R. Hill
NAFEC

ADDENDUM TO
FUEL IGNITION TESTS ON HOT SURFACES

Report No. Dev-2357

Date: 4-30-57

TESTING DIVISION

DOUGLAS

Prepared by:

John O. Crouch
Materials Research & Process Engineering

Approved by:

D. P. Jensen, Chemical Engineer
Materials Research & Process Engineering

F. T. Wood, Jr., Chief
Materials Research & Process Engineer

Approved by:

J. C. Londelius, Chief Test Engineer,
Testing Division

W. H. P. Drummond, Assistant Director,
Engineering, Testing Division

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SUMMARY

Additional data were required on the gas turbine lubricant, fuel, and hydraulic oil ignition temperatures to aid in the design of the DC-8 engine compartment.

Tests were performed on 1/10 to 4 Ml charges of Kerosene, JP-4 Fuel, MIL-O-5606 Hydraulic Oil, and MIL-L-7808 Lubricating Oil by introducing samples at 5/8", 1", 2", 4" and 6" gap heights by squirt, drop, pour and spray methods on the model described in the main report modified with an electric heater. Two additional samples of JP-4 and six additional samples of kerosene were tested to show the expected range of ignition temperature for fuels from several different crude oil sources.

The effect of air velocity on the ignition temperature was again measured for the four fluids, but over a more complete velocity range. A determination was made of the effect of introducing the sample fluids on heated surfaces covered with insulation and also on heated surfaces covered with insulation that had been slashed, exposing a predetermined area of surface.

The results are presented as tables showing the following:

a. Minimum ignition temperatures for the four fluids by squirt, drop, pour and spray methods at heights from 5/8" to 6" and sample volumes from 1/10 Ml to 4 Ml. Some intermediate points were requested to more clearly define the graphs.

b. Minimum ignition temperatures of the additional samples of JP-4 fuel and kerosene.

c. Effect of air velocity on minimum ignition temperature.

d. Minimum ignition temperature with no cover and no sides.

e. Fuel ignition test on heated surface covered with insulation where the hottest surface thermocouple was 750°F.

f. Fuel ignition test on heated surface covered with insulation where the hottest surface thermocouple was 750°F and where a 1" x 1" hole was cut in the insulation to expose the heated surface.

g. Fuel ignition test on heated surface covered with insulation where the hottest surface thermocouple was 1200°F and where a 1" x 1" hole was cut in the insulation to expose the heated surface.

h. Physical properties of the Kerosenes and JP-4 Fuels used.

Test results indicated that fuels, hydraulic oil and lubricants which leak or otherwise get out onto hot metal surfaces in configurations similar to that of the model constitute a fire hazard; however, introduction of air flow over these surfaces materially reduces the hazard. In all tests in which the fluids were applied to a hot surface covered with Fiberglas insulation, no ignition occurred when the surface was below 1090°F, and no self-sustaining fires could be produced.

PURPOSE:

The purpose of the addendum is to present additional fuel, lubricant and hydraulic oil ignition temperature data applicable to DC-8 engine compartment design.

APPARATUS AND MATERIALS:

(Only those not previously described in main report)

A. Test Fluids

1. Kerosene

a. Kerosene, Lot E-2956E21
b. Kerosene, Lot WS2841, Richfield Oil Co., Wilmington, Calif.
c. Kerosene, Lot WS2483, Richfield Oil Co., Wilmington, Calif.
d. Kerosene, Lot WS2844, Richfield Oil Co., Wilmington, Calif.
e. Kerosene, Pearl Oil, Standard Oil Co. of California
f. Kerosene, East Coast, Esso Research & Eng. Co., Bayway Refinery, Linden, N. J., Shipped Nov. 1955.
g. Kerosene, Coastal, Esso Research & Eng. Co., Bayway Refinery, Linden, N. J., Shipped Nov. 1955.

2. JP-4 Fuel

a. JP-4 Fuel, Socony Mobil, Djakarta, Indonesia
b. JP-4 Fuel, Richfield Lot WR8644, Richfield Oil Co., Wilmington, Calif.

3. MIL-O-5606, Hydraulic Oil, DPM 366

4. MIL-L-7808, Turbine Lubricant, Penola, Turbo 15, Lot 294-14, as described in main report.

B. Test Instrumentation and Equipment

1. Stainless steel model simulating a portion of the engine compartment, (see drawings pages A5 and A6, Report No. Dev-2357, dated June 21, 1955 for details and accessories) here modified by spotwelding the electric heater (Item 4 below) to the lower surface of the heated plate. This is referred to below as Model 1.

2. Stainless steel model with no external attachments other than thermocouples and non-adjustable sides (See Photo SM229188, page B1), hereafter referred to as Model 2.

3. Variable Autotransformer, Powerstat, Superior Electric Co., Type 236, 220 Volts.

4. Electric Heater, MPC 92 Chromolox Microtube Electric Range Unit, 8" diam., 230-240 Volts.

APPARATUS AND MATERIALS: - (Cont'd)

B. 5. Insulation, Type FB-2 Fiberglas blanket, baked to 750°F.

6. Insulation, Type FB-2 Fiberglas blanket, baked to 1200°F.

7. Hypodermic Syringe, B-D, Yale, Insulin Syringe, 10 Ml capacity.

PROCEDURE:

A. Tests using Model I:

1. Determine the minimum ignition temperature of Kerosene, JP-4 Fuel, MIL-O-5606 Hydraulic Oil and MIL-L-7808 Lubricating Oil by:

a. Introducing 1/10 Ml, 1/2 Ml, 1 Ml, 2 Ml, and 4 Ml charges.

b. Introducing these charges at gap heights (hot surface to cover) of 5/8", 1", 2", 4", and 6".

c. Introducing these charges through the center hole in the cover, at the stipulated heights by the following four methods:

1. Squirt - inject charge via glass hypodermic syringe (without metal needle attachment).

2. Drop - drop charge at the rate of 2 drops per second, using medium dropper.

3. Pour - pour charge through the hole using graduate.

4. Spray - spray charge at 20 psi air pressure using atomizer.

2. Determine the minumum ignition temperature of 1 Ml of each of the two additional samples of JP-4 Fuel at all heights by squirt and pour methods.

Also determine the minimum ignition temperature of 1 Ml, of each of the six additional samples of kerosene at all heights by squirt and pour methods.

3. Determine the effect of air velocity on the minimum ignition temperature at the critical gap height configurations obtained in A1.

4. Determine the minimum ignition temperature for 1/4 Ml, 1/2 Ml, 1 Ml, a and 2 Ml of Kerosene, JP-4 Fuel, MIL-O-5606 Hydraulic Oil and MIL-L-7808 Lubricating Oil by squirt, drop and pour methods on the heated model surface with no sides and no cover.

The following procedure shall be used to determine the minimum (autogenous)* ignition temperature for all configurations:

* The heated steel surface is the only source of ignition energy.

PROCEDURE: - (Cont'd)

The model temperature shall be raised in 20-30° increments until ignition by the squirt method occurs. Once having achieved this, the temperature shall be lowered in 10° increments until ignition no longer occurs. Testing shall be continued in decrements of 10° to a temperature of 100° below the lowest temperature at which ignition occurs. The model shall be again heated to the temperature at which the lowest ignition occurs and the three remaining methods of application shall be attempted in a similar fashion. Should the fluid ignite by drop, pour or spray, the original procedure shall be repeated.

B. Tests using Model 2:

1. Determine whether ignition occurs for 1/4 Ml, 1/2 Ml, 1 Ml, 2 Ml, and 4 Ml charges of Kerosene, JP-4 Fuel, MIL-O-5606 Hydraulic Oil, and MIL-L-7808 Turbine Lubricant by:

   a. Introducing these charges through 8" of insulation compressed to 1/2". (See photographs SM229187, page B2 and SM229189, page B3) The charge is to be placed on the surface of the heated plate, the temperature of which is maintained at 750°F.

   b. The insulation shall be removed from a 1" x 1" area over the hottest thermocouple and the sample shall be squirted on the exposed surface. Plate temperature shall be maintained at 750°F.

   c. Step B.1.b shall be repeated with a plate temperature of 1200°F.

In order to determine whether ignition occurs within the insulation where visual observations cannot be made, insert a probe thermocouple into the layers of insulation but not touching the metal surface. Report all temperature increases as well as any visible ignition.

2. Determine the minimum ignition temperature of all fluids that give any indication of ignition in B.1.a, b, or c.

RESULTS:

A1. IGNITION TEMPERATURES IN °F. PER PROCEDURE A.1.

KEROSENE (Sample 1.a) (See graph, page A1)

SAMPLE	SQUIRT					DROP					POUR					SPRAY				
Vol.(Ml)	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"
1/10	650	670	730	850	840	>650	640^{4}	>730	>850	>840	>630	630	>730	820	>840	>650	>670	>730	>850	>840
1/2	670	620	610	720	830	>670	610^{30}	630^{1}	>720	>830	>670	600	570	>720	810	>670	>620	>630	>720	>830
1	640	670	575	560	690	620^{6}	630^{30}	>575	>560	>720	>640	670	540	>560	>720	>640	>670	>575	>560	>720
2	790	700	620	590	620	650^{7}	620^{20}	520^{90}	>590	>620	660	660	510	>590	>620	640	>700	>620	>590	>620
4	900	880	680	600	670	640^{14}	650^{30}	630^{20}	>600	>670	740	690	640	>600	>670	850	730	>680	>600	>670

RESULTS: - (Cont'd)

JP-4 FUEL (Sample 2b) (See graph, page A2)

SAMPLE	SQUIRT					DROP					POUR					SPRAY				
Vol. (Ml)	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"
1/10	960	690	>1000	910	>1000	820[4]	>690	960[6]	>910	910[4]	770	>690	980	900	890	>960	>690	>1000	>910	>1000
1/2	810	720	750	860	960	780[6]	700[8]	>750	>900	950[5]	800	720	>750	>900	870	>810	>720	>750	>900	>1000
1	820	790	680	710	840	780[4]	690[9]	>680	>710	>840	820	740	>680	>710	>840	>820	>790	>680	>710	>840
2	940	820	780	710	780	800[6]	680[7]	>780	>710	>790	850	720	>780	>710	>780	920	>820	>780	>710	>790
4	970	<1000	870	710	810	790[8]	690[12]	870[12]	>760	>890	900	780	820	>710	>890	>970	970	>870	>760	>890

MIL-O-5606 HYDRAULIC FLUID (Sample 3) (See graph, page A3)

SAMPLE	SQUIRT					DROP					POUR					SPRAY				
Vol. (Ml)	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"
1/10	640	640	810	840	>1000	>640	>640	>810	>840	900[4]	>640	640	>810	>840	930	>640	>640	>810	>840	>1000
1/2	660	590	740	780	810	>660	>590	740[30]	>780	810[30]	>660	>590	740	>780	790	>660	>590	>740	>780	>810
1	670	630	600	625	670	660[8]	610[60]	>600	>625	>670	670	630	>600	>625	>670	640	>630	>600	>625	>670
2	650	620	670	640	690	>650	610[8]	>670	>640	>690	>650	610	>670	>640	>690	>650	>620	>670	>640	>690
4	720	660	690	730	760	660[9]	660[12]	>690	>730	>760	700	>660.	680	>730	720	>720	>660	>690	>730	>760

MIL-L-7808 TURBINE LUBRICANT (Sample 4) (See graph, page A4)

SAMPLE	SQUIRT					DROP					POUR					SPRAY				
Vol. (Ml)	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"	5/8"	1"	2"	4"	6"
1/10	840	830	>1000	950	>1000	>840	820[4]	940[6]	930[4]	960[4]	>840	810	940	>950	940	>840	>840	>1000	>950	>1000
1/2	900	820	900	>1000	930	860[6]	>820	>900	950[8]	>930	900	>820	>900	900	>930	>900	>820	>900	>1000	>930
1	940	820	780	860	885	870[8]	>820	>780	>860	>890	920	>820	>780	>860	>890	>940	>820	>780	>860	>890
2	970	800	880	970	>1000	870[6]	>810	>880	930[120]	940[14]	920	800	860	>970	980	>970	>810	>880	>970	>1000
4	860	820	880	1000	990	860[90]	>820	>880	>1000	>990	>860	820	>880	1000	>990	>860	>820	>880	>1000	>990

INTERMEDIATE POINTS (Requested later to aid in graphing results above)

	1"	2"	4"				6"		
	1 1/2 Ml	1 1/2 Ml	1 1/2 Ml	2 1/2 Ml	3 Ml	3 1/2 Ml	2 1/2 Ml	3 Ml	3 1/2 Ml
SQUIRT JP-4	-	-	760	750	690	710	-	750 640	760 630
Kerosene	-	-	610	-	600	-	650	630	-
5606	-	-	690	-	-	-	-	700	-
7808	810	-	980	-	-	-	-	-	-
POUR 5606	-	-	-	-	-	-	-	710	-
DROP Kerosene	-	700[90]	-	-	-	-	-	-	-

Superscripts denote the number of drops introduced at the time ignition occurred. Fluids averaged 60 drops per milliliter.

RESULTS: - (Cont'd)

A2. IGNITION TEMPERATURES OF ADDITIONAL SAMPLES (See graphs, page A5 for the Kerosene and A6 for the JP-4)

SAMPLES:	5/8"		1"		2"		4"		6"	
KEROSENES:	SQUIRT	POUR	SQUIRT	POUR	SQUIRT	POUR	SQUIRT	POUR	SQUIRT	POUR
2841	750	730	720	720	690	670	760	760	900	850
2843	790	770	770	750	800	>800	790	780	>1000	900
2844	720	690	700	>700	620	>620	670	>670	690	670
East Coast	670	670	640	640	610	610	630	620	700	>700.
Coastal	750	710	730	710	720	720	810	810	830	>830
Pearl Oil	650	>650	660	640	610	610	620	>620	620	>620
Djakarta JP-4	880	870	790	780	780	>780	830	>830	970	>970

A3. EFFECT OF AIR VELOCITY ON MINIMUM IGNITION TEMPERATURE.
(See graph, page A7)

Gap height (heated surface to cover) 2 inches throughout air velocity tests. Method of lowest ignition indicated. One MI charge used throughout. Cover pulled forward 2" in all subsequent tests except for a.

a. Air velocity over heated surface 0 feet/min.

Kerosene	620 Squirt
JP-4	740 Pour
5606	680 Squirt
7808	880 Squirt

b. Air velocity over heated surface 120 feet/min.

Kerosene	720 Squirt and Pour
JP-4	960 Pour
5606	830 Squirt
7808	1020 Pour

c. Air velocity over heated surface 180 feet/min.

Kerosene	870 Pour
JP-4	1050 Squirt and Pour
5606	990 Squirt
7808	1080 Pour

d. Air velocity over heated surface 210 feet/min.

JP-4	1150 Pour
7808	1140 Pour

RESULTS: - (Cont'd)

A3. e. Air velocity over heated surface 240 feet/min. 4 FPS

Kerosene	1060 Pour
5606	1120 Pour

A4. MINIMUM IGNITION TEST TEMPERATURE WITH NO COVER AND NO SIDES.

Sample	Method of Application	Volume* (Ml.)	Min. Ign. Temp. (°F.)
Kerosene	Drop	0.2	1010
MIL-O-5606	Drop	1.0	1040
MIL-L-7808	Drop	0.3	1050
JP-4	Drop	0.1	1060

B-1a. Fuel Ignition Test on Insulated Heated Surface FB-2 Fiberglas Blanket.
(See graph, page A8)
8" Compressed to 1/2"
Hottest Surface Thermocouple 750°F.

Sample	Volume	Probe Thermocouple Initial Temp. (°F.)	Probe Thermocouple Final Temp. (°F.)	Time lag in min.
Kerosene	1/4 Ml	550	No increase	-
	1/2 Ml	590	680	1.5
	1 Ml	590	680	1.0
	2 Ml	540	660	3.5
	3 Ml	550	660	3.5
	5 Ml	550	660	4.0
	7 Ml	550	660	5.0
	10 Ml	550	660	10.0
JP-4	1/4 Ml	550	No increase	-
	1/2 Ml	550	No increase	-
	1 Ml	550	570	0.2
	2 Ml	550	No increase	-
5606	1/4 Ml	550	No increase	-
	1/2 Ml	550	No increase	-
	1 Ml	580	650	2.0
	2 Ml	550	No increase	-
	5 Ml	550	No increase	-
7808	1/4 Ml	580	680	10.0
	1/2 Ml	580	740	11.0
	1 Ml	520	890	10.0
	2 Ml	580	780	10.0
	5 Ml	570	750	15.0

No visible ignition occurred.

* Volume approximate due to excessive evaporation upon application of test fluid.

RESULTS: - (Cont'd)

B-1b. Fuel Ignition Test on Insulated Heated Surface
1" x 1" Hole Cut in Insulation to Expose Heated Model Surface.
(See graph, page A9)
8" FB-2 Fiberglas Blanket Compressed to 1/2"
Hottest Surface Thermocouple 750°F.

Sample	Volume	Probe Thermocouple Initial Temp. (°F.)	Probe Thermocouple Final Temp. (°F.)	Time lag in min.
Kerosene	1/4 Ml	610	No Increase	-
	1/2 Ml	620	No Increase	-
	1 Ml	620	630	0.7
	2 Ml	600	630	1.0
	5 Ml	610	620	5.0
JP-4	1/4 Ml	600	No Increase	-
	1/2 Ml	600	No Increase	-
	1 Ml	600	No Increase	-
	2 Ml	600	No Increase	-
5606	1/4 Ml	670	No Increase	-
	1/2 Ml	680	690	1.0
	1 Ml	680	700	1.0
	2 Ml	680	No Increase	-
	5 Ml	680	690	1.0
7808	1/4 Ml	560	580	0.5
	1/2 Ml	560	610	1.0
	1 Ml	560	660	1.0
	2 Ml	560	700	3.0
	5 Ml	570	740	8.0

No visible ignition occurred.

RESULTS: - (Cont'd)

B-1c. Fuel Ignition Test on Insulated Heated Surface
1" x 1" Hole Cut in Insulation to Expose Heated Model Surface
(See graph, page A10)
8" FB-2 Fiberglas Blanket Compressed to 1/2"
Hottest Surface Thermocouple 1200°F.

Sample	Volume	Probe Thermocouple Initial Temp. (°F.)	Final Temp. (°F.)	Time lag in min.
Kerosene	1/4 Ml	1020	No Increase	-
	1/2 Ml	1020	No Increase	-
	1 Ml	1040	No Increase	-
	2 Ml	1040	No Increase	-
	5 Ml	1040	No Increase	-
	10 Ml	1020	No Increase	-
JP-4	1/4 Ml	1040	No Increase	-
	1/2 Ml	1040	No Increase	-
	1 Ml	1040	No Increase	-
	2 Ml	1040	No Increase	-
	5 Ml	1040	No Increase	-
5606	1/4 Ml	1050	No Increase	-
	1/2 Ml	1050	1070	0.5
	1 Ml	1040	1080	0.5
	2 Ml	1040	1070	1.0
	5 Ml	1040	1100*	1.5
	1/5 Ml	1040	1060*	0.5
	2 Drops	1040	1050*	0.1
7808	1/4 Ml	1010	1020	0.5
	1/2 Ml	1010	1020	0.5
	1 Ml	1010	1030*	0.5
	2 Ml	1010	1030	1.0
	5 Ml	1000	1020	5.0

* Visible ignition.

B-2. Plate temperature was decreased until ignition no longer occurred with 2 drop samples of MIL-L-7808 and MIL-O-5606. Minimum ignition temperature for 5606 - 1090°F; for 7808 - 1200°F.

DISCUSSION:

A. Tests using Model 1:

1. The reproducibility of results was usually ± 20°F. In a few instances variations of up to ± 50°F. were observed on supposedly identical tests. The variables thought to be responsible for this are listed in the main report.

   The catalytic effect caused by oxidized material is thought to be the variable causing the greatest effect on the ignition temperature. Testing frequently indicated no ignition at, for example, 700°F. 740°F. and 760°F., but when ignition finally occurred at 770°F., the oxidized hydrocarbon products acted as catalysts and ignition then took place at every decrement of 10°F. down to 680°F.

2. Laboratory reports showing physical properties of all samples of JP-4 Fuels and Kerosenes are included in the appendix, pages C1 and C2.

3. The minimum ignition temperature is directly proportional to the air velocity as shown by the graph. (See page A7) No ignition occurred above an air velocity of 4 ft/sec (240 ft/min) with the maximum attainable temperature of 1260°F.

4. All fluids tested required temperatures in excess of 1000°F. for ignition on the model with no cover and no sides.

B. Tests using Model 2:

1. No visible ignition occurred when samples of all fluids were injected through the compressed insulation onto the surface of Model 2 when heated to 750°F.

2. No visible ignition occurred when samples of all fluids were injected into a 1" x 1" hole cut in the center of the insulation onto the surface of Model 2 when heated to 750°F.

3. No visible ignition occurred when samples of Kerosene and JP-4 Fuel were injected into a 1" x 1" hole cut in the center of the insulation and onto the surface of Model 2 when heated to 1200°F.

4. Testing was continued on MIL-O-5606 and MIL-L-7808 by injecting 2 drop samples into a 1" x 1" hole cut in the center of the insulation onto the surface of Model 2. The temperature was decreased from 1200°F. in steps of 10°F. MIL-L-7808 would not ignite below 1200°F. Ignition of MIL-O-5606 occurred at 1090°F. minimum.

5. Temperature increases (without visible ignition) of from 10° to 370°F. were recorded.

CONCLUSIONS:

The minimum ignition temperatures obtained during these tests were never lower than the ASTM Autogenous Ignition Temperatures and were in direct agreement

CONCLUSIONS: - (Cont'd)

with the results obtained in the original "Fuel Ignition Test on Hot Surfaces", Report No. DEV-2357, dated June 21, 1955. Many of the values obtained were again below the expected maximum engine surface temperature of 800°F. An air velocity of 4 ft/sec (240 ft/min) across the model raised the minimum ignition temperature of all fluids above 1000°F.

No self-sustaining fires occurred in any of the tests where the fluids were applied to the model surface which was completely covered with Fiberglas insulation. No visible ignition occurred in a 1" x 1" hole cut in the Fiberglas insulation when the model surface was below 1090°F.

REFERENCES:

PCR Book 9097, pages 9-24 incl.

PCR Book 9324, pages 23-50 incl.

PCR Book 9325, pages 1-15 incl., 17-50 incl.

PCR Book 9888, pages 1-50 incl.

PCR Book 9918, pages 1-50 incl.

PCR Book 10039, pages 1-50 incl.

PCR Book 10194, pages 1-50 incl.

PCR Book 10215, pages 1-50 incl.

PCR Book 9937, pages 36, 37

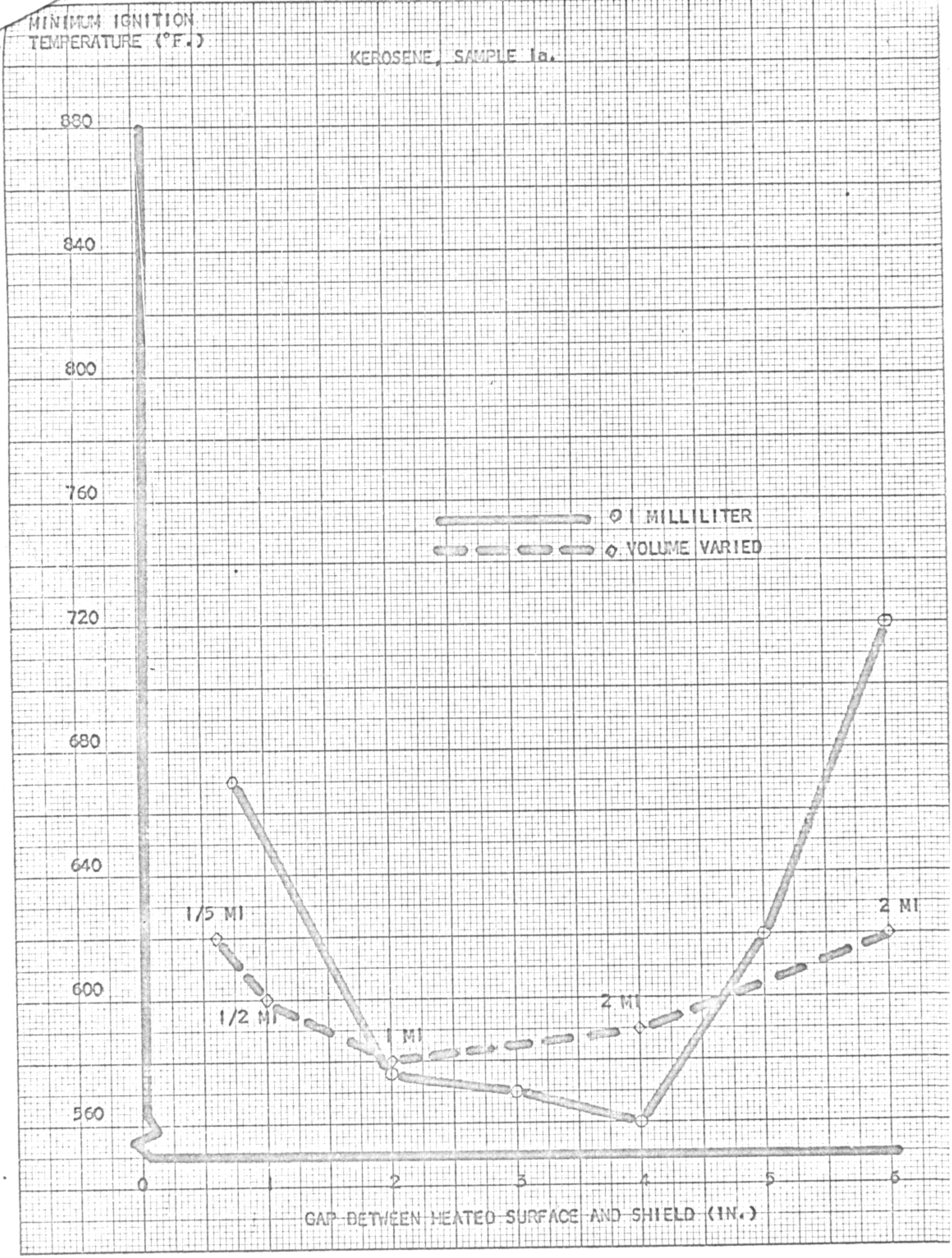
PCR Book 8999, pages 26, 27

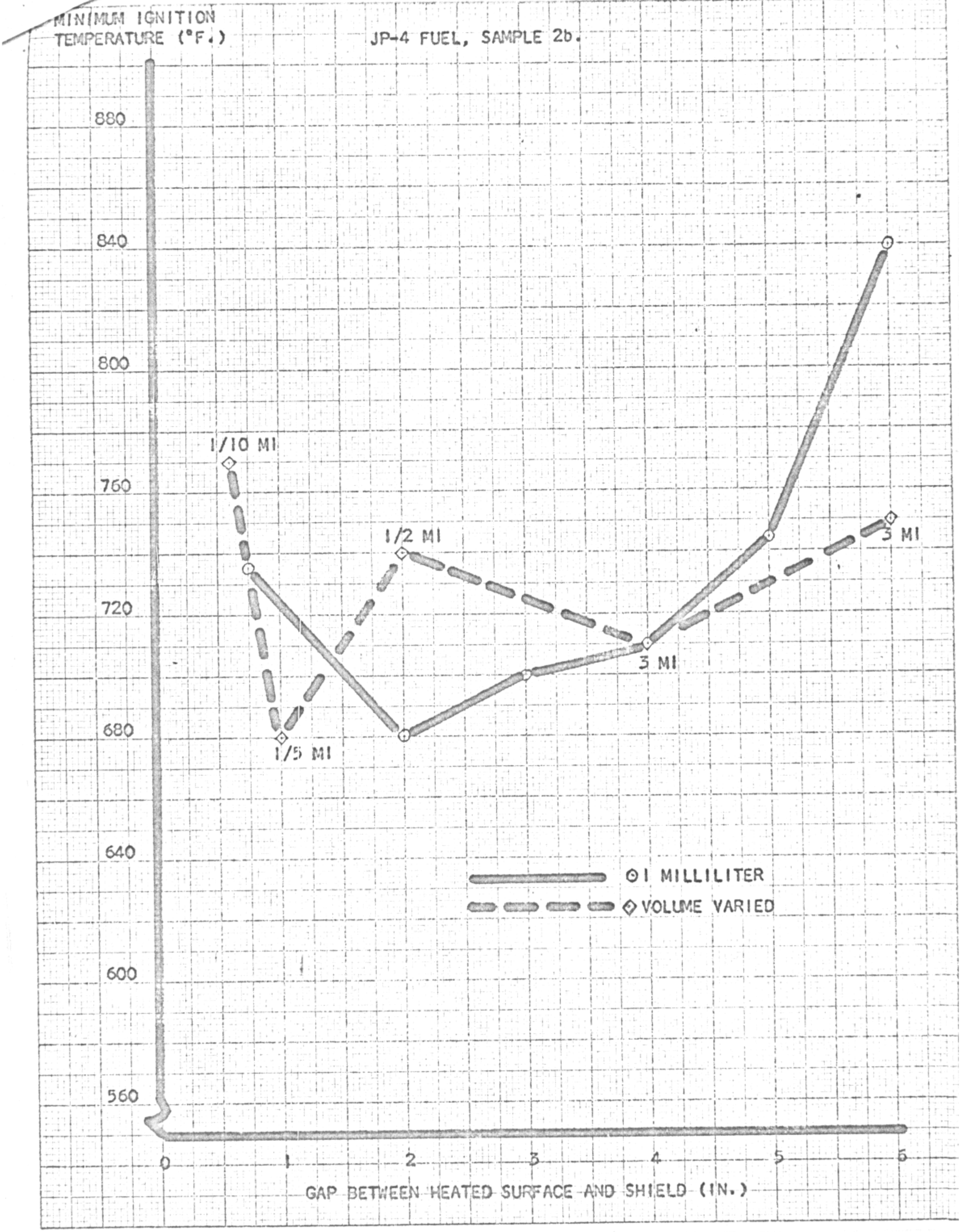
PCR Book 9534, page 17

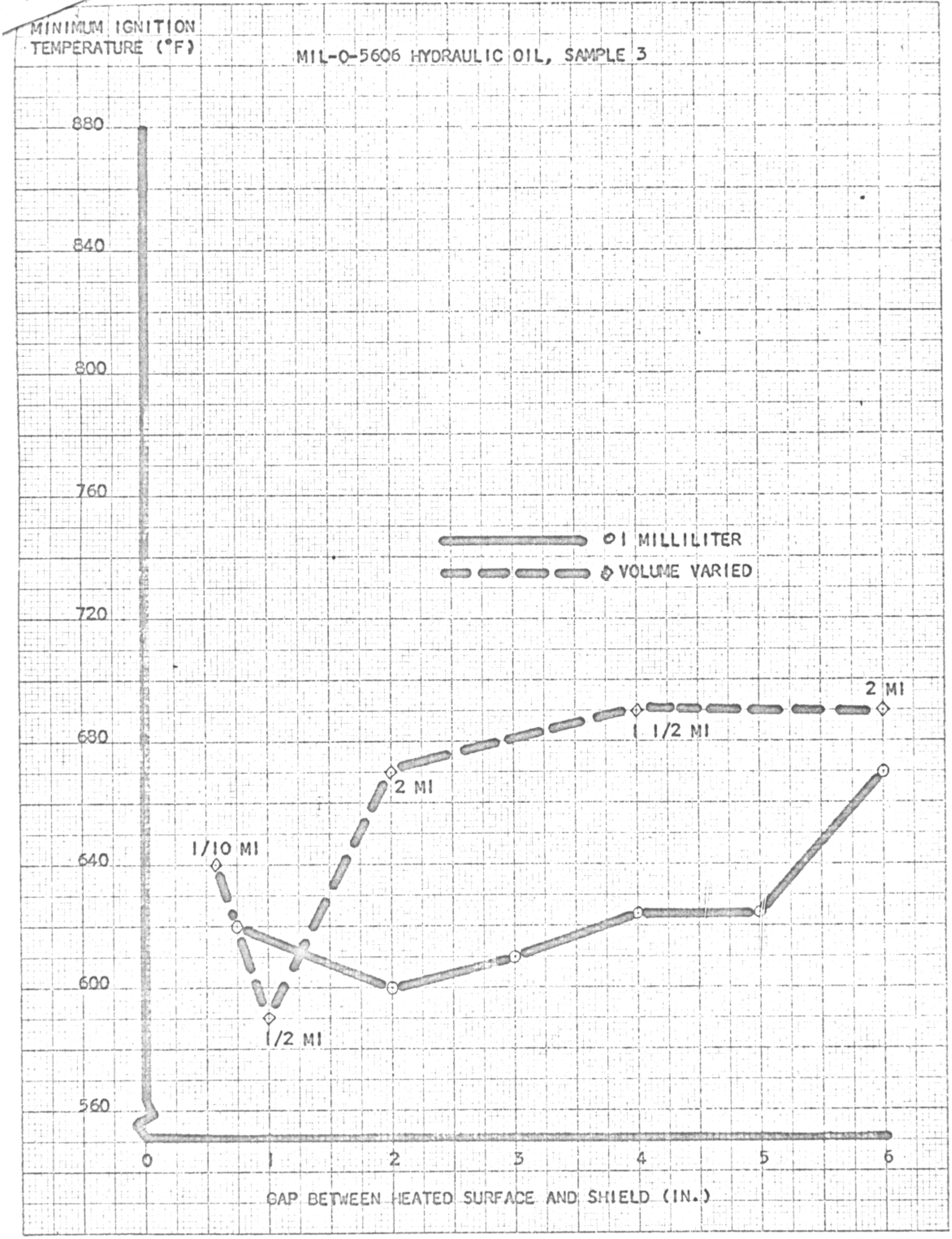
Materials & Process Engineering Laboratory Report MP 10,373.

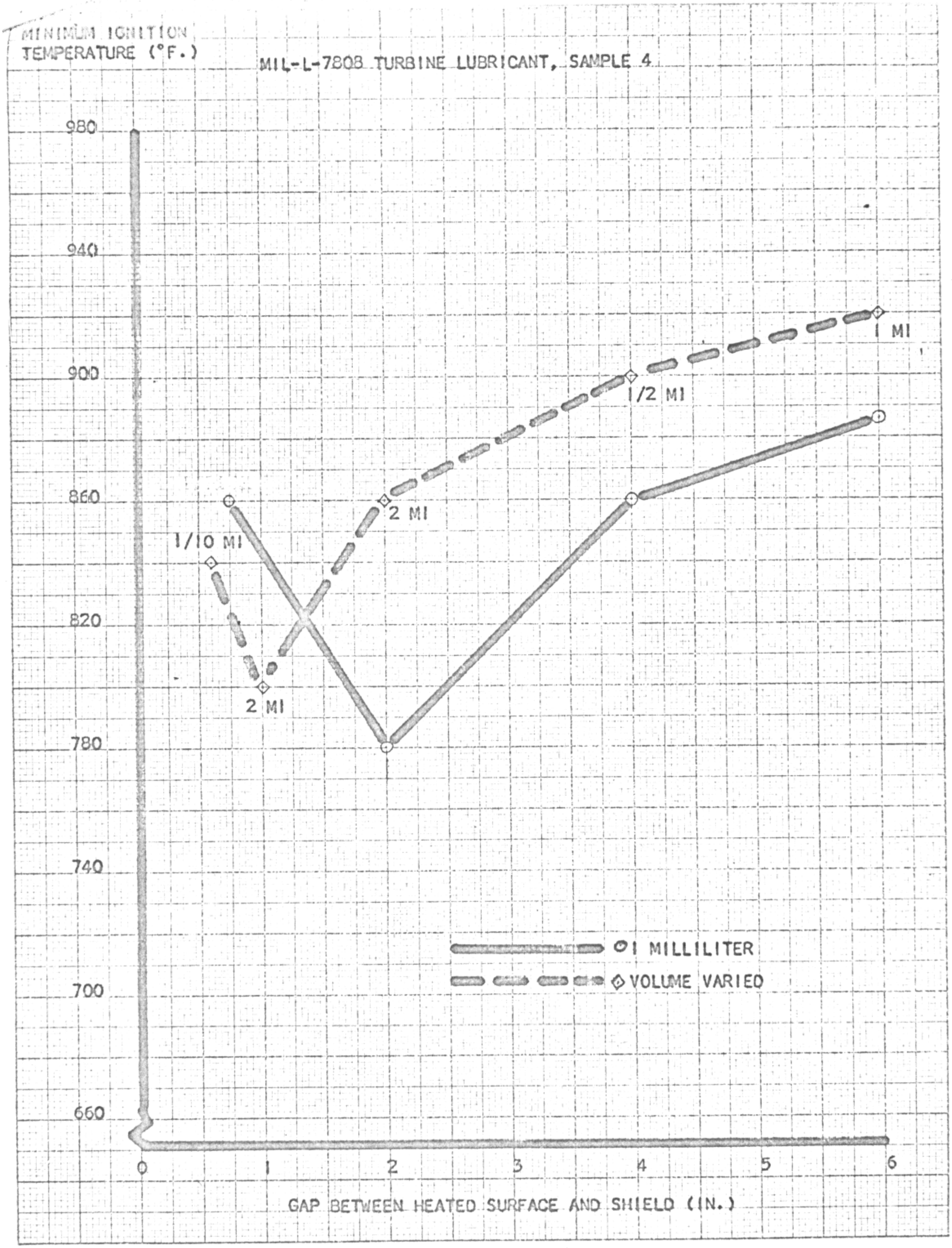
" " " " " MP 10,596.

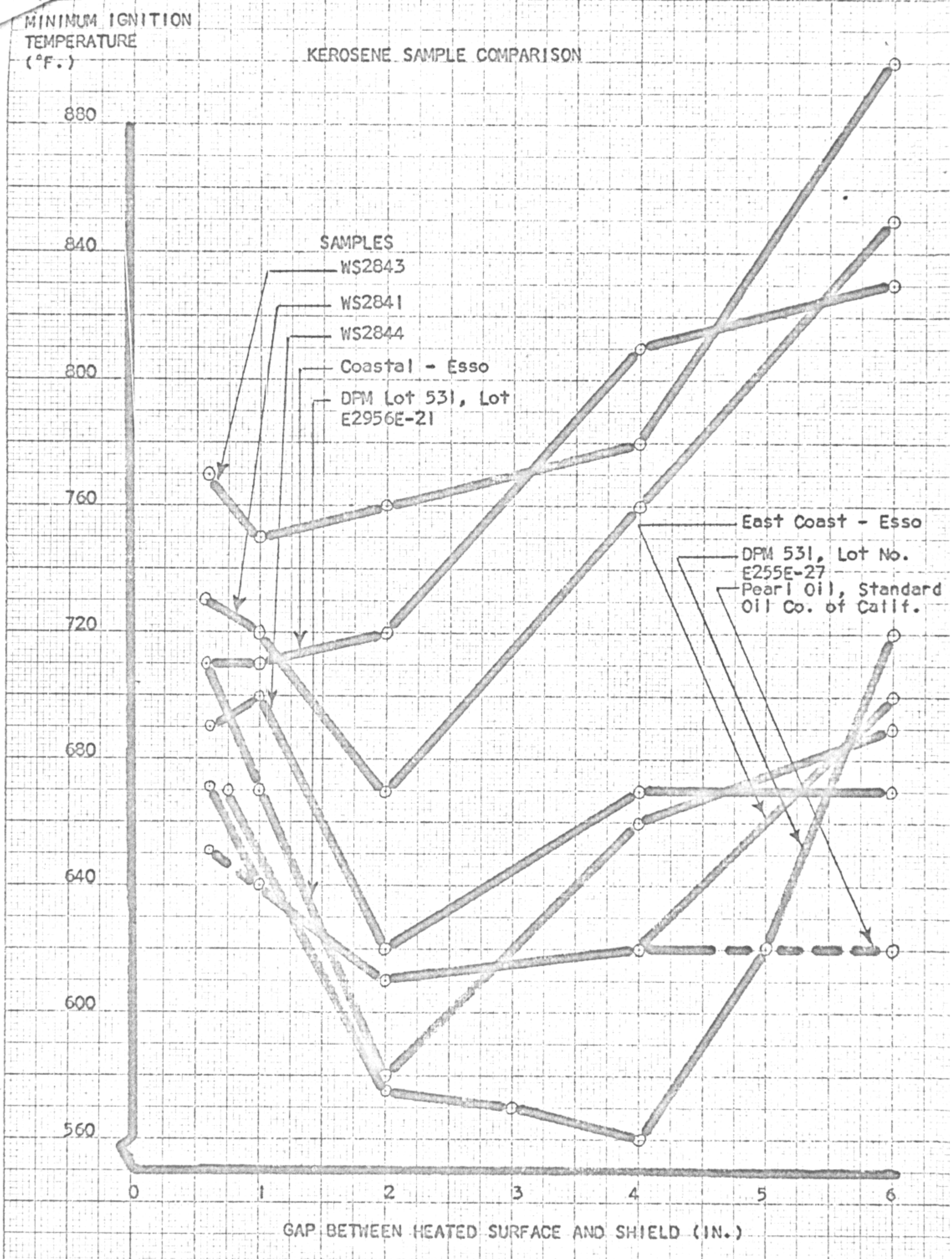
MINIMUM IGNITION TEMPERATURE VS.

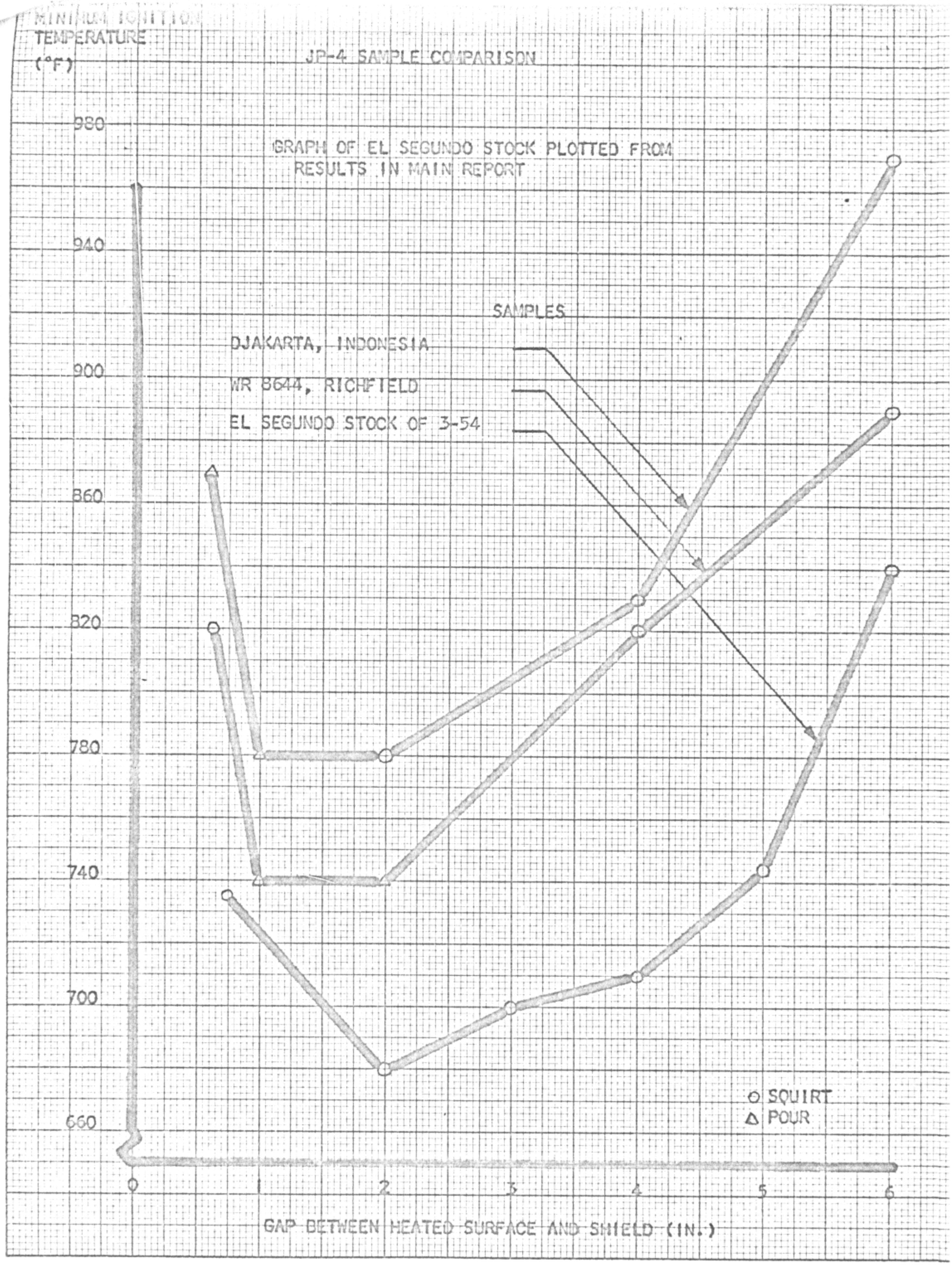



MINIMUM IGNITION TEMPERATURE (°F.)
JP-4 FUEL, SAMPLE 2b.
880
840
800
760
720
680
640
600
560
1/10 MI
1/5 MI
1/2 MI
3 MI
3 MI
⊙ 1 MILLILITER
◇ VOLUME VARIED
0
1
2
3
4
5
6
GAP BETWEEN HEATED SURFACE AND SHIELD (IN.)

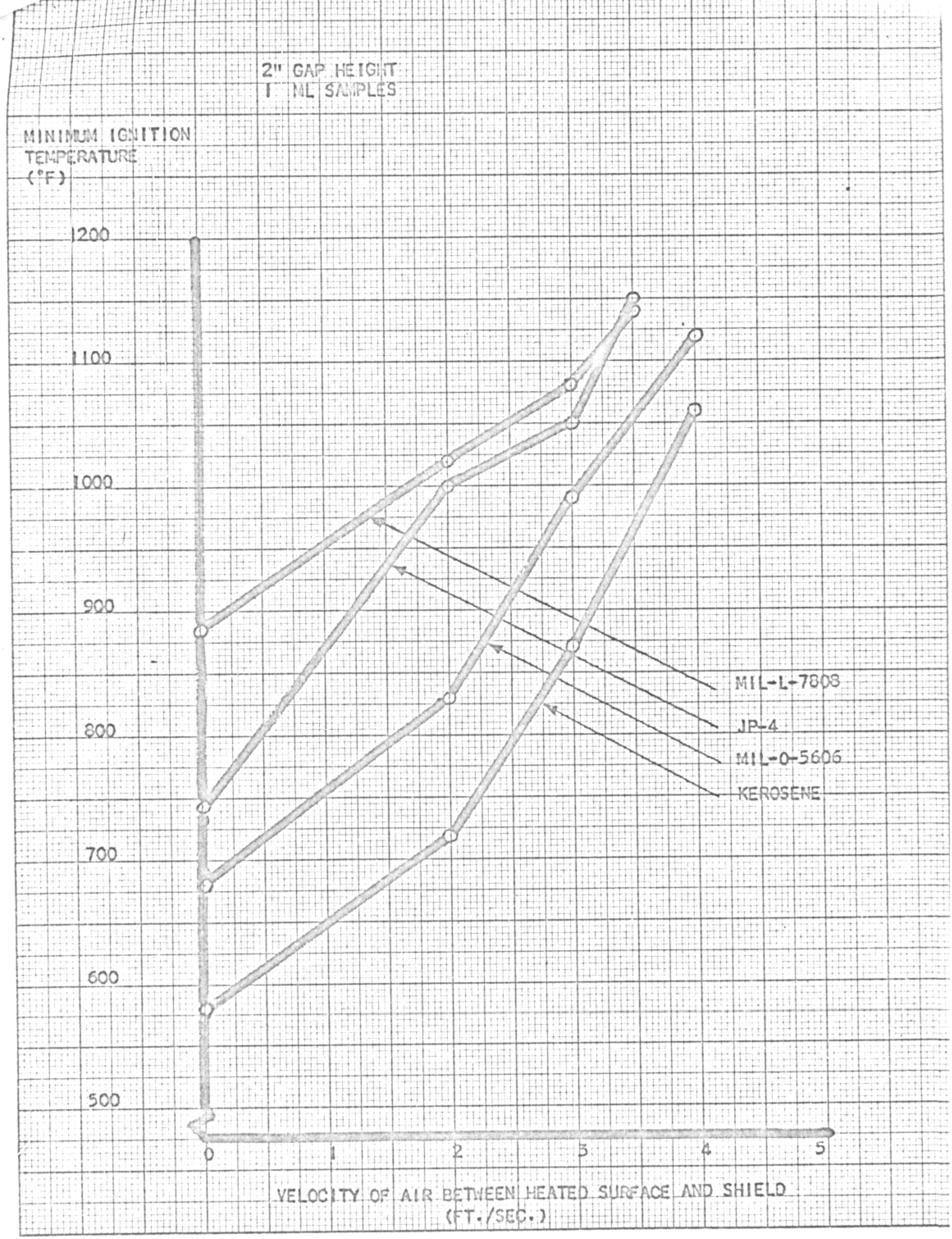

MINIMUM IGNITION
TEMPERATURE (°F)
MIL-O-5606 HYDRAULIC OIL, SAMPLE 3
880
840
800
760
720
680
640
600
560
○ 1 MILLILITER
◇ VOLUME VARIED
1/10 Ml
1/2 Ml
2 Ml
1 1/2 Ml
2 Ml
0
1
2
3
4
5
6
GAP BETWEEN HEATED SURFACE AND SHIELD (IN.)


MINIMUM IGNITION TEMPERATURE (°F.)
MIL-L-7808 TURBINE LUBRICANT, SAMPLE 4
980
940
900
860
820
780
740
700
660
0
1
2
3
4
5
6
GAP BETWEEN HEATED SURFACE AND SHIELD (IN.)
1/10 MI
2 MI
2 MI
1/2 MI
1 MI
1 MILLILITER
VOLUME VARIED

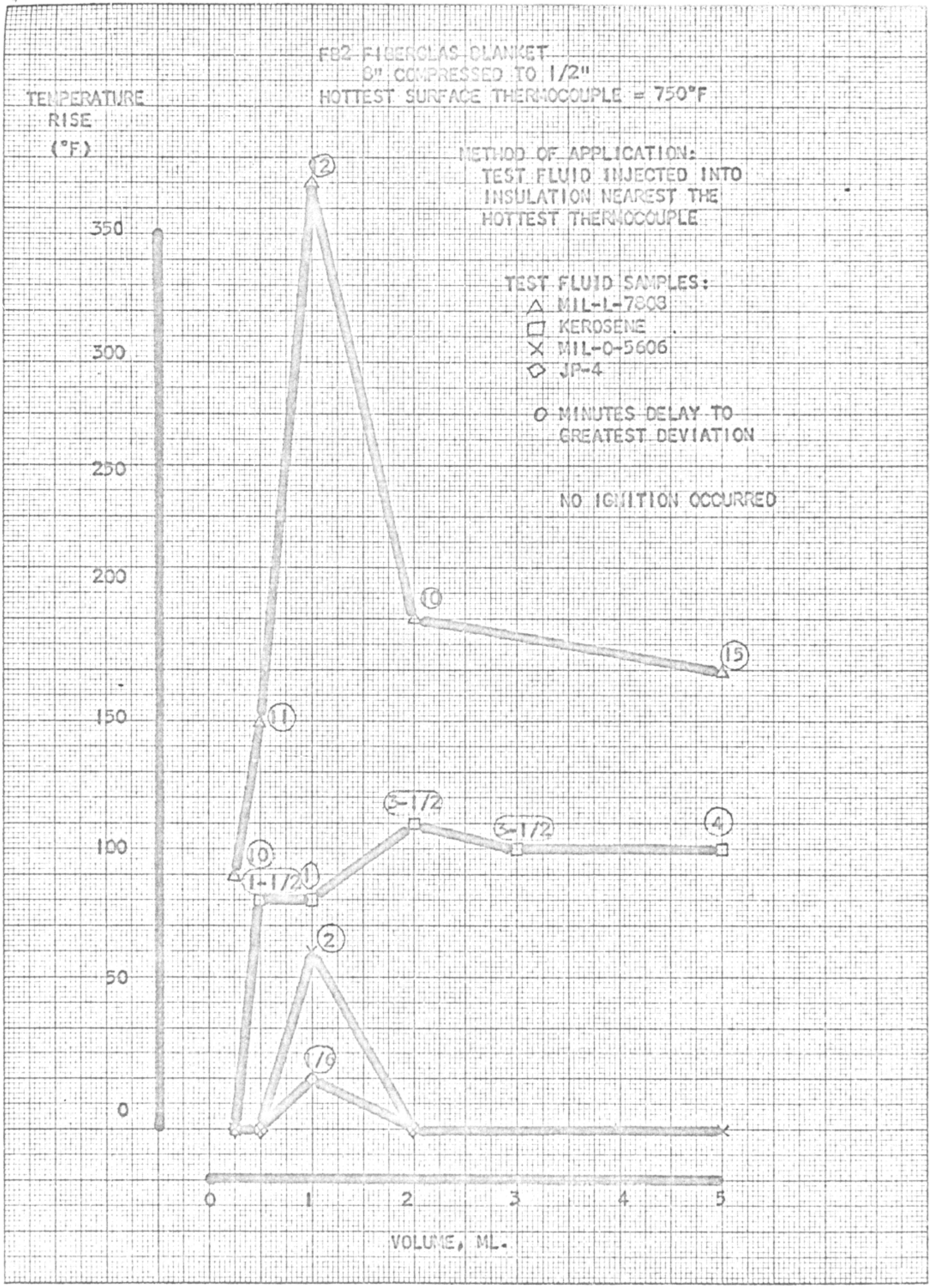

MINIMUM IGNITION TEMPERATURE (°F.)
KEROSENE SAMPLE COMPARISON
880
840
800
760
720
680
640
600
560
SAMPLES
WS2843
WS2841
WS2844
Coastal - Esso
DPM Lot 531, Lot E2956E-21
East Coast - Esso
DPM 531, Lot No. E255E-27
Pearl Oil, Standard Oil Co. of Calif.
0
1
2
3
4
5
6
GAP BETWEEN HEATED SURFACE AND SHIELD (IN.)

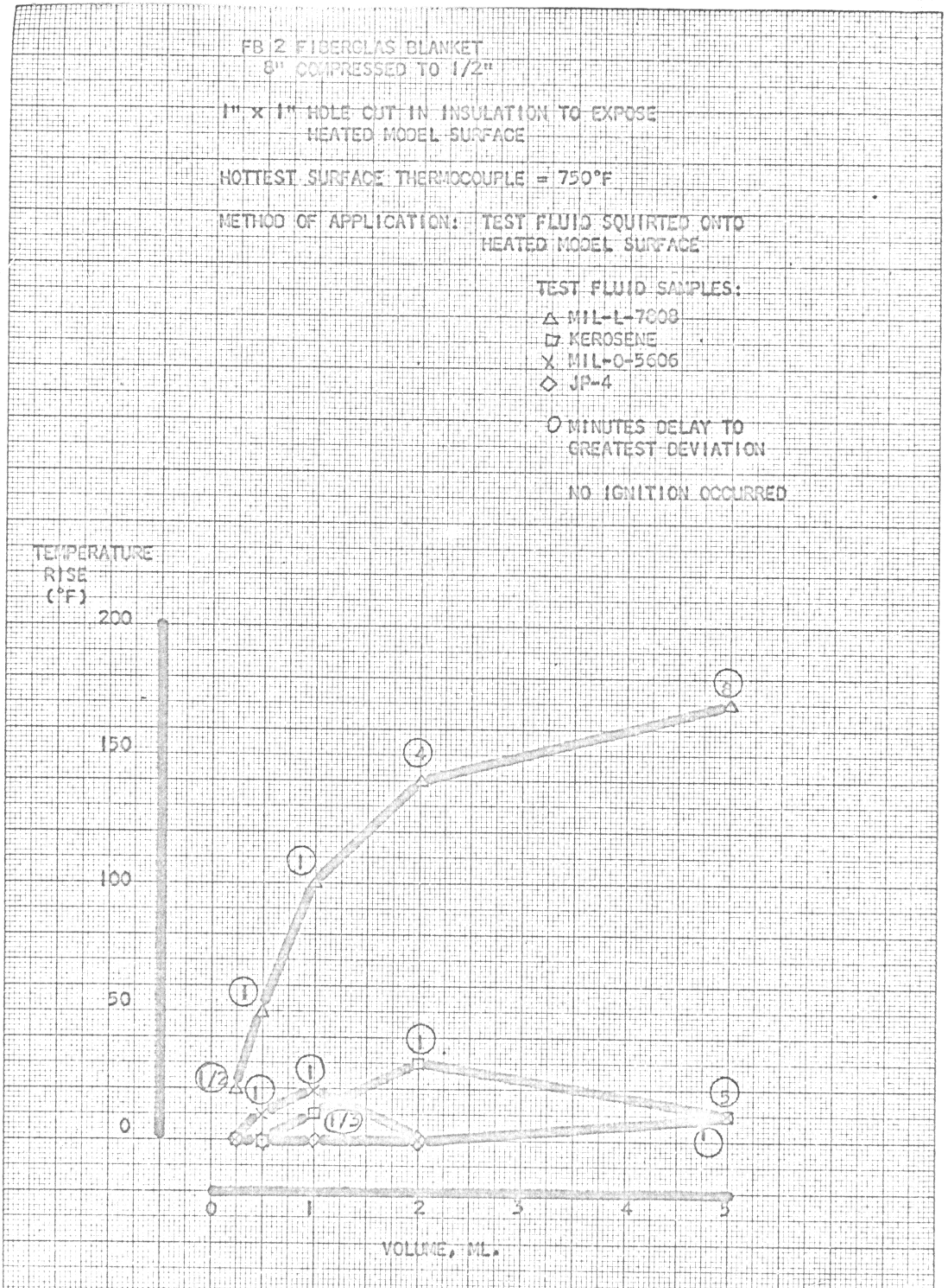

MINIMUM IGNITION TEMPERATURE (°F)
JP-4 SAMPLE COMPARISON
GRAPH OF EL SEGUNDO STOCK PLOTTED FROM RESULTS IN MAIN REPORT
SAMPLES
DJAKARTA, INDONESIA
WR 8644, RICHFIELD
EL SEGUNDO STOCK OF 3-54
980
940
900
860
820
780
740
700
660
0
1
2
3
4
5
6
O SQUIRT
Δ POUR
GAP BETWEEN HEATED SURFACE AND SHIELD (IN.)

MINIMUM IGNITION TEMPERATURE VS. AIR VELOCITY



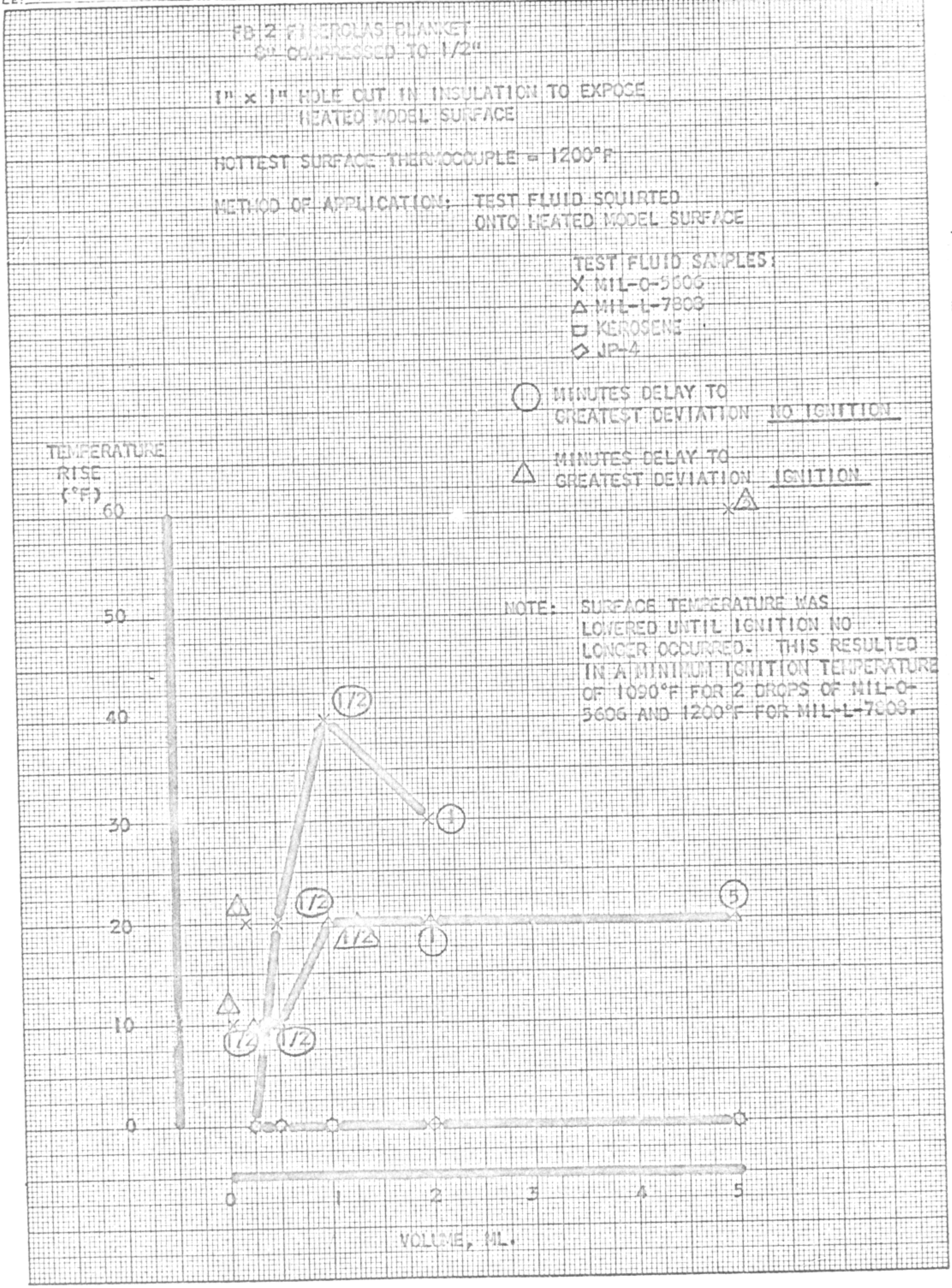
TITLE: FUEL IGNITION TEST ON INSULATED HEATED SURFACE

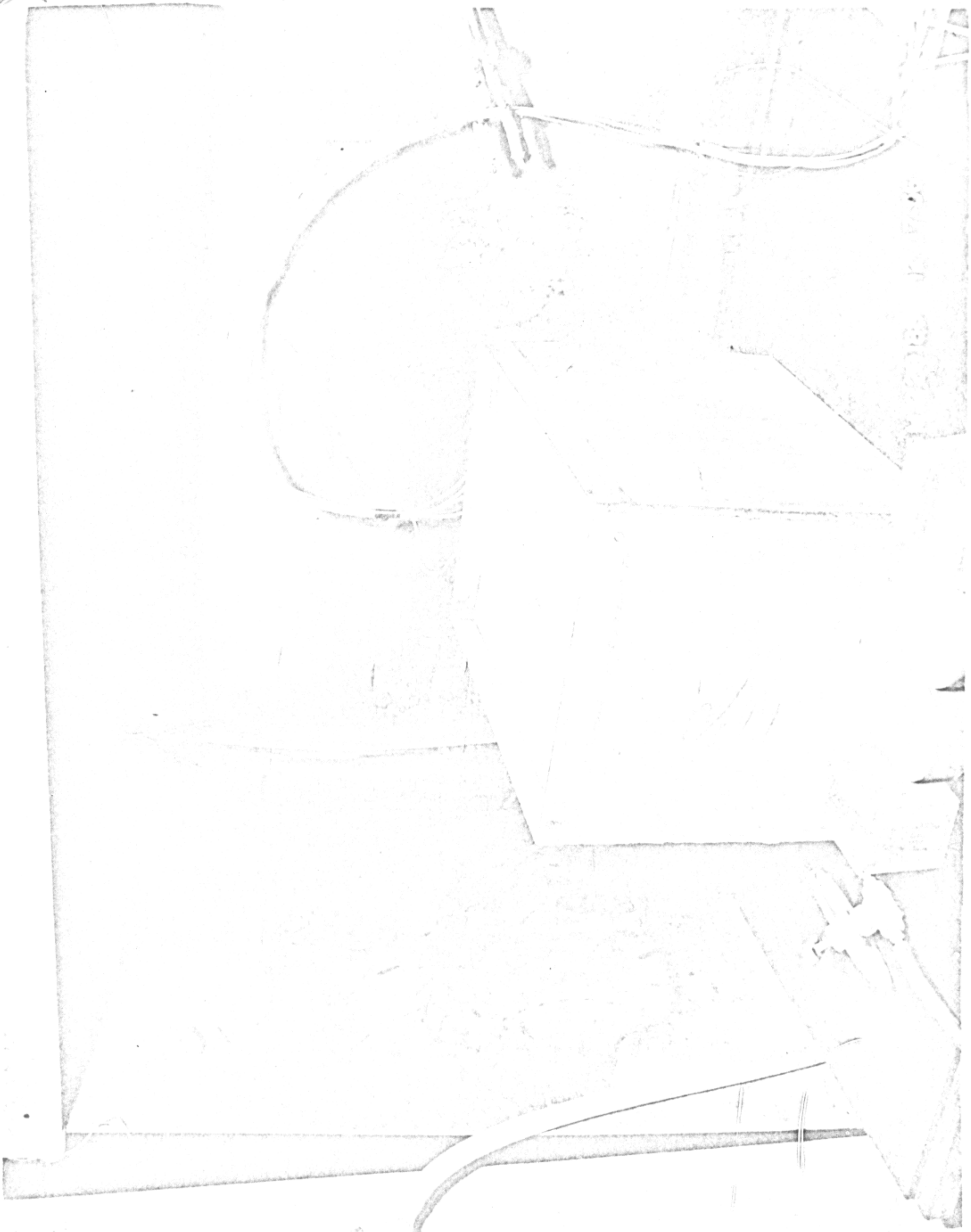



FB 2 FIBERGLAS BLANKET
8" COMPRESSED TO 1/2"
1" x 1" HOLE CUT IN INSULATION TO EXPOSE HEATED MODEL SURFACE
HOTTEST SURFACE THERMOCOUPLE = 750°F
METHOD OF APPLICATION: TEST FLUID SQUIRTED ONTO HEATED MODEL SURFACE
TEST FLUID SAMPLES:
△ MIL-L-7808
□ KEROSENE
X MIL-O-5606
◇ JP-4
○ MINUTES DELAY TO GREATEST DEVIATION
NO IGNITION OCCURRED
TEMPERATURE RISE (°F)
200
150
100
50
0
1/2
1
1
1
1/3
1
4
8
5
1
0
1
2
3
4
5
VOLUME, ML.

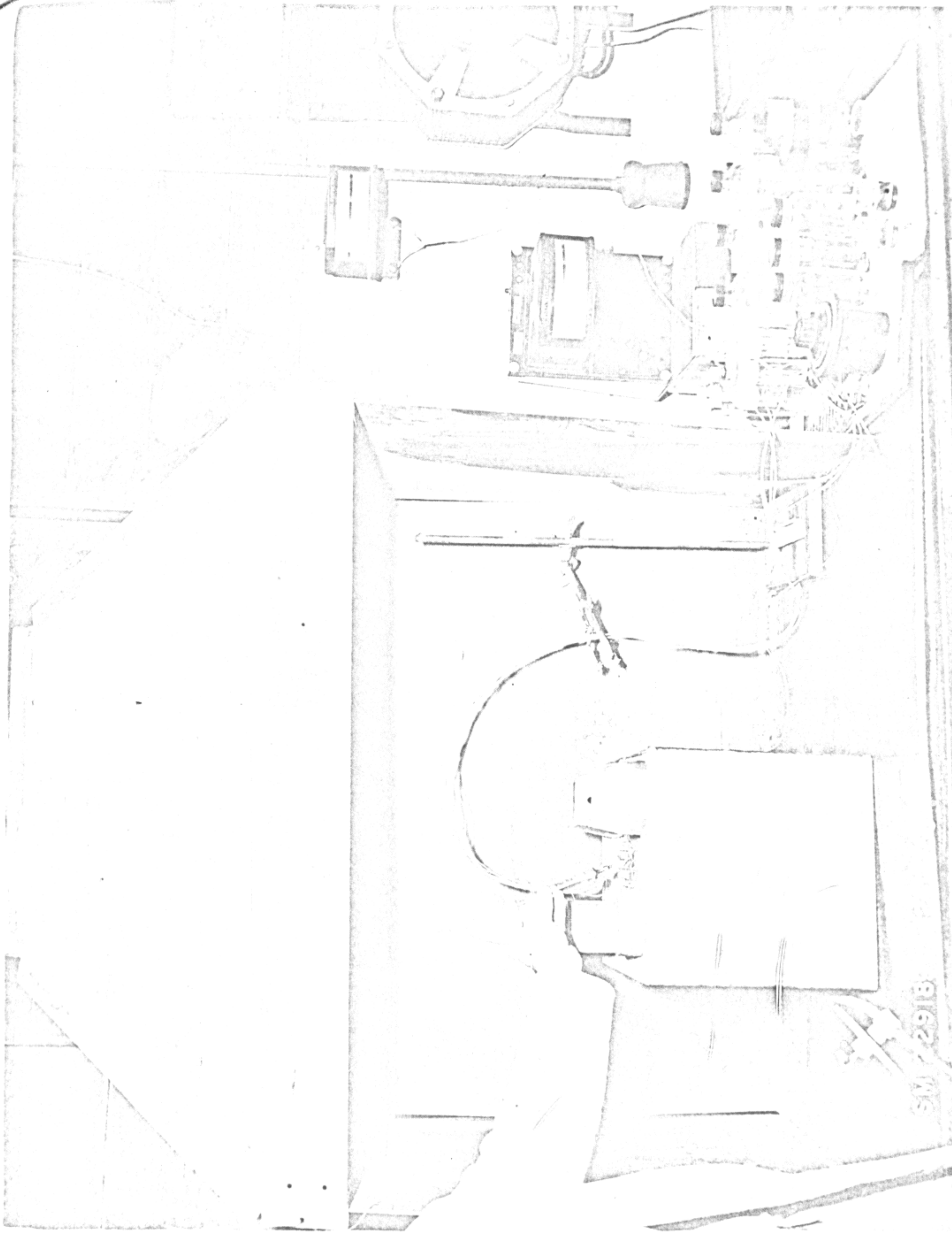
Santa Monica Testing Division

TITLE: FUEL IGNITION TEST ON INSULATED HEATED SURFACE





Page B-3



TITLE: PHYSICAL PROPERTIES OF ADDITIONAL KEROSENE SAMPLES OBTAINED FROM THREE DIFFERENT CRUDE SOURCES.

	Low Sulfur High Aromatic WS-2841	Naphthenic Crude WS-2843	High Sulfur High Aromatic WS-2844	
Gravity, °API	37.9	34.1	40.4	
Corrosion, 3 hrs/212°F	Pass	Pass	Fail	
RVP, PSI	--	--	--	
Freezing Point, °F	-40	-76	-46	
Aniline Point, °F	132	127	141	
Flash Point, °F	150	148	153	
Viscosity at -30°F, cs.	13.4	21.2	13.0	
Existent Gum, mg/100 ml	0.6	0.8	2.6	
Potential Gum, mg/100 ml	0.6	0.6	11.2	
Smoke Point, mm.	15.0	15.0	20.0	
Sulfur, Weight %	0.027	0.062	0.590	
Mercaptan Sulfur, Wt.%	0.0009	0.002	0.116	
Aromatics, Volume %	21.8	18.0	15.6	
Olefins, Volume %	9.5	13.3	4.5	
Distillation, °F				
IBP	350	366	372	
10%	394	408	413	
50%	448	455	441	
90%	504	508	470	
FBP	534	534	492	
BTU/Lb	18,405	18,419	18,542	(Richfield
Gravity, °API	37.7	34.1	40.6	(Smith-Emery
Viscosity at -30°F, cs.	13.7 *	21.5 *	13.4	DACo
Viscosity at -40°F, cs.	-- **	30.3 *	18.0	"
Specific Gravity:				
-30°/60°F	0.871 *	0.891 *	0.856	"
-40°/60°F	-- **	0.894 *	0.860	"

* Material cloudy at these temperatures

** No value obtainable. Material approximately 50% solid phase after five minutes at this temperature.