American Water Works Association

ANSI/AWWA B100-01
(Revision of ANSI/AWWA B100-96)

AWWA STANDARD
FOR
GRANULAR FILTER MATERIAL

American National Standards Institute

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AMERICAN WATER WORKS ASSOCIATION

6666 West Quincy Avenue, Denver, Colorado 80235

www.awwa.org

AWWA Standard

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Committee Personnel

The AWWA standards subcommittee that reviewed this standard had the following personnel at the time of approval:

Subcommittee on References, Cross-Referencing and Bibliography:

John L. Cleasby, *Chair*

Appiah Amirtharajah, Georgia Institute of Technology, Atlanta, Ga.	(AWWA)
J.L. Cleasby, Iowa State University, Ames, Iowa	(AWWA)

Subcommittee on Definitions:

W. Kirk Corliss, *Chair*

J.L. Cleasby, Iowa State University, Ames, Iowa	(AWWA)
W.K. Corliss Jr., Mechanicsburg, Pa.	(AWWA)
R.L. Roberts, Roberts Filter Group, Darby, Pa.	(AWWA)
C.M. Triolo, Fairfax County Water Authority, Merrifield, Va.	(AWWA)

Subcommittee on Filter Material Physical Requirements:

R. Lee Roberts, *Chair*

S.L. Bishop, Metcalf & Eddy Inc., Wakefield, Mass.	(NEWWA)
W.K. Corliss Jr., Mechanicsburg, Pa.	(AWWA)
A.C. Fiedler, Colorado Silica Sand Inc., Colorado Springs, Colo.	(AWWA)
R.H. Moser, American Water Works Service Company, Voorhees, N.J.	(AWWA)
R.L. Roberts, Roberts Filter Group, Darby, Pa.	(AWWA)

Subcommittee on Anthracite:

Richard H. Moser, *Chair*

K.A. DeCompli, Lang Filter Media, Mars, Pa.	(AWWA)
M.A. Eggleston, Unifilt Corporation, Wilkes Barre, Pa.	(AWWA)
D.M. Hambley, Anthratech Western Inc., Calgary, Alb.	(AWWA)
F.E. Jamerson, Washington Suburban Sanitary Commission, Glen Burnie, Md.	(AWWA)

R.H. Moser, American Water Works Service Company, Voorhees, N.J. (AWWA)
K.J. Roberts, Toronto, Ont. (AWWA)
L.M. Zukas Jr., F.B. Leopold Company Inc., Zelienope, Pa. (AWWA)

Subcommittee on Placing Filter Materials, Preparing Filter for Service and Replenishing Filter Media:

David M. Hambley, *Chair*

J.A. Byron, Lang Filter Media, Mars, Pa. (AWWA)
D.M. Hambley, Anthratech Western Inc., Calgary, Alb. (AWWA)
F.E. Jamerson, Washington Suburban Sanitary Commission, Glen Burnie, Md. (AWWA)

Subcommittee on Removing Filter Materials and Re-Use:

Thomas M. Getting, *Chair*

T.M. Getting, F.B. Leopold Company Inc., Zelienople, Pa. (AWWA)
K.J. Roberts, Toronto, Ont. (AWWA)

Subcommittee on Sampling:

Franklin W. Pogge, *Chair*

M.A. Eggleston, Unifilt Corporation, Wilkes Barre, Pa. (AWWA)
J.L. Geibel, F.B. Leopold Company Inc., Zelienople, Pa. (AWWA)
J.L. Meltzer, Northern Gravel Company, Muscatine, Iowa (AWWA)
F.W. Pogge, Kansas City Water Services Department, Kansas City, Mo. (AWWA)

Subcommittee on Test Procedures:

Kevin T. Walsh, *Chair*

J.L. Meltzer, Northern Gravel Company, Muscatine, Iowa (AWWA)
K.T. Walsh, The Connecticut Water Company, Clinton, Conn. (NEWWA)
L.M. Zukas Jr., F.B. Leopold Company Inc., Zelienope, Pa. (AWWA)

Subcommittee on Ordering and Delivery:

Lindsay E. Gorrill, *Chair*

L.E. Gorrill, Western Garnet International, Coeur d'Alene, Idaho (AWWA)

P.H. Kreft, Montgomery Watson, Portland, Ore. (AWWA)

T.P. Walter, Unifilt Corporation, Wilkes Barr, Pa. (AWWA)

Subcommittee on GAC:

Stephen L. Bishop, *Chair*

S.L. Bishop, Metcalf & Eddy Inc., Wakefield, Mass. (NEWWA)

S.L. Butterworth, Calgon Carbon Corporation, Pittsburgh, Pa. (AWWA)

R.H. Moser, American Water Works Service Company, Voorhees, N.J. (AWWA)

K.T. Walsh, The Connecticut Water Company, Clinton, Conn. (NEWWA)

Subcommittee on Air Wash:

Appiah Amirtharajah, *Chair*

Appiah Amirtharajah, Georgia Institute of Technology, Atlanta, Ga. (AWWA)

J.L. Geibel, F.B. Leopold Company Inc., Zelienople, Pa. (AWWA)

R.L. Roberts, Roberts Filter Group, Darby, Pa. (AWWA)

C.M. Triolo, Fairfax County Water Authority, Merrifield, Va. (AWWA)

Subcommittee on Filter Bed Support:

Steven L. Butterworth, *Chair*

S.L. Butterworth, Calgon Carbon Corporation, Pittsburgh, Pa. (AWWA)

J.L. Cleasby, Iowa State University, Ames, Iowa (AWWA)

T.M. Getting, F.B. Leopold Company Inc., Zelienople, Pa. (AWWA)

K.T. Walsh, The Connecticut Water Company, Clinton, Conn. (NEWWA)

The AWWA Standards Committee on Granular Filter Material that reviewed and approved this standard had the following personnel at the time of approval:

W. Kirk Corliss, *Chair*

R. Lee Roberts, *Vice-Chair*

Consumer Members

F.E. Jamerson, Washington Suburban Sanitary Commission, Laurel, Md.	(AWWA)
R.H. Moser, American Waterworks Service Company, Voorhees, N.J.	(AWWA)
F.W. Pogge, Kansas City Water Services Department, Kansas City, Mo.	(AWWA)
C.M. Triolo, Fairfax County Water Authority, Merrifield, Va.	(AWWA)
K.T. Walsh, The Connecticut Water Company, Clinton, Conn.	(AWWA)

General Interest Members

Appiah Amirtharajah, Georgia Institute of Technology, Atlanta, Ga.	(AWWA)
S.L. Bishop, Metcalf & Eddy Inc., Wakefield, Mass.	(NEWWA)
J.L. Cleasby, Iowa State University, Ames, Iowa	(AWWA)
W.K. Corliss Jr., Mechanicsburg, Pa.	(AWWA)
P.J. Olson,* Standards Engineer Liaison, AWWA, Denver, Colo.	(AWWA)
K.J. Roberts, Toronto, Ont.	(AWWA)

Producer Members

S.L. Butterworth, Calgon Carbon Corporation, Pittsburgh, Pa.	(AWWA)
M.A. Eggleston, Unifilt Corporation, Wilkes Barre, Pa.	(AWWA)
T.M. Getting, F.B. Leopold Company Inc., Zelienople, Pa.	(AWWA)
L.E. Gorrill, Western Garnet International, Coeur d'Alene, Idaho	(AWWA)
R.L. Roberts, Roberts Filter Group, Darby, Pa.	(AWWA)

*Liaison, nonvoting

Contents

All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

Foreword

This foreword is for information only and is not a part of ANSI/AWWA B100.

I. Introduction.

I.A. *Background.* The purpose of ANSI/AWWA B100 is to provide purchasers with a standard for the purchase and installation of granular filter material (filter material).

A wealth of information on innovations in filter design is available from various sources, including *Journal AWWA* and *Water Treatment Plant Design** and others in Appendix A. These sources include design parameters for filters using single and multiple media. As a result, ANSI/AWWA B100 makes reference to filter design only as the design relates to the filter materials used. ANSI/AWWA B604 Standard for Granular Activated Carbon should be consulted when using GAC as a filter medium, because GAC is not specifically covered in B100. NOTE: ANSI/AWWA Standard B604-96 describes GAC as a filter medium.

I.B. *History.* The AWWA Standard for Filtering Material was approved as tentative by the AWWA Board of Directors on Nov. 15, 1948, and as a standard on Jan. 16, 1950. Revisions were approved on June 2, 1953, Jan. 31, 1972, June 20, 1980, Jan. 29, 1989, and Dec. 1, 1996. The original standard was approved and promulgated in the course of activities of the Water Purification Division and under jurisdiction of the Committee on Water Works Practice. This edition was approved by the Board of Directors on June 17, 2001, and the standard title was changed from Filtering Material to Granular Filter Material.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for all direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AWWARF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

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* *Water Treatment Plant Design*, AWWA, ASCE, and CSSE, Denver, Colo. (1998).

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including:

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.

2. Specific policies of the state or local agency.

3. Two standards developed under the direction of NSF, ANSI†/NSF‡ 60, Drinking Water Treatment Chemicals—Health Effects, and ANSI/NSF 61, Drinking Water System Components—Health Effects.

4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex,*§ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with ANSI/NSF 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to ANSI/NSF 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

AWWA B100 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to:

1. Determine additives requirements, including applicable standards.

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*Persons in Canada, Mexico, and non-North American countries should contact the appropriate authority having jurisdiction.

† American National Standards Institute, 25 W. 43rd St., New York, NY 10036.

‡ NSF International, 789 N. Dixboro Rd., Ann Arbor, MI 48105.

§Both publications available from National Academy of Sciences, 2102 Constitution Ave. N.W., Washington, DC 20418.

2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.

3. Determine current information on product certification.

II. Special Issues.

II.A. *Source of Supply.* Filter material, such as silica sand, high-density sand, granular activated carbon, or anthracite, as well as support gravel, should be obtained from sources that are expressly qualified to produce and supply these materials for water treatment plants.

II.B. *Filter Media.* Filter media is the portion of the filter bed that removes particulate matter from the water during the filtration process. This standard describes anthracite, silica sand, and high-density sand. Properties of granular activated carbon when used as a filter medium are described in AWWA B604, Standard for Granular Activated Carbon. Properties of media used in precoat filters (such as diatomaceous earth) can be found in AWWA Standard B101. Synthetic media, such as ceramic media, is used in some filters but is not included in this standard.

Sand or anthracite filter media used in a wide range of bed depths and particle sizes have produced satisfactory results. Selection of the bed depth or particle size to be used in any particular filter is the responsibility of the designer and should be done with careful consideration of raw water conditions and plant pretreatment facilities.

In general, for a given pretreatment of raw water and at a given filtration rate, coarse media will permit longer filter runs between washings than fine media. With good pretreatment facilities and close technical control, coarse media will yield water of satisfactory quality. With all other conditions fixed, removal of particulate matter is a function of both media size and filter bed depth, and removal generally improves with greater filter depth or with smaller media size, or both.

Dual- or multiple-media filters have been used instead of single-medium filters in many water treatment applications. The dual or multiple media are selected to maintain coarse media in the upper portion of the bed and fine media in the lower portion of the bed. The coarse-to-fine grading tends to combine the longer filter runs characteristic of coarse media, with the superior filtration, characteristic of fine media, for improved overall performance. Proper selections of particle size range and specific gravity for the different layers of media are necessary to maintain the coarse-to-fine gradation during filtration and after repeated backwashing.

Granular activated carbon (GAC) is suitable for use as a filter medium either alone or as a dual media with sand. Long-term experience indicates that GAC performs effectively in a dual role as a filter medium and as an absorber for control of taste and odors. AWWA B604 provides information on the use of GAC as a filter medium including its properties, sampling, testing, shipping, placement, and preparation for service.

Where anthracite is used in dual- or multiple-media filters, the size of the anthracite depends on the size and specific gravity of the sand or other material used beneath the anthracite. If the anthracite grains are too small, excessive losses will be incurred during the minimum backwash required to clean the sand effectively. If the anthracite grains are too large, excessive mixing of the two materials will occur at the interface.

High-specific-gravity (high-density) filter media consisting of garnet, ilmenite, hematite, magnetite, or associated minerals of those ores are used by some utilities in an attempt to remove more suspended solids at higher filtration rates. This small, high-density media remains as a layer under the silica sand as a result of particle size and specific gravity differences in the same way that silica sand remains separated from overlaid coal in a dual-media filter. Some intermixing usually occurs at the interfaces between the layers.

Garnet refers to several different minerals (mostly almandite and andradite) that are silicates of iron, aluminum, and calcium mixtures. However, garnet could also be grossularite, spessartite, and uvarovite, the latter being a chromium mineral. Ilmenite is an iron titanium mineral, which invariably is associated with hematite and magnetite, both iron oxides.

Particle size distribution. There are two methods of classifying particle size distribution. Either method may be used. The first method assigns limiting sizes to stated percentages by weight. For example, 10 percent, by weight, of the total lot of filter media shall measure between *X* mm and *Y* mm; 60 percent shall measure between *A* mm and *B* mm; and 90 percent shall measure between *S* mm and *T* mm. Because sieves will not separate the media into fractions exactly equal to 10, 60, and 90 percent of the total weight, the sizes corresponding to the percentages must be interpolated from a plot of the percentage of sample passing each sieve against the separation size of that sieve. The plot should be made on log-probability paper or arithmetic graph paper.

The second method of classifying particle size distribution defines the percentage of media that shall be finer than a stated particle size. For example, the percentage of media finer than 0.4 mm shall be between *X* percent and *Y* percent of the total lot of filter media. By fixing percentages *X* and *Y* that correspond to the separation sizes of standard sieves, the results of a sieve analysis can be used directly without plotting.

In addition to classifying particle size distribution as described above, media gradation also may also be described in terms of effective size and uniformity coefficient as defined in Sec. 3.3 and Sec. 3.13 of AWWA B100, respectively. In 1892, Hazen found that the permeability of sand in a loose state correlates with the effective size and uniformity coefficient, and subsequent practice has indicated that these terms are useful for characterizing filter media gradations.

When specifying filter media size, the purchaser should use either (1) the effective size and uniformity coefficient *or* (2) one of the two methods of classifying particle size distribution previously discussed. Attempting to specify media size by both techniques may result in specifying a particle size distribution that cannot be attained by media producers.

Anthracite sizes. Effective sizes of anthracite generally range from a low of 0.6 mm to a high of 1.6 mm, and uniformity coefficients are generally 1.7 or lower.

Silica sand sizes. Effective sizes of silica sand generally range from a low of 0.35 mm to a high of 0.65 mm, and uniformity coefficients are generally 1.7 or lower.

High-density sand sizes. Effective sizes for high-density sand generally range from a low of 0.18 mm to a high of 0.60 mm, and uniformity coefficients are generally 2.2 or lower.

II.C. *Filter Gravel.* If the openings in the underdrain system are larger than the filter media, a system of supporting layers of gravel is required to prevent the filter media from entering and blocking the underdrain system and to help distribute backwash water evenly. The size and depth of the gravel layers must be selected to achieve both objectives and also ensure that the gravel will not be displaced by the rising wash water.

The following guidelines can be used to select the sizes and depths of gravel layers for a conventional gravel system.

The grains of each layer should be as uniform in size as possible, with the ratio of maximum particle size to minimum particle size not greater than 2. The minimum particle size of the top layer of fine gravel should be four to four-and-a-half times the effective size of the finest filter media to be retained. From layer to layer, the ratio of maximum particle size of the coarser layer should not be greater than four times the minimum particle size of the finer layer. The gravel of the bottom layer should be coarse enough to prevent its displacement by the jets of air or water emerging from the orifices of the underdrain system. The minimum particle size of the lowest layer should be at least two times the size of the underdrain openings.

The thickness of each layer of gravel should be at least three times the maximum particle size of the gravel in the layer, but not less than 3 in. in any case, except for gravel larger than 1 in. in which case the supplier of the underdrain should establish the layer thickness. In the case of irregular underdrain bottoms, such as pipe laterals, the lowest layer should completely surround or cover the underdrain to provide a uniform upper gravel surface on which the next gravel layer is placed.

Many combinations of gravel size and layer thickness have been used. Table F.1 describes two typical series of gravel layers that generally meet the guidelines stipulated above. The top layer gradation is controlled by the fine filter-media size to be retained, and the bottom layer gradation is controlled by the underdrain orifice sizes. The examples use commercially available gravel sizes indicated by their ASTM E11 sieve designations.

In some designs, a high-density filter gravel is used as a replacement for, or in addition to, the top layer in the gravel system to give added stability to the gravel system during backwashing. The range in size and thickness of the high-density filter gravel layer must be closely coordinated with the other gravel layers and the overlying media. Generally, at least 92 percent by weight shall pass through a No. 4 sieve and no more than 8 percent by dry weight shall pass through a No. 10 sieve. The layer thickness normally ranges between 2 in. and 4 in.

For triple media filters with a layer of high-density sand, an additional layer of high-density gravel may be required to satisfy the 4 to 4½ ratio between the media effective size and the top gravel layer.

For special applications, high-density gravels are available for all layers. These applications are not described in this standard.

Special provisions are required when air scour delivered through the gravel layers is used to assist the backwashing. These special provisions are not described in this standard.

Table F.1 Gravel layers for two sizes of fine filter media and two sizes of underdrain orifices*

Gravel Layers From Top to Bottom	Fine Filter Media Effective Size 0.40 mm–0.50 mm Underdrain Orifice Size 6.35 mm (0.25 in.)		Fine Filter Media Effective Size 0.50 mm–0.60 mm Underdrain Orifice Size 12.7 mm (0.5 in.)	
	Gradation of Gravel†	Thickness of Layer	Graduation	Thickness
1st‡	3.35 mm–1.70 mm (No. 6–No. 12)	76 mm (3 in.)	4.75 mm–2.36 mm (No. 4–No. 8)	76 mm (3 in.)
2nd	6.3 mm–3.35 mm (1/4 in.–No. 6)	76 mm (3 in.)	9.5mm–4.75 mm (3/8 in.–No. 4)	76 mm (3 in.)
3rd	12.5 mm–6.3 mm (1/2 in.–1/4 in.)	76 mm (3 in.)	19.0 mm–9.5 mm (3/4 in.–3/8 in.)	76 mm (3 in.)
4th	25.0 mm–16.0 mm (1 in.–5/8 in.)§	76 mm–102 mm (3 in.–4 in.)	37.5 mm–19.0 mm (1½ in.–3/4 in.)	76 mm–127 mm (3 in.–5 in.)
5th	None		63 mm–37.5 mm (2½ in.–1½ in.)	127 mm–203 mm (5 in.–8 in.)

* These examples do not apply when air scour is delivered through the gravel layers.

† Standard sieve sizes from ASTM E11 (Standard designation and alternative designation. See Table B.1, column 1, subcolumns 1 and 2.)

‡ This layer may be replaced or supplemented by high-density gravel. Gradation and thickness of layer must be coordinated with the other gravel layers and the filter media.

§ ¾-in. to ½-in. size may be considered as an alternate.

II.D. *Acid Solubility.* An acid-solubility test is included in this standard to provide a means of measuring acid-soluble minerals or other impurities that may be present in the filter material. The limits for acid solubility given in this standard are based on tests of filter material with proven performances in a wide range of water treatment applications. Acid-solubility limits are necessary to ensure against substantial quantities of detrimental minerals or other substances in the filter material and also to ensure against substantial solution of filter material in acidic waters or during an acid cleaning. In many cases, the principal acid-soluble impurity in filter silica sand and gravel is calcium carbonate (limestone).

II.E. *Anthracite Quality Tests.* Based on some utility experiences of high anthracite loss during use in filters and the problem with Mohs' scale of hardness not accurately defining the hardness of coal, the committee during the 1996 revision period investigated other abrasion tests. Samples of anthracite (new and used, soft and hard, good and poor performing) were subjected to a battery of tests for abrasion (Mohs' scale of hardness, paint shaker friability, and Hardgroves Grindability Index [HGI]). These data were correlated to other characteristics (volatiles, ash, carbon content). The committee also arranged for presentations by a major filter equipment supplier who extensively studied various sources of anthracite, and an anthracite expert who had significant experience specifying anthracite for other industries. Both outside experts concluded that HGI and the other above-mentioned characteristics were also valuable in defining a high-quality coal.

Despite the consensus on the value of these new parameters, the committee could not agree with changing the standard at that time because more data needed to be obtained. The committee was also concerned that many current coal suppliers might not be able to meet the new standard, and, therefore, supply to the entire water industry might be jeopardized. With more data, the committee believed precise limits for new parameters might be obtainable. Therefore, discussion of these new anthracite characteristics were confined to the foreword only. Users of anthracite were encouraged to immediately request data on the following anthracite characteristics from their suppliers: HGI, percent volatiles (dry ash-free), ash percent (dry), carbon percent, and washability characteristic (percent material with specific gravity below 1.4 and percent material with specific gravity above 1.95).

These new characteristics can be tested by using the following:

ASTM D409—Standard Test Method for Grindability of Coal by the Hardgrove-Machine Method.

ASTM D3174—Test Method for Ash in the Analysis Sample of Coal and Coke.

ASTM D3175—Test Method for Volatile Matter in the Analysis Sample of Coal and Coke.

ASTM C123—Test Method for Light Particles in Aggregate.

Since the 1996 revision, the committee surveyed over 100 of the largest water utilities in the United States to determine if there is a performance problem related to anthracite quality. Sixty-six percent said they had "capped" or added anthracite coal to their filters. The majority of these utilities reported that loss of anthracite coal was caused primarily by operational problems. Excessive backwash flow rate, backwashing in combination with air or surface wash, and uncontrolled entrained air were common causes for loss of anthracite media. The committee recommends that all operators monitor, check, and record excessive flow rates, loss of anthracite during air or surface wash, and uncontrolled air when they occur during filter backwashing. Manual backwash sequences also should be checked to ensure that all operators are familiar with the current backwash methods and flow rates. If excessive flow rates, loss of anthracite during air or surface wash, and uncontrolled air are found, the operator should rectify the situation to reduce loss of anthracite media.

Eight utilities reported that loss of anthracite was caused by the quality of the anthracite coal or anthracite fractures/abrasions. Most of the filter beds were in service more than 10 years. During 1999, the anthracite subcommittee searched for a better method to evaluate abrasion of anthracite. Several possibilities were investigated, but either they did not relate to use in a water filter, or there was no laboratory prepared to conduct the test. The subcommittee will continue the search to find an appropriate abrasion test.

The committee continues to strongly urge users to request HGI, percent volatiles (dry ash-free), ash percent (dry), carbon percent, and washability characteristics (percent material with specific gravity below 1.4 and percent material with specific gravity above 1.95) as well as the other parameters stated in the standard. With data now becoming available since the 1996 revision, plus additional data according to this revision, the committee should have sufficient data to determine what range in values, if any, of the above parameters might establish high-quality anthracite coal for filters.

II.F. *Bulk Shipment.* The issue of protecting filter material from contamination during shipment is addressed in this standard.

Bulk shipment is not recommended; however, when trucks or rail cars are specified for hauling a bulk shipment of filter material, it is recommended that an impermeable plastic liner be used because these trucks or rail cars may be contaminated from hauling previous bulk material.

Vibration during transit will result in segregation of the filter material, with the coarser material migrating toward the top. If one compartment of the bulk shipment is divided between two or more filters or filter halves, their media is likely to have different size gradations and consequently perform differently. Therefore, if bulk shipment is allowed, the container should be required to be compartmentalized so that each compartment fills no more than one filter cell. If it is specified, representative filter media samples for analysis can be obtained at the point of production or loading. If the purchaser requires sampling at the point of installation, this requirement should be stated in the specifications.

II.G. *Media Records.* Users are encouraged to maintain records of the physical characteristics and chemical composition of all filter material installed in filters. For limits on undesirable impurities, refer to NSF Standard No. 61 and Sec. I.C in the foreword.

II.H. *Removal of Filter Material and Reuse.* Occasionally, there are times, such as a blown filter or an underdrain or header-lateral distribution system problem, when filter material has to be removed from the filter cell and either replaced or reused. Unless the filter material is new or found by visual inspection to be in near original condition, reuse is not encouraged because the material will be worn to some degree, could be coated, could be damaged or contaminated during handling, and could create potential filtering problems if not properly combined with new material to obtain a desired gradation. In addition, removed material could be installed in another filter plant without proper investigation of process and filter gradation requirements.

Removal may be performed hydraulically or by hand. Extreme care must be taken not to damage filter cell components such as the underdrain or header lateral system. If any component is damaged, it should be replaced immediately. If the filter material is to be replaced, it should be disposed of at an approved site. If the filter material is to be reused, extreme care must be taken not to damage or contaminate it. The filter material should be stored in clean containers or on clean reinforced impervious tarpaulins which have not been used for any other purpose. The containers or tarpaulins shall then be covered with a durable opaque material to protect the filter material from the weather and air pollution. If any filter material becomes contaminated, it shall be replaced or cleaned to the user's satisfaction.

Prior to reuse, gravel should be sieved to its original gradations. Filter media components (high-density sand, silica sand, or anthracite) will be intermixed and should be separated through sieving or other approved methods. A small quantity of the filter media may still remain intermixed but should restratify during backwashing. Any additional high-density sand and silica sand required should have the same sizing characteristics as the originally specified sands. Anthracite to be reused should have representative samples taken and tested to determine its uniformity coefficient and effective size so that any additional anthracite required can be properly sized to provide a combined anthracite bed meeting original specifications.

Placement of the filter material in the filter cell, backwashing, and disinfection should be in accordance with procedures stated in this standard. Reuse of GAC does not apply to this standard. See AWWA B604, Granulated Activated Carbon for its reuse requirements

II.I. *Possible Adverse Effects on Submerged Concrete Walls in Filter Box.* Aggressive waters have been identified as being responsible for attacking submerged surfaces of concrete structures. The filter backwashing process may be responsible for accelerating this action by removing loose or softened materials at the surface of the concrete in filter boxes. The engineer may want to evaluate the need to provide a protective coating on submerged surfaces of concrete based on the quality of the water being filtered.

III. Use of This Standard. AWWA has no responsibility for the suitability or compatibility of the provisions of this standard to any intended application by any user. Accordingly, each user of this standard is responsible for determining that the standard's provisions are suitable for and compatible with that user's intended application.

III.A. *Purchaser Options and Alternatives.* The following items should be covered in the purchaser's specifications:

1. Standard used—that is, ANSI/AWWA B100, Standard for Granular Filter Material, of latest revision.
2. Method of measurement and payment, and whether this project covers providing filter material only, or providing and placement of the materials and preparation for service.
3. Method of disinfecting (Sec. 4.5.3) and who will perform the disinfection procedure.
4. Whether an affidavit of compliance is required or whether the purchaser will select a representative to inspect supply for compliance with this standard.
5. Whether representative approval samples are required before shipment (Sec. 5.1) or in-place (Sec. 4.5.2.4).
6. Sizes, types, and characteristics of filter material required and quantities of each (foreword II.B and II.C, Sec. 4.1.1, and Sec. 4.1.2). If the supplier, manufacturer, or constructor is to be held responsible for meeting a specification regarding particle size for filter media in-place, the specifications should require that the supplier, manufacturer, or constructor supervise the transportation, handling, on-site storage, placement, and field preparation of the filter media for sampling. This includes all backwashing of filter media prior to sampling.
7. Method of placing the material, if there is a preference (Sec. 4.4.2).
8. Method of checking elevation of top surface of each layer, if there is a preference (Sec. 4.4.2.5).

III.B. *Modification to Standard.* Any modification to the provisions, definition, or terminology in this standard must be provided in the purchaser's specifications.

IV. Major Revisions. Major revisions made to the standard in this edition include the following:

1. Changed standard title to Granular Filter Material.
2. Addition of paragraph to Sec. II.C, Filter Gravel in the foreword related to triple media filters.
3. Revision of Table F-1 in the foreword.
4. Updated investigation into potentially new anthracite standard, Sec. II.E, Anthracite Quality Tests in the foreword.
5. Addition of Sec. II.H, Removal of Filter Material and Reuse, in the foreword.
6. Addition of Sec. II.I, Possible Adverse Effects on Submerged Concrete Walls in Filter Box in the foreword.
7. Addition of five definitions to Sec. 3, Definitions.
8. Additions and revisions to anthracite, silica sand, and high-density sand in Sec. 4.1, Physical Requirements.
9. Addition of detail in Sec. 4.4, Placing Filter Material.
10. Replacement of maximum backwash rates with fluidization backwash rates in Sec. 4.5, Preparing Filter for Service.
11. Addition of new Sec. 4.6, Replenishing Filter Media in Existing Filter Bed.
12. Addition of lot size definition and jobsite sampling procedures in Sec. 5.2, Sampling.
13. Addition of test procedure in Sec. 5.3.5, Mohs' scale of hardness.
14. Replacement of Appendix A, Bibliography with updated bibliography.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer & Technical Support Group, (303) 794-7711 Ext. 6283, FAX (303) 794-6303, or write to the group at 6666 W. Quincy Ave., Denver, Colorado 80235.

American Water Works Association

ANSI/AWWA B100-01
(Revision of ANSI/AWWA B100-96)

AWWA STANDARD FOR

GRANULAR FILTER MATERIAL

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes gravel, high-density gravel, silica sand, high-density media, anthracite filter materials, and the placement of the materials in filters for water supply service application. ANSI/AWWA B604 Standard for Granular Activated Carbon addresses use of GAC as a filter medium and as an adsorbent.

Sec. 1.2 Purpose

The purpose of this standard is to provide purchasers with a standard for purchasing and installing granular filter material (filter material) and is not a guide for filter design.

Sec. 1.3 Application

This standard can be referenced in specifications for purchasing and receiving filter material and can be used as a guide for testing the physical and chemical properties of filter material samples. The stipulations of this standard apply when this document has been referenced and only to filter materials used in the treatment of drinking water supplies.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, these documents form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

ASTM* C40—Test Method for Organic Impurities in Fine Aggregates for Concrete.

ASTM C117—Test Method for Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing.

ASTM C123—Test Method for Lightweight Particles in Aggregate.

ASTM C127—Test Method for Specific Gravity and Absorption of Coarse Aggregate.

ASTM C128—Test Method for Specific Gravity and Absorption of Fine Aggregate.

ASTM C136—Test Method for Sieve Analysis of Fine and Coarse Aggregates.

ASTM C702—Standard Practice for Reducing Samples of Aggregate to Testing Size.

ASTM D75—Practice for Sampling Aggregates.

ASTM E11—Standard Specification for Wire Cloth and Sieves for Testing Purposes.

MIL-STD-105D (1963)—Sampling Procedures for Inspection by Attributes.

AWWA C653—Standard for Disinfection of Water Treatment Plants.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Bag*: A plastic, paper, or woven container generally containing approximately 1 ft^3 or less of filter material.

2. *Constructor*: The party that provides the work and materials for placement or installation.

3. *Effective size*: The size opening that will just pass 10 percent (by dry weight) of a representative sample of the filter material; that is, if the size distribution of the particles is such that 10 percent (by dry weight) of a sample is finer than 0.45 mm, the filter material has an effective size of 0.45 mm.

4. *Filter bed:* One or more layers of filter media plus any supporting gravel layers, if used, that are installed in the filter cell.

* American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

5. *Filter gravel:* One or more layers of granular material of defined size gradation used to support the filter media when the openings in the underdrain system are larger than the filter media and to help distribute backwash water evenly across the filter bed.

6. *Filter material:* Granular materials used for filter media and supporting gravel systems in deep bed filters for water treatment.

7. *Filter media:* The high-density sand (if provided), silica sand, and anthracite portion of the filter bed that removes particulate matter from the water during the filtration process.

8. *Manufacturer*: The party that manufactures, fabricates, or produces materials or products.

9. *Particle size:* Various sizes and dimension range descriptions of the grains of a particular filter material determined by standard sieve analysis procedures.

10. *Purchaser*: The person, company, or organization that purchases any materials or work to be performed.

11. *Semibulk container*: A large plastic or woven bulk container generally containing approximately 1 ton or more of filter material. These are commonly referred to as sacks.

12. *Supplier*: The party that supplies materials or services. A supplier may or may not be the manufacturer.

13. *Uniformity coefficient*: A ratio calculated as the size opening that will just pass 60 percent (by dry weight) of a representative sample of the filter material divided by the size opening that will just pass 10 percent (by dry weight) of the same sample.

SECTION 4: REQUIREMENTS

Sec. 4.1 Physical Requirements

4.1.1 *Filter media.*

4.1.1.1 Anthracite.

1. Filter anthracite shall consist of hard, durable anthracite coal particles of various sizes. Blending of non-anthracite material to meet any portion of this standard is not acceptable.

2. The anthracite shall have a Mohs' scale of hardness greater than 2.7, and specific gravity and acid solubility as indicated in Table 1.

Table 1 Specific gravity and acid solubility levels for filter media

	Characteristics	
Filter Media	Specific Gravity	Acid Solubility %
Anthracite*	> 1.4	< 5
Silica sand	> 2.5	< 5
High-density sand	> 3.8	< 5

*See foreword for suggestions on additional anthracite tests.

3. The anthracite shall be visibly free of shale, clay, and other extraneous debris.

NOTE: Testing for shale, clay, and other extraneous debris is normally not necessary. However, if deleterious materials are noticeable, the anthracite shall be within the following limits: (1) a maximum of 1.0 percent minus No. 200 (0.074 mm) material by washing, as determined by ASTM C117; and (2) a maximum of 0.5 percent of organic impurities, such as wood timber, roots or twigs, as determined by ASTM C123 for lightweight pieces in aggregate (except use dry basis not saturated surface dry and remove the float immediately) using a liquid with a 1.0 specific gravity.

4.1.1.2 Silica sand.

1. Silica sand shall consist of hard, durable, and dense grains of at least 85 percent siliceous material that will resist degradation during handling and use.

2. The silica sand shall have specific gravity and acid solubility as indicated in Table 1.

3. The silica sand shall be visibly free of clay, dust, and micaceous and organic matter.

4.1.1.3 High-density sand.

1. High-density sand shall consist of hard, durable, and dense grain garnet, ilmenite, hematite, magnetite, or associated minerals of those ores that will resist degradation during handling and use and shall be made up of at least 95 percent of the associated material with a specific gravity of 3.80 or higher.

2. The high-density media shall have specific gravity and acid solubility as indicated in Table 1.

3. The high-density sand shall be visibly free of clay, dust, and micaceous and organic matter.

NOTE: Testing for clay, dust, and micaceous and organic matter is normally not necessary. However, if deleterious materials are noticeable, the media shall be within the following limits: (1) a maximum of 2 percent minus No. 200 (0.074 mm) material by washing, as determined by ASTM C117; and (2) a color not darker than the standard color in ASTM C40 for organic impurities in fine aggregate.

4.1.1.4 Media size.

1. The media size is commonly specified in terms of effective size (ES) and uniformity coefficient (UC) or in terms of particle size range. Only one of the following shall be used:

a. The effective size, as defined in Sec. 3.3, and the uniformity coefficient, as described in Sec. 3.13, shall be as specified by the purchaser.

b. The particle size range, including allowable percentage, by weight, of undersize and oversize particles, shall be as specified by the purchaser. The size range shall state the 90 percent, 60 percent, and 10 percent sizes passing by dry weight or other information pertinent to special applications.

4.1.2 *Filter gravel.*

4.1.2.1 Silica gravel.

NOTE: Testing for clay, shale, or organic impurities is normally not necessary. However, but if deleterious materials are noticeable, the gravel shall be within the following limits: (1) a maximum of 1.0 percent minus No. 200 (0.074 mm) material by washing, as determined by ASTM C117; and (2) a maximum of 0.5 percent coal, lignite, and other organic impurities, such as roots or twigs, as determined by ASTM C123 for lightweight pieces in aggregate using a liquid with a 2.0 specific gravity.

1. Silica gravel shall consist of coarse aggregate in which a high proportion of the particles are round or equidimensional in shape. It shall possess sufficient strength and hardness to resist degradation during handling and use, be substantially free of deleterious materials, and exceed the minimum specific gravity requirement.

2. Silica gravel shall have a saturated-surface-dry specific gravity of not less than 2.5, unless a higher minimum specific gravity requirement is specified to meet a design requirement for a particular layer or filter.

3. Not more than 25 percent by dry weight of the particles shall have more than one fractured face (Sec. 5.3.2).

4. Not more than 2 percent by dry weight of the particles shall be flat or elongated to the extent that the longest axis of a circumscribing rectangular prism exceeds five times the shortest axis (Sec. 5.3.2).

5. The silica gravel shall be visibly free of clay, shale, or organic impurities.

4.1.2.2 High-density filter gravel.

1. High-density filter gravel shall be a coarse aggregate consisting of garnet, ilmenite, hematite, magnetite, or associated minerals of those ores in which a high proportion of the particles are either round or equidimensional in shape. It shall possess sufficient strength and hardness to resist degradation during handling and use, be substantially free of deleterious materials, and exceed the minimum density requirement.

2. High-density filter gravel shall have a specific gravity of not less than 3.8, meaning that at least 95 percent of the material shall have a specific gravity of 3.8 or higher.

3. Not more than 2 percent by dry weight of the particles shall be flat or elongated to the extent that the longest axis of a circumscribing rectangular prism exceeds five times the shortest axis (Sec. 5.3.2).

4. The high-density gravel shall be visibly free of clay, shale, or organic impurities.

4.1.2.3 Gravel size. Filter gravel shall be provided in the particle size ranges stated in the purchaser's specification. For each size range of gravel specified, not more than 8 percent by dry weight shall be finer than the lowest designated size limit, and a minimum of 92 percent by dry weight shall be finer than the highest designated size limit.

4.1.2.4 Acid solubility. Acid solubility shall not exceed 5 percent for sizes smaller than No. 8 (2.36 mm), 17.5 percent for sizes larger than No. 8 (2.36 mm) but smaller than 25.4 mm (1 in.) and 25 percent for sizes 25.4 mm (1 in.) and larger. If gravels contain materials larger and smaller than the specified size, and if the total sample does not meet the specified solubility limit for the smaller material, the gravel shall be separated into two portions and the acid solubility of each portion must meet the appropriate designated percent solubility.

Sec. 4.2 Chemical Requirements

This standard has no applicable information for this section.

Sec. 4.3 Impurities

The granular filter material supplied according to this standard shall contain no substances in quantities capable of producing deleterious or injurious effects on the health of those consuming water that has been properly treated with granular filter material. Refer to the acceptance section (Sec. I.C) in the foreword.

Sec. 4.4 Placing Filter Material

4.4.1 *Preparing filter cell.* Filter cells shall be prepared according to the following procedures:

4.4.1.1 Cleaning and examining filter cell. Each filter cell shall be cleaned and examined thoroughly before any filter material is placed. All debris, dirt, dust, and any other foreign substance shall be removed from the underdrain plenum, which may need to be vacuumed, filter underdrain system, piping, wash water troughs, walls and any other filter cell component. Each cell shall be kept clean throughout placement operations. After cleaning, the underdrain system, wash water troughs, and any air or surface wash piping shall be checked to ensure they are level within specifications, undamaged, and complete. All underdrain grout shall be in place, cured, and free of defects. All deficiencies shall be corrected prior to any placement of filter material.

4.4.1.2 Testing of new filter cell prior to placing filter material. In new filter construction, the placement of filter material should only follow after operational testing of the backwash system, including air or surface wash systems if applicable, and assurance that the filter box is watertight. See Table 2 for appropriate fluidization backwash rates.

4.4.1.3 Marking each layer. Before any filter material is placed, the top elevation of each layer shall be marked by a level line on the inside of the filter cell.

4.4.1.4 Storing and handling materials. Filter materials shall be kept clean. If material cannot be placed immediately into the filter cell, the bulk materials shall be stored on a clean, hard, dry surface and covered at the water utility site to prevent contamination. Materials shipped in bags or semibulk containers shall be covered with a durable opaque material to block sunlight and to provide protection from weather. Bags and semibulk containers shall be stored on pallets or dunnage. Each size and type of filter material shall be stored separately. When material is shipped in bags or semibulk containers, under no circumstance shall the material be removed from the bags or semibulk containers before placement in the filter, except for

Table 2 Appropriate fluidization backwash rates

Water Temperature		Fluidization Backwash Rate, *gpm/ft*^{2}	
		Sand	Anthracite Coal
°C	(°F)	($d_{60\%}$ size of 0.7 *mm*)	($d_{60\%}$ size of 1.5 *mm*)
5	41	12	15
10	50	13.5	16.5
15	59	15	18
20	68	16.5	20
25	77	18	22
30	86	20	24

Note: These fluidization backwash rates are guidelines for media with a grain size of $d_{60\%}$ (effective size × uniformity coefficient). The specific gravities are: sand = 2.65 and anthracite coal = 1.65. The rates should be adjusted as necessary for other filter materials. The appropriate fluidization backwash rate should be that which fluidizes the bed with adequate expansion and attains sufficient velocities to bring fines to the surface. Fluidization is defined as the upward flow of a fluid through a granular bed at sufficient velocity to suspend the grains in the fluid and depends on filter media properties, backwash water temperature, and backwash water flow rates.

sampling. Any filter material that becomes contaminated by contact with dirt or any other foreign substance shall be removed from the project site and replaced or if approved by the utility owner, completely cleaned of the contaminant prior to placement.

4.4.2 *Placing filter material.*

4.4.2.1 Placement caution. The bottom layer of gravel shall be carefully placed to avoid damaging the filter underdrain system. Workers shall not stand or walk directly on the filter gravel and media. They shall walk on boards or plywood that will support their weight without displacing the material. The same care should be taken when an air wash system is installed above the gravel.

4.4.2.2 Placing layers. Each layer shall be completed before the layer above it is started. Each layer of filter material shall be deposited to a uniform thickness and screeded level. Care shall be exercised in placing each layer to avoid disturbing the integrity of the layer beneath.

For deep bed anthracite filters, it is recommended that placement be performed in lifts not to exceed 3 feet. Each lift should be backwashed and scraped and sampled, if required, prior to placement of the next lift.

4.4.2.3 Alternate method of placement. Bulk materials may be placed dry by using a chute or conveyer to discharge the materials onto a platform from which they may be distributed with a hand shovel. Vertical dropping of the material on the platform is unacceptable, as it may damage the material. Alternatively, bulk materials may be placed hydraulically by pump or ejector. In all cases, care shall be taken not to damage the underdrain system.

For filter sand or anthracite placed using the wet method, the materials shall be added through the water and then backwashed for leveling. Pneumatic handling of anthracite is not recommended.

4.4.2.4 Placing material from bags or semibulk containers. When filter material is shipped in bags or semibulk containers and hydraulic placement is not used, the bags or semibulk containers shall be placed in the filter and the material distributed directly from them. (Caution: Do not disturb any layers already in place.) For the top filter media layer, only 90 percent of its intended depth should be added, then the initial backwashing and scraping shall proceed. Following this, the additional 10 percent or whatever is necessary to reach the finished elevation shall be added.

4.4.2.5 Layer elevation. The elevation of the top surface of each layer shall be checked by filling the filter with water to the level line previously marked on the inside of the filter cell. Filter material shall be 0.5± in. of the water surface, with the area of material above and below the water surface within 10 percent of each other.

4.4.2.6 Washing gravel layer. After all filter gravel is placed and before any filter sand or anthracite is placed, the filter should be washed for 5 min at the maximum available rate, not to exceed 25 gpm/ft^2 of filter area. Ramping up to the maximum wash rate should take place over at least a 3-min period. Care shall be taken not to disturb the graded gravel, especially if air is present in the underdrain. Any gravel that becomes disturbed by the wash shall be removed and replaced with clean material of the proper type and size.

4.4.2.7 Washing other material. With a dual- or multiple-media filter bed, each material shall be washed and scraped using procedures similar to Sec. 4.5 or as the purchaser requires to remove excess fine materials before the next material is installed.

4.4.3 *Top Surface Elevation.* The top surface of the filter media after initial washing (Sec. 4.5.1.1) shall have an elevation equal to the finished elevation plus the thickness of material to be removed by scraping.

4.4.4 *Contamination.* Any filter material that becomes contaminated after placement shall be removed and replaced with clean material of the proper type and size.

Sec. 4.5 Preparing Filter for Service

4.5.1 *Washing.*

4.5.1.1 Initial wash. After all filter materials have been placed, wash water shall be admitted slowly upward through the underdrain system until the entire bed is flooded. The bed shall be allowed to stand for as long a period as the purchaser requires to saturate the filter material before initial wash. This period shall not be less than 12 hr if the bed has been installed dry or allowed to stand dry. The wash rate shall be increased gradually during the initial wash to remove air from the bed.

4.5.1.2 Backwash rate. During each backwash, the water shall be applied at an initial rate of not more than 2 gpm/ft^2 of filter area. The backwash rate shall then be increased gradually over a period of 3 min to the rate that achieves fluidization and maintained at that rate for not less than 5 min. Table 2 presents fluidization backwash rate guidelines for a commonly used filter media. As noted, these rates need adjustment for other size filter media. The filter media producer and underdrain manufacturer should be consulted for these rates. If an air wash system is provided, it should be employed in accordance with the filter underdrain system manufacturer's recommendations.

4.5.2 *Scraping.* After the initial wash, the filter shall be partially drained and a layer of fine material approximately $^3/_{16}$-in. thick shall be removed from the surface of the filter by scraping.

4.5.2.1 Repetitions. The scraping operation shall be repeated as many times as necessary to remove all fine material (these fines will be visible, giving a smooth appearance rather than the desired rough surface texture), to remove all organic particles, such as wood, timber, roots, and twigs, and, in addition in the case of anthracite, to remove all flat particles.

4.5.2.2 Number of washes. The filter bed shall be washed at least three times between scrapings. Each wash shall last at least 5 min and shall be at an appropriate rate as listed in Table 2 or recommended by the filter media producer and underdrain manufacturer.

4.5.2.3 Additional filter media. If additional filter media is required to bring the top surface of the filter to the specified finished elevation, sufficient filter media shall be added before the final scraping operation. Adequate filter media shall be added to anticipate the final scraping.

4.5.2.4 In-place filter media sampling and testing. If in-place samples of filter media are required by the purchaser, composite samples shall be prepared from a minimum of four filters after they have been backwashed and drained. For deep bed anthracite filters placed in lifts, the samples should be taken at the same filter bed locations after each lift is backwashed and scraped because of the difficulty in taking a deep bed sample. Core samples shall be taken using a 2-in. diameter core sampler. It shall be inserted to the elevation just above the gravel interface and subsequent lift interface for deep bed anthracite filters, and then removed by excavating around it in order to extract a complete profile of material above that elevation. Composite samples of each type of filter media (i.e., anthracite, silica sand, and high-density sand if installed) taken from each filter shall be prepared by combining equal portions of that particular media taken from a minimum of five cores distributed over each media filter surface.

1. Sample preparation. Upon receipt of the samples, the laboratory shall prepare them in the following manner:

a. Place 0.25 L to 0.5 L of filter media sample into a 1-L or 1-gal bottle.

b. Fill the bottle to within 1 in. of the top with clean water.

c. Place cap on bottle and shake for 2 min using two or three forward and backward motions per second.

d. Allow the filter media to settle, then decant the supernatant liquid into a clean container.

e. Repeat steps b through d until supernatant is clean.

f. If coal or granular activated carbon is used as the top layer, then separate that filter media from the sand by using the technique described in ASTM D4371.

2. Testing. Test samples in accordance with Sec. 5.3.

4.5.3 *Disinfecting.* After all work related to placement of filter media has been completed, and before the filter is placed in service, the entire filter shall be disinfected by chlorination in accordance with ANSI/AWWA C653, unless specified otherwise in the purchaser's specifications. The procedure for disinfection of granular activated carbon is stipulated in ANSI/AWWA B604.

Sec. 4.6 Replenishing Filter Media in Existing Filter Bed

4.6.1 *Sampling and testing.* Prior to replenishing lost filter media in a filter bed(s), the full depth of the top layer of the filter media shall be sampled and tested in accordance with Sec. 4.5.2.4 to determine its effective size and uniformity coefficient.

4.6.2 *New filter media sizing.* New filter media effective size and uniformity coefficient shall be determined by the media producer taking into account the following:

1. Volume of existing top layer of filter media.
2. Volume of filter bed that must be replenished.
3. Effective size and uniformity coefficient of existing top layer of filter media.
4. Effective size and uniformity coefficient of original specified top layer of filter media or new specifications, if appropriate.

4.6.3 *Placement of filter media.* The new filter media shall be placed on top of the existing filter bed in accordance with applicable sections in Sec. 4.4 and then backwashed and scraped at least two times in accordance with Sec. 4.5. If in-place sampling is required to verify the final top layer of filter media effective size and uniformity coefficient, it shall be performed after the last backwash and scraping in accordance with Sec. 4.5.2.4.

4.6.4 *Disinfection.* Prior to placing the filter cell back into service, the filter cell shall be disinfected in accordance with Sec. 4.5.3.

SECTION 5: VERIFICATION

Sec. 5.1 Approval Samples

When specified, a representative sample of each size of filter material shall be submitted for approval before shipment. The sample shall be submitted in clean, dust-tight containers plainly marked with the name and address of the supplier and the size or grade of the contents. After approval of the samples, shipments shall be of a quality equal to the sample. Site samples shall meet the requirements of Sec. 5.2.

Sec. 5.2 Sampling

Sampling of filter material shall be performed in accordance with ASTM D75 as modified and supplemented herein. The size of the composite samples shall be as indicated in Table 3.

5.2.1. *Bulk shipments.* Bulk shipments are not recommended (see foreword). If, however, bulk shipment is required, representative filter material samples shall be obtained at either the production or loading point. When a truck or rail car is filled at the production site, sampling across the cross section of flow of the material being loaded is recommended. The composite sample shall be prepared in accordance with Sec. 5.2.4, with the weight of the sample as stated in Table 3. When filling at a loading site, the composite sample shall be taken as each rail car or truck is filled. It is not recommended that filter materials be sampled on receipt at the job site because of segregation during shipment. However, if the purchaser specifies sampling on receipt, samples shall be taken from 10 locations in the rail car or truck. The rail car or truck shall be sampled near, but not in, each corner, at the center, and at five other random locations.

5.2.2 *Bag shipments.* While bags are being filled at the production site, sampling across the cross section of the material being loaded for each lot is recommended. When filter material is shipped to the job site in bags and job site sampling is required in addition to production site samplings, representative samples for each lot shall be collected using a core sampler prior to placement in the filter. The representative samples from each sampled bag in a lot shall be combined to produce the required composite sample for the lot. The minimum size of the composite sample is stated in Table 3. The number of bags to be sampled per lot and the definition of a lot are indicated in Table 4. If possible, all bags for a filter shall come from one production lot.

5.2.3 *Semibulk container shipments.* While semibulk containers are filled at the production site, sampling across the cross section of the material being loaded is recommended. The composite sample shall be prepared in accordance with Sec. 5.2.4 with the weight of the sample as indicated in Table 3. The number of semibulk containers to be sampled during a lot filling shall be as indicated in Table 4.

5.2.3.1 Job site sampling of filter material shipped in semi-bulk containers. When job site sampling is required in addition to production site sampling, the filter material shall be sampled upon arrival at the job site and before

Table 3 Minimum size of composite sample

Maximum Size of Particle in Sample		Minimum Sample Size	
mm	*(in.)*	*kg*	*(lb)*
63.0	(2½)	45.0	(100)
37.5	(1½)	32.0	(70)
25.4	(1)	23.0	(50)
19.0	(¾)	14.0	(30)
12.5	(½)	9.0	(20)
9.5	(⅜) and smaller	4.5	(10)

Table 4 Sampling of bagged filter material*

Lot Size† (number of bags)	Minimum Sample Sizes (number of bags)
2 – 8	2
9 – 15	3
16 – 25	5
26 – 50	8
51 – 90	13
91 – 150	20
151 – 280	32
281 – 500	50
501 – 1,200	80
1,201 – 3,200	125
3,201 – 10,000	200
10,001 – 35,000	315
35,001 – 150,000	500

*Refer to Military Standard MIL-STD-105D (1963).
†Lot size at the producers plant is the number of bags produced in a batch. Lot size at the job site is the number of bags of a particular production batch delivered to the project site.

placement in the filter by either the method described in Sec. 5.2.3.1.1 or in Sec. 5.2.3.1.2. The composite sample for each lot shall be prepared in accordance with Sec. 5.2.4 with weight of the sample as indicated in Table 3. The number of bags to be individually sampled shall be in accordance with Table 4. If possible, all bags for a filter shall come from one production lot.

5.2.3.1.1 The expedient method of obtaining samples upon delivery is normally sufficient for filter media size verification. It requires that a “thief” be made using approximately 2-in. thin-walled tubing approximately 48-in. long or a brass seed sampler consisting of two nested tubes, which contain slotted openings. First, the top of the sack is opened and 2 in. of material is pushed to the outside forming a depression in the center. The “thief” or brass seed sampler is then pushed into the center as far as possible and extracted with the sample, which is then removed to the compositing container. Care shall be exercised not to force the “thief” or sampler into the sack, such as with a hammer or hard rotating force on the tube, as this may cause attrition of the material being sampled. At least 3 stabs are made, each angling off in a different direction.

NOTE: If the material is too dry to stay in the “thief” or sampler, pour water down the tube after it has been inserted. Sometimes the materials may be too large for this method, in which case the method described in 5.2.3.1.2 is recommended.

5.2.3.1.2 For situations where expedient field samples have resulted in mixed, conflicting, or disputed results or a more representative sample is required, the following method is recommended. An open top box at least one foot deep with at least 40 ft^2 of area (i.e., a 40-ft^3 shallow-depth container) shall be provided at the job site. In accordance with Table 4, the appropriate number of sacks shall be chosen at random and dumped one at a time into the box where the contents can be spread out in a thin uniform layer less than 12 in. thick. Small, total depth representative grab samples shall then be taken near but not at each corner and from the center of the box. These grab samples shall be composited into one test sample for each sampling unit determined from Table 4. The remaining filter material shall then be shoveled back into the sack, the next randomly chosen sacks dumped, and the procedure repeated until the field composite sample is obtained.

5.2.4 *Composite sample.* The composite sample shall be reduced to representative samples for testing in accordance with ASTM C702. Samples shall be tested by the methods indicated in Sec. 5.3.

Sec. 5.3 Test Procedures—General

If filter material testing is not witnessed at the shipping point by the purchaser, the material should be tested at the job site. The material shall be sampled in accordance with Sec. 5.2.3.1 and reduced to testing size in accordance with ASTM C702. A portion of the reduced sample should be retained for possible independent analysis.

5.3.1 *Acid solubility.* The acid-solubility test is performed by immersing a known weight of material in 1:1 hydrochloric acid (HC1) (made by combining equal volumes of 1.18 specific gravity HC1 and H_2O) until the acid-soluble materials are dissolved, then determining the weight loss of the material. The minimum sample size and the minimum quantity of concentrated HC1 diluted one-to-one with distilled water are indicated in Table 5.

5.3.1.1 Procedure. The procedure for testing acid-solubility shall include the following:

1. Wash sample in distilled water and dry at 110°C ± 5°C to constant weight.
2. Allow sample to cool in a desiccator. Weigh dried sample to the nearest 0.1 percent of the weight of the sample.
3. Place sample in beaker and add enough 1:1 HC1 to immerse the sample completely but not less than the quantity indicated in Table 5.

Table 5 Minimum sample and acid quantities for acid-solubility tests

Maximum Size of Particle in Sample		Minimum Sample Weight	Minimum Quantity 1:1 HCI
mm	*(in.)*	*g*	*mL*
63.0	(2½)	4,000	7,000
37.5	(1½)	250	800
25.4	(1)	250	800
19.0	(¾)	250	800
12.5	(½)	250	800
9.5	(⅜) and smaller	100	320

4. Allow to stand, with occasional stirring, at room temperature for 30 min after effervescence ceases.

5. Wash sample several times in distilled water and dry at 110°C ± 5°C to constant weight.

6. Allow sample to cool in a desiccator and weigh to the nearest 0.1 percent of the weight of the sample.

7. Report the loss in weight as acid-soluble material.

5.3.1.2 Calculation.

$$\text{acid solubility (\%)} = \frac{\text{loss of weight}}{\text{original weight}} \times 100 \qquad \text{(Eq 1)}$$

Duplicate tests shall be made on each size of material and the two results averaged. If the two results do not agree within 2 percent of the total sample weight, then two additional tests shall be made and the four determinations averaged.

5.3.2 *Gravel shape.* The following definitions and tests shall be used in identifying fractured, flat, or elongated pieces of gravel. Identification of fractured, flat, or elongated particles is to be done by visual separation.

5.3.2.1 Fractured face definition. A fractured face is defined as a surface surrounded by sharp edges, such as those produced by crushing, that occupy more than approximately 10 percent of the total surface area of the particle. This is intended to exclude a surface with small nicks and chips from classification as a fractured face.

5.3.2.2 Shape determination. The ratio of the longest axis to the shortest axis of the circumscribing rectangular prism for a piece of gravel shall be determined using a caliper or a proportional divider. Suspected elongated pieces can be checked by comparing the minimum thickness of the particle, as measured at its approximate midpoint, with the maximum length dimension.

5.3.3 *Specific gravity.* The specific gravity of filter silica gravel shall be determined in accordance with ASTM C127 and shall be reported as saturated-surface-dry specific gravity or the Noble Large Aggregate Test. The specific gravity of high-density gravel, high-density sand, silica sand, and filter anthracite shall be determined in accordance with ASTM C128 and shall be reported as apparent specific gravity. Anthracite may also be tested for float/sink in accordance with ASTM C123 (See Figure 1).

5.3.3.1 Noble large aggregate test procedure

1. Soak sample in water at room temperature (approx. 73°F) for 24 hr.
2. Set the water reservoir on a level surface with the cylinder valve closed.
3. Fill the reservoir with room temperature water to a depth where the valve opening is totally submerged.
4. After 5 min, open the valve and allow the excessive water to drain. Close the valve after the last drop has drained.
5. Remove the presoaked sample from the water and pat sample dry with dry cloth or paper towels to a saturated surface dry (SSD) condition.
6. Immediately weigh sample to nearest 0.1 g.

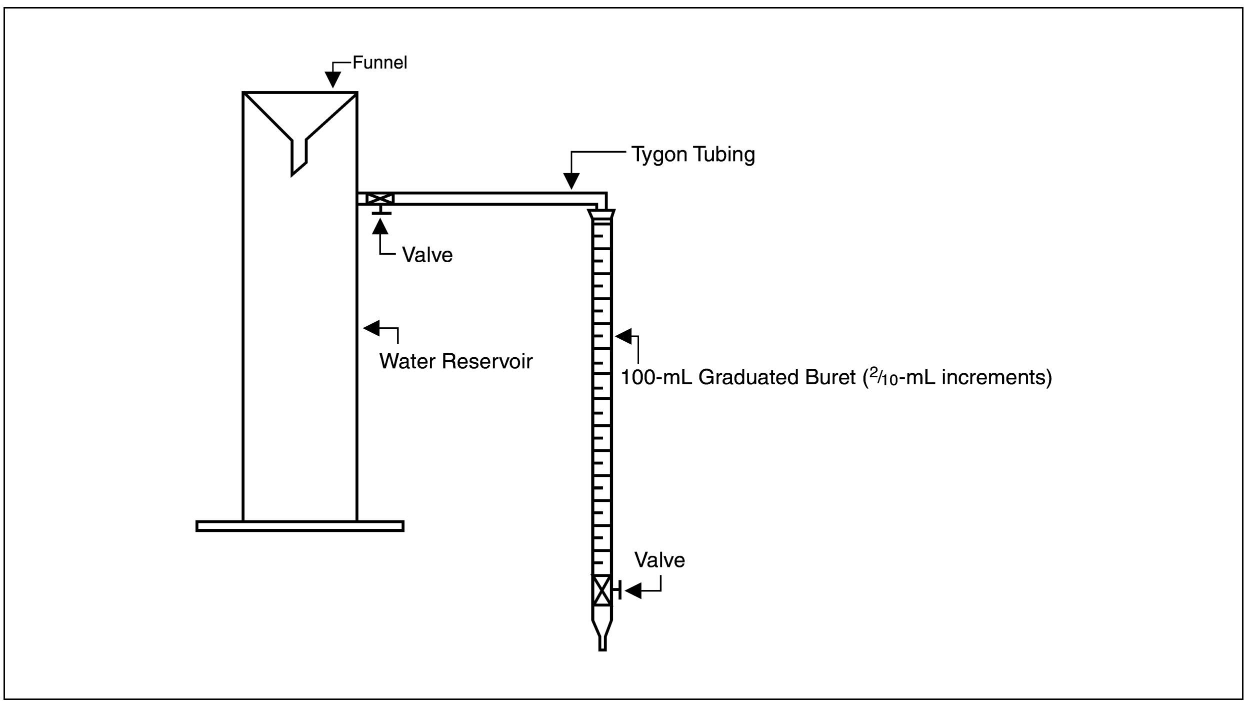

Figure 1 Specific gravity test apparatus

7. With a funnel or by hand carefully drop the preweighed sample into the water reservoir. Leave the sample submerged for 15 min while tapping on the sides of the reservoir and stirring to free the entrapped air.

8. Place the graduated buret (with valve closed) under the tygon tubing. Open the cylinder valve to allow the displaced water to drain into the graduated buret to its last drop. Allow the buret tip to fill before taking final volume reading.

9. Read the water volume in millilitres.

10. Calculation.

Bulk specific gravity (SSD) = Item 6/Item 9

5.3.4 *Sieve analyses.* Sieve analyses for filter material shall be performed in accordance with ASTM C136, as modified and supplemented in this standard.

5.3.4.1 Principle. Particle sizes shall be determined by screening through standard sieves conforming to ASTM E11. Particle size shall be defined in terms of the smallest sieve opening through which the particle passes.

5.3.4.2 Sample size. The minimum sample size for sieve analyses shall be as indicated in Table 6.

5.3.4.3 Procedure. The sieving procedure shall be in accordance with ASTM C136. Care shall be taken to avoid breaking anthracite particles when sieving. Generally, sieves require machine shaking-times of 10 min ± 0.5 min for sand or gravel and 5 min ±0.5 min for anthracite. All standard sieves used for testing filter material shall conform to the tolerances required in ASTM E11. If questions of compliance to specifications arise when nominal standard sieve openings are used, standard reference materials (glass spheres) certified by the National Bureau of Standards should be used in accordance with their calibration procedure to accurately determine the effective opening size of each sieve. If standard reference material for calibration is not used, then the data shall be replotted using both the

Table 6 Minimum sample size for sieve analyses

Maximum Size of Particle in Sample		Minimum Sample Weight	
63.0 mm	(2½ in.)	23.0 kg	(50 lb)
37.5 mm	(1½ in.)	16.0 kg	(35 lb)
25.4 mm	(1 in.)	11.0 kg	(25 lb)
19.0 mm	(¾ in.)	6.8 kg	(15 lb)
12.5 mm	(½ in.)	4.5 kg	(10 lb)
9.5 mm	(⅜ in.)	2.3 kg	(5 lb)
No. 4 (4.75 mm)		500 g	
No. 8 (2.36 mm)		75 to 150 g	

maximum and minimum permissible variation of the average opening from the standard sieve designation as shown in Table 1, column 4 of ASTM E11. (Sections of ASTM E11, column 4, are reprinted in appendix B, Table B.1.) The material shall be in compliance if either of the plots agrees with the specifications.

To avoid excessive interpolation when determining the effective size, the sieves used on a particular sieve analysis shall have openings such that the ratio between adjacent sizes is the fourth root of 2 or 1.1892. The sieves shall be chosen so that the nominal opening of only one sieve is smaller than the smallest allowable effective size and so that the greatest range of particle size distribution can be measured in one standard nest of six sieves with the largest sieve not retaining more than 5 percent of the grains by weight. If the filter media specification limits the quantity of fines, an additional sieve shall be added for a total of seven sieves, so that there are two sieve measurements taken below the effective size.

5.3.4.4 Calculation. The cumulative percent passing each sieve shall be calculated and plotted on log-probability paper or arithmetic graph paper, with the sieve opening on the log scale and the cumulative percent passing on the probability scale or linear scale. A smooth curve shall be drawn through the points plotted.

5.3.4.5 Uniformity coefficient. Read from the curve the particle size corresponding to the 10 percent size, which is the effective size in millimetres. Read the 60 percent size and divide this by the 10 percent size. This ratio is the uniformity coefficient.

5.3.5 *Mohs' scale of hardness.* There is no ASTM test method for Mohs' scale of hardness. The test is a very subjective test where various geologic flat-faced rocks of known increasing hardness are given numbers and used to determine the hardness of the sample by a scratching process. Geology for Engineers, referenced in appendix A, presents Mohs' scale of hardness numbers for known geological rocks. The steps between the numbers are not of equal value. The difference in hardness, for example, between 9 and 10 is much greater than 1 and 2. To determine the hardness of a material, it is necessary to determine which of the standard materials the unknown will scratch. The hardness will lie between two points on the scale; the point between the last standard rock that can be scratched and the next harder rock that cannot be scratched. The Mohs' scale of hardness is recorded as greater than the number of the last standard rock that can be scratched.

5.3.5.1 For determining the Mohs' hardness for anthracite, it is recommended that pieces of the anthracite test sample be epoxyed to 15 wood or metal applicator sticks. After curing, take each applicator stick and try to scratch the standard samples in increasing order of hardness using a firm, constant pressure stroke. Record for each test the last number of the standard sample rock that the anthracite scratched. Add the 15 test numbers and divide by 15 to obtain the average hardness of the total test sample. Record the Mohs' hardness as greater than the average number, i.e. > 2.8.

5.3.5.2 As stated above, the Mohs' hardness test is a very subjective test. It only should be performed by commercial laboratories that regularly perform filter media Mohs' scale of hardness testing.

5.3.6 *Rejection.* If any filter material does not meet the applicable requirements of this standard, it shall be removed from the site. An independent laboratory, acceptable to the purchaser, may be employed by the constructor, manufacturer, or supplier to sample and test the disputed material before removal. Once media has been placed in filters, every filter must meet the size specifications.

5.3.6.1 Additional field tests. At the option of the purchaser or constructor, manufacturer, or supplier, two additional tests shall be conducted using two additional representative samples and a mutually acceptable independent laboratory. Unless otherwise agreed on between the purchaser and constructor, only valid test results from samples obtained by the box method shall be averaged arithmetically in order to determine compliance. If the independent laboratory reports that the material complies with the applicable requirements of this standard, the purchaser shall accept the material. If the material does not meet the requirements of this standard, the constructor shall promptly remove the material from the job site.

5.3.6.2 Alternative to removal. As an alternative to removing the rejected material, the constructor may, with the purchaser's approval and control, reprocess the material at the job site to meet the applicable requirements.

SECTION 6: DELIVERY

Sec. 6.1 Marking

6.1.1 *Required.* Each package and container shall have legibly marked on it the name of the material, the gradation, filling date, the net weight of the contents, the name of the manufacturer, the lot number, and the brand name (if any). These markings shall be indelibly stenciled on the bag. Each package shall bear other markings as are required by the US Department of Transportation and other applicable laws. When shipped in bulk, this information shall accompany the bill of lading.

6.1.2 *Optional.* Packages may also bear the statement, "This material meets the requirements of B100, AWWA Standard for Granular Filter Material," provided that the requirements of this standard are met, and the material is not of a different quality in separate agreement between the supplier or constructor and purchaser.

Sec. 6.2 Packaging and Shipping

Shipment shall be made in bags or semibulk containers or in clean, lined rail cars or trucks with tight closures to avoid loss or contamination of material in transit.

6.2.1 *Bags.* When specified, shipment shall be made in suitable new and unused heavy-duty cloth, paper, woven polypropylene or polyethylene bags that contain UV light inhibitors and shall contain not more than 1 ft^3 of material. Each bag shall be marked in an appropriate manner so that its contents are identified.

6.2.2 *Semibulk containers.* When specified, shipment shall be made in suitable new, unused, heavy-duty, woven, polypropylene semibulk containers, treated with UV light inhibitors, and having a safety factor of at least 5:1. Each container shall hold one or more tons of material. To aid in handling, semibulk containers should have attached straps or sleeves strong enough to support their entire weight when full. Each semibulk container shall be marked so that its contents are identified.

6.2.3 *Bulk.*

1. Bulk shipment is not recommended because of potential contamination and segregation of the material caused by vibration during transit. This latter event creates size gradation problems if the load is placed in two or more filter cells.

2. When truck shipment is specified, only trucks exclusively dedicated for hauling potable water filter material shall be used. Truck containers shall be cleaned by washing with 180°F or hotter water before an impermeable plastic liner is installed. Provisions for tight covering shall be made to avoid loss and to prevent contamination.

3. When railroad hopper car shipment is specified, shipment shall be made in cars washed with 180°F or hotter water before being lined with an impermeable plastic liner and having tight closures to avoid loss and contamination. If open-top cars are used, they shall be tightly covered. The purchaser is cautioned that potential

contamination of the product is possible because of the unavailability of hopper cars dedicated solely to filter material.

6.2.4. *Shipping notice.* When a shipment of material is loaded, the constructor shall notify the purchaser of the rail car number and the date to be shipped. The shipping notice shall contain a certification of the particle size distribution of the material in the shipment.

Sec. 6.3 Affidavit of Compliance

When specified by the purchaser, the manufacturer, supplier, or constructor shall provide an affidavit of compliance stating that the filter material provided complies with the applicable provisions of this standard.

APPENDIX A

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APPENDIX B

Sieves

This appendix is for information only and is not a part of ANSI/AWWA B100.

SECTION B.1 CALIBRATION OF SIEVES

Sec. B.1.1 Precision of Sieves

Although sieves are made from carefully selected brass wire cloth having as nearly as possible square and even-sized meshes, it is rare that they will give exactly the same size openings, even when made from the same piece of material. For precise work, all sieves should be calibrated according to procedures in ASTM* E11, Specification for Wire-Cloth Sieves for Testing Purposes. (For nominal dimensions for wire cloth of standard test sieves, see Table B.1).

Sec. B.1.2 Glass Spheres

For routine checking of sieves and for determining the effective sieve openings, a method employing glass spheres is recommended. The glass spheres should not be used to determine conformity to specifications. Glass spheres for sieve calibration may be obtained from the National Institute of Standards.† Four of these standard reference materials are now available: SRM 1019a for calibrating sieves No. 8 to No. 35; SRM 1018a for calibrating sieves No. 20 to No. 70; SRM 1017a for calibrating sieves No. 50 to No. 170; and SRM 1004 for calibrating sieves No. 140 to No. 400. Detailed instructions for the use of the glass spheres for calibrating sieves are provided with each sample.

*American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

†National Institute of Standards and Technology, Supply Division, Bldg. 301, Gaithersburg, MD 20899.

Table B.1 Nominal dimensions, permissible variations for wire cloth of standard test sieves (USA Standard series)*

Sieve Designation Standard†	Sieve Designation Alternative	Nominal Sieve Opening *in.*‡	Permissible Variation of Average Opening From the Standard Sieve Designation	Maximum Opening Size for Not More Than 5 Percent of Openings	Maximum Individual Opening	Nominal Wire Diameter *mm*§
125 mm	5 in.	5	±3.7 mm	130.0 mm	130.9 mm	8.0
106 mm	4.24 in.	4.24	±3.2 mm	110.2 mm	111.1 mm	6.40
100 mm**	4 in.**	4	±3.0 mm	104.0 mm	104.8 mm	6.30
90 mm	3½ in.	3.5	±2.7 mm	93.6 mm	94.4 mm	6.08
75 mm	3 in.	3	±2.2 mm	78.1 mm	78.7 mm	5.80
63 mm	2½ in.	2.5	±1.9 mm	65.6 mm	66.2 mm	5.50
53 mm	2.12 in.	2.12	±1.6 mm	55.2 mm	55.7 mm	5.15
50 mm**	2 in.	2	±1.5 mm	52.1 mm	52.6 mm	5.05
45 mm	1¾ in.	1.75	±1.4 mm	46.9 mm	47.4 mm	4.85
37.5 mm	1½ in.	1.5	±1.1 mm	39.1 mm	39.5 mm	4.59
31.5 mm	1¼ in.	1.25	±1.0 mm	32.9 mm	33.2 mm	4.23
26.5 mm	1.06 in.	1.06	±0.8 mm	27.7 mm	28.0 mm	3.90
25.0 mm**	1 in.**	1	±0.8 mm	26.1 mm	26.4 mm	3.80
22.4 mm	⅞ in.	0.875	±0.7 mm	23.4 mm	23.7 mm	3.50
19.0 mm	¾ in.	0.750	±0.6 mm	19.9 mm	20.1 mm	3.30
16.0 mm	5/8 in.	0.625	±0.5 mm	16.7 mm	17.0 mm	3.00
13.2 mm	0.530 in.	0.530	±0.41 mm	13.83 mm	14.05 mm	2.75
12.5 mm**	½ in.**	0.500	±0.39 mm	13.10 mm	13.31 mm	2.67
11.2 mm	7/16 in.	0.438	±0.35 mm	11.75 mm	11.94 mm	2.45
9.5 mm	⅜ in.	0.375	±0.30 mm	9.97 mm	10.16 mm	2.27
8.0 mm	5/16 in.	0.312	±0.25 mm	8.41 mm	8.58 mm	2.07
6.7 mm	0.265 in.	0.265	±0.21 mm	7.05 mm	7.20 mm	1.87
6.3 mm**	¼ in.**	0.250	±0.20 mm	6.64 mm	6.78 mm	1.82
5.6 mm	No. 3½††	0.223	±0.18 mm	5.90 mm	6.04 mm	1.68
4.75 mm	No. 4	0.187	±0.15 mm	5.02 mm	5.14 mm	1.54
4.00 mm	No. 5	0.157	±0.13 mm	4.23 mm	4.35 mm	1.37
3.35 mm	No. 6	0.132	±0.11 mm	3.55 mm	3.66 mm	1.23
2.80 mm	No. 7	0.111	±0.095 mm	2.975 mm	3.070 mm	1.10
2.36 mm	No. 8	0.0937	±0.080 mm	2.515 mm	2.600 mm	1.00
2.00 mm	No. 10	0.0787	±0.070 mm	2.135 mm	2.215 mm	0.900
1.70 mm	No. 12	0.0661	±0.060 mm	1.820 mm	1.890 mm	0.810
1.40 mm	No. 14	0.0555	±0.050 mm	1.505 mm	1.565 mm	0.725
1.18 mm	No. 16	0.0469	±0.045 mm	1.270 mm	1.330 mm	0.650
1.00 mm	No. 18	0.0394	±0.040 mm	1.080 mm	1.135 mm	0.580
850 µm‡‡	No. 20	0.0331	±35 µm	925 µm	970 µm	0.510
710 µm	No. 25	0.0278	±30 µm	774 µm	815 µm	0.450
600 µm	No. 30	0.0234	±25 µm	660 µm	695 µm	0.390
500 µm	No. 35	0.0197	±20 µm	550 µm	585 µm	0.340
425 µm	No. 40	0.0165	±19 µm	471 µm	502 µm	0.290
355 µm	No. 45	0.0139	±16 µm	396 µm	425 µm	0.247

* From ASTM E11 (Reprinted, with permission).

† These standard designations correspond to the value for test sieve apertures recommended by the International Organization for Standardization (ISO), Geneva, Switzerland.

‡ Only approximately equivalent to the metric values in column 1.

§ The average diameter of the warp and of the shoot wires, taken separately, of the cloth of any sieve shall not deviate from the nominal values by more than the following:
- Sieves coarser than 600 µm5 percent
- Sieves 600–125 µm7.5 percent
- Sieves finer than 125 µm10 percent

** These sieves are not in the standard series, but they have been included because they are in common usage.

†† These numbers (3½–400) are the approximate number of openings per linear inch, but it is preferred that the sieve be identified by the standard designation in millimetres or micrometres.

‡‡ 1,000 µm = 1 mm.

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