

FEDERAL AVIATION AGENCY
Bureau of Research and Development
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Director
Bureau of Research and Development
Federal Aviation Agency
Washington 25, D. C.

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Subject: Test and Experimentation Division Letter Report, Titled
"Feasibility Study on the Gelatinization of Aviation Fuels"

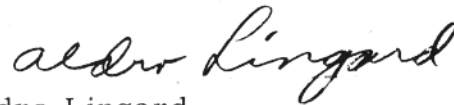
Dear Sir:

This letter report, titled "Feasibility Study on the Gelatinization of Aviation Fuels" was made on the basis of the suggestion submitted by Mr. Frank T. Hall, Converse Rubber Company, Malden 48, Massachusetts.

Mr. Hall originally introduced his suggestion to the Civil Aeronautics Board and from there it was forwarded to the Federal Aviation Agency Administrator for appropriate action.

The letter report covering this study is herewith enclosed.

Sincerely,



Aldro Lingard
Chief, Test and
Experimentation Division

Enclosure - 1

LETTER REPORT
ON
FEASIBILITY STUDY ON THE
GELATINIZATION OF AVIATION FUELS

1. The purpose of this study was to investigate the feasibility of minimizing the fire hazards of aviation fuel spillage during a crash by rapidly increasing the fuel's viscosity, thereby decreasing its flow rate and the subsequent gaseous vapor envelope that ensues.

2. Mr. Frank T. Hall of Converse Rubber Company, Malden, Massachusetts, submitted the names of two available chemical additives that possibly could be utilized to change gasoline into a jelly substance. Mr. Hall's idea was to install a capsule of a suitable compound and also a capsule-bursting mechanism in each fuel tank. In case of an imminent crash, the pilot would release the compound and thereby gel the gasoline before it could flood a large area and contact an ignition source.

3. The recommended CAB-O-SIL, M-5, and CARBOPOL #934 compounds were obtained from the Godfrey L. Cabot, Inc., and the B. F. Goodrich Chemical Co., respectively. Upon receipt of the above materials and the accompanying technical data brochures, it was learned that the CARBOPOL #934 compound was an acid polymer and would require an additional neutralizing agent to develop its maximum properties. The decision was made not to use the CARBOPOL compound because of the additional testing required to determine a suitable neutralizer, a correct pH, and the effect of the pH on the viscosity of the mixture.

4. The CAB-O-SIL, M-5, compound utilized in the tests is a submicroscopic particulate silica that is prepared in a hot gaseous environment (1100° C.) by the vapor phase hydrolysis of a silicon compound. The compound, as advertised in the Godfrey L. Cabot Bulletin CGen-1, dated January 1955, has the following chemical and physical properties:

*a. Specific Gravity	2.1
b. Color	White
c. pH (4 Per Cent Aqueous Dispersion)	3.5 - 4.2
*d. Bulking Value	0.057 Gallon/Pound
e. Apparent Bulk Density	2.5 - 3.5 Pounds/Cubic Foot
f. Silica Content (Moisture-Free Basis)	99.0 - 99.7 Per Cent

*Based on the compound being in a solid state and free of all voids.

The compound is not commercially available in a compressed state to produce a specific gravity of 2.1 or the equivalent weight of 131 pounds per cubic foot. Therefore, the available compound, having an average value of 3 pounds per cubic foot (reference the apparent bulk density in paragraph 4) with an equivalent specific gravity of .048, was utilized in the tests. A survey was not made of other marketable compounds having characteristics equivalent to the two already mentioned. However, since this experiment was not for the purpose of choosing the type of compound, but rather to check the feasibility of gelling fuels, the CAB-O-SIL product was considered to be representative of colloidal silica agents.

5. Table I shows the storage space and weight of CAB-O-SIL required to gelatinize the full fuel supply of each of 18 different aircraft.

6. The exploratory test program was divided into the following phases:

- a. Mixing Phase
- b. Splatter Phase
- c. Burning Phase
- d. Moisture-Absorption Phase
- e. Corrosion Phase

7. Mixing Phase: JP-4 fuel and 115-octane fuels were used in the experiments. Clear plastic bags, supported at their open ends, were used as containers for the 1-quart sample of fuel (1.46 pounds of gasoline or 1.67 pounds of JP-4).

a. The No. 1 mixture was made with the 115-octane fuel and 7 per cent (by weight) of the silica compound. The compound was added to the top of the fuel which became completely gelatinized after mixing.

b. The No. 2 mixture was made with 115-octane fuel and 8 per cent (by weight) of the silica compound. The compound again was added to the top of the fuel and mixed until complete gelatinization was obtained.

c. The No. 3 mixture was made with the JP-4 fuel and 7 per cent (by weight) of the silica compound. The compound was added to the top of the fuel and the fuel became completely gelatinized after mixing.

8. Splatter Phase: A plastic container of mixture No. 3 (reference paragraph 7c), together with a plastic container of 1 quart of JP-4 fuel, was used for the drop tests to study splatter characteristics. The open ends of the plastic containers were tied off and each container was dropped from a height of 12 feet to a concrete surface. The splatter patterns for both drops are shown in Figs. 1 and 2.

9. Burning Phase: Mixtures Nos. 2 and 3, described in paragraphs 7b and 7c above, respectively, were utilized for this phase. The mixtures were ignited with an open flame after each had been dropped in the splatter phase.

10. Moisture-Absorption Phase: Twenty grams of the silica compound were placed in a sealed plastic container and left to weather outdoors for a period of three weeks. The container then was equipped with a vent pipe and left to weather outdoors for an additional period of four weeks. Temperatures of 50^o F. to 90^o F. and humidities from 45 per cent to 97 per cent were encountered during the outdoor tests.

11. Corrosion Phase: Eight ounces of mixture No. 1 (reference paragraph 7a) were placed on a laminated nylon/buna-N fabric and on an aluminum alloy test panel. Each test panel was placed in an individually sealed container and left undisturbed for a period of four weeks.

12. The results of this exploratory experiment were as follows:

a. Mixing Phase: The 7 per cent (by weight) of the silica compound in mixture No. 1 produced a syrupy fluid in 1 3/4 minutes. The percentages of compound used in mixtures Nos. 2 and 3 produced a good gel in 1 minute and 1 3/4 minutes, respectively. Agitation was required continually to break up the agglomerates that formed during the three mixing phases.

b. Splatter Phase: A greater percentage, by volume, of the gelatinous JP-4 fuel mixture remained nearer to the zero drop point than did the raw JP-4 fuel. This is shown in Figs. 1 and 2.

c. Burning Phase: Mixture No. 2 (115 octane) did not ignite in a manner as violently as raw gasoline. The mixture continued to burn in a way a can of liquid heat would burn. Particulates of the jelly-like mixture continued to burn after the flaming mixture had been hurled against a vertical wall. The No. 3 mixture (JP-4) was difficult to ignite and burned rather slowly. The flaming mixture continued to burn after being dispersed into smaller portions.

d. Moisture-Absorption Phase: The silica compound, in the plastic container during the sealed and vented moisture-absorption phase, increased its moisture content by a small percentage. During the three weeks of being in the sealed plastic container the compound lost some of its fluffiness. The venting of the plastic container allowed the moisture content to build up and form tiny lumps in the compound.

e. Corrosion Phase: The acid content of the jellied fuel had no adverse effects on the aluminum alloy or the nylon/buna-N fabric material. It is of interest to note that, after 24 hours, most of the fuel had bled out of the mixture that had been placed on the material samples.

13. The conclusions which may be drawn from this experiment are:

a. The average time of 1.5 minutes required for the mixing phase involving a 1-quart fuel sample is excessive when considering a "no-warning" crash condition of an aircraft carrying several hundred gallons of fuel.

b. Aviation fuels could be satisfactorily jellified to most any viscosity and at different time intervals by varying the quantity of the CAB-O-SIL additive. An increased percentage of the additive would tend to increase rate and degree of jelling.

c. The weight and space requirements of CAB-O-SIL, as noted in Table I, for the larger aircraft would be appreciable.

d. A gelatinization process would reduce the rapid flow characteristics of the fuel while leaving a ruptured tank.

e. The CAB-O-SIL compound does not support combustion and therefore acts as a mild retarding agent.

f. A method of dispersing the compound throughout a fuel tank in a rapid manner would have to be developed in order to make the gelatinization of aviation fuels feasible. The design of the dispersal system would vary in accordance with the many fuel tank complexes and/or fuel tank configurations.

g. The present packaging methods would have to be greatly improved toward reaching the ultimate bulking value of 131 pounds per cubic foot in order to reduce the storage space requirements.

h. An extensive test program is needed to study the moisture effects on the compound during long-term storage.

i. The components of a fuel system can be reclaimed satisfactorily after having been subjected to gelatinized fuel mixtures by using the base fuel as a solvent.

j. The full value of an emergency system that would gelatinize the contents of a fuel tank complex could be realized only after such a system were designed, installed, and tested in a full-scale aircraft.

k. The exploratory tests on the one compound, namely CAB-O-SIL, M-5, indicate that the product is not wholly suitable for an emergency gelatinization process in an aircraft fuel system.

l. A test program is needed to exploit all phases of the gelatinization process for aircraft fuel systems, to include the fire-retarding effectiveness using existing additives in full-scale crash tests, the development of fast-acting additives, and the design and testing of a dispersal system.

TABLE I

CAB-O-SIL REQUIREMENTS FOR
VARIOUS MODEL AIRCRAFT

Airplane **	Number of Engines	Fixed Wing		Max. Lbs. of Fuel	Req'd Lbs. CAB-O-SIL (8%) ***	Storage Space - Cu. Ft. **** CAB-O-SIL (Sp. Gr. 0.048)
		Wing Position*	Max. Gal.			
Beechcraft Bonanza	1	L	67	388.6	31.09	10
Cessna 170 and 180	1	H	42	243.6	19.49	6
Colonial Skimmer	1	S	30	174.0	13.92	5
Mooney Mark 20	1	L	50	290.0	23.20	8
Piper Super Cub #95	1	H	18	104.4	8.35	3
Piper Tri-Pacer	1	H	36	208.8	16.70	6
Taylorcraft #20 (Ranch Wagon)	1	H	66	382.8	30.62	10
Aero Commander	2	H	150	870.0	69.60	23
Beechcraft Twin Bonanza	2	L	134	772.0	61.76	21
Cessna 310	2	L	100	580.0	46.40	15
Convair 340	2	L	1,750	10,150.0	812.00	204
Learstar	2	L	1,114	6,461.2	516.90	172
Piper Apache	2	L	72	417.6	33.41	11
Douglas DC-7B	4	L	6,400	37,120.0	2,969.60	990
Lockheed Super Constellation - G	4	L	7,750	44,950.0	3,596.00	1,199
<u>Rotary Wing</u>						
Sikorsky S-55	-	-	190	1,102.0	88.16	29
Hiller 12B	-	-	28	162.4	12.91	4
Bell 47H	-	-	43	249.4	19.95	6

* H - high wing; S - shoulder wing; L - low wing.

** Jane's All the World's Aircraft, 25 Gilbert Street, London, IN-1 1955-56.

*** Does not include weight of the mechanical components of the dispersal system.

**** Storage area could easily be reduced as ways are found to increase bulk density.

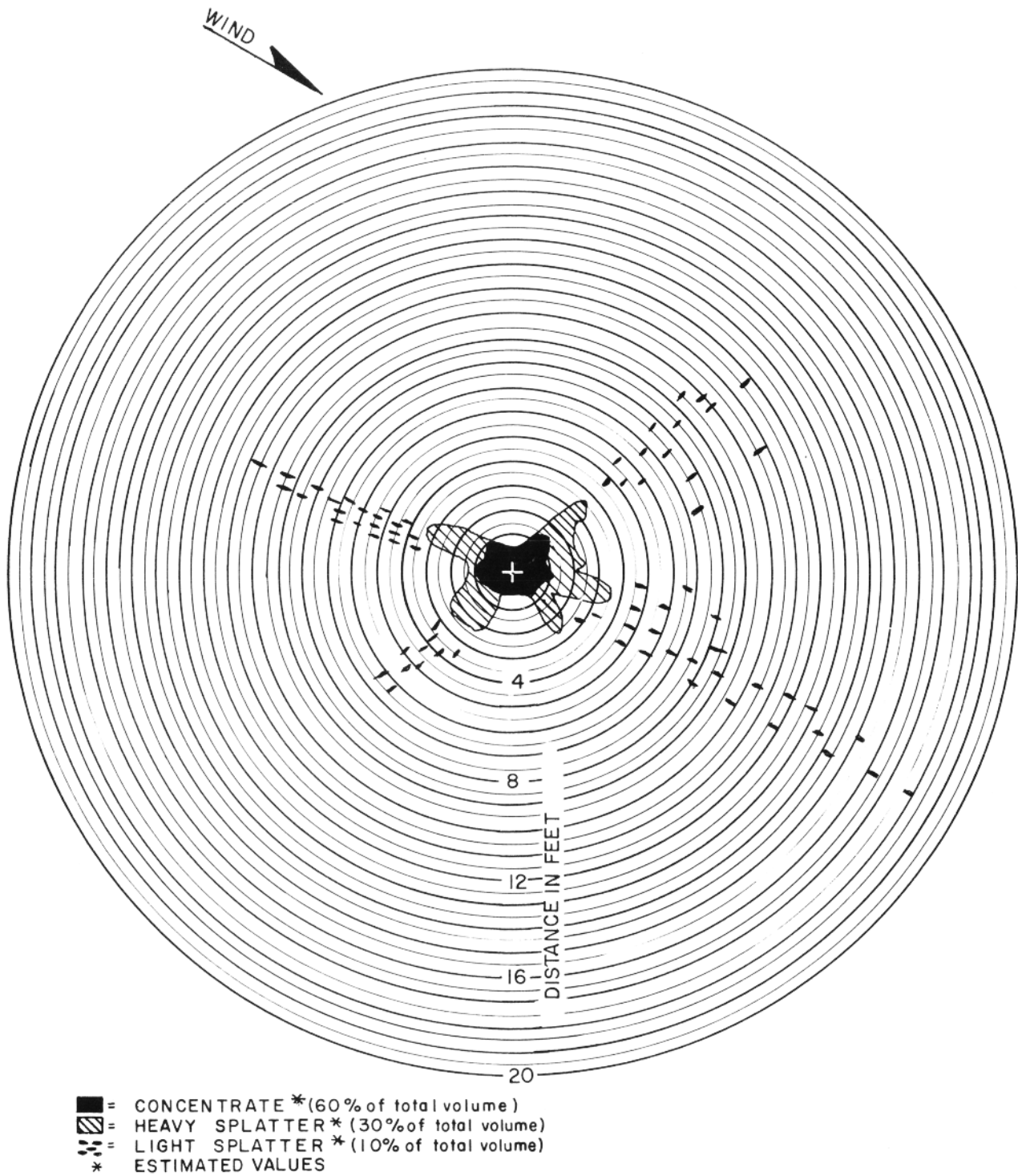
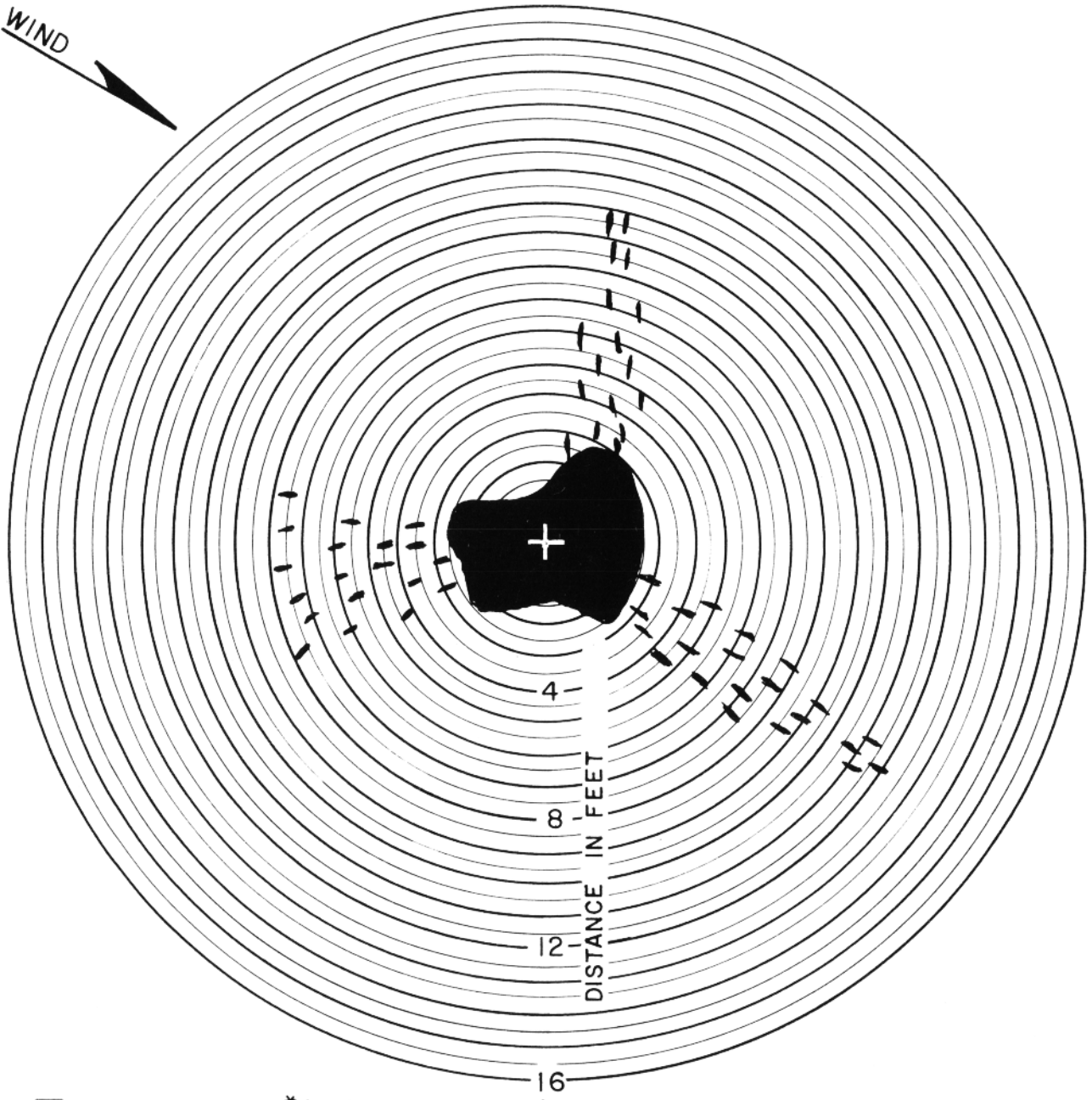


FIG. 1 SPLATTER PATTERN FOR GELATINOUS JP-4 FUEL

WIND



- = CONCENTRATE * (75% of total volume)
- - - = HEAVY TO LIGHT SPLATTER* (25% of total volume)
- * ESTIMATED VALUES

FIG. 2 SPLATTER PATTERN FOR JP-4 FUEL