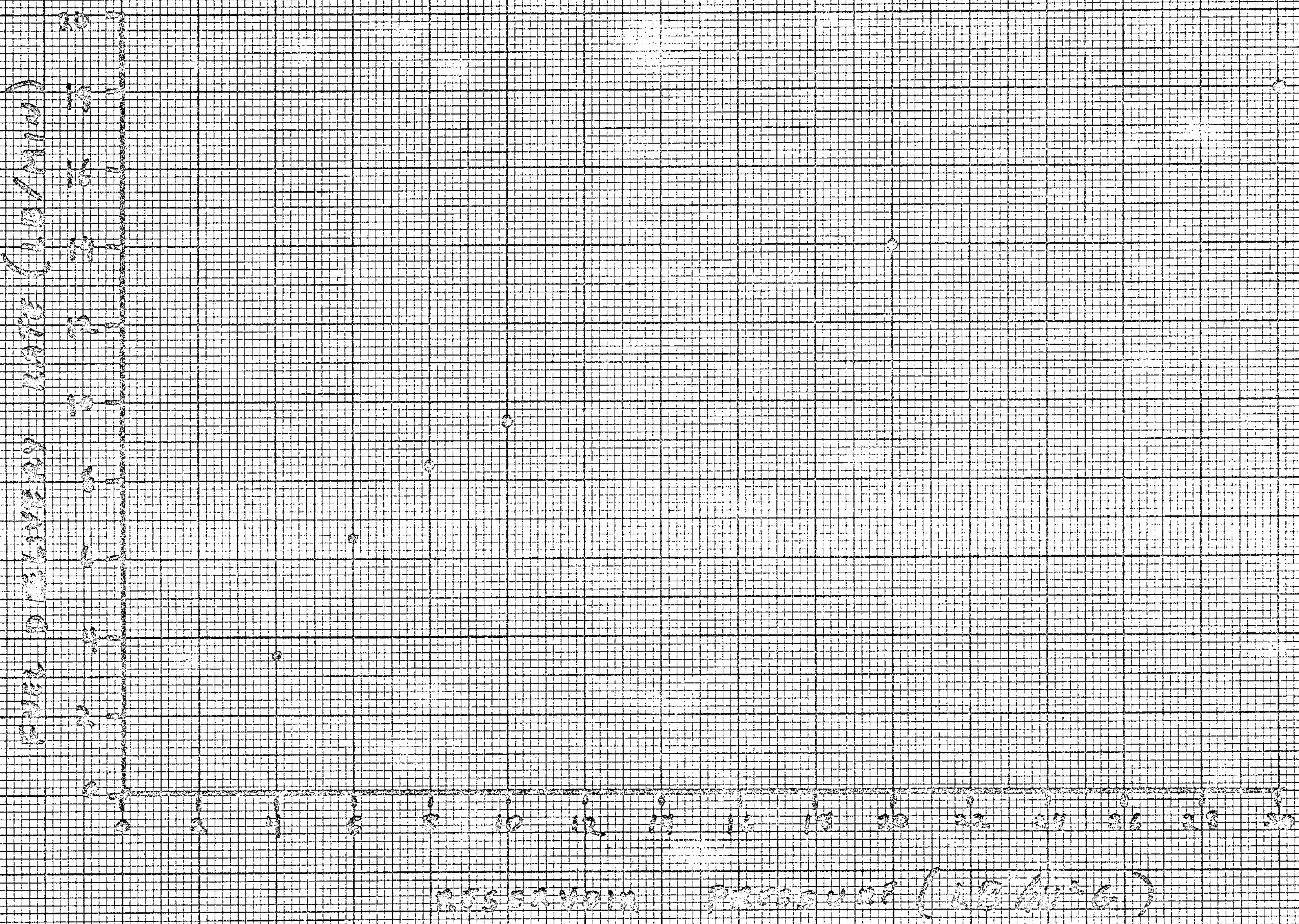

FIG. 2 - FM-9 FUEL FLOW CALIBRATION