



# Standard Test Method for Linear Flame Propagation Rate of Lubricating Oils and Hydraulic Fluids<sup>1</sup>

This standard is issued under the fixed designation D 5306; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>e1</sup> NOTE—Warning statements were moved from notes to text editorially in March 2003.

## 1. Scope

1.1 This test method covers the determination of the linear flame propagation rates of lubricating oils and hydraulic fluids supported on the surfaces of and impregnated into ceramic fiber media. Data thus generated are to be used for the comparison of relative flammability.

1.2 This test method should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test method may be used as elements of fire risk which takes into account all of the factors that are pertinent to an assessment of the fire hazard of a particular end use.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

E 691 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods<sup>2</sup>

### 2.2 Military Specifications:

MIL-H-83282C Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft NATO Code Number H-537<sup>3</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.N0.06 on Fire Resistant Fluids.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>3</sup> Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098

MIL-H-46170B Amm.1, Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base<sup>3</sup>

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *linear flame propagation rate, n*—the average quotient of the distance of flame travel and the time required for the flame front to travel that distance.

## 4. Summary of Test Method

4.1 A section of a ceramic fiber support medium (string) is impregnated with the sample under specific conditions. The impregnated fiber is placed on a standard support. The sample is ignited and the time required for the flame front to propagate across a measured distance is determined by use of a thermo-electric system. The average propagation rate is then calculated from the measured distance of flame travel and the time required for the flame front to propagate over that distance.

## 5. Significance and Use

5.1 The linear flame propagation rate of a sample is a property that is relevant to the overall assessment of the flammability or relative ignitability of fire resistance lubricants and hydraulic fluids. It is intended to be used as a bench-scale test for distinguishing between the relative resistance to ignition of such materials. It is not intended to be used for the evaluation of the relative flammability of flammable, extremely flammable, or volatile fuels, solvents, or chemicals.

## 6. Apparatus

6.1 Apparatus for measurement of linear flame propagation rates:

6.1.1 *Open Top Stainless Steel Box*, as shown in Fig. 1.

6.1.2 *Recorder*, stripchart, fast responses. A zero-centered recorder with a  $\pm 5$  mV range and a one-half second full-scale deflection capacity has been found to be satisfactory. A chart speed of at least 1 in./min has been used for most studies.

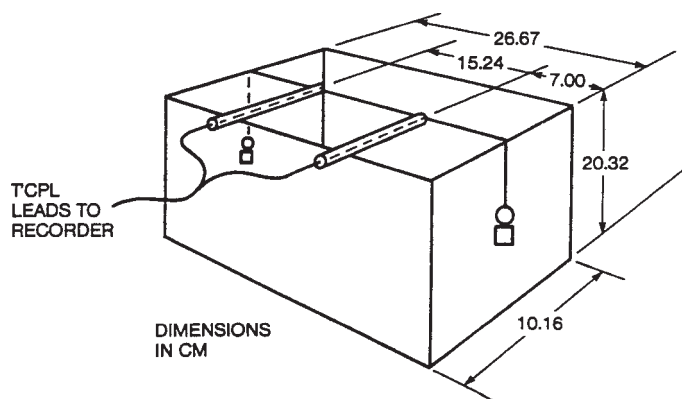


FIG. 1 Apparatus for Determination of Linear Flame Propagation Rates

6.1.3 *Differential Thermocouple Pair*, 30 gage with bare junctions and double fiberglass wrap insulation, ISA, Type J or Type K may be prepared from any premium grade thermocouple wire.

6.1.4 *Fume Hood*, draft-free when ventilation system is not operative.

6.1.5 *Weights*, 50 ± 0.01 g, with attached hooks; two required.

6.1.6 *Chrome-Plated Tube or Rod*, 15 mm diameter by 375 mm long.

6.1.7 *Porcelain or Glass Dish*, approximately 135 mL capacity.

## 7. Materials

7.1 *Absorbent Paper Wipers*, 375 by 213 mm.

7.2 *Ceramic Fiber*,<sup>4</sup> twisted yarn type 390/312, 4/5, 2.72 or type 390/312, 3/4, 2.72. Ceramic fiber size used shall be agreed upon by supplier and consumer and shall be specified in test report.

7.3 *Ignition Source*, any paper book matches or wooden kitchen matches can be used.

## 8. Procedure

8.1 Tie small loops in each end of a 500 mm section of ceramic fiber support (string). Place a few millilitres of the sample to be studied in an evaporating dish. Immerse the ceramic fiber support (string) in the liquid sample for 60 s. Avoid immersion of the loops at the end of the string.

8.2 While the ceramic fiber support (string) is immersed in the sample, carefully wrap an absorbent paper wiper around the 15 mm diameter chrome plated rod. Leave one end of the rod uncovered by the wiper.

8.3 Remove the ceramic fiber support (string) section from the liquid sample and attach a 50 g weight to the loop at each end. Fix the chrome-plated rod with its absorbent paper wrapping in a horizontal position and hang the soaked string

section with attached weights over the unwrapped section of the rod. Press down gently on the uppermost weight to cause the soaked string to pass over the bare rod, flexing gently as it moves. When the lower weight has been drawn up to the rod, reverse the process until the first weight has again been drawn up the rod. Repeat the cycle four times to work the sample thoroughly into the string.

8.4 Transfer the string with attached weights to the covered portion of the chrome-plated rod. Pass the string over the absorbent paper in the manner described in 8.3. After each complete double cycle, lift the string from the paper, rotate it through 180° as it is held taut in a vertical position and then replace it on a fresh area of the absorbent medium. Again pass the string over the paper in the manner described in 8.3. Repeat until four double cycles have been completed.

8.5 Place the string support and thermocouple holder in a draft-free hood with the ventilation turned off. Level the apparatus with a spirit level. Place the prepared string on the string supports. The attached weights should be left in place to provide tension in the string. Adjust the differential thermocouple junctions so that they are exactly 2 mm directly above the string. Connect the differential thermocouple pair to the fast-response, zero-centered strip chart recorder.

8.6 Start the recorder chart after an appropriate warm-up period. With an ignition source, ignite the sample on the string near its support at one end of the apparatus. Permit the flame to advance along the string past each thermocouple until it extinguishes itself upon reaching the opposite string support. Stop the recorder and start the hood ventilator to exhaust the combustion products of the sample. (**Warning**—Take extreme care to avoid inhalation of the combustion products as extremely toxic substances are formed during the combustion of some synthetic materials, especially halogenated and phosphorus-based compounds.)

8.7 Measure the horizontal distance between the thermocouples and interval between the first thermal effects as shown in Fig. 2. From the measured interval, the chart speed of the recorder and the known horizontal distance between thermocouples in the test apparatus, calculate and report the horizontal linear flame propagation rate in millimetres per second. If the flame does not advance during the experimental run, or if it extinguishes itself before passing both thermocouples, record that fact. Replicate runs shall be made as required.

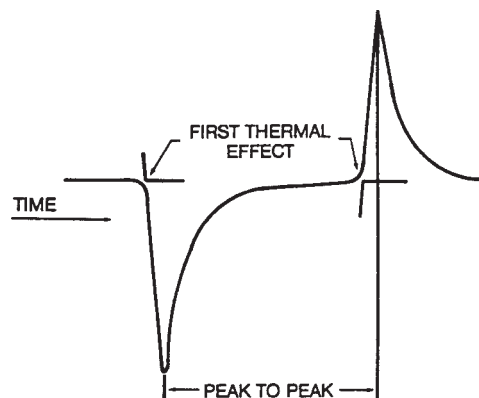


FIG. 2 Determination of Linear Flame Propagation Rates: Typical Stripchart Record

<sup>4</sup> The sole source of supply of the ceramic fiber known to the committee at this time is Nextel Ceramic Fiber, manufactured by the 3M Company, 219-1-1, 3M Center, St. Paul, MN 55144. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee<sup>1</sup>, which you may attend.

## 9. Calculation and Report

9.1 Calculate the linear flame propagation rate as follows:

$$\text{linear flame propagation rate} = \frac{dv}{p} \quad (1)$$

where:

- $d$  = distance between thermocouples, mm (see Fig. 1),
- $v$  = chart speed in mm/s, and
- $p$  = distance measured peak to peak between thermal effects, mm (see Fig. 2).

## 10. Precision and Bias <sup>5</sup>

10.1 *Precision:*

10.1.1 Eight laboratories participated in a collaborative study to determine the precision and bias of this test method. The study was conducted by sending seven different fluids to participating laboratories. Since two different test procedures were used in Laboratory Number 4, some data were reported for Lab 4 and Lab 4A. For analysis purposes, Lab 4 and 4A were treated as independent, resulting in a total of nine laboratories.

10.1.2 The seven fluids used in the study are: Silicate Ester I, Phosphate Ester, MIL-H-5606, MIL-H-83282 I, MIL-H-5606 II, MIL H-83282 II, and Silicate Ester II. Each fluid was used in conjunction with two support materials,  $\frac{3}{4}$  and  $\frac{4}{5}$ . Each combination of fluid and support was replicated five times.

10.1.3 Appendix X1 contains a table of summary data. The average flame propagation rate in millimetres per second is reported for each fluid and support combination for each laboratory. This was calculated from five replicates, except as noted. An overall average and a standard deviation,  $S$ , for each

combination of fluid and support materials is reported as well. Note that all values in Table X1.1 are reported to three significant figures since the majority of raw data points were reported that way. Laboratories 4, 4A, and 8 reported two significant figures while Laboratory 7 reported four significant figures.

10.1.4 Annex A1 contains a table of precision statistics. The repeatability standard deviation,  $S_r$ , refers to an intralab variation. The reproducibility standard deviation,  $S_R$ , refers to lab-to-lab variation. The 95 % repeatability and reproducibility limits are  $r$  and  $R$ , respectively.

10.1.5 The precision of this test method as obtained by statistical examination of interlaboratory test results is as shown in 10.1.5.1 and 10.1.5.2.

10.1.5.1 The difference between successive test results obtained by the same operator with the same apparatus under constant operating conditions on identical test material, would in the long run, in the normal and correct operation of this test method exceed the repeatability limits ( $r$ ) listed in the tables of precision statistics (see Annex A1) only in one case in twenty.

10.1.5.2 The difference between independent results obtained by different operators working in different laboratories on identical test material, would in the long run, in the normal and correct operation of this test method exceed the reproducibility limits ( $R$ ) listed in the table of precision statistics (see Annex A1) only in one case in twenty.

10.2 *Bias*—The linear flame propagation rate is defined by the present test procedure. No independent measurement is available upon which to base a statement of test bias. No bias statement is possible for this reason.

## 11. Keywords

11.1 fire resistance; flame propagation; flammability; hydraulic fluids

<sup>5</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1294.

**ANNEX**
**(Mandatory Information)**
**A1. INTERLABORATORY STUDY OF LINEAR FLAME PROPAGATION RATES PRECISION STATISTICS**

A1.1 Table A1.1 is an interlaboratory study of linear flame propagation rates precision statistics.

**TABLE A1.1 Interlaboratory Study of Linear Flame Propagation Rates Precision Statistics<sup>A</sup>**

NOTE—All table values are represented in mm/s.

Sample Fluid	Support	$\bar{X}$	$S_x$	$S_r$	$S_R$	$r$	$R$
Silicate	¾	2.08	0.186	0.126	0.217	0.352	0.608
Ester I	⅘	1.54	0.139	0.0917	0.161	0.257	0.452
Phosphate	¾	<sup>B</sup>	<sup>B</sup>	<sup>B</sup>	<sup>B</sup>	<sup>B</sup>	<sup>B</sup>
Ester	⅘	<sup>B</sup>	<sup>B</sup>	<sup>B</sup>	<sup>B</sup>	<sup>B</sup>	<sup>B</sup>
MIL-H-5606 I	¾	7.98	1.20	0.973	1.50	2.72	4.19
	⅘	7.57	2.15	0.862	2.28	2.41	6.40
MIL-H-83282 I	¾	2.56	0.256	0.128	0.280	0.357	0.783
	⅘	1.85	0.220	0.0860	0.233	0.241	0.652
MIL-H-5606 II	¾	7.91	1.30	0.476	1.37	1.33	3.83
	⅘	7.17	1.83	0.628	1.91	1.76	5.35
MIL-H-83282 II	¾	2.50	0.230	0.115	0.251	0.321	0.704
	⅘	1.86	0.189	0.0689	0.198	0.193	0.550
Silicate	¾	2.17	0.241	0.0991	0.257	0.278	0.719
Ester II	⅘	1.60	0.174	0.0610	0.182	0.171	0.511

<sup>A</sup> The precision statistics were calculated using Practice E 691.

where:

$\bar{x}$  = average of the lab averages.

$S_x$  = standard deviation of the lab averages.

$S_r$  = repeatability standard deviation.

$S_R$  = reproducibility standard deviation.

$r$  = 95 % repeatability limit.

$R$  = 95 % reproducibility limit.

<sup>B</sup> There was no flame propagation of phosphate ester in any laboratory.

**APPENDIX**
**(Nonmandatory Information)**
**X1. INTERLABORATORY STUDY OF LINEAR FLAME PROPAGATION RATES SUMMARY DATA**

X1.1 Table X1.1 is an interlaboratory study of linear flame propagation rates summary data.

**TABLE X1.1 Interlaboratory Study of Linear Flame Propagation Rates Summary Data**

NOTE—Average rate, mm/s (average of five replicates except as noted).

Sample Fluid:	33 23 1 Silicate Ester I	33 23 2 Phosphate Ester	33 23 3 MIL-H 5606 I	33 23 4 MIL-H 83282 I	33 23 5 MIL-H 5606 II	33 23 6 MIL-H 83282 II	33 23 7 Silicate Ester II
Support <sup>3</sup> / <sub>4</sub>							
Lab 1	2.01	0	9.49	2.69	9.47	2.74	2.51
Lab 2 <sup>A</sup>	2.01	0	...	...	6.85	2.62	2.06
Lab 3 <sup>A</sup>	2.93	0	7.79	2.21	8.17	2.06	1.88
Lab 4 <sup>B</sup>	2.23	0	...	2.90	9.57	2.50	2.33
Lab 4A <sup>B</sup>	...	0	8.26	...	8.20	...	...
Lab 5	1.83	0	5.95	2.42	5.56	2.39	1.94
Lab 6 <sup>C</sup>	2.07	0	6.98	2.30	7.12	1.33	2.04
Lab 7	2.43	0	8.97	2.79	7.47	2.74	2.48
Lab 8	2.10	0	8.42	2.58	8.80	2.58	2.08
Average	2.08	0	7.98	2.56	7.91	2.50	2.17
Standard Deviation	0.186	...	1.20	0.256	1.30	0.230	0.241
Support <sup>1</sup> / <sub>5</sub>							
Lab 1	1.63	0	11.1	2.14	11.1	1.17	1.44
Lab 2 <sup>A</sup>	1.34	0	...	...	5.82	1.65	1.44
Lab 3 <sup>A</sup>	1.40	0	7.83	1.54	6.99	1.62	1.42
Lab 4 <sup>B</sup>	1.63	0	...	1.98	7.17	1.93	1.63
Lab 4A <sup>B</sup>	...	0	7.18	...	...	...	...
Lab 5	1.39	0	4.72	1.82	4.96	1.88	1.42
Lab 6 <sup>C</sup>	1.57	0	5.91	1.58	6.16	1.69	1.49
Lab 7	1.67	0	9.43	1.96	7.56	1.94	1.78
Lab 8	1.68	0	6.82	1.92	7.62	1.96	1.76
Average	1.54	0	7.57	1.85	7.17	1.86	1.60
Standard Deviation	0.139	...	2.15	0.220	1.83	0.187	0.174

<sup>A</sup> Deviated from standard procedure by timing flame speed visually with a stopwatch.

<sup>B</sup> Deviated from standard procedure by averaging three replicates in most cases, although five replicates were used twice and eleven once.

<sup>C</sup> Deviated from standard procedure by averaging six replicates twice.

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