PLAINTIFF'S EXHIBIT

CT-782

FORM P927 8-62

TECHNICAL SPECIFICATIONS

CERTAIN-TEED PRODUCTS CORPORATION ASBESTOS CEMENT PIPE	NUMBER: TM-3	PAGE 1
	SUPERSEDES:	DATE OF ISSUE: May 22, 1964

APPLICABLE TO:	CLASSIFICATION:
Ambler R&D and All Plants	Test Method

DESCRIPTION: Method of Test for Determination of Fineness of Portland Cement & Silica by Blaine Air Permeability Apparatus.

TM 3

A. Scope

1. This method of test covers the procedure for determining the fineness of Portland cement and silica in terms of specific surface expressed as total surface area in square centimeters per gram (cm^2/gram) of cement, by use of the Blaine air permeability apparatus.

   Note: The Blaine apparatus was originally designed for determining the fineness or surface area of Portland cement; however since it operates on the principle of porosity, it can be easily and accurately used to determine the surface area of silicas.

B. Apparatus

1. The Blaine air permeability apparatus consists essentially of a means of drawing a definite quantity of air through a prepared bed of cement or silica of definite porosity. The number and size of the pores in a prepared bed of definite porosity is a function of the size of the particles and determines the rate of air flow through the bed.

2. The Blaine apparatus shall consist of the following parts:

   a. Permeability Cell
   b. Disk (Perforated)
   c. Plunger
   d. Filter Paper
   e. Manometer
   f. Manometer liquid
   g. Timer

   All the individual parts of the Blaine apparatus shall be in accordance with the requirements as specified in ASTM C 204-55 "Standard Method of Test for Fineness of Portland Cement by Air Permeability Apparatus".

PREPARED BY: F. J. Law	APPROVED BY: Frank J. Law

CTD010108

FORM P-6054

TECHNICAL CHANGE ORDER

CERTAIN-TEED PRODUCTS CORPORATION
PIPE DIVISION

CERTAINTEED

APPLICABLE TO:

General Standards Manual Section F
Standard Test Method TM 3

DATE OF ISSUE:	T.C.O. NO.:	PAGE NO.:
April 18, 1969	1	1

DESCRIPTION:

Standard Test Methods

PURPOSE

1. To update the existing procedure.
2. Change the procedure on testing of cement from oven dried to as received.
3. To make the test method readable.

EFFECTIVE DATE

Date of issue.

DISPOSITION OF SUPERSEDED PAGES

Upon receipt of this T.C.O. replace pages 1,2,3,4,5, dated May 22, 1964, with the attached pages.

CTD010109

PREPARED BY:	APPROVED BY:	R & D	MFG.	SALES	I.E.	OTHERS

ASTM

Blaine

Fisher

Mark Wright So River 201-CL-7HV TO

Ray Rogers

Travel Sands Lusk

Silver Springs 301-587-1400

Mrs. Hill

Mr. Gaynor to call.

Portland Cement Association – 5420 Old Orch Rd. Phone

Skokie Ill 60078

293-9015 Allentown Cement

Keystone Bob Sweet 2 Bath Pa.

1-800-422-8100 Ken Wenzel. Plant

215-926-3575 215 926-1024

1. M C-204

ASTM C 204 Cenco Soil Test. Blaine

Mountainside N.J.

237 Sheffield

201-233-1188,

Humboldt - Chicago

Hagen Tobler 301- Rockville Md.

CTD010110

FORM P927

TECHNICAL SPECIFICATIONS

CERTAIN-TEED PRODUCTS CORPORATION
PIPE DIVISION

SPECIFICATIONS CLASSIFICATION: Standard Test Methods		
T.C.O. REF. NO. 1	SPECIFICATION NO: TM - 3	PAGE NO.: 1
SUPERSEDES: May 22, 1964		DATE OF ISSUE: April 18, 1969

DESCRIPTION:

Method Of Test For Determination Of Fineness Of Portland Cement And Silica By Blaine Air Permeability Apparatus

A. Scope

1. This method of test covers the procedure for determining the fineness of Portland cement and silica in terms of specific surface expressed as total surface area in square centimeters per gram (cm^2/gram) of cement, by use of the Blaine air permeability apparatus.

   Note: The Blaine apparatus was originally designed for determining the fineness or surface area of Portland cement; however since it operates on the principle of porosity, it can be easily and accurately used to determine the surface area of silicas.

B. Apparatus

1. The Blaine air permeability apparatus consists essentially of a means of drawing a definite quantity of air through a prepared bed of cement or silica of definite porosity. The number and size of the pores in a prepared bed of definite porosity is a function of the size of the particles and determines the rate of air flow through the bed.

2. The Blaine apparatus shall consist of the following parts:

   4/21/77 - Conco Soil Test Co. 237 Sheffield Mountainside N.J. (201) 233-1188

   a. Permeability Cell
   b. Disk (Perforated)
   c. Plunger
   d. Filter Paper
   e. Manometer
   f. Manometer liquid
   g. Timer

   All the individual parts of the Blaine apparatus shall be in accordance with the requirements as specified in ASTM C 204-55 "Standard Method of Test for Fineness of Portland Cement by Air Permeability Apparatus".

C. Calibration of Apparatus

1. The calibration of the Blaine apparatus shall be in accordance with the requirements as specified in ASTM C 204-55. The National Bureau of Standards No. 114 Standard Sample may be obtained from the U. S. Department of Commerce, National Bureau of Standards, Washington 25, D. C. (A charge of approximately $2.50 is made for each standard sample).

2. A method of checking to determine if the volume and weight of standard sample used is correct is:

$$P = \left(V - \frac{W}{3.15}\right)$$

   Where: P = Porosity (should be 0.500 ± 0.005)
   V = Volume of cement bed.
   W = Weight of standard cement sample.

D. Calculations

1. For Cement

$$S = \frac{Ss\sqrt{T}}{\sqrt{T_s}} \quad (a)$$

For Silica

$$S = \frac{Ss\ Ps\ (1-e_s)}{P\ (1-e)}\cdot\frac{\sqrt{e^3}}{\sqrt{e^3_s}}\cdot\frac{\sqrt{T}}{\sqrt{T_s}} \quad (c)$$

$$Ss = \frac{Ss\sqrt{\eta_s}\sqrt{T_s}}{\sqrt{\eta}\sqrt{T}} \quad (b)$$

$$Ss = \frac{Ss\ Ps\ (1-e_s)}{P\ (1-e)}\cdot\frac{\sqrt{\eta_s}}{\sqrt{\eta}}\cdot\frac{\sqrt{e^3}}{\sqrt{e^3_s}}\cdot\frac{\sqrt{T}}{\sqrt{T_s}} \quad (d)$$

PREPARED BY | APPROVED BY | DESIGN | PROD. | QA/QC | MFG.

CTD010111

Where:

S = Specific surface in sq. cm. per gram of test sample.
Ss = Specific surface in sq. cm. per gram of standard sample used in calibration of the apparatus.
T = Time in seconds for measured manometer drop of test sample.
Ts = Time in seconds for measured manometer drop of standard sample used in calibration of the apparatus.
n = Viscosity of air in poises at the temperature of test of the test sample.
ns = Viscosity of air in poises at the temperature of test of the standard sample used in calibration of the apparatus.
e = Porosity of prepared bed of test sample.
es = Porosity of prepared bed of standard sample used in calibration of the apparatus.
P = Specific Gravity of test sample - 3.15 shall be used for Portland cement and 2.65 shall be used for silica.
Ps = Specific gravity of standard sample used in calibration of the apparatus - 3.15 is used.

Note: Values for $\sqrt{\eta}$ $\sqrt{e^3}$ and $\sqrt{T}$ may be taken from the Tables I, II and III as shown in ASTM C 204-55.

i.e. In the Technical Service Materials Laboratory

The Volume is 1.824 cu. cm.

The Weight of the standard cement sample is 2.87 grams.

9/6/74
Vol = 1.824 cm³
Porosity = 0.499
Sp. gravity Cement = 2.90 gm
Sample size Silica = 2.44 gm

$$\frac{2.87}{\frac{1.824 - 3.15}{1.824}} =$$

$$\frac{1.824 - 0.911}{1.824} =$$

$$\frac{0.913}{1.824} = 0.5005 \text{ Porosity}$$

Using this wt
Surface Area
for ~~Silica~~ Cement
Malls Lab Blaine
$416\sqrt{T}$
calibrated to Ft/s Stds
Cement May 5, 1969

2. When using the Blaine apparatus to determine the surface area of silica the weight of the sample must be adjusted due to the difference in the specific gravity of the silica so that the porosity remains the same. This can be calculated from the standard cement sample as follows:

Cement = $\frac{2.60}{\sqrt{T_s}}$
$410\sqrt{T}$ = sample calc for Cement SA
$428\sqrt{T}$ = Sample calc for Silica

$$\frac{2.65}{3.15} = \frac{S}{W} = 0.8413$$

Where: 2.65 is the Specific Gravity of Silica
3.15 is the Specific Gravity of Cement
S = Weight of Silica
W = Weight of Cement

i.e. At Technical Service:

$$\frac{2.65}{3.15} = \frac{S}{2.87}$$

S = 2.42 grams

With this wt Surface Area of
Malls Lab Blaine $489\sqrt{T}$ calibrated
Bur Stds
May 5, 1969

3. The surface area may be checked by varying the porosity and substituting the values in the formula as shown in the tables in ASTM C 204-55. By varying the porosity from .495 to .505 the surface area should be within 300 cm²/gm.

E. Test

The surface area of the material shall be determined on representative samples of the material using the same weight of sample as has been determined from the calibration of the apparatus using the standard sample. All silica must be oven dried for 24 hours at 210°F. ± 5°F. or to constant weight and allowed to cool at room temperature in a dessicator before making the surface area determinations. Cement shall be tested on the as-received basis. Five determinations shall be made on separate samples of each material. The average of these test results shall be recorded.

F. Sampling

When incoming shipments of cement and silica are sampled, each compartment of each truck and/or railroad car shall be sampled. The sample should be obtained from the material at least one foot below the top surface. The samples obtained from each compartment of the truck or railroad car shall be combined to form a composite sample. The composite sample shall be kept in an airtight container (polyethylene bag or jar will suffice). The container should be identified by Vendor and date. The composite sample should be a minimum of 5 pounds.

U. S. Department of Commerce
Frederick B. Dent
Secretary

National Bureau of Standards
Richard W. Roberts, Director

Recd 6/2/77

National Bureau of Standards Certificate of Analysis

Standard Reference Material 114m

Portland Cement

This Standard Reference Material is intended for use in calibrating the Wagner turbidimeter, the Blaine fineness meter, and the 2-inch diameter No. 325 sieve in accordance with Federal Test Method Standard 158 where applicable or ASTM methods of test for fineness of cement. The air-permeability test should be made at a porosity of 0.500.

Residue on No. 325 sieve, electro-formed sheet (45.0 μm), wet method	6.9 percent
Surface area (Wagner turbidimeter) by ASTM Method C115-70 (or subsequent issue)	2040 cm^2/g
Surface area (air-permeability)	3930 cm^2/g
Mean particle diameter (air-permeability)	4.85 μm

The surface areas and mean particle diameter reported on this Standard Reference Material are calculated on the assumption that its specific gravity is 3.15, and this value should be used in all calibration computations.

The overall direction and technical measurements leading to certification were performed under the direction of J. R. Dise and A. R. Woolf, Materials Reference Laboratories, Products Evaluation Technology Division.

The technical and support aspects involved in the preparation, certification, and issuance of this Standard Reference Material were coordinated through the Office of Standard Reference Materials by A. R. Woolf, C. L. Stanley, and R. E. Michaelis.

Washington D. C. 20234
April 5, 1973

J. Paul Cail, Chief
Office of Standard Reference Materials

(over)

CTD010113

U. S. Department of Commerce
Alexander B. Trowbridge
Secretary

National Bureau of Standards
I. C. Schoonover, Acting Director

Samples Rec'd

Certificate of Surface Area Analysis

Standard Reference Material 114 L

Portland Cement

Residue on No. 325 sieve bronze cloth, wet method	6.8 percent
Residue on No. 325 sieve electro-formed sheet (44.0μ), wet method	12.2 percent
Surface area (Wagner turbidimeter)	1820 cm²/g
Surface area (air-permeability)	3380 cm²/g
Mean particle diameter (air-permeability)	5.64 microns

These values are for use in calibrating the Wagner turbidimeter and Blaine fineness meter in accordance with the methods of the current issue of Federal Test Method Standard 158, or ASTM methods of test for fineness of cement. The air-permeability tests should be made at a porosity of 0.500.

The surface areas and mean particle diameter reported on this standard reference material are calculated on the assumption that its specific gravity is 3.15, and, therefore, the value 3.15 should be used in all calibration computations.

The certificate value for residue on the No. 325 sieve assigned to the first issue of standard reference material 114 over 30 years ago was based on a set of carefully selected sieves with bronze cloth. Subsequent issues of sample No. 114 have had assigned residues consistent with the first issue. Over the years, woven cloth has become available with more uniform hole size than the cloth upon which the No. 114 residue figure is based. An anomaly has developed, thereby, where the better sieves have the larger correction factors. As a first step in correcting this situation, standard reference material No. 114 L has two assigned residues, one on bronze cloth, which is consistent with values for previous issues, and one on electro-formed sheet, which is based on measurements with sieves fitted with such material. Electro-formed sheet differs from wire cloth in not being woven, and in being free from grossly oversize openings.

The bronze cloth figure should be used in connection with the Wagner turbidimeter test. In many tests, such as the fineness of fly ash, the specification limit will need to be adjusted before the electro-formed figure can be substituted for the bronze figure.

Washington, D.C. 20234
August 25, 1967

W. Wayne Meinke, Chief
Office of Standard Reference Materials

Cement $\frac{\text{Std}}{\text{Test}} = .841 \frac{2.65 \text{ Density}}{3.15 \text{ Density Cement}}$

Silica $= \frac{\text{Std}}{\text{Test}} \times .841$

(Over)

CTD010114

To open the vial, make a deep scratch with a file about ¼ inch from the bottom of the vial. Invert the vial and press a red hot file point against the scratch to cause a circumferential crack around the vial. Remove the end of the vial carefully and remove any glass fragments which may have fallen into the sample.

The specific surface of cement changes on being exposed to the air. Therefore, after opening the container, the sample must be protected from atmospheric moisture until the time of test. The sample should be used as soon as possible after opening—in any case within 8 hrs.

For use with the Blaine air-permeability apparatus, the sample should be fluffed in a 4- to 6-ounce bottle as described in the current issue of Federal Test Method Standard 158 or ASTM Method C 204, before being used.

This standard was prepared and calibrated in the Institute for Applied Technology, Building Research Division, by members of the Codes and Standards Section, B. E. Foster Chief.

FORM P927 8-62

TECHNICAL SPECIFICATIONS

CERTAIN-TEED PRODUCTS CORPORATION ASBESTOS CEMENT PIPE	NUMBER: TM-3	PAGE 2
	SUPERSEDES:	DATE OF ISSUE: May 22, 1964

APPLICABLE TO:	CLASSIFICATION:
Ambler R&D and All Plants	Test Method

DESCRIPTION: **Method of Test for Determination of Fineness of Portland Cement & Silica by Blaine Air Permeability Apparatus.**

C. Calibration of Apparatus

1. The calibration of the Blaine apparatus shall be in accordance with the requirements as specified in ASTM C 204-55. The National Bureau of Standards No. 114 Standard Sample may be obtained from the U.S. Department of Commerce, National Bureau of Standards, Washington 25, D.C. (A charge of approximately $2.50 is made for each standard sample).

2. A method of checking to determine if the volume and weight of standard sample used is correct is:

$$P = \left(V - \frac{W}{3.15}\right)$$

Where: P = Porosity (should be 0.500 ± 0.005)
V = Volume of cement bed
W = Weight of standard cement sample.

D. Calculations

1. For Cement

$$S = \frac{Ss\sqrt{T}}{\sqrt{T_s}} \quad (a)$$

$$S = \frac{Ss\sqrt{n_s}\sqrt{T}}{\sqrt{T_s}\sqrt{n}} \quad (b)$$

For Silica

$$S = \frac{Ss\ Ps\ (1-e_s)\sqrt{Ve^3}\sqrt{T}}{P\ (1-e)\sqrt{Ve^3_s}\sqrt{T_s}} \quad (c)$$

$$S = \frac{Ss\ Ps\ (1-e_s)\sqrt{n_s}\sqrt{Ve^3}\sqrt{T}}{P\ (1-e)\sqrt{Ve^3_s}\sqrt{T_s}\sqrt{n}} \quad (d)$$

CEMENT - 2.873 gms $\quad \frac{S_s}{\sqrt{T_s}} = 365$

Ss = constant $\quad 365\sqrt{T}$

Standard surf area supplied with std. Sample from Bur. Stds Recalibrated values gms cement 2.873 gm Sample $411\sqrt{T}$

SILICA - 2.417 gms $\quad \frac{S_s}{\sqrt{T_s}} = 436$

$436\sqrt{T}$

Silica 2.42 gm $489\sqrt{T}$

PREPARED BY:	APPROVED BY:
F. J. Law	

CTD010116

FORM P927 8-62

TECHNICAL SPECIFICATIONS

CERTAIN-TEED PRODUCTS CORPORATION ASBESTOS CEMENT PIPE	NUMBER: TM-3	PAGE 3
	SUPERSEDES:	DATE OF ISSUE: May 22, 1964

APPLICABLE TO:	CLASSIFICATION:
Ambler R&D and All Plants	Test Method

DESCRIPTION: Method of Test for Determination of Fineness of Portland Cement & Silica by Blaine Air Permeability Apparatus.

Where:

S = Specific surface in sq. cm. per gram of test sample.
Ss = Specific surface in sq. cm. per gram of standard sample used in calibration of the apparatus.
T = Time in seconds for measured manometer drop of test sample.
Ts = Time in seconds for measured manometer drop of standard sample used in calibration of the apparatus.
n = Viscosity of air in poises at the temperature of test of the test sample.
ns = Viscosity of air in poises at the temperature of test of the standard sample used in calibration of the apparatus.
e = Porosity of prepared bed of test sample.
es = Porosity of prepared bed of standard sample used in calibration of the apparatus.
P = Specific Gravity of test sample - 3.15 shall be used for Portland cement and 2.65 shall be used for silica.
Ps = Specific gravity of standard sample used in calibration of the apparatus - 3.15 is used.

Note: Values for $\sqrt{n}$ $\sqrt{e^3}$ and $\sqrt{T}$ may be taken from the Tables I, II and III as shown in ASTM C 204-55.

i.e. In the Materials Laboratory in Ambler --

The Volume is 1.824 cu. cm.

The Weight of the standard cement sample in 2.87 grams.

$$\frac{1.824 - \frac{2.87}{3.15}}{1.824} =$$

$$\frac{1.824 - 0.911}{1.824} =$$

$$\frac{0.913}{1.824} = 0.5005 \text{ Porosity.}$$

PREPARED BY:	APPROVED BY:
F. J. Law	Frank J. Law

CTD010117

FORM P927 8-62

TECHNICAL SPECIFICATIONS

CERTAIN-TEED PRODUCTS CORPORATION ASBESTOS CEMENT PIPE	NUMBER: TM-3	PAGE 4
	SUPERSEDES:	DATE OF ISSUE: May 22, 1964

APPLICABLE TO:	CLASSIFICATION:
Ambler R&D and All Plants	Test Method

DESCRIPTION: Method of Test for Determination of Fineness of Portland Cement & Silica by Blaine Air Permeability Apparatus.

2. When using the Blaine apparatus to determine the surface area of silica the weight of the sample must be adjusted due to the difference in the specific gravity of the silica so that the porosity remains the same. This can be calculated from the standard cement sample as follows:

$$\frac{2.65}{3.15} = \frac{S}{W}$$

Where: 2.65 is the Specific Gravity of Silica
3.15 is the Specific Gravity of Cement
S = Weight of Silica
W = Weight of Cement

i.e. in Ambler --

$$\frac{2.65}{3.15} = \frac{S}{2.87}$$

S = 2.42 grams

3. The surface area may be checked by varying the porosity and substituting the values in the formula as shown in the tables in ASTM C 204-55. By varying the porosity from .495 to .505 the surface area should be within 300 cm^2/gm.

E. Test

The surface area of the material (s) shall be determined on representative samples of the material (s) using the same weight of sample as has been determined from the calibration of the apparatus using the standard sample. All samples must be oven dried for 24 hours at 210°F. ± 5°F, or to constant weight and allowed to cool at room temperature in a dessicator before making the surface area determinations. Five determinations shall be made on separate samples of each material. The average of these test results shall be recorded. The test shall be performed on incoming shipment of silica and cement from each Vendor at least once a week.

PREPARED BY:	APPROVED BY:
F. J. Law	Frank J. Law

CTD010118

FORM P927 6-62

TECHNICAL SPECIFICATIONS

CERTAIN-TEED PRODUCTS CORPORATION ASBESTOS CEMENT PIPE	NUMBER: TM-3	PAGE 5
	SUPERSEDES:	DATE OF ISSUE: May 22, 1964

APPLICABLE TO:	CLASSIFICATION:
Ambler R&D and All Plants	Test Method

DESCRIPTION: Method of Test for Determination of Fineness of Portland Cement & Silica by Blaine Air Permeability Apparatus.

F. Sampling

When incoming shipments of cement and silica are sampled, each compartment of each truck and/or railroad car shall be sampled. The sample should be obtained from the material at least one foot below the top surface. The samples obtained from each compartment of the truck or railroad car shall be combined to form a composite sample. The composite sample shall be kept in an airtight container (polyethylene bag or jar will suffice). The container should be identified by Vendor and date. The composite sample should be a minimum of 5 pounds.

PREPARED BY:	APPROVED BY:
F. J. Law	Frank J. Law

CTD010119

AMERICAN ASSOCIATION STATE HIGHWAY OFFICIALS STANDARD A.A.S.H.O. NO.: T 153

Standard Method of Test for

FINENESS OF PORTLAND CEMENT BY AIR PERMEABILITY APPARATUS[1]

ASTM Designation: C 204 - 55

ADOPTED, 1951; REVISED, 1955.[2]

This Standard of the American Society for Testing Materials is issued under the fixed designation C 204; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision.

NOTE.—An editorial change in Section 3 (*e*) was made in June, 1956. Editorial changes in Section 5 were made in June, 1958. Editorial change in Sections 2(*f*), 3(*b*) and (*e*), and Table II were made in August, 1959.

Scope

1. This method of test covers the Blaine air permeability apparatus and procedure for determining the fineness of portland cement in terms of the specific surface expressed as total surface area in square centimeters per gram of cement.

Apparatus

2. (*a*) *Nature of Apparatus.*—The Blaine air permeability apparatus consists essentially of a means of drawing a definite quantity of air through a prepared bed of cement of definite porosity. The number and size of the pores in a prepared bed of definite porosity is a function of the size of the particles and determines the rate of air flow through the bed. The apparatus, illustrated in Fig. 1, shall consist specifically of the parts described in Paragraphs (*b*) to (*h*).

(*b*) *Permeability Cell.*—The permeability cell shall consist of a rigid cylinder 1.27 ± 0.10 cm in inside diameter, constructed of glass or noncorroding metal. The top of the cell shall be at right angles to the principal axis of the cell. The bottom of the cell shall form an air-tight connection with the top of the manometer. A ledge ½ to 1 mm in width shall be an integral part of the cell or firmly fixed in the cell 5.0 ± 1.5 cm from the top of the cell for support of the perforated metal disk.

(*c*) *Disk.*—The disk shall be constructed of noncorroding metal and shall be 0.9 ± 0.1 mm in thickness, perforated with 30 to 40 holes 1 mm in diameter equally distributed over its area. The disk shall fit the inside of the cell snugly.

(*d*) *Plunger.*—The plunger shall fit into the cell with a clearance of not more than 0.1 mm. The bottom of the plunger shall have sharp square edges and shall be at right angles to the principal axis.

[1] Under the standardization procedure of the Society, this method is under the jurisdiction of the ASTM Committee C-1 on Cement.

[2] Prior to adoption as standard, this method was published as tentative from 1946 to 1951, being revised in 1951.

A "tentative revision" of this standard appears on p. 155.

An air vent shall be provided either in the center or on one side of the plunger. The top of the plunger shall be provided with a collar such that when the plunger is placed in the cell and the collar brought in contact with the top of the cell, the distance between the bottom of the plunger and the top of the perforated disk shall be 1.5 ± 0.1 cm.

(*e*) *Filter Paper.*—The filter paper shall be medium retentive, corresponding

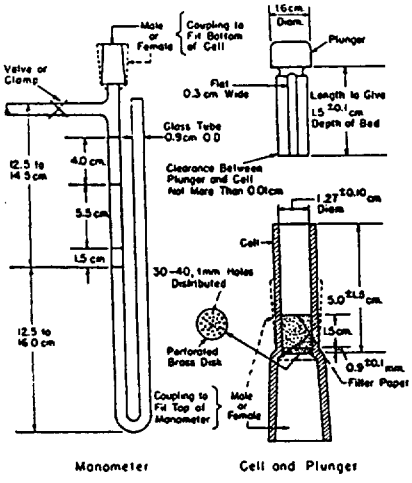

FIG. 1.—Blaine Air Permeability Apparatus

to type 1, grade B, as prescribed in Federal Specification for Paper; Filtering (UU-P-236). The filter paper disks shall be circular, with smooth edges, and shall have the same diameter (Note) as the inside of the cell.

NOTE.—Filter paper disks that are too small may leave part of the sample adhering to the inner wall of the cell above the top disk. When too large in diameter, the disks have a tendency to buckle and cause erratic results.

(*f*) *Manometer.*—The *U*-tube manometer shall be constructed according to the design indicated in Fig. 1, using nominal 9-mm outside diameter, standard-wall, glass tubing. The top of one arm of the manometer shall form an airtight connection with the permeability cell. The manometer arm connected to the permeability cell shall have a line etched around the tube at 12.5 to 14.5 cm below the top of the side outlet and also others at distances of 1.5 cm, 7.0 cm, and 11.0 cm above that line. A side outlet shall be provided at 25.0 to 30.5 cm above the bottom of the manometer for use in the evacuation of the manometer arm connected to the permeability cell. A positive airtight valve or clamp shall be provided on the side outlet not more than 5 cm from the manometer arm. The manometer shall be mounted firmly and in such a manner that the arms are vertical.

(*g*) *Manometer Liquid.*—The manometer shall be filled to the mid-point with a nonvolatile, nonhygroscopic liquid of low viscosity and density, such as dibutylphthalate (dibutyl 1,2-benzenedicarboxylate) or a light grade of mineral oil.

(*h*) *Timer.*—The timer shall have a positive starting and stopping mechanism and shall be capable of being read to the nearest 0.5 sec or less. The timer shall be accurate to 0.5 sec or less for time intervals up to 60 sec, and to 1 per cent or less for time intervals of 60 to 300 sec.

Calibration of Apparatus

3. (*a*) *Sample.*—The calibration of the air permeability apparatus shall be made using the current lot of National Bureau of Standards standard sample No. 114. The sample shall be at room temperature when tested.

(*b*) *Bulk Volume of Compacted Bed of Powder.*—The bulk volume of the compacted bed of powder shall be determined by the mercury displacement method as follows:

Place two filter paper disks in the permeability cell, pressing down the edges with a rod slightly smaller than the cell diameter until the filter disks are flat

on the perforated metal disk; then fill the cell with mercury, removing any air bubbles adhering to the wall of the cell. Use tongs when handling the cell. If the cell is made of material that will amalgamate with mercury, the interior of the cell shall be protected by a very thin film of oil just prior to adding the mercury. Level the mercury with the top of the cell by means of a small glass plate. Remove the mercury from the cell, weigh, and record the weight of the mercury. Remove one of the filter disks from the cell.

TABLE I.—DENSITY OF MERCURY,[a] VISCOSITY OF AIR (n), AND $\sqrt{n}$ AT GIVEN TEMPERATURES.

Room Temperature, deg Cent	Density of Mercury,[a] g per cu cm	Viscosity of Air, n, poises	$\sqrt{n}$
16	13.56	0.0001788	0.01337
18	13.55	0.0001798	0.01341
20	13.55	0.0001808	0.01344
22	13.54	0.0001818	0.01348
24	13.54	0.0001828	0.01352
26	13.53	0.0001837	0.01355
28	13.53	0.0001847	0.01359
30	13.52	0.0001857	0.01362
32	13.52	0.0001867	0.01366
34	13.51	0.0001876	0.01369

[a] The density of the mercury shall be determined.

Using a trial quantity of 2.80 g of cement (Note 1) compress the cement (Note 2) in accordance with Paragraph (*e*) with one filter disk above and one below the sample. Fill the space remaining in the top of the cell with mercury, remove entrapped air, and level off the top as before. Remove the mercury from the cell, weigh, and record the weight of mercury.

The bulk volume occupied by the cement shall be calculated to the nearest 0.005 cu cm as follows:

$$V = \frac{W_A - W_B}{D} \quad \ldots\ldots (1)$$

where:

V = bulk volume of cement in cubic centimeters,
W_A = grams of mercury required to fill cell, no cement being in cell,
W_B = grams of mercury required to fill the portion of the cell not occupied by the prepared bed of cement in the cell, and
D = density of mercury at temperature of test in grams per cubic centimeter (see Table I).

At least two determinations of bulk volume of cement shall be made, using separate compactions for each determination. The bulk volume value used for subsequent calculations shall be the average of two values agreeing within plus or minus 0.005 cu cm. The temperature in the vicinity of the cell shall be noted and recorded at the beginning and end of the determination.

NOTE 1.—It is not necessary to use the standard sample for the bulk volume determination.

NOTE 2.—The prepared bed of cement shall be firm. If too loose or if the cement cannot be compressed to the desired volume, adjust the trial quantity of cement used.

(*c*) *Preparation of Sample.*—The contents of a vial of the standard cement sample shall be enclosed in a 4-oz jar and shaken vigorously for 2 min to fluff the cement and break up lumps or agglomerates.

(*d*) *Weight of Sample.*—The weight of the standard sample used for the calibration test shall be that required to produce a bed of cement having a porosity of 0.500 ± 0.005, and shall be calculated as follows:

$$W = 3.15V(1 - e) \quad \ldots\ldots (2)$$

where:

W = grams of sample required,
3.15 = value taken as the specific gravity of portland cement,
V = bulk volume of bed of cement in cubic centimeters, as determined in accordance with Paragraph (*b*), and

e = desired porosity of bed of cement (0.500 ± 0.005).

(*e*) *Preparation of Bed of Cement.*—The perforated disk shall be seated on the ledge in the permeability cell. A filter paper disk shall be placed on the metal disk and the edges pressed down with a rod slightly smaller than the cell diameter. A quantity of cement determined in accordance with Paragraph (*d*) and weighed to the nearest 0.001 g shall be placed in the cell. The side of the cell shall be tapped lightly in order to level the bed of cement. A filter paper disk shall be placed on top of the cement and the cement compressed with the plunger until the plunger collar is in contact with the top of the cell. The plunger shall then be removed slowly. Use of fresh disks is required for each determination.

(*f*) *Permeability Test.*—The permeability cell shall be attached to the manometer tube, making certain that an airtight connection is obtained (Note 3) and taking care not to jar or disturb the prepared bed of cement.

The air in the one arm of the manometer *U*-tube shall be slowly evacuated until the liquid reaches the top mark, and the valve shall then be closed tightly. The timer shall be started as the bottom of the meniscus of the manometer liquid reaches the second (next to the top) mark and shall be stopped as the bottom of the meniscus of liquid reaches the third (next to the bottom) mark. The time interval measured shall be noted and recorded in seconds. The temperature of test shall be noted and recorded in degrees Centigrade.

In the calibration of the instrument, at least three determinations of the time of flow shall be made on each of three separately prepared beds of the standard sample (Note 4). The calibration shall be made by the same operator who makes the fineness determination.

NOTE 3.—If a rubber stopper is used for the connection, it should be moistened with water; if a standard-taper joint is used a little stopcock grease should be applied. The efficiency of the connection can be determined by stoppering the top of the cell attached to the manometer and then partially evacuating the one arm of the manometer; then closing the valve. Any continuous drop in pressure indicates a leak in the system.

NOTE 4.—The sample may be refluffed and reused for preparation of the test bed, provided that it is kept dry and all tests are made within 4 hr of the opening of the sample.

TABLE II.—VALUES FOR POROSITY OF CEMENT BED.

Porosity of Bed, ϵ	$\sqrt{\epsilon^3}$
0.495	0.348
0.496	0.349
0.497	0.350
0.498	0.351
0.499	0.352
0.500	0.354
0.501	0.355
0.502	0.356
0.503	0.357
0.504	0.358
0.505	0.359
0.506	0.360
0.507	0.361
0.508	0.362
0.509	0.363
0.510	0.364
0.525	0.380
0.526	0.381
0.527	0.383
0.528	0.384
0.529	0.385
0.530	0.386
0.531	0.387
0.532	0.388
0.533	0.389
0.534	0.390
0.535	0.391

(*g*) *Recalibration.*—The apparatus shall be recalibrated (Note 5):

(*1*) At periodic intervals to correct for possible wear on plunger or permeability cell,

(*2*) If any loss in manometer fluid occurs, and

(*3*) If a change is made in the type or quality of the filter paper used for the tests.

T	$\sqrt{\epsilon^3}$	ϵ
26	5.[illegible]	[illegible]
26½	5.[illegible]	[illegible]
27	5.[illegible]	[illegible]
27½	5.[illegible]	[illegible]
28	5.[illegible]	[illegible]
28½	5.[illegible]	[illegible]
29	5.[illegible]	[illegible]
29½	5.[illegible]	[illegible]
30	5.[illegible]	[illegible]
30½	5.52	[illegible]
31	5.57	[illegible]
31½	5.63	[illegible]
32	5.68	[illegible]
32½	5.74	[illegible]
33	5.74	[illegible]
33½	5.79	[illegible]
34	5.83	[illegible]
34½	5.87	[illegible]
35	5.92	[illegible]
35½	5.96	[illegible]
36	6.00	[illegible]
36½	6.04	[illegible]
37	6.08	[illegible]
37½	6.12	[illegible]
38	6.16	[illegible]
38½	6.20	[illegible]
39	6.24	[illegible]
39½	6.28	[illegible]
40	6.32	[illegible]
40½	6.36	[illegible]
41	6.40	[illegible]
41½	6.44	[illegible]
42	6.48	[illegible]
42½	6.52	[illegible]
43	6.56	[illegible]
43½	6.60	[illegible]
44	6.63	[illegible]
44½	6.67	[illegible]
45	6.71	[illegible]
45½	6.74	[illegible]
46	6.78	[illegible]
46½	6.82	[illegible]
47	6.86	[illegible]
47½	6.89	[illegible]
48	6.93	[illegible]
48½	6.96	[illegible]
49	7.00	[illegible]
49½	7.04	[illegible]
50	7.07	[illegible]
50½	7.10	[illegible]

TABLE III.—TIME OF AIR FLOW.

T = time of air flow in seconds; $\sqrt{T}$ = the factor for use in the equations.

T	$\sqrt{T}$	T	$\sqrt{T}$	T	$\sqrt{T}$	T	$\sqrt{T}$	T	$\sqrt{T}$	T	$\sqrt{T}$
26	5.10	51	7.14	76	8.72	101	10.05	151	12.29	201	14.18
26½	5.15	51½	7.18	76½	8.75	102	10.10	152	12.33	202	14.21
27	5.20	52	7.21	77	8.77	103	10.15	153	12.37	203	14.25
27½	5.25	52½	7.24	77½	8.80	104	10.20	154	12.41	204	14.28
28	5.29	53	7.28	78	8.83	105	10.25	155	12.45	205	14.32
28½	5.31	53½	7.31	78½	8.86	106	10.30	156	12.49	206	14.35
29	5.39	54	7.35	79	8.89	107	10.34	157	12.53	207	14.39
29½	5.44	54½	7.38	79½	8.92	108	10.39	158	12.57	208	14.42
30	5.48	55	7.42	80	8.94	109	10.44	159	12.61	209	14.46
30½	5.52	55½	7.45	80½	8.97	110	10.49	160	12.65	210	14.49
31	5.57	56	7.48	81	9.00	111	10.54	161	12.69	211	14.53
31½	5.61	56½	7.51	81½	9.03	112	10.58	162	12.73	212	14.56
32	5.66	57	7.55	82	9.06	113	10.63	163	12.77	213	14.59
32½	5.70	57½	7.58	82½	9.09	114	10.68	164	12.81	214	14.63
33	5.74	58	7.62	83	9.11	115	10.72	165	12.85	215	14.66
33½	5.79	58½	7.65	83½	9.14	116	10.77	166	12.88	216	14.70
34	5.83	59	7.68	84	9.17	117	10.82	167	12.92	217	14.73
34½	5.87	59½	7.71	84½	9.20	118	10.86	168	12.96	218	14.76
35	5.92	60	7.75	85	9.22	119	10.91	169	13.00	219	14.80
35½	5.96	60½	7.78	85½	9.25	120	10.95	170	13.04	220	14.83
36	6.00	61	7.81	86	9.27	121	11.00	171	13.08	222	14.90
36½	6.04	61½	7.84	86½	9.30	122	11.05	172	13.11	224	14.97
37	6.08	62	7.87	87	9.33	123	11.09	173	13.15	226	15.03
37½	6.12	62½	7.90	87½	9.36	124	11.14	174	13.19	228	15.10
38	6.16	63	7.94	88	9.38	125	11.18	175	13.23	230	15.17
38½	6.20	63½	7.96	88½	9.41	126	11.22	176	13.27	232	15.23
39	6.24	64	8.00	89	9.43	127	11.27	177	13.30	234	15.30
39½	6.28	64½	8.03	89½	9.46	128	11.31	178	13.34	236	15.36
40	6.32	65	8.06	90	9.49	129	11.36	179	13.38	238	15.43
40½	6.36	65½	8.09	90½	9.51	130	11.40	180	13.42	240	15.49
41	6.40	66	8.12	91	9.54	131	11.45	181	13.45	242	15.56
41½	6.44	66½	8.16	91½	9.57	132	11.49	182	13.49	244	15.62
42	6.48	67	8.19	92	9.59	133	11.53	183	13.53	246	15.68
42½	6.52	67½	8.22	92½	9.62	134	11.58	184	13.56	248	15.75
43	6.56	68	8.25	93	9.64	135	11.62	185	13.60	250	15.81
43½	6.60	68½	8.28	93½	9.67	136	11.66	186	13.64	252	15.87
44	6.63	69	8.31	94	9.70	137	11.70	187	13.67	254	15.94
44½	6.67	69½	8.34	94½	9.73	138	11.75	188	13.71	256	16.00
45	6.71	70	8.37	95	9.75	139	11.79	189	13.75	258	16.06
45½	6.74	70½	8.40	95½	9.78	140	11.83	190	13.78	260	16.12
46	6.78	71	8.43	96	9.80	141	11.87	191	13.82	262	16.19
46½	6.82	71½	8.46	96½	9.83	142	11.92	192	13.86	264	16.25
47	6.86	72	8.49	97	9.85	143	11.96	193	13.89	266	16.31
47½	6.89	72½	8.52	97½	9.88	144	12.00	194	13.93	268	16.37
48	6.93	73	8.54	98	9.90	145	12.04	195	13.96	270	16.43
48½	6.96	73½	8.57	98½	9.93	146	12.08	196	14.00	272	16.49
49	7.00	74	8.60	99	9.95	147	12.12	197	14.04	274	16.55
49½	7.04	74½	8.63	99½	9.98	148	12.17	198	14.07	276	16.61
50	7.07	75	8.66	100	10.00	149	12.21	199	14.11	278	16.67
50½	7.10	75½	8.68	100½	10.03	150	12.25	200	14.14	280	16.73