



Designation: D 2196 – 99

# Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield type) Viscometer<sup>1</sup>

This standard is issued under the fixed designation D 2196; 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.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 These test methods cover the determination of the apparent viscosity and the shear thinning and thixotropic properties of non-Newtonian materials in the shear rate range from 0.1 to 50  $\text{s}^{-1}$ .

1.2 *This standard does not purport to address 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 1 Specification for ASTM Thermometers<sup>2</sup>

## 3. Summary of Test Method

3.1 Test Method A consists of determining the apparent viscosity of coatings and related materials by measuring the torque on a spindle rotating at a constant speed in the material.

3.2 Test Methods B and C consist of determining the shear thinning and thixotropic (time-dependent) rheological properties of the materials.<sup>3</sup> The viscosities of these materials are determined at a series of prescribed speeds of a rotational-type viscometer. The agitation of the material immediately preceding the viscosity measurements is carefully controlled.

## 4. Significance and Use

4.1 Test Method A is used for determining the apparent viscosity at a given rotational speed, although viscosities at two or more speeds better characterize a non-Newtonian material than does the single viscosity measurement.

4.2 With Test Methods B and C, the extent of shear thinning is indicated by the drop in viscosity with increasing viscometer speed. The degree of thixotropy is indicated by comparison of viscosities at increasing and decreasing viscometer speeds (Test Method B), viscosity recovery (Test Method B), or viscosities before and after high shear (combination of Test Methods B and C). The high-shear treatment in Test Method C approximates shearing during paint application. The viscosity behavior measured after high shear is indicative of the characteristics of the paint soon after application.

## 5. Apparatus

5.1 Rotational-type viscometers having at least four speeds, such as:

5.1.1 *Brookfield Viscometer*, Model LVF, or equivalent having four rotational speeds, or Model LVT having eight rotational speeds, with set of four spindles; or

5.1.2 *Brookfield Viscometer*, Model RVF, having four rotational speeds, or Model RVT or equivalent having eight rotational speeds, with set of seven spindles.

5.2 *Thermometer*—ASTM thermometer having a range from 20 to 70°C and conforming to the requirements for Thermometer 49C as prescribed in Specification E 1.

5.3 *Containers*, round 1-pt (0.5-L) can, 3 $\frac{3}{8}$  in. (85 mm) in diameter, or 1-qt (1-L) can, 4 in. (100 mm) in diameter.

5.4 *Shaker*, or equivalent machine capable of vigorously shaking the test specimen.

## 6. Materials

6.1 *Standard Oils*, calibrated in absolute viscosity, millipascal seconds.

## 7. Calibration of Apparatus

7.1 Select at least two standard oils of viscosities differing by at least 5 P (0.5 Pa·s) within the viscosity range of the material being measured and in the range of the viscometer. Condition the oils as closely as possible to 25.0°C (or other agreed-upon temperature) for 1 h in a 1-pt (0.5-L) can, 3 $\frac{3}{8}$  in. (85 mm) in diameter. Measure the viscosities of each oil as described in Test Method B (Section 13) taking readings only

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and are the direct responsibility of Subcommittee D01.24 on Physical Properties of Liquid Paints and Paint Materials.

Current edition approved April 10, 1999. Published May 1999. Originally published as D 2196 – 63 T. Last previous edition D 2196 – 86 (1991) <sup>$\epsilon$ 1</sup>.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 14.03.

<sup>3</sup> Pierce, P. E., "Measurement of Rheology of Thixotropic Organic Coatings and Resins with the Brookfield Viscometer," *Journal of Paint Technology*, Vol 43, No. 557, 1971, pp. 35–43.

at increasing speeds (13.7). Make certain that the spindle is centered in the container prior to taking measurements.

NOTE 1—The Brookfield LV and RV series viscometers are equipped with a spindle guard leg. The spindle/speed multiplying factors (Table 1) are designed for use with the guard leg in place except for the following conditions: RV series when the factors are the same with or without the guard leg for spindles No. 3 through 7; or LV series when the factors are the same with or without the guard leg for spindles No. 3 and 4.

7.1.1 Calibration in a 1-pt (0.5-L) can is always possible with the LV series viscometer with the guard leg attached. Calibration of the RV series viscometer in the 1-pt can must be done with spindles No. 3 through 7 without the guard leg. If the No. 1 or No. 2 spindles are to be used, calibration is carried out in the 1-qt (1-L) can with the guard leg attached.

7.2 Combining the tolerance of the viscometer ( $\pm 1\%$ , equal to the spindle/speed factor) and the tolerance of the temperature control (typically  $\pm 0.5^\circ\text{C}$  at  $25^\circ\text{C}$ ) it is reasonable to assume that a viscometer is calibrated if the calculated viscosities are within  $\pm 5\%$  of the stated values (see Table 2 for examples of the considerable change in viscosity with temperature exhibited by standard oils). If measurements are not made at  $25^\circ\text{C}$ , then the stated viscosities should be corrected to the temperature at which they are measured. If the viscosities determined in 7.1 differ from the stated values of the viscosity standard by more than  $5\%$ , calculate new factors for each spindle/speed combination as follows:

$$f = Vs \quad (1)$$

where:

$f$  = new factor for converting scale reading to viscosity, cP (mPa·s),

$V$  = viscosity of standard oil, mPa·s, and

$s$  = scale reading of the viscometer.

**TABLE 1 Factors for Converting Brookfield Dial Readings to Centipoises (Millipascal Seconds)**

NOTE 1—M = 1000.

Speed, rpm	RV Series Factors Spindles						
	1	2	3	4	5	6	7
0.5	200	800	2000	4000	8000	20M	80M
1	100	400	1000	2000	4000	10M	40M
2	50	200	500	1000	2000	5M	20M
2.5	40	160	400	800	1600	4M	16M
4	25	100	250	500	1000	2.5M	10M
5	20	80	200	400	800	2M	8M
10	10	40	100	200	400	1M	4M
20	5	20	50	100	200	500	2M
50	2	8	20	40	80	200	800
100	1	4	10	20	40	100	400

  

Speed, rpm	LV Series Factors Spindles			
	1	2	3	4
0.3	200	1000	4000	20M
0.6	100	500	2000	10M
1.5	40	200	800	4M
3.0	20	100	400	2M
6	10	50	200	1M
12	5	25	100	500
30	2	10	40	200
60	1	5	20	100

**TABLE 2 Viscosity Variation of Cannon Viscosity Standards About the  $25^\circ\text{C}$  Temperature Point**

Cannon Viscosity Standard	Viscosity at $25^\circ\text{C}$ , cP (mPa·s)	Viscosity Change With $+1^\circ\text{C}$ at $25^\circ\text{C}$ , cP (mPa·s)
S-600	1 400	87.7 (6.26 %)
S-2000	4 900	332 (6.77 %)
S-8000	20 000	1462.3 (7.31 %)

7.3 Prepare a table of new factors similar to that furnished with the viscometer (Table 1) for the spindle/speed combinations worked out in 7.2. Spindle/speed factors vary inversely with speed.

## 8. Preparation of Specimen

8.1 Fill a 1-pt or 1-qt can with sample to within 1 in. (25 mm) of the top with the sample and bring it as close as possible to a temperature of  $25^\circ\text{C}$  or other agreed-upon temperature prior to test.

8.2 Vigorously shake the specimen on the shaker or equivalent for 10 min, remove it from the shaker, and allow it to stand undisturbed for 60 min at  $25^\circ\text{C}$  prior to testing (Note 2). Start the test no later than 65 min after removing the can from the shaker. Do not transfer the specimen from the container in which it was shaken.

NOTE 2—Shake time may be reduced if necessary, or as agreed upon between the purchaser and manufacturer, but, in any case, should not be less than 3 min.

## TEST METHOD A—APPARENT VISCOSITY

### 9. Procedure

9.1 Make all measurements as close as possible to  $25^\circ\text{C}$ , or other agreed-upon temperature.

9.2 Place the instrument on the adjustable stand. Lower the viscometer to a level that will immerse the spindle to the proper depth. Level the instrument using the attached spirit level.

9.3 Tilt the selected spindle (Note 3), insert it into one side of the center of the surface of the material, and attach the spindle to the instrument as follows: Firmly hold the upper shaft coupling with thumb and forefinger; screw left-hand thread spindle coupling securely to the upper shaft coupling being very careful when connecting to avoid undue side pressure which might affect alignment. Avoid rotating the dial so that pointer touches the stops at either extreme of the scale.

NOTE 3—Select the spindle/speed combination that will give a minimum scale reading of 10 but preferably in the middle or upper portion of the scale. The speed and spindle to be used may differ from this by agreement between user and producer.

9.4 Lower the viscometer until the groove (immersion mark) on the shaft just touches the material. Adjust the viscometer level if necessary. Move the container slowly in a horizontal plane until the spindle is located in approximately the center of the container so that the test will be run in a region undisturbed by the lowering of the spindle.

9.5 Turn on the viscometer. Adjust the viscometer to the rpm selected (Note 3) for the material under test. Allow the viscometer to run until the pointer has stabilized (Note 4). After