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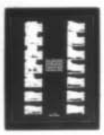

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NRL Memorandum Report 3780

Further Studies of Fuels from Alternate Sources—Fire Extinguishment Experiments with JP-5 Jet Turbine Fuel Derived from Shale

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Chemistry Division

May 1978

NAVAL RESEARCH LABORATORY
Washington, D.C.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	NRL Memorandum Report 3780
2. GOVT ACCESSION NO.	
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle)	6 FURTHER STUDIES OF FUELS FROM ALTERNATE SOURCES – FIRE EXTINGUISHMENT EXPERIMENTS WITH JP–5 JET TURBINE FUEL DERIVED FROM SHALE
5. TYPE OF REPORT & PERIOD COVERED	Final report on one phase of an NRL problem.
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s)	10 [illegible] N. Hazlett, [illegible] A. Affens, G. W. McLaren* and [illegible] S. Butler
8. CONTRACT OR GRANT NUMBER(s)	WF-57-571-301
9. PERFORMING ORGANIZATION NAME AND ADDRESS	Naval Research Laboratory Washington, D. C. 20375
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	NRL Problem C01-01A
11. CONTROLLING OFFICE NAME AND ADDRESS	Naval Air Propulsion Test Center Trenton, New Jersey 08628
12. REPORT DATE	11 May 1978
13. NUMBER OF PAGES	15
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	9 Final rept.
15. SECURITY CLASS. (of this report)	UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

12 13p. 14 NRL-MR-3780

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

16 F57571 / 17 WF57571301

18. SUPPLEMENTARY NOTES

*One of the authors, G. W. McLaren, is deceased.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

- Fire extinguishment
- JP-5 jet fuel
- Synthetic fuels
- Aqueous film forming foam
- AFFF
- Fuels from shale

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Fire extinguishment experiments with JP-5 jet fuels derived from shale crude oil and also from petroleum (for comparison) were conducted at NRL's Chesapeake Bay facility. The experiments were conducted in a 40-foot diameter circular pool using Aqueous Film Forming Foam (AFFF) as the fire extinguishing agent. The results with both types of fuel were similar, and it was concluded that the techniques and agents for AFFF application, which have been developed for petroleum fuel fires, can also be used for shale derived jet fuel.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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FURTHER STUDIES OF FUELS FROM ALTERNATE SOURCES - FIRE EXTINGUISHMENT EXPERIMENTS WITH JP-5 JET TURBINE FUEL DERIVED FROM SHALE

INTRODUCTION

As part of the coordinated synthetic fuels research and development program of the Navy and other agencies of the Department of Defense, National Aeronautics and Space Administration, Departments of Energy and the Interior and the Maritime Administration, the Navy has been evaluating the properties and behavior of new liquid fuels prepared from alternate fossil energy sources - shale oil, tar sands and coal. In addition to other properties, NRL has been investigating the flammability and ignition behavior of these fuels (1,2). Related NRL work has been concerned with the suitability of fire suppression agents (currently used to control and extinguish fuel fires) against fires involving these new fuels. An earlier report (3) described fire extinguishment experiments with JP-5 fuel derived from tar sands. This report is concerned with fire extinguishment experiments with JP-5 fuel derived from shale.

FUEL SAMPLES

A JP-5 type fuel (NRL #76-1) was prepared by refining shale crude oil made by the Paraho process (4), and the fuel met most of the specification requirements of JP-5 jet turbine fuel (5). For comparison purposes, a conventional JP-5 fuel from petroleum (NRL #76-3) was also tested.

FLASH POINT AND DISTILLATION PROPERTIES OF THE FUELS

Two important flammability properties of the fuels were determined in the laboratory before fire extinguishment experiments were made. The measured properties -- flash point (6) and distillation range (7) -- are shown in Table 1. These properties, which are vapor pressure related, govern both the ignitability of a pool of liquid fuel and the rate at which a flame can spread across its surface. They play a part in determining whether and how readily a fuel fire will occur, the time available for escape from such a fire, and the difficulties of extinguishing such a fire once it is started. These laboratory data, therefore, should be useful in comparing fire extinguishment data of different fuels. The flash points were determined

Note: Manuscript submitted April 27, 1978.

by Tag Closed Cup (6) rather than by the Pensky-Martens method (8). The 57°C flash point of the shale-derived fuel is below that of the 60°C (Pensky-Martens) minimum requirement of the specification (5). However, since Tag flash points tend to be about 3°C (on the average) lower than that of Pensky-Martens for fuels in this flash point range (9), the fuel can be considered to have met the flash point requirement. The petroleum-derived fuel, it will be noted, had a flash point of 62°C, well above the minimum requirement. The distillation range data for the fuels are consistent with the flash points in that the initial fractions of the lower flash point fuel (shale) distilled at lower temperatures than that of the petroleum fuel. For these reasons, flames of the shale derived fuel might be somewhat more difficult to extinguish than that of petroleum.

FIRE EXTINGUISHMENT EXPERIMENTS

Fire extinguishment tests with Aqueous Film Forming Foam (AFFF) (10) compared the behavior of shale oil derived fuel with that of petroleum derived JP-5. The tests were conducted with 1260 sq. ft. (about 40 ft. diameter) circular pool fires at NRL's Chesapeake Bay facility. A total of eight tests were run alternating between the shale and petroleum fuels. This sequence allowed comparison between shale and petroleum fuels at similar weather conditions. The quantity of fuel used for each test was 275 gallons of fuel layered over a pool of water. AFFF was applied from a standard nozzle on a 1 1/2 inch handline controlled by an experienced fire research technician. A standard AFFF application rate of 0.05 gal. per min./sq.ft. (equivalent to about 60 GPM onto the total pool) was utilized. Two sets of tests (four each) were conducted. The first set used FC-206 AFFF at the specification concentration of 6% in fresh water (10), and the second set used a more dilute mix, 3% AFFF. The tests were run over two days. Because of the relatively high flash points of the fuels (well above ambient temperatures), it was necessary to add aviation gasoline to aid the ignition, which was with a kerosene torch. Fifteen gallons of avgas were added to the jet fuel just prior to ignition, but the avgas burned off before extinguishing agent was applied. The fire spread rapidly and involved the whole fuel surface in 15-20 seconds. The fire continued for 30 seconds at full involvement before AFFF application was initiated. The extinguishing agent is applied to the fire with the wind at the fireman's back. This reduces the hazard for the fireman and also aids in spreading the foam across the surface of the pool.

For additional information, the hydrocarbon vapor concentration about 6 in. above the pool was monitored after extinguishment by sampling and pumping these vapors through a 36 ft., 1/4 in. copper tubing sample line to a hydrogen flame ionization detector (FID) (11).

Since pool temperature during and shortly after the fire was well above ambient, the copper sample lines and the FID were heated by electrical heaters to prevent vapor condensation in the sample lines or in the instrument. Pool temperatures (37 - 71°C) and sample line temperatures (57 - 71°C) were monitored by temperature probes.

Both still and motion pictures of the fire extinguishment experiments were taken.

RESULTS

The results of the fire extinguishment tests are shown in Table II. Ambient temperatures (not shown in the table) were about 22°C for the first four tests (first day), and from 17 to 22°C for the last four tests (second day). In addition to fuel and AFFF data, the table shows wind welocity and time in seconds for 90% and 100% extinguishment. The data in Table II show that 90% and 100% extinguishment in these large JP-5 fires was attained in less than 30 seconds in all but two tests (Tests 5 and 6). In one of these, Test 5 with 3% AFFF on petroleum, the wind shifted after ignition and drastically curtailed the spread of the foam. In the other test, No. 6 with 3% AFFF on shale fuel, 90% extinguishment came in 30 sec but 100% extinguishment required 38 seconds.

It is noteworthy that most of the tests with shale fuel were similar to those of petroleum jet fuel. Where there were differences, extinguishment of the shale fuel on the average, required less foam. This appears to be contrary to the flash point and distillation data.

The FID results were not definitive. The first two tests (at sensitivity settings down to concentrations of about 0.03% hydrocarbon vapors) showed no measurable readings, although readings increased significantly when the avgas was added near the sample probe. The other tests were made at much more sensitive adjustments, and in the case of tests 3 through 8, recorder trace variations were noted. It was possible to observe significant changes in readings, for example, when the wind blew the foam clear of the pool in the vicinity of the sample probe, or when the foam recovered the pool. Because of calibration problems at these very low hydrocarbon concentrations, the actual hydrocarbon concentrations were not estimated.

Photographs of some of the fire extinguishment tests are shown in Figures 1-3. Figure 1 shows shale fuel being poured from drums into the pool in preparation for tests. Figure 2 illustrates examples of fires for shale fuel at full intensity just before application of the fire extinguishing agent. Figure 3 compares frames from a movie of a petroleum fuel fire (test 3) with that of shale fuel (test 4). The frames which are shown were taken at 4 second intervals. It is seen that the timing of events in these two sequences is remarkably similar.

CONCLUSIONS

Excellent extinguishment was attained with the liquid fuel fires tested in this work. It is concluded that the techniques and agents for AFFF application which have been developed for petroleum fuel fires, can be used for shale derived jet fuel also.

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TABLE I

PROPERTIES OF TEST FUELS

	SHALE DERIVED	PETROLEUM DERIVED
Flash Point (Tag C.C.) (6) (°C)	57	62
Distillation (°C) (7)		
IBP	172	184
5%	184	193
10	191	197
20	199	203
30	206	207
40	213	212
50	219	217
60	227	222
70	234	227
80	243	234
90	254	243
95	264	251
End Pt.	272	256

TABLE II - FIRE EXTINGUISHMENT TESTS

TEST NUMBER	FUEL SOURCE	AFFF CONCENTRATION (PERCENT)	WIND VELOCITY	TIME IN SECONDS TO 90% EXTINGUISHMENT	TIME IN SECONDS TO 100% EXTINGUISHMENT
1	Petroleum	6	3-5 Knots, gusts to 8	17	28
2	Shale	6	3-5 Knots, gusts to 10	10	17
3	Petroleum	6	3-5	15	23
4	Shale	6	1-3	16	25
5*	Petroleum	3	1-2	70	86
6	Shale	3	5-8	30	38
7	Petroleum	3	6	13	16
8	Shale	3	8	10	19

* Wind shifted after ignition and blew towards the fireman.

Fig. 1 — Pouring fuel (shale) into pool in preparation for fire tests

Fig. 2 — Fire at full intensity just prior to application of AFFF — shale jet fuel

Fig. 3 — Movie sequences comparing petroleum fire, test 3 (right), with that of shale, test 4 (left). Frames at 4-second intervals from *full fire (top) to complete* extinquishment (bottom).