



## Standard Test Method for Fineness of Portland Cement by the Turbidimeter<sup>1</sup>

This standard is issued under the fixed designation C 115; 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.

### 1. Scope

1.1 This test method covers determination of the fineness of portland cement as represented by a calculated measure of specific surface, expressed as square centimetres of total surface area per gram, or square metres of total surface area per kilogram, of cement, using the Wagner turbidimeter.<sup>2</sup>

1.2 *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.*

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound equivalents may be approximate.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

C 114 Test Methods for Chemical Analysis of Hydraulic Cement<sup>3</sup>

C 430 Test Method for Fineness of Hydraulic Cement by the 45- $\mu\text{m}$  (No. 325) Sieve<sup>3</sup>

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials<sup>4</sup>

### 3. Significance and Use

3.1 The purpose of this test method is to determine whether or not the hydraulic cement under test meets the Wagner turbidimetric fineness requirements of the applicable hydraulic cement specification for which the test is being made. Fineness of the cement component is only one of the many characteristics that influence the strength capabilities of concrete.

### 4. Apparatus

4.1 *Nature of Apparatus*—The Wagner turbidimeter consists essentially of a source of light maintained at constant intensity

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee C-1 on Cement and is the direct responsibility of Subcommittee C01.25 on Fineness.

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<sup>2</sup> This turbidimeter was developed by L. A. Wagner, Research Associate of the Cement Reference Laboratory, National Institute of Standards and Technology, Washington, DC. A description of the apparatus and the original mathematical derivations of formulas used are given in the paper: Wagner, L. A., "A Rapid Method for the Determination of the Specific Surface of Portland Cement," *Proceedings*, ASTM, ASTEA, Vol 33, Part II, 1933, p. 553.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 04.02.

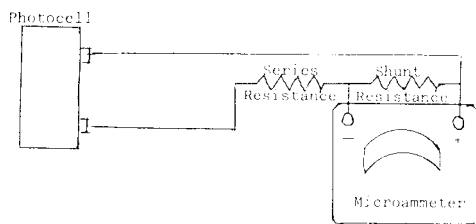
and adjusted so that approximately parallel rays of light pass through a suspension of the cement to be tested and impinge upon the sensitive plate of a photoelectric cell. The current generated in the cell is measured by means of a microammeter and the indicated reading is a measure of the turbidity of the suspension. General considerations indicate that turbidity is in turn a measure of the surface area of the suspended sample of cement. The apparatus shall consist specifically of the parts described in 4.2-4.7 and shall be constructed in accordance with the detailed design and dimensional requirements shown in Fig. 1 and Table 1, except that the case may be either of wood or of metal.

4.2 *Turbidimeter*, mounted in a suitable wood or metal case including the following features:

4.2.1 *Source of Light*—The source of light (Fig. 1) shall consist of a concentrated-filament electric lamp of between 3 and 6 cd operated by a source of constant emf. The lamp shall be mounted rigidly in the socket. A clean, bright parabolic metallic reflector shall be rigidly mounted behind the lamp, focused so that approximately parallel rays of light will pass through the sedimentation tank and impinge upon the photoelectric cell. The light intensity shall be regulated by two rheostats of approximately 6 and 30  $\Omega$ , respectively, and they shall possess such characteristics that uniform changes in light intensity may be obtained over the full range of resistance. The rheostats shall be mounted in parallel with each other and in series with the lamp.

4.2.2 *Heat-Absorbing Device*—The light shall pass through a suitable heat absorbing device before entering the sedimentation tank in order that radiant heat from the beam shall be absorbed, the device being either (1) a water cell or (2) a special heat-absorbing glass filter. The water cell shall be made from 76-mm (3-in.) outside diameter seamless brass tubing, 3-mm ( $\frac{1}{8}$ -in.) thick wall, 102-mm (4 in.) in length with glass windows sealed in the ends. The cell shall contain a hole for filling with distilled water. The hole shall be sealed with a metal plug. The cell, when mounted on the movable shelf, may have the plug in either the top or bottom position. The heat-absorbing device shall be so arranged that essentially all rays of light entering the sedimentation tank shall first pass through the heat-absorbing device.

4.2.3 *Retarding Filter*—A light-retarding glass or other device shall be provided that will reduce the intensity of light from that corresponding to 100  $\mu\text{A}$  to a reading of 20 to 30  $\mu\text{A}$ . The light intensity shall be uniformly retarded over the entire



Microammeter Internal Resistance = 90  $\Omega$   
 Shunt Equivalent Resistance:  
 $470 \Omega$  in parallel with  $100 \Omega = \frac{470 \times 100}{470 + 100} = 82 \Omega$   
 Meter & Shunt Equivalent + Resistance:  
 $90 \Omega$  in parallel with  $82 \Omega = \frac{90 \times 82}{90 + 82} = 43 \Omega$   
 Series Resistance =  $90 - 43 = 47 \Omega$

**FIG. 1 Illustrated Example of D'Arsonval Meter Circuit for  $I_x$  Determination**

area of that portion of the cell which is exposed to light during a test. The retarding filter shall be mounted in a carrier on the shield and shall be capable of being swung out of the light path by means of a handle.

**4.2.4 Sedimentation Tank**—The sedimentation tank shall be either (1) constructed of 5 to 6-mm ( $\frac{3}{16}$  to  $\frac{1}{4}$ -in.) plate glass or borosilicate glass cemented or sealed together to form a rectangular tank, or (2) a molded glass tank having walls approximately 5-mm ( $\frac{3}{16}$  in.) thick with plane surfaces. The inside dimensions of the rectangular tank shall be 51 mm by 38 mm (2 by  $1\frac{1}{2}$  in.) by 203 mm (8 in.) in height. The permissible variation on the inside dimensions of the tank shall be  $\pm 2.5$  mm (0.1 in.) in length and  $\pm 0.76$  mm (0.03 in.) in width. The 51-mm faces of the tank shall be equidistant within 0.25 mm (0.1 in.) at all points. A mark shall be placed on the side of the tank to indicate a volumetric content of 335 mL, which is the level to which the tank will be filled in a test. A tank filled to the mark with clear kerosine and placed in the turbidimeter light beam shall yield uniform microammeter readings, within  $\pm 0.1 \mu\text{A}$ , for the entire usable portion of the tank.

**4.2.5 Photoelectric Cell**—The means of measuring the light intensity shall be a sensitive photoelectric cell<sup>5</sup> connected directly to a microammeter. A hood with a horizontal slot 13 mm ( $\frac{1}{2}$  in.) in height by 35 mm ( $1\frac{3}{8}$  in.) in width shall be mounted over the photoelectric cell. The front of the hood shall be  $25 \pm 1$  mm ( $1 \pm \frac{1}{16}$  in.) in front of the face of the cell. The face of the photocell shall be parallel to the tank faces within 0.5 mm (0.02 in.).

**4.2.6 Shield**—A metallic shield having a slot 16 mm ( $\frac{5}{8}$  in.) in height by 38 mm ( $1\frac{1}{2}$  in.) in width, as indicated in Fig. 1, shall be placed between the heat absorbing device and the sedimentation tank.

**4.2.7 Elevating Device**—The source of the light, the heat-absorbing device, the photoelectric cell, the retarding filter, and the shield shall be mounted on a movable shelf which may be raised or lowered by two connected lead screws, and which may be readily and accurately adjusted so that the turbidity of the suspension may be determined at any desired depth. The center of the light source, the heat absorbing device, the photocell, the center of the slots of the metal shield, and the

hood shall be on a straight line which is parallel to the shelf. The sedimentation tank shall be mounted on a base which is independent of the rest of the apparatus so that the tank shall be free from vibration caused by moving the shelf. Care shall be taken that the shelf shall be level at all points of elevation and that the tank shall be normal to the shelf. The distance between the tank and the edges of the opening in the shelf shall vary not more than  $\frac{1}{64}$  in. (0.4 mm) between the “30–50” and “0” positions. The level of the light beam with reference to the surface of the suspension shall be indicated by a pointer which will travel along a scale mounted on the cabinet. The zero of the scale shall indicate that position at which the center lines of the slots for the light beam are at the same elevation as the surface of the liquid in the tank when filled to the 335-mL level. The lines on the scale to be marked 7.5, 10, 15, 20, 25, and 30–50, shall be located at distances from the zero mark equal to suspension depth values,  $h$ , in Table 2. The scale, when compared with a standard scale accurate to within 0.1 mm at all points, shall not show a deviation at any point greater than 0.25 mm and shall indicate the positions at which the pointer should be located when turbidity readings for these values of  $h$  are taken. The interior of the turbidimeter cabinet and the exterior surfaces of the shelf, the parabolic reflector, the heat absorbing device, the shield, and the photoelectric cell hood shall be painted with a dull flat black paint.

NOTE 1—The requirement of the 0 to 50 markings on the scale shall apply only to new Wagner Turbidimeters and not to equipment in use which meets the other requirements of this method.

#### 4.3 Microammeters:

**4.3.1 D'Arsonval-Type Microammeters** shall have a range from 0 to 50  $\mu\text{A}$  and shall be readable to 0.1  $\mu\text{A}$ . New microammeters shall be accurate to  $\pm 0.5\%$  of full scale value at any part of the scale value at any part of the scale at 77°F (25°C). For microammeters, in use, the accuracy shall be the same as for new instruments except that the accuracy at 40 and 50  $\mu\text{A}$  shall be  $\pm 1\%$  of full scale. The internal resistance of the microammeter shall be between 50 and 150  $\Omega$ . The microammeter shall not be mounted upon a working surface containing or consisting of iron or steel, or near other magnetic influence.

#### 4.3.2 Digital Microammeter:

NOTE 2—A meter with a range of 199.9  $\mu\text{A}$  is satisfactory for use and enables the operator to read the theoretical  $I_0$  directly without supplementary devices. The high internal resistance of the digital microammeter does not affect the linearity of readings at the light intensity levels encountered in a Wagner turbidimetric determination of fineness.

**4.4 Source of Current**—A 6-V automobile starting and lighting storage battery or a source of constant emf shall be used for supplying current to the lamp.

**4.5 Sieve**—The sieve shall conform to the requirements of Test Method C 430.

**4.6 Stirring Apparatus**—The stirring apparatus shall consist of either (1) a cylindrical brush, 19 mm ( $\frac{3}{4}$  in.) in diameter and about 45 mm ( $1\frac{3}{4}$  in.) in length, with an end approximately fitting the contour of the bottom of a 22-mm ( $\frac{7}{8}$ -in.) diameter test tube, or (2) any other stirring device that will be equally efficient in dispersion as measured by specific surface determinations on a standard sample. The stirring apparatus shall rotate at a speed of approximately 3500 r/min.

<sup>5</sup> Weston Photronic type, Model 594YY is acceptable.

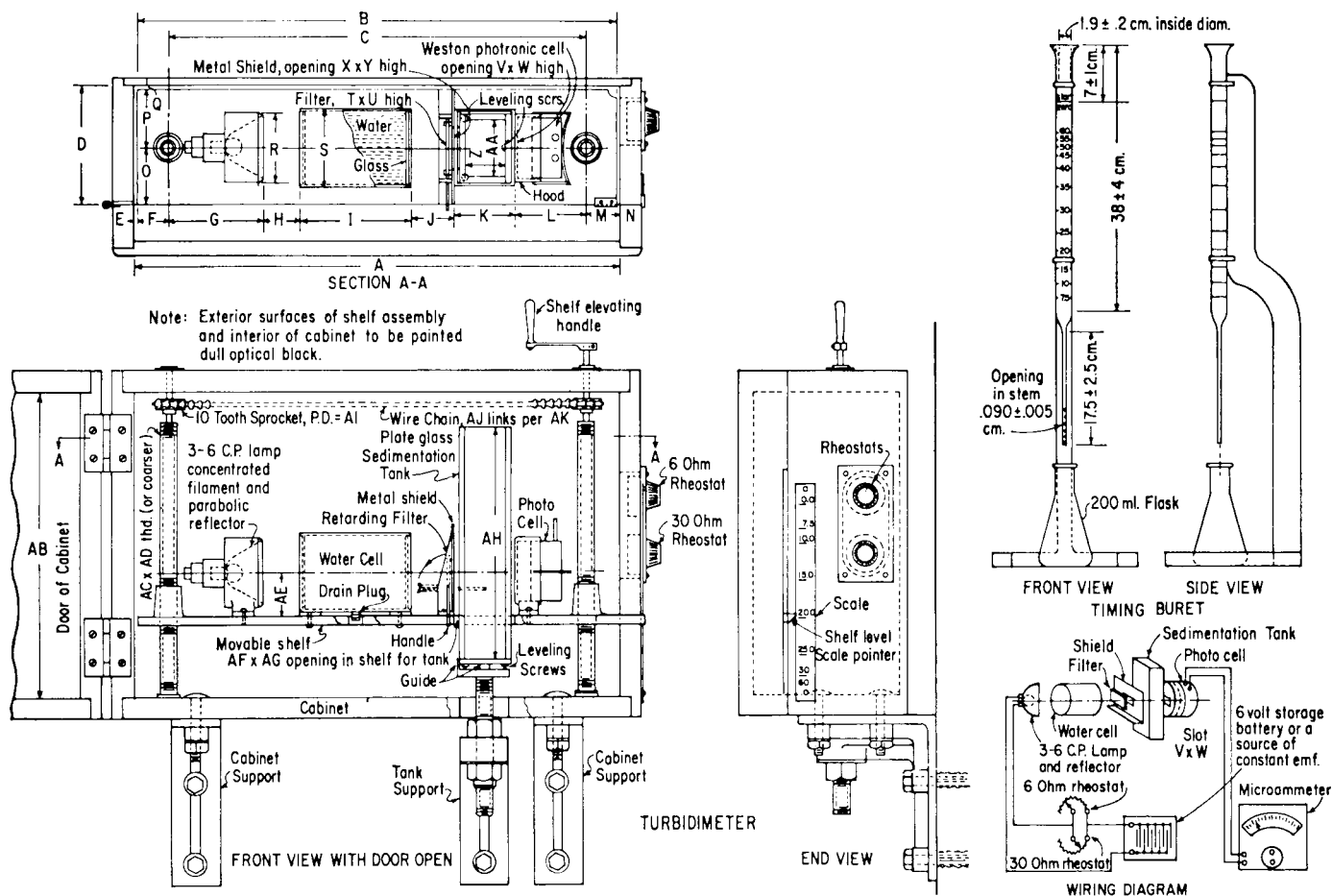


FIG. 2 Dimensional Details of Turbidimeter Fineness Test Apparatus (see Table 1)

TABLE 1 Turbidimeter Apparatus Dimensions (see Fig. 1)

Letter	mm	in.	Letter	mm	in.
A	445	17½	T	51	2
B	438	17¼	U	22.2	7/8
C	381	15	V	34.9	1⅜
D	105	4⅞	W	13	½
E	3.0	1/8	X	38	1½
F	28.6	1⅛	Y	15.9	5/8
G	85.7	3⅜	Z	38 ± 0.76	1½ ± 0.03
H	33.3	1⅝	AA	51 ± 2.5	2 ± 0.10
I	102	4	AB	267	10½
J	39.7	1⅞	AC	...	5/8 <sup>A</sup>
K	55.6	2⅜	AD	...	11 <sup>A</sup>
L	65.1	2⅞	AE	39.7	1⅞
M	28.6	1⅛	AF	55.6	2⅜
N	3.0	1/8	AG	66.7	2⅝
O	51	2	AH	203	8
P	51	2	AI	23.6	0.93
Q	3.0	1/8	AJ	1.38 <sup>A</sup>	3½ <sup>A</sup>
R	61.1	2⅜	AK	cm <sup>A</sup>	in. <sup>A</sup>
S	69.8	2¾			

<sup>A</sup> These are pure numbers such as parts of a thread designation and numbers of links per unit; consequently, they do not correspond with the column titles.

4.7 *Timing Buret*—The time of settling for the different-sized particles shall be obtained by use of a buret from which kerosine is allowed to flow. The buret shall consist of a glass tube having a capillary tube fused into the lower end. The upper end of the large tube shall be flared to serve as a funnel for introducing kerosine into the tube. The buret shall conform

to the limiting dimensions given in Table 3. The graduation lines on the buret shall be complete circles. A filter made of No. 325 (45- $\mu$ m) wire cloth shall be used with the timing buret and a cover shall be placed over the top of the buret when it is not in use.

4.8 *Weights and Weighing Devices*, shall conform to the

**TABLE 2 Values of  $h$ ,  $d$ , and  $h/d^2$  to be Used in Calibration of the Turbidimeter Apparatus**

Particle Diameter, $d$ , $\mu\text{m}$	Depth of Suspension, $h$ , cm	$h/d^2$
50	15	0.00600
45	15	0.00741
40	15	0.00938
35	15	0.01224
30	15	0.01667
25	13.1	0.0210
20	10	0.0250
15	6.6	0.0293
10	3.3	0.0330
7.5	2.1	0.0373

**TABLE 3 Buret Dimensions<sup>A</sup>**

	Dimension, cm	Permissible Variation, cm
Length of large tube	38	$\pm 4$
Inside diameter of large tube	1.9	$\pm 0.2$
Length of capillary	17.5	$\pm 2.5$
Diameter of capillary	0.09	$\pm 0.005$
Top of buret to zero line	7	$\pm 1$

<sup>A</sup> Since glass tubing of desired dimensions is not always obtainable, the wide permissible variations listed above allow selection of dimensions to produce a buret having a duration of flow which will permit calibration as described in 7.1.1.

requirements of Methods C 114.

## 5. Materials

5.1 *Suspending Liquid*—Clear white kerosine shall be used with the turbidimeter apparatus. The kerosine shall not be reused.

## 6. Test Specimen or Sample

6.1 *Size of Test Sample*—Select the size of the sample of cement for test so that the initial microammeter reading is between 12 and 20  $\mu\text{A}$ .

NOTE 3—The following approximations will be helpful in many instances in selecting the size of sample: 0.25 g for normal fineness cements and 0.20 g for high fineness cements.

## 7. Calibration

7.1 *Calibration of Turbidimeter*—Calibrate the turbidimeter apparatus in accordance with the following procedure:

### 7.1.1 Calibration of Buret Scale:

7.1.1.1 For calibration of the buret scale use a kerosine having a known viscosity and density for the temperature at which the calibration is to be made. Density and viscosity of the kerosine should be determined. Calculate the times of flow from the buret that correspond to the times of settling for the different sized particles, from the following equation:

$$t = [1,837,000\eta/(\rho_1 - \rho_2)] \times (h/d^2) \quad (1)$$

where:

$t$  = time of settling, or time of flow, s,

$\eta$  = viscosity of kerosine at the temperature of calibration, P,

$\rho_1$  = density of cement particles,  $\text{Mg/m}^3(\text{g/cm}^3) = 3.15$  for portland cement (Note 4),

$\rho_2$  = density of kerosine,  $\text{Mg/m}^3$  at the temperature of calibration,

$h$  = depth of suspension to level of light, cm, and

$d$  = diameter of particle,  $\mu\text{m}$ .

Values of  $h/d^2$  re given in Table 2.

7.1.1.2 Fill the buret with kerosine at the calibrating temperature, start a timing clock at the instant the kerosine in the buret drains past the zero line, and mark on the buret the levels reached by the draining kerosine for each of the time intervals,  $t$ , calculated as described above. At these marks, etch permanent lines and numbers on the buret indicating the corresponding diameters (Note 5). The construction and the graduation of the buret shall be such that at the temperature of calibration the time required for the kerosine to pass the permanent lines of the buret agrees with the calculated time of settling within 1 percent, except that the permissible variation shall be not less than 1 s.

NOTE 4—The density of portland cement does not vary greatly and in this work it is considered constant at 3.15. A variation of 0.15 from this value when substituted in Stokes' law gives a variation of 2.5 % in the diameter of the particle measured.

NOTE 5—By using the calibrated buret the apparatus may be used within the normal range of room temperatures without further correction, the change in rate of flow of the kerosine from the buret automatically compensating for change in viscosity of the suspension due to temperature. The temperature of the kerosine in the buret and that of the suspension should be kept the same within  $0.5^\circ\text{C}$  ( $1^\circ\text{F}$ ). This condition will ordinarily exist if the supply of kerosine is kept in the same room as the apparatus.

Care must be taken to ascertain that only clean kerosine is used in the buret, and, in addition, the capillary should be examined frequently to make sure that no small pieces of lint or other foreign material have become lodged in it.

7.1.2 *Calibration of No. 325 (45- $\mu\text{m}$ ) Sieve*—Calibration shall be made in accordance with Method C 430, basing the percentage sieve correction on the difference between the test residue obtained and the assigned residue value indicated by the electroformed sheet sieve fineness specified for the standard sample, expressed as a percentage of the test residue.

### 7.1.3 Determination of the Proper Light Intensity, $I_r$ :

7.1.3.1 Fill the sedimentation tank to the mark with clear kerosine.

7.1.3.2 For a turbidimeter equipped with a digital-type microammeter with a range of 199.9  $\mu\text{A}$ , place the sedimentation tank containing clear kerosine against the guides of the tank support in the turbidimeter. Set the light intensity so that the microammeter reads 100.0  $\mu\text{A}$ . Readjust the light intensity until equilibrium is established at this reading. Place the light retarding filter in the path of the light beam. When equilibrium is established, record this meter reading as  $I_r$ . This meter reading becomes the reference value for the intensity of the light. Meter readings are also taken at the beginning and end of each test through the light retarding filter alone to check the requirements of 8.3.8.

7.1.3.3 For a turbidimeter equipped with a D'Arsonval-type microammeter, place the sedimentation tank containing clear kerosine against the guides of the turbidimeter. Set the light intensity so that the microammeter reads 50.0  $\mu\text{A}$  with the light retarding filter removed from the light path. Readjust the light



intensity until equilibrium is established at this reading. Connect resistors or resistor combinations as indicated in Fig. 1 so that the meter reading is reduced to an equilibrium value between 23.0 and 25.0  $\mu\text{A}$ . Increase the light intensity until the equilibrium light reading obtained between 23.0 and 25.0  $\mu\text{A}$  is exactly doubled. Readjust the light intensity until the equilibrium is established at this doubled meter reading level. Place the light-retarding filter in the path of the light beam. Remove the resistors from the meter circuit. When equilibrium is established, record this meter reading as  $I_r$ . This becomes the reference value for the intensity of the light. Adjust the rheostats at the beginning of each test to give this meter reading through the filter plus the tank of clear kerosine. This meter reading corresponds to a meter reading of 100.0  $\mu\text{A}$  through the tank containing clear kerosine with the light filter removed from the light path. Meter readings are also taken at the beginning and at the end of each test through the light retarding filter alone to check the requirements of 8.3.8.

NOTE 6—A half-watt carbon resistor preferably with 5 % tolerance limits can be used to obtain the desired meter readings. The shunt resistor or resistor combination as shown in Fig. 1 shall have a resistance value between 85 and 100 % of the value of the internal resistance of the meter as printed on the card in the meter cover. The series resistor shall have a resistance value equal to the difference between the internal resistance of the meter and the calculated resistance of the meter and shunt combination.

NOTE 7—A less exact but still acceptable procedure for determining a meter setting that corresponds to a current of 100.0  $\mu\text{A}$  through the meter with the light filter removed from the light path can be achieved by eliminating the series resistor in the meter circuit. The internal resistance of the photocell is sufficiently large to cause only a minor error of approximately 0.5 % in the desired setting when the series resistor is omitted from the circuit.

7.1.3.4 *Example*—If the internal resistance of the meter is 90  $\Omega$ , and the meter is shunted with a 470- $\Omega$  resistor in parallel with a 100  $\Omega$  resistor, the combined resistance of the meter and shunts would be reduced to 43  $\Omega$ . This would reduce the meter reading from 50.0  $\mu\text{A}$  to a calculated value of 23.9  $\mu\text{A}$ .

7.1.4 *Determination of the Value of K in the Specific Surface Equation*—Using the regular procedure in 8.1-8.3; and with the light adjusted in accordance with the appropriate procedure in 7.1.3, make a specific surface determination on the current lot of National Institute of Standards and Technology's Reference Material No. 114.<sup>6</sup> Determine the value of  $K$  in the specific surface equation in 10.1.1 by dividing the assigned specific surface of the standard sample by the value obtained for the expression in brackets [ ]. Repeat this calibration procedure twice more. Use the average of the three results (Note 8) obtained for the value of  $K$  during calibration in specific surface equation in 10.1.1.

7.1.5 *Frequency of Calibration*—The turbidimeter apparatus shall have been calibrated within 6 months prior to testing a cement sample.

NOTE 8—The three individual values of  $K$  determined during calibration should not vary from the average value by more than 1.5 %.

<sup>6</sup> Obtainable at the National Institute of Standards and Technology, (NIST), Gaithersburg, MD 20899.

## 8. Procedure

8.1 *Sieve Determination*—Make a No. 325 (45- $\mu\text{m}$ ) sieve determination on a 1-g sample of cement in accordance with the procedure stated in Test Method C 430. Record the percentage (corrected) of cement passing the sieve as  $r$ .

8.2 *Preparation of the Suspension*:

8.2.1 *Dispersion of the Sample*—Place the cement sample in a test tube together with 10 to 15 mL of kerosine and 5 drops of dispersing agent—oleic acid or aged linseed oil (Note 9). Stir the mixture for 1 min, using the apparatus described in 4.6, and then transfer to the sedimentation tank. Wash the stirring apparatus and the tube with clear kerosine, which is then added together with additional clear kerosine until the total volume of the suspension in the tank is 335 mL (Note 10).

NOTE 9—The oleic acid, if used, shall be of USP grade. The aged linseed oil, if used, shall have a density in the range from 0.948 to 0.953  $\text{Mg}/\text{m}^3$  ( $\text{g}/\text{cm}^3$ ). These dispersing agents have slight or no effect on the viscosity of the kerosine. Each of these dispersing agents changes with age or with exposure to heat and light—hence should be kept in well-stoppered, dark-glass bottles. Dropping bottles should be emptied, thoroughly cleaned, dried, and refilled periodically. Where conditions are such that poor dispersion is obtained with oleic acid or when foaming of the suspension occurs (possibly due to traces of water in the kerosine) aged linseed oil shall be used as the dispersing agent. The same dispersing agent shall be used for both the instrument calibration and the fineness determination.

NOTE 10—Since it is important that the level of the liquid in the tank coincide with the zero mark on the scale of the instrument (see 4.2.7), it is correspondingly important that the volume of the suspension be close to 335 mL, as specified. This may be accomplished by the use of a flask, calibrated to deliver 335 mL, from which all the kerosine used in making up a suspension is taken; or a point gage may be used, consisting essentially of a flat plate approximately 50 by 63 mm (2 by 2½ in), to the center of which is attached vertically a metal pin of such length that, when the plate is placed in position on top of the tank, the point of the pin is at the 335-mL level. Either of these methods should ensure the position of the liquid level within a few tenths of a millimetre.

8.2.2 *Agitation of the Suspension*—Just before placing the tank in the path of the light beam, agitate the contents to effect a uniformity of the suspension. Cover the tank with a ground-glass cover and oscillate 180° about a horizontal axis through the center of the tank, turning the tank upside down and back again to its original upright position approximately once each second for about 1 min (Note 11). Take care to prevent loss of kerosine (Note 12). The suspension is then ready to place in its proper position in the path of the light beam.

NOTE 11—The procedure described for oscillating the suspension shall be carefully followed. The procedure used in shaking a cocktail shall not be employed.

NOTE 12—The lid to the tank shall fit so that no kerosine drains down the outside faces of the tank. The faces of the glass tank shall be clean when the suspension is added, and care shall be taken to avoid the necessity of cleaning the faces until the determination is complete.

8.3 *Operation of Turbidimeter*—Operate the turbidimeter apparatus in accordance with the following procedure:

8.3.1 With retarding filter and sedimentation tank containing approximately 100 mL of clear kerosine in the light path, adjust the light to the intensity,  $I_r$ , as determined in 7.1.3 by taking repeated readings at 1-min intervals until an unchanging value indicates that the lamp and the photoelectric cell are in

equilibrium. Remove the tank, check and record the intensity of the lamp.

NOTE 13—To protect the microammeter, the lamp shall be turned on only with a suspension or the retarding filter in position to reduce the light intensity to a value within the range of the microammeter. A freshly charged storage battery should be momentarily short-circuited to reduce the voltage to constant value. If the microammeter indication continues to fluctuate, look for loose connections in the lamp and photoelectric cell circuits, see that the rheostat contacts are clean, and make certain that the lamp, socket, and reflector are rigidly fixed in their mounting.

8.3.2 Weigh the sample of cement in the appropriate amount and record the weight to the nearest 0.0002 g. Prepare a suspension in accordance with 8.2.

8.3.3 Place the shelf level pointer at the 30–50 μm position.

8.3.4 Fill the buret to the predetermined height with kerosine from the same lot and at the same temperature as the kerosine used in the suspension, and start oscillation of the tank containing the suspension in accordance with 8.2.2. Continue the oscillation until the kerosine drains to the zero line on the buret; then stop the agitation. Immediately place the tank in position in the path of the light beam.

8.3.5 Immediately remove the retarding filter from the light path and close the cabinet door.

8.3.6 Read the microammeter to the nearest 0.1 μA at the instant the kerosine in the buret drains past marks 50, 45, 40, 35, and 30.

8.3.7 Raise the shelf successively to the marks 25, 20, 15, 10, and 7.5 on the pointer scale, reading the microammeter at each position as the kerosine drains past the corresponding mark on the buret.

8.3.8 Lower the shelf to the 30–50 μm position. Replace the filter in the path of the light beam, remove the tank, and check the intensity of the lamp. If the microammeter indication has shifted more than 0.3μ A from the initial setting through the filter alone, the test must be repeated.

## 9. Data Recording

9.1 The form shown in Table 4 is suggested for the recording of turbidimeter data and for the calculation of specific surface.

## 10. Calculation

10.1 *Calculation of Specific Surface:*

10.1.1 Calculate the turbimetric specific surface as follows:

$$S = K \left[ \frac{r(2 - \log I_{50})}{1.5 + 0.75 \log I_{7.5} + \log I_{10} + \log I_{15} \dots + \log I_{45} - 9.5 \log I_{50}} \right] \quad (2)$$

where:

$S$  = specific surface of the sample, m<sup>2</sup>/kg,

$K$  = calibration factor as determined in 7.1.4

$r$  = corrected weight percent of sample passing the 45-μm (No. 325) sieve (Note 14), and  $I_{7.5}$ ,  $I_{10}$ ,  $I_{15}$ ...,  $I_{50}$  = microammeter readings, μA, that correspond to the particle diameters 7.5, 10, 15 ..., 50 μm.

NOTE 14—The value of  $K$  as determined in 7.1.3 applies only to a material having the density of portland cement (approximately 3.15 Mg/m<sup>3</sup> or g/cm<sup>3</sup>). For any other material, the corresponding value must be

**TABLE 4 Illustrative Form for Recording Turbidimeter Test Data and Calculation of Specific Surface**

NOTE 1—Values shown are for purpose of illustration only.

Particle Size, μm	$I$ , μA	log $I$	sample X
50	17.3	...	90.4
45	17.4	1.241	33.9
40	17.6	1.246	
35	17.9	1.253	
30	18.4	1.265	
25	19.1	1.281	
20	20.1	1.303	
15	21.6	1.334	
10	23.9	1.378	
7.5	25.6	...	1.408 <sup>A</sup>
	0.75 × 1.408 =	1.056	
		1.500	
	Sum =	12.857	
	9.5 × 1.238 =	11.761	
	Difference =	1.096	
$S = (33.9 \times 90.4 \times 0.762) / 1.096 = 2131 \text{ cm}^2/\text{g}$ (Round to 2130 cm <sup>2</sup> /g or 213 m <sup>2</sup> /kg)			

<sup>A</sup> For convenience in calculation, log  $I_{50}$  and log  $I_{7.5}$  are recorded in a separate column.

calculated for this factor which, in the derivation of the formula, varies inversely as the density of the particles (g/cm<sup>3</sup>).

10.1.2 To calculate the specific surface values in square metres per kilogram, multiply the surface area in cm<sup>2</sup>/g by the factor of 0.1.

10.1.3 Round values in cm<sup>2</sup>/g to the nearest 10 units (in m<sup>2</sup>/kg to the nearest unit).

10.2 *Specific Surface From First Turbidity Reading  $I_{50}$* —This test method may be used for successive determinations from the same plant, provided that the same size test samples are used and that there is no great change in fineness, color, or other properties of the cement. Under these conditions the specific surface of a sample may be calculated from the first turbidity reading,  $I_{50}$ , by using the following equation:

$$S = c(2 - \log I_{50}) \quad (3)$$

where:

$S$  = specific surface of the sample, m<sup>2</sup>/kg,

$I_{50}$  = microammeter reading corresponding to particle diameter of 50 μm, and

$c$  = transmittancy constant for the particular plant.

NOTE 15—The transmittancy constant,  $c$ , may be evaluated by substituting in the above equation known values of  $S$  and  $2 - \log I_{50}$  as determined from a complete turbidimeter test. The average of not less than five values of  $c$ , as determined from complete tests, should be used in the above equation.

10.3 If fineness of a sample as determined in accordance with 10.2 fails to conform with the specification requirements for fineness, a retest shall be made using the complete procedure in 8.3, 9.1, and 10.1.

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**11. Precision and Bias**

11.1 *Single-Operator Precision*—The single-operator coefficient of variation has been found to be 2.6 % (Note 16). Therefore, results of two properly conducted tests by the same operator, on the same sample should not differ by more than 7.3 % (Note 13) of their average.

11.2 *Multilaboratory Precision*—The multilaboratory coefficient of variation has been found to be 3.8 % (Note 16). Therefore, results of two different laboratories on identical samples of a material should not differ from each other by more than 10.6 % (Note 16) of their average.

NOTE 16—These numbers represent, respectively, the (D1S %) and (D2S %) limits as described in Practice C 670.

11.3 Since there is no accepted reference material suitable for determining any bias that may be associated with this test method, no statement on bias is being made.

**12. Keywords**

12.1 fineness; portland cement; turbidimeter; Wagner

**APPENDIX**

**(Nonmandatory Information)**

**X1. CALCULATION OF PARTICLE SIZE DISTRIBUTION**

X1.1 For research or comparative purposes particle-size distributions to a minimum of 7.5 μm may be of value.

The form shown in Table X1.1 is suggested for the calculation of particle size distribution.

X1.2 Calculate the particle size distribution as follows:

**TABLE X1.1 Illustrative Form for Calculation of Particle Size Distribution from Recorded Turbidimetric Test Data**

Particle Size, μm	$I, \mu A$	$\log I$	Difference	Average Particle Size, $d_1$	$d_1 \times$ Difference	Weight, %	
						Fractional	Cumulative
50	17.3	1.238	0.003	47.5	.143	2.34	90.4
45	17.4	1.241	0.005	42.5	.213	3.49	88.1
40	17.6	1.246	0.007	37.5	.263	4.31	84.6
35	17.9	1.253	0.012	32.5	.390	6.39	80.3
30	18.4	1.265	0.016	27.5	.440	7.21	73.9
25	19.1	1.281	0.022	22.5	.495	8.11	66.7
20	20.1	1.303	0.031	17.5	.543	8.89	58.6
15	21.6	1.334	0.044	12.5	.550	9.01	49.7
10	23.9	1.378	0.030	8.75	.263	4.31	40.7
7.5	25.6	1.408	0.592	3.75	2.220	36.36	36.4
(0)	(100.0)	(2.000)			...		
					5.520		

$$F = r/\text{Sum}(d_1 \times \text{diff}) = 90.4/5.520 = 16.377$$

$$\% \text{ fraction} = F(d_1 \times \text{diff})$$

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