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**AN INVESTIGATION OF THE THERMAL STABILITY
OF POTENTIAL SUPERSONIC JET FUELS**

J. J. BIALY
R. A. FROST
K. L. BILLE

XON



**TEXACO INC.
TEXACO RESEARCH CENTER
BEACON, N. Y.**

**PROGRESS REPORT NO. 3
FOR**

**DIRECTORATE OF MATERIALS AND PROCESSES
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO**

**CONTRACT NO. AF 33(616)-8045
TASK NO. 30178**

**PROJECT NO. 1(10-3048)
APRIL 1, 1962**

NO OTS

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Task No. 30178

Project No. 1(10-3048)
April 1, 1962

Submitted by


K. L. DILLE
PROJECT LEADER

FOREWORD

This is the third progress report on work done under Contract No. AF 33(616)-8045, Project No. 1 (10-3048), Task No. 30178 and covers work completed during December 1, 1961 to April 1, 1962. This work was performed at the Texaco Research Center, Beacon, New York and was sponsored by Directorate of Materials and Processes, Aeronautical Systems Division with Mr. C. J. Johnson as the Project Engineer.

Texaco personnel contributing to this contract included Messrs: Jerzy J. Bialy, Kenneth L. Dille, Frank P. Frascati, Richard A. Frost and Thomas A. Norris.

ABSTRACT

During the third four months of this program, project activity has been concerned with (1) maintaining and refining the Texaco Research Coker, (2) continuing the pretreatment and analytical testing of the project fuels, (3) evaluating and comparing the thermal stability of the project fuels, and (4) investigating the effects of high temperature storage on the properties of a kerosine fuel. It is estimated that 80 per cent of the program is complete.

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I. INTRODUCTION

With the advent of aircraft capable of sustained Mach 3-4 speeds, the high temperature to which the aircraft is subjected during such a flight becomes of major concern. Some of the heat generated during high-speed flight is transferred to the fuel and consequently the bulk fuel temperature increases. The bulk fuel temperature for Mach 3-4 flight may range from 200 to 500°F depending on fuel tank location, insulation, duration of flight, the amount of fuel and the heat capacity of the fuel.

Previous work has shown that heating fuels to 300°F for two hours adversely affects their thermal stabilities. Only limited work has been conducted on the effect of high thermal stress on other fuel properties. It is the purpose of this program to conduct applied research on the techniques for predicting the effect of high temperature storage on jet fuel properties. The high temperature storage conditions being investigated are 200 to 500°F for periods up to ten hours.

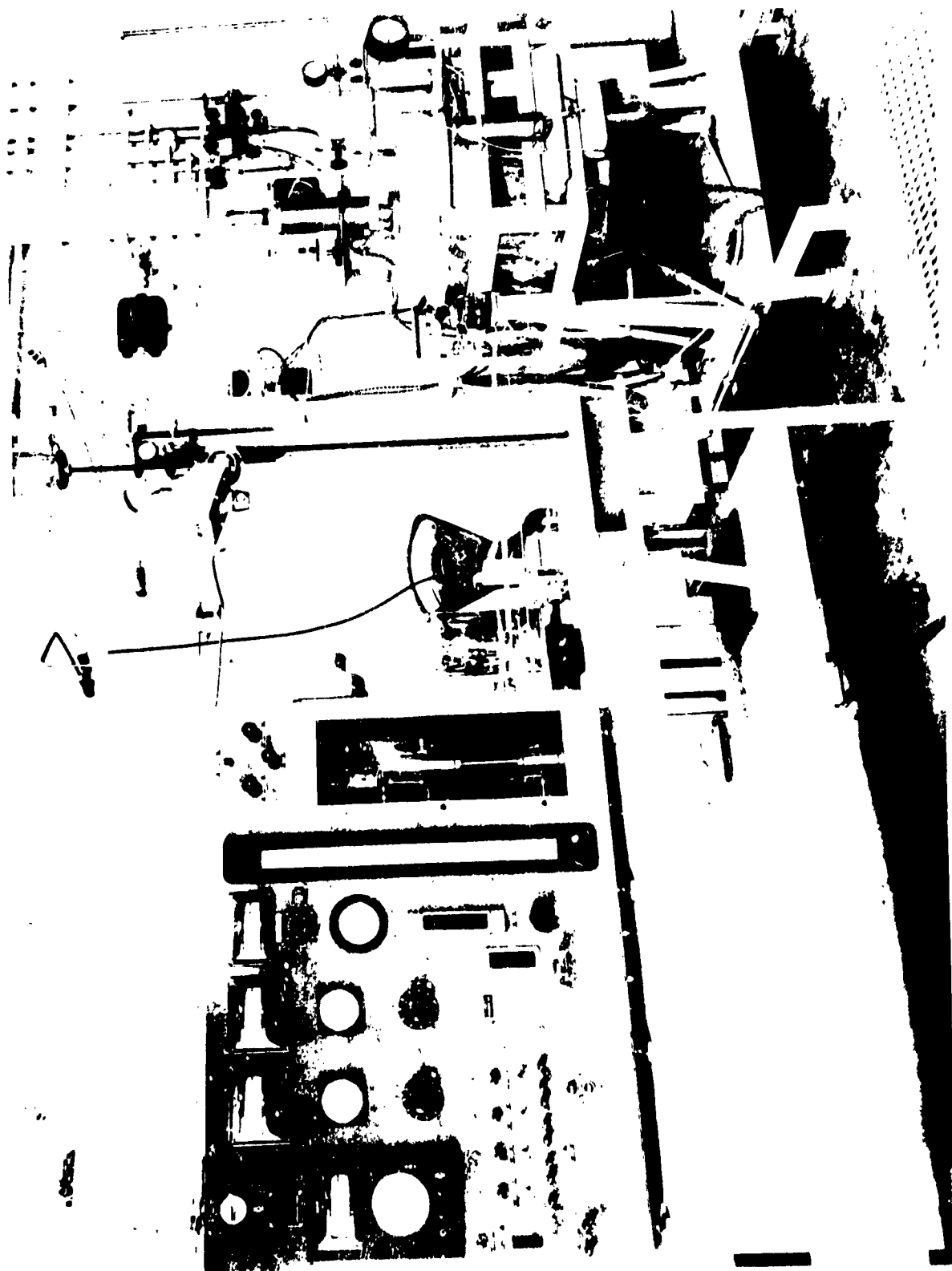
This program includes the following phases:

- (1) Design and fabrication of a reservoir capable of simulating the thermal stresses anticipated in the fuel tanks of aircraft traveling at Mach 3-4.
- (2) Investigation of the thermal stability, vapor phase decomposition and other fuel properties for nine fuels before and after high temperature storage in the reservoir.
- (3) Evaluation of the effects on fuel properties produced by varying (a) temperature of the reservoir, (b) time in the reservoir, (c) oxygen availability, (d) trace compounds in the fuel, (e) specific heat of the fuels and (f) solid contamination.

Progress Report No. 1 submitted on August 1, 1961 covers the work completed during April 1 to August 1, 1961 on phase 1. Progress Report No. 2 briefly summarizes the work on phase 1 and covers the work completed during August 1 to December 1, 1961.

II. DISCUSSION

During the third four months of this program, project activity has been concerned with (1) maintaining and refining the Texaco Research Coker, (2) continuing the pretreatment and analytical testing of the project fuels, (3) evaluating and comparing the thermal stability of the project fuels, and (4) investigating the effects of high temperature storage on the properties of a kerosine fuel. These items are discussed below.



TEXACO RESEARCH COKER

FIGURE 1

A. Test Equipment

Figure 1 illustrates the equipment used to evaluate thermal stability of the fuels at high temperature. Details of this equipment, operating procedure and repeatability data are given in Progress Report No. 2 (December 1, 1961).

During the past four months problems have been encountered with the pumps. As a result two pumps in series are now being used to transfer the fuel from the reservoir to the coker preheater section. Difficulties have also occurred with the magnetic stirrer on the reservoir and with the electrical heaters, however, these problems have been solved and no further difficulties of this type are expected in the near future.

B. Fuels

The fuels investigated in this program are listed in Table I. These fuels were selected to cover a wide gamut of diverse hydrocarbon compositions. With the exception of JP-6 fuel these fuels were processed to meet volatility specification of 50 psia maximum at 500°F, and were clay percolated and inhibited to enhance their thermal stability characteristics. Detailed description of the fuel treatment is given on pages 13-14, of the Appendix. Results of analytical tests on the program fuels are also given in the Appendix, pages 18 through 25.

C. Test Program

1. Comparison of Supersonic Jet Fuels

Eight project fuels were compared with respect to their relative thermal stability using their threshold temperatures as criteria. The fuels were heated in the reservoir for one hour at 350°F and their threshold temperatures determined. The results from this phase of the program are summarized in Figure 2, page 5. These results show that the lowest thermal stability was exhibited by the JP-6 fuel. It should be pointed out that this was the only fuel which was not treated or inhibited prior to heating. There seems to be no significant difference in thermal stability of conventional JP-5 fuel and SO₂ extracted paraffinic kerosine and moreover between the above fuels and hydrogenated lauryl alcohol. On the other hand, there seems to be a consistent 50 degrees spread in threshold temperature between the SO₂ extracted paraffinic and naphthenic kerosine and although this spread falls within the repeatability limits of the test it favors the naphthenic stock very consistently. These data are confirmed further by the fact that two of the three most thermally stable fuels found were naphthenic in nature. The third stable fuel was somewhat of a surprise due to the fact that usually aromatic fuels exhibit poor thermal stability. From the present results it appears that from the thermal stability point of view alone it is not necessary to remove aromatic components from jet fuels.

TABLE I
PROGRAM FUELS

<u>Fuel</u>	<u>Type</u>	<u>Source</u>
1. SO ₂ Extracted Kerosine	Paraffinic	Texaco
2. SO ₂ Extracted Kerosine	Naphthenic	Texaco
3. Furfural Extract of LCGO	Aromatic	Texaco
4. JP-5 Fuel	Mixture	Texaco
5. JP-6 Fuel	Mixture	ASD
6. Hydrogenated Lauryl Alcohol	normal-C ₁₂ paraffin	ASD
7. Isopropyl Bicyclohexyl (HTF-27)	Naphthenic	ASD
8. Alkyl Decalins (HTF-35)	Naphthenic	ASD
9. Soltrol 170	Isoparaffins	ASD

Fuel 1 is the base fuel for this work.

FIGURE 2

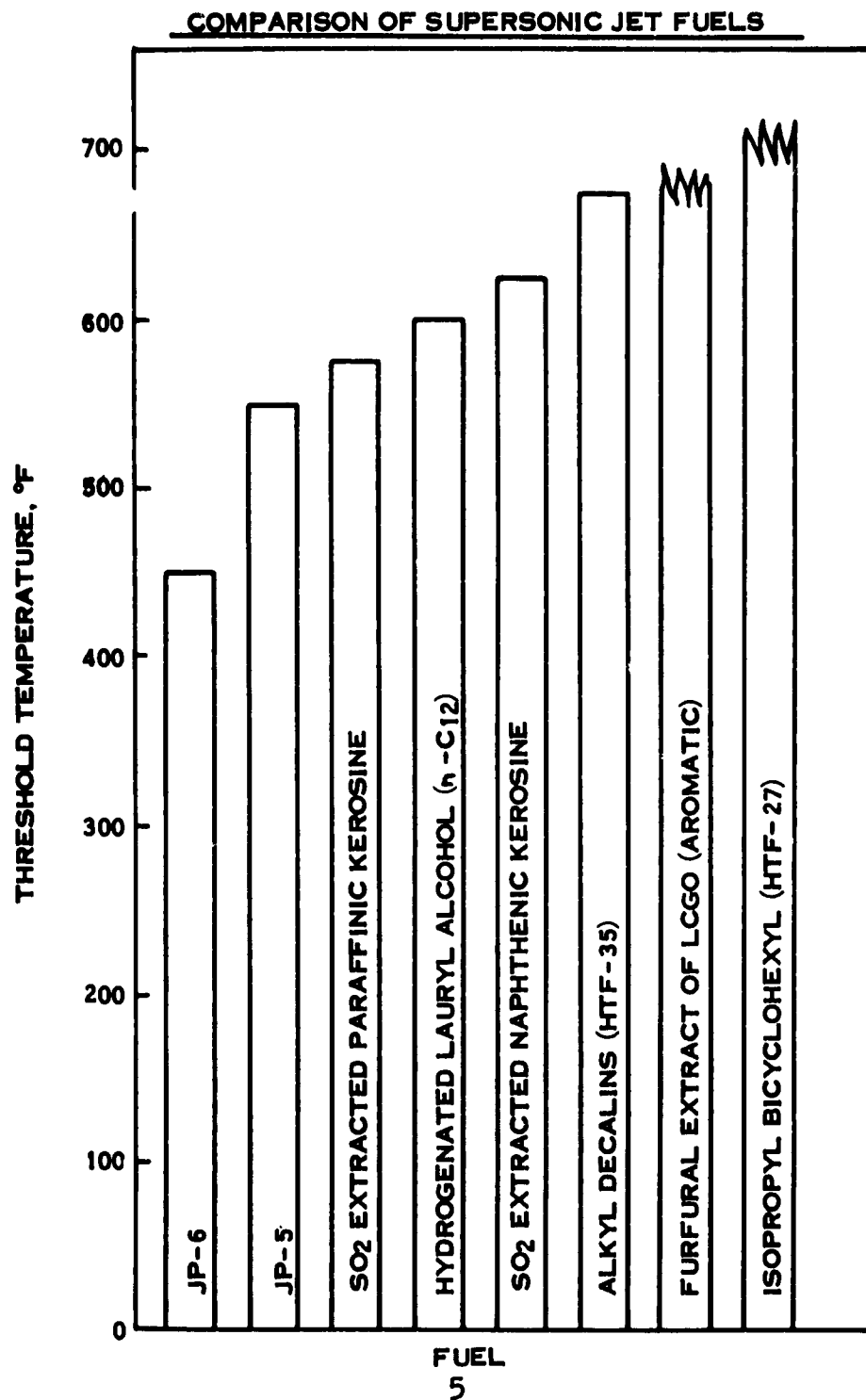
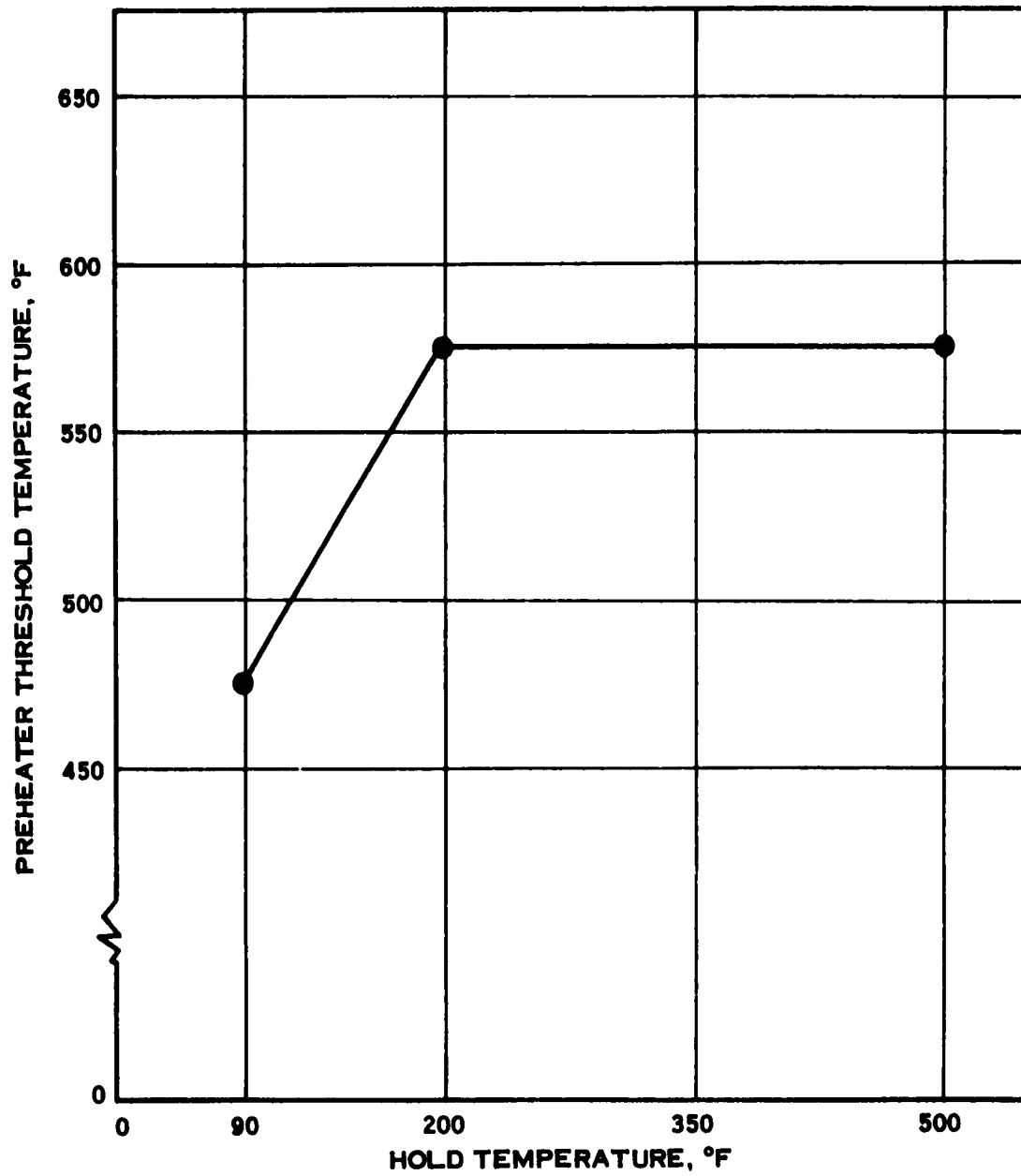


FIGURE 3

PREHEATER THRESHOLD TEMPERATURE VS HOLD TEMPERATURE
AT 0 HOLD TIME



2. Effect of Storage on Thermal Stability

The time-temperature interchangeability with respect to the influence of heat on fuel thermal stability has been studied on the base fuel. This phase of the program has been completed with the exception of one run. The results obtained are shown in Figure 3 and 4, pages 6 and 8. Detailed run data are shown in Table II, in the Appendix.

The results summarized in Figure 3 indicate that significant improvement in thermal stability occurs after the fuel has been soaked for a short time at elevated temperature. There is no additional improvement with further increase in soaking temperature.

Figure 4 shows results of the various time and temperature conditions to which the base fuel was subjected. The results indicate that there is no significant change in fuel thermal stability with increase of the soaking time. Visual inspection of the inside surfaces of the reservoir did not show any discernible deposits. On the other hand careful inspection of the test coupon on the reservoir lid showed a slight increase in deposit level with increase in hold temperature, but not with the increase of hold time. The results showing various deposit levels on the test coupons are shown in Figure 5, page 9.

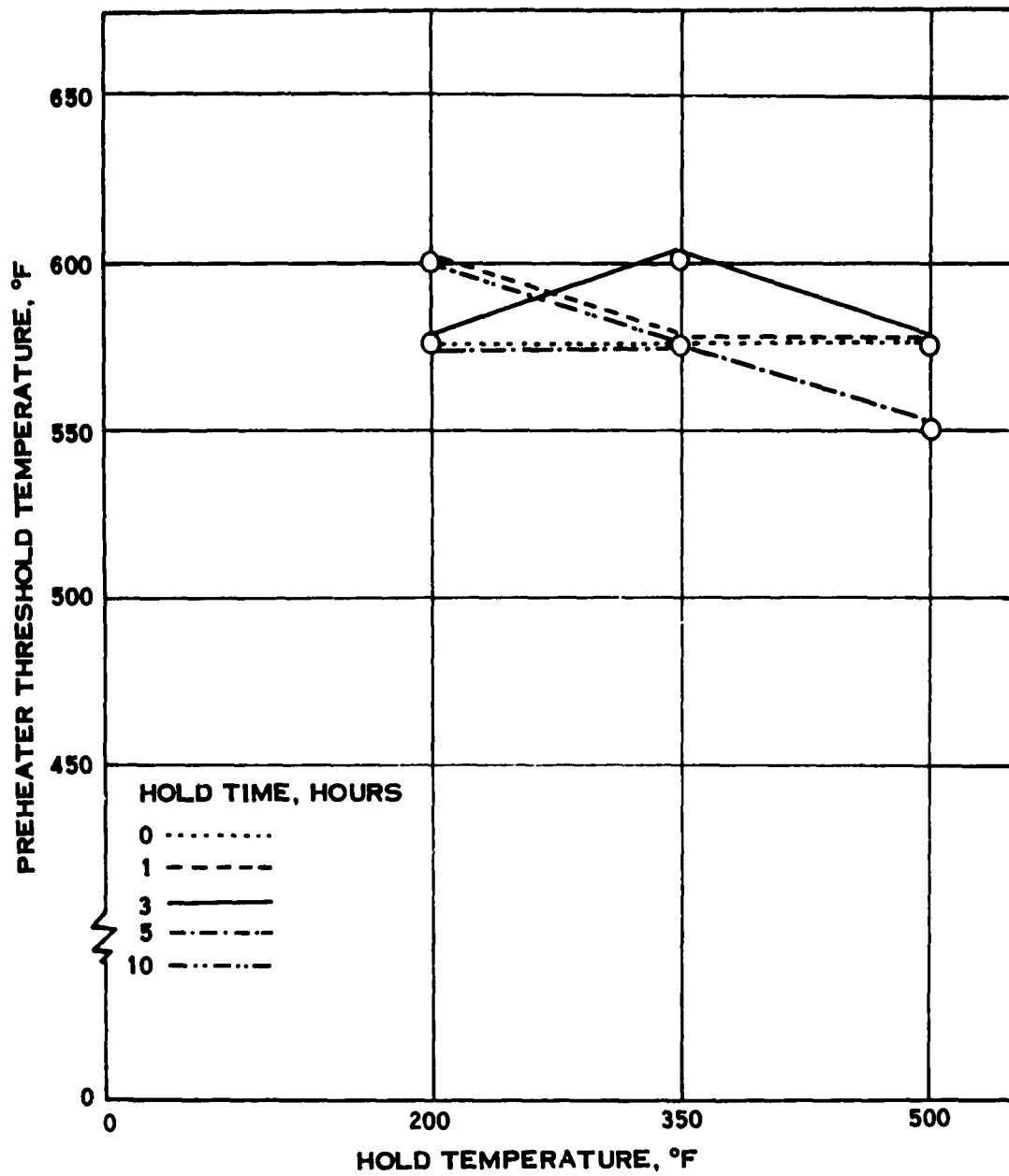
III. PROJECT STATUS

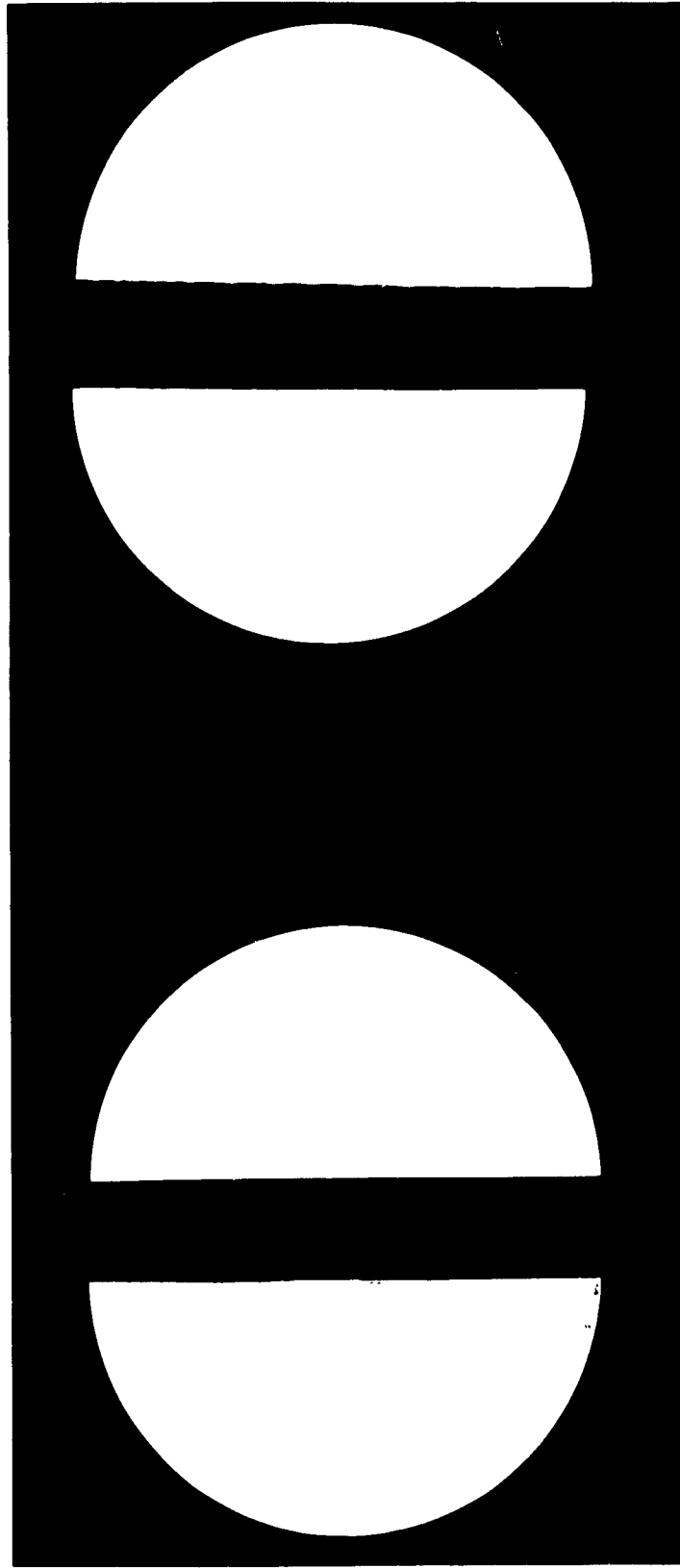
It is estimated that the project is 80 per cent complete. Specific items accomplished are:

1. Procurement and construction of test apparatus - 100 per cent complete.
2. Shakedown runs on Texaco Research Coker - 100 per cent complete.
3. Development of operating procedure for Texaco Research Coker - 100 per cent complete.
4. Procurement of project fuels - 90 per cent complete.
5. Pretreating project fuels - 90 per cent complete.
6. Inspection tests on project fuels - 60 per cent complete.
7. Determination of repeatability of CRC Research Coker - 100 per cent complete.
8. Comparison of the thermal stability of project fuels - 85 per cent complete.

FIGURE 4

PREHEATER THRESHOLD TEMPERATURE VS HOLD TEMPERATURE





500°F

350°F

200°F

BLANK

DEPOSIT LEVELS AT VARIOUS HOLD TEMPERATURES

HOLD TIME - 10 HOURS

FIGURE 5

9. Effect of high temperature storage on project fuels - 95 per cent complete.

10. Effect of impurities on the thermal stability of project fuels - 0 per cent complete.

IV. FUTURE WORK

Project activity during the final four month period will be to complete the unfinished items listed under section III and to initiate and complete the work outlined for PR 164349 RCN.

V. APPENDIX

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APPENDIX

FINISHING TREATMENT OF TEST FUELS Contract No. AF 33(616)-8045

1. Clay Percolation

a. Apparatus

The percolating column used in fuel treating consisted of a ten foot Pyrex glass pipe (6" I.D.) joined at the bottom to a twelve inch Pyrex glass pipe (3" I.D.) through a Pyrex glass reducer. All flanges and fittings on the effluent side of the column were stainless steel. The top of the column was equipped with an automatic fuel level controller with a provision for fuel overflow to return to the feed drum. A conventional brass fuel pump was used for transferring the fuel from the feed drum to the top of the column.

b. Materials

The adsorbent material used in fuel treating was commercially available 60-90 mesh, LVM grade Attapulugus clay. This clay was used as delivered, without any pretreatment prior to use.

Pyrex glass wool was used at the bottom of the column to prevent clay particles from entering the flow regulating valve.

c. Procedure

Fuel was pumped directly from a drum into the top of the column which was filled with an appropriate amount of clay (8 lbs/bbl). The fuel was allowed to percolate by gravity into a clean receiving drum without changing the flow rate. Every effort was made to maintain an undisturbed equilibrium within the column. The flow rate was predominantly limited by viscosity of the fuel and usually varied between 1 to 2 gal/hr. When more than one drum was treated, the fuel was combined from all the receiving drums to get a homogeneous effluent fuel.

2. Inhibition

The clay treated fuel was uninhibited with 2 lbs/M bbl of DMD and 5 lbs/M bbls of Parabar 441 by adding the required amounts of additives directly into the drums and stirring the fuel vigorously with an air driven stirrer for one hour.

3. Filtration

Just prior to the thermal stability evaluation the fuel was filtered through a millipore 0.45 μ filter.

4. Gas Saturation

The filtered fuel was either evaluated without gas saturation or saturated with air or nitrogen.

TABLE II
SUMMARY OF THERMAL STABILITY DATA ON THE
SO₂ EXTRACTED PARAFFINIC KEROSENE

Test No.	Fuel No.	Air	N ₂	Reactor Type	Reactor Hrs	Temp. °F	Fuel Flow lbs/hr	Filter AP/time* in.-Hg/Min	Tube Rating	Bubbles in Rotometer	Remarks
18203-19	61-5416		X	TICO	0	450	6.00	0.70	2	X	
-18					0	475	5.75	2.92	3		
-20					0	450	5.99	20.65	1		Overheated vapor phase, broken Te
-21					0	500	6.00	7.00	1		Water solenoid failure
-22					0	500	6.00	0.60	2		
-23					0	500	6.00	0.60	2		
-24					0	500	6.00	5.95	6		
-25					1	500	6.00	0.30	2		
-26					1	500	6.00	5.75	2		
-27					1	500	6.00	0.45	3		
-28					1	500	6.00	0.65	2		
-29					1	500	6.00	0.65	2		
-30					1	500	6.00	0.70	2		
-31					3	600	5.99	23.65/216	4		By-passed filter after 228 min
18203-30					5	550	6.01	0.30	2		
-31					5	575	5.98	0.15	2		
-32					10	550	6.02	21.50/72.8	2		By-passed filter
-33					10	575	5.99	24.0/6.1	2		By-passed filter
-34					10	600	5.99	0.2	4		By-passed filter
-35					0	350	6.00	24.65/107.0	2		
-36					0	350	6.00	1.65	4		
-37					1	350	6.00	1.00	2		
-38					1	350	5.99	1.25	2		
-39					3	350	5.98	0.7	2		Vapor Phase heater burned out
-40					3	350	6.01	1.25	2		
-41					3	350	6.01	0.10	2		
-42					3	350	6.00	0.70	2		
-43					3	350	6.00	0.85	2		
-44					10	350	6.00	3.15	2		
-45					10	350	6.02	1.05	2		
-46					0	500	5.99	9.25	2		2 shutdowns - Pump trouble and By-pass leaking
-47					0	500	6.00	22.30	3		High and low pressure valves inoperative
19047-6					1	500	5.99	0.00	2		Pump trouble - 1 shutdown 12 min
18203-49					1	500	5.97	25.00/57.4	3		Filter furnace and transfer pump failure
19047-3					3	500	6.00	0.75	Void		By-passed filter
-10					3	500	5.98	1.75	1		
-9					3	500	5.99	25.00/273.9	3		
-12					3	500	5.99	6.90	1		
-1					3	500	5.98	5.05	1		
-2					3	500	5.98	3.00 ^a	1		
-4					10	500	6.00	25.00/212.0	2 ^b		
-11					3	500	6.01	25.0/215.8	3		
-24					0	500	6.00	0.65	3		
18203-48					0	400	5.99	9.60	3		
19047-5					0	300	6.01	24.9	3		

*282.0 min reading Pump trouble, shutdown 20 min.
bSection dark 1 or light 7.
c 300 min unless noted

TABLE III

SUMMARY OF THERMAL STABILITY DATA ON THE
SO₂ EXTRACTED NAIPHENIC KEROSENE

Test No.	Fuel No.	Air	E ₂	Temp °C	Temp. Frontal °C	Temp. 7 °C	Fuel Flow lb/hr	Filter ΔP/time ¹ In.-H ₂ O/min	Tube Rating	Bubbles in Permeator	Remarks
19047-14 ^a	61-5103		X	390	575	675	6.00	25.0/143.3	2a	-	By-passed filter
-15 ^a				390	600	700	5.98	14.65/56.8	2	X	By-passed filter 10 in. initial pressure
-16 ^a				390	650	750	-	-	Void	-	Shut down after 32.0 min
-17 ^a				390	650	750	5.99	25.0/226.4	6	X	Bearing on reservoir stirrer gone
-18 ^a				390	625	725	-	25.0/205.9	- 8 void	-	By-passed filter
-19 ^a				390	625	725	6.05	24.85/100.0	2b	X	Shut down at 211.1 min Filter leaked
-21 ^a		X		300	500	600	6.00	3.05	3	-	By-passed filter
-29	62-510		X	390	575	675	5.99	By-passed	2	-	
-30				390	600	700	Void	-	-	-	
-33				390	600	700	6.01	25/109	7	X	
-28				390	600	700	6.0	25/176.5	2	X	
-27		X		390	625	725	5.98	25/159.8	4	X	
				300	500	600	6.01	0.90	2	-	

¹300 min unless noted.
^arainbow effect on sections of the tube.
^bSections of tube dark 2 or light 7.

TABLE IV
SUMMARY OF THERMAL STABILITY
DATA ON OTHER FUELS

Test No.	Fuel No.	Air	E ₂	Type	Hold Hrs.	Temp. °F.	Temp. °F.	Fuel Flow lb/hr	Filter Δ ^a /min In.-H ₂ O	Tube Rating	Bubbles in Potometer	Remarks
190A7-20 -21 -22	61-8792		X	TICG	1	350	350	6.01	0.15	1a	X	
			X	TICG	1	350	350	6.01	0.35	2b	X	
			X	TICG	1	350	350	6.01	-	Void	-	Shut down at 62.8 min. Stirrer not working properly.
190A7-26 -27		X	X	TICG	1	350	350	6.01	6.15	3	X	
				MC	0	300	300	6.01	0.05	4	-	
190A7-44 -45 -46 -47 -48 -49 -7	58-10646		X	TICG	1	350	350	6.01	16.7	1	X	
			X	TICG	1	350	350	6.01	4.55	2	X	
			X	TICG	1	350	350	6.01	13.3	2	X	
			X	TICG	1	350	350	6.01	-	Void	-	Preheater seal leakage
			X	TICG	1	350	350	6.01	-	Void	-	Preheater seal leakage
			X	TICG	1	350	350	6.01	NA	2	X	Preheater seal leakage
			X	MC	0	300	300	6.01	6.0	4	-	Preheater seal leakage
190A7-33 -34 -35 -36 -37 -38 -39 -40	62-404		X	TICG	1	350	350	6.01	4.70	2	X	
			X	TICG	1	350	350	6.01	2.05	2	X	
			X	TICG	1	350	350	6.01	0.70	2	X	
			X	TICG	1	350	350	6.01	25/152.4	Void	-	Filter Furnace leaked
			X	MC	0	300	300	6.01	0.25	3	-	
				MC	0	300	300	6.01	-	Void	-	Preheater flange leaked
			X	TICG	1	350	350	6.01	0.10	2c	-	
			X	TICG	1	350	350	6.01	0.25	2e	-	
				MC	0	300	300	6.01	-	2	-	
190A8-2 -3 -4 -5 -6	61-4142		X	TICG	1	350	350	6.01	25/281	2	X	
			X	TICG	1	350	350	6.01	12.1	1	X	
			X	TICG	1	350	350	6.01	25.85/205	5	X	
			X	TICG	1	350	350	6.01	18.70	3	X	
			X	TICG	1	350	350	6.01	25/284	3	X	
			X	MC	0	300	300	6.01	6.0	4	-	
190A8-6 -7	61-5731		X	TICG	1	350	350	6.01	2.15	3	X	
			X	TICG	1	350	350	6.01	0.30	3	X	

^aParts of tube peacock color, other parts dark 2 or light 7
bParts of tube dark 2 or light 7
cNo bubbles. Rating nearer to 1. Run stopped at 210 min/w
bad filter leak.
*300 min unless noted

Sample Number TRCB 62-40B
Description Isopropylbicyclohexyl

MIL-F-25656 and MIL-J-5624
Inspection Tests

Distillation

<u>% Recovered</u>	<u>Temp, °F</u>		
IBP	510	Recovery, %	98.5
5	520	Residue, %	Coke
10	524	Loss, %	1.5
20	527	<u>% Evaporated</u>	<u>Temp. °F</u>
30	529	10	523
40	592	40	528
50	530	50	529
60	530	90	533
70	531		
80	532		
90	534		
95	537		
EP	541		

Gravity, °API	28.2
Existent Gum, mg/100 ml	<1
Potential Gum, mg/100 ml	<1
Sulfur, Total, %	<0.002
Mercaptan Sulfur, %	0.000
RVP, lb.	0.0
Freezing Point, °F	-26
Thermal Value	
Heat of Combustion, Btu/lb., gross	19,656
net	18,507
Aniline-Gravity Product	8,903
Viscosity, cs - 30°F	651.9
Aromatics, vol %	4.0
Olefins, vol %	0.3
Smoke Point, mm	20
Smoke Volatility Index	None
Explosiveness, %	10
Corrosion, Cu Strip	1A
Water Reaction	Clean and clear
Flash Point, °F	no increase in volume
Aniline Point, °F	235
	181.7

Exhibit A Tests (b through j)

Particulate Matter in Hydrocarbons

Total Contamination, mg/l	2.80
Noncombustible Contamination, mg/l	0.11

Particle Analysis

<u>Size Range,</u>	<u>Number/Ml</u>	<u>% In Each Size Range</u>
2 to 5	26.0	75.9
5 to 10	4.71	13.7
10 to 20	0.69	2.0
20 to 30	1.51	4.4
30 to 50	0.75	2.2
50 to 100	0.63	1.8
100 or larger		
Total Larger than 2	34.3	
Largest Particle Observed	250 μ	

Saybolt Color	+30
Peroxide Number	0.0
Neutralization and Acid Number	TAN 0.01
Basic Nitrogen, ppm	1
Water Content, %	0.002
Total Oxygen, %	0.15
Naphthalenes, % wt	0.02
Gas Chromatographic Analysis (complete fuel)	

Additional Tests

Specific Heat	100°F-0.44, 200°F-0.50, 300°F-0.57 cal/g/°C
Luminometer Number	56.6
Potential Deposit Test	< #1 no discoloration
Thermal Stability	

Test Conditions

Preheater Temperature, °F	400
Filter Temperature, °F	500
Nominal Fuel Flow Rate	6
Fuel Container Weight	
Before	32.7
After	2.7
Exact Average Fuel Flow Rate	6

Test Data

	<u>Manometer Reading</u>	<u>Minutes</u>
Conditions Set	0.0	0
0.3 in. Hg Δ P above conditions set		
1.0 in. Hg Δ P		
3.0 in. Hg Δ P		
10 in. Hg Δ P		
25 in. Hg Δ P		
End of Test	0.0	300
Preheater Tube Deposit Rating		
CRC Rate	³	
CRC Rate, inches	4/0 5/2 4/3	

Sample Number TRCB 61-8792
Description Hydrogenated Lauryl Alcohol

MIL-F-25656 and MIL-J-5624
Inspection Tests

Distillation

<u>% Recovered</u>	<u>Temp, °F</u>		
IBP	406	Recovery, %	98.0
5	408	Residue, %	1.2
10	410	Loss, %	0.8
20	411	<u>% Evaporated</u>	<u>Temp, °F</u>
30	412	10	409
40	414	40	413
50	414	50	413
60	415	90	420
70	416		
80	418		
90	421		
95	430		
E.P.	474		

Gravity, °API	56.2
Existent Gum, mg/100 ml	<1
Potential Gum, mg/100 ml	<1
Sulfur, Total	<0.002
Mercaptan Sulfur	0.000
RVP, lb	0.0
Freezing Point, ° F	+10
Thermal Value	
Heat of Combustion, Btu/lb., gross	20,336
net	19,006
Aniline-Gravity Product	15,117
Viscosity, cs -30°F	Not suitable
Aromatics, vol. %	5.0
Olefins, vol %	5.0
Smoke Point, mm	45
Smoke Volatility Index	None
Explosiveness, %	15
Corrosion, Cu Strip	1A
Water Reaction	Clean and clear
Flash Point, °F	190
Aniline Point, °F	

Exhibit A Tests (b through j)

Particulate Matter in Hydrocarbons

Total Contamination, mg/l	0.26
Noncombustible Contamination, mg/l	0.26

Particle Analysis

<u>Size Range,</u>	<u>Number/Ml</u>	<u>% In Each Size Range</u>
2 to 5	14.7	39.8
5 to 10	9.8	26.7
10 to 20	4.6	12.5
20 to 30	3.45	9.4
30 to 50	3.48	9.2
50 to 100	0.98	2.6
100 or larger		
Total Larger than 2	36.9	
Largest Particle Observed	125 μ	

Saybolt Color	+30
Peroxide Number	-0.05
Neutralization and Acid Number	TAN 0.03
Basic Nitrogen, ppm	<1
Water Content	0.002
Total Oxygen	
Naphthalenes, % (wt)	0.05
Gas Chromatographic Analysis (complete fuel)	

Additional Tests

Specific Heat	100°F-0.54, 200°F-59, 300°F-0.64
Luminometer Number	159.3
Potential Deposit Test	<1 no discoloration
Thermal Stability	

Test Conditions

Preheater Temperature, °F	400
Filter Temperature, °F	500
Nominal Fuel Flow Rate, lb/hr	6
Fuel Container Weight, lb.	
Before	32.7
After	2.7
Exact Average Fuel Flow Rate, lb/hr	30.0

Test Data

	<u>Manometer Reading</u>	<u>Minutes</u>
Conditions Set	0.0	0
0.3 in. Hg Δ P above conditions set		
1.0 in. Hg Δ P		
3.0 in. Hg Δ P		
10 in. Hg Δ P		
25 in. Hg Δ P		
End of Test	0.0	300
Preheater Tube Deposit Rating		
CRC Rate	2	
CRC Rate, inches	6/0 2/1 5/2	

Sample Number 62-40-A
Description Alkyldecalin

MIL-F-25656 and MIL-J-5624
Inspection Tests

Distillation

<u>% Recovered</u>	<u>Temp, °F</u>		
IBP	408	Recovery, %	98.0
5	418	Residue, %	1.5
10	420	Loss, %	0.5
20	420	<u>% Evaporated</u>	<u>Temp, °F</u>
30	420	10	419
40	420	40	419
50	420	50	419
60	420	90	425
70	424		
80	424		
90	426		
95	430		
EP	433		

Gravity, °API	33.1
Existent Gum, mg/100 ml	<1
Potential Gum, mg/100 ml	<1
Sulfur, Total, %	<0.002
Mercaptan Sulfur	0.000
RVP, lb.	0.0
Freezing Point, °F	-46
Thermal Value	
Heat of Combustion, Btu/lb., gross	19,517
net	18,331
Aniline-Gravity Product	4296.4
Viscosity, cs - 30°F	131.4
Aromatics, Vol, %	2.0
Olefins, vol, %	0.5
Smoke Point, mm	21
Smoke Volatility Index	21
Explosiveness, %	24.0
Corrosion, Cu Strip	1B
Water Reaction	Clean and clear
Flash Point, °F	165
Aniline Point, °F	129.8

Exhibit A Tests (b through j)

Particulate Matter in Hydrocarbons

Total Contamination, mg/l	0.26
Noncombustible Contamination, mg/l	
Particle Analysis	

Saybolt Color	+30
Peroxide Number	0.02
Neutralization and Acid Number	Ph 7.9, TAN 0.01
Basic Nitrogen, ppm	1
Water Content	0.003
Total Oxygen	
Naphthalenes, % wt	0.02
Gas Chromatographic Analysis (complete fuel)	

Additional Tests

Specific Heat	100°F-.432, 200°F-.496, 300°F-.560
Luminometer Number	47.7
Potential Deposit Test	< 1 no discoloration
Thermal Stability	

Test Conditions

Preheater Temperature, °F	400
Filter Temperature, °F	500
Nominal Fuel Flow Rate, lb/hr	6
Fuel Container Weight, lb	
Before	32.7
After	2.7
Exact Average Fuel Flow Rate, lb/hr	6

Test Data

	<u>Manometer Reading</u>	<u>Minutes</u>
Conditions Set	0.0	0
0.3 in. Hg Δ P above conditions set		
1.0 in. Hg Δ P		
3.0 in. Hg Δ P		
10 in. Hg Δ P		
25 in. Hg Δ P		
End of Test	0.0	300
Preheater Tube Deposit Rating		
CRC Rate	3	
CRC Rate, inches	1/10 4/1 6/2 2/3	