American Water Works Association

Dedicated to the World's Most Important Resource®

ANSI/AWWA B100-16
(Revision of ANSI/AWWA B100-09)

AWWA Standard

Granular Filter Material

Effective date: May 1, 2016.
First edition approved by AWWA Board of Directors Nov. 15, 1948.
This edition approved Jan. 16, 2016.
Approved by American National Standards Institute Dec. 10, 2015.

American Water Works Association STANDARD *Since 1881*

Approved American National Standard ANSI

AWWA Standard

This document is an American Water Works Association (AWWA) standard. It is not a specification. AWWA standards describe minimum requirements and do not contain all of the engineering and administrative information normally contained in specifications. The AWWA standards usually contain options that must be evaluated by the user of the standard. Until each optional feature is specified by the user, the product or service is not fully defined. AWWA publication of a standard does not constitute endorsement of any product or product type, nor does AWWA test, certify, or approve any product. The use of AWWA standards is entirely voluntary. This standard does not supersede or take precedence over or displace any applicable law, regulation, or code of any governmental authority. AWWA standards are intended to represent a consensus of the water supply industry that the product described will provide satisfactory service. When AWWA revises or withdraws this standard, an official notice of action will be placed on the first page of the Official Notice section of *Journal – American Water Works Association*. The action becomes effective on the first day of the month following the month of *Journal – American Water Works Association* publication of the official notice.

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether that person has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic review, and users are cautioned to obtain the latest editions. Producers of goods made in conformity with an American National Standard are encouraged to state on their own responsibility in advertising and promotional materials or on tags or labels that the goods are produced in conformity with particular American National Standards.

Caution Notice: The American National Standards Institute (ANSI) approval date on the front cover of this standard indicates completion of the ANSI approval process. This American National Standard may be revised or withdrawn at any time. ANSI procedures require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036; 212.642.4900; or emailing info@ansi.org.

ISBN-13, print: 978-1-62576-153-8

eISBN-13, electronic: 978-1-61300-376-3

DOI: http://dx.doi.org/10.12999/AWWA.B100.16

Committee Personnel

The AWWA Standards Committee on Filtering Materials, which reviewed and approved this standard, had the following personnel at the time of approval:

William W. Allis Jr., *Chair*
R. Lee Roberts, *Vice-Chair*

General Interest Members

W.W. Allis Jr., Gannett Fleming Inc., Camp Hill, Pa.	(AWWA)
W.F. Clunie, AECOM, Manchester, N.H.	(NEWWA)
W. Conlon, Parsons Corporation, Tampa, Fla.	(AWWA)
J.R. DeWolfe, Hazen and Sawyer, State College, Pa.	(AWWA)
I. Diaz,* Gannett Fleming Inc., Miami, Fla.	(AWWA)
K.M. Heffernan, CH2M, Englewood, Colo.	(AWWA)
R.E. Hubel, Water Counsel LLC, Virginia Beach, Va.	(AWWA)
D.S. Koch, Black & Veatch Corporation, Chicago, Ill.	(AWWA)
C.V. Lauderdale, Consultant, Arlington, Va.	(AWWA)
T.J. McCandless,† Standards Engineer Liaison, AWWA, Denver, Colo.	(AWWA)
R.R. Rogers, CDM Smith, Chicago, Ill.	(AWWA)
L. Thomas,† Standards Council Liaison, Stanley Consultants, Crystal Lake, Ill.	(AWWA)

Producer Members

K.T. Brown, Northern Filter Media, Quincy, Ill.	(AWWA)
T.M. Getting, Leopold, A Xylem Brand, Zelienople, Pa.	(AWWA)
D.M. Oreskovich, Red Flint Sand and Gravel, Eau Claire, Wis.	(AWWA)
R.L. Roberts, Roberts Filter Group, Media, Pa.	(AWWA)
K. Ryan, Calgon Carbon Corporation, Moon Township, Pa.	(AWWA)
T.P. Walter, Unifilt Corporation, Wilkes Barre Township, Pa.	(AWWA)
L.M. Zukus,* Leopold, A Xylem Brand, Watsontown, Pa.	(AWWA)

* Alternate
† Liaison, nonvoting

User Members

M.G. Barsotti, Champlain Water District, South Burlington, Vt.	(AWWA)
D.W. Boone, Boyd Lake Water Treatment Plant, Loveland, Colo.	(AWWA)
S.E. Creel, American Water, Pennsauken, N.J.	(AWWA)
M.J. McFadden, Capital Region Water, Harrisburg, Pa.	(AWWA)
T. Meckes, City Water Light and Power, Springfield, Ill.	(AWWA)

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*, *Water Treatment Plant Design*,† and references found 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 (GAC), should be consulted when using GAC as a filter medium, because GAC is not specifically covered in ANSI/AWWA B100.

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, Dec. 1, 1996, and June 17, 2001. 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. The last edition was approved on Jan. 25, 2009. This edition was approved on Jan. 16, 2016.

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 direct and indirect drinking water additives. Other members of the original consortium included the Water Research Foundation (formerly 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.

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

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† AWWA, ASCE, and CSSE. *Water Treatment Plant Design*, 5th Ed. Denver, Colo. (2012).
‡ Persons outside the United States should contact the appropriate authority having jurisdiction.

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*: NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 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 NSF/ANSI 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdictions. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 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.

ANSI/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.

2. Determine the status of certifications by 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 can certify the site-specific manufacturing facilities are

* NSF International, 789 North Dixboro Road, Ann Arbor, MI 48105.

† Both publications available from National Academy of Sciences, 500 Fifth Street, NW, Washington, DC 20001.

expressly qualified to produce and supply these materials for water treatment plants, in compliance with the ANSI/AWWA B100 standard.

II.B. *Filter Media.* Filter media are the component of a filter that removes particulate matter from the water during the filtration process. This standard describes anthracite, silica sand, high-density sand, and filter-media support gravel material.

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. These small, high-density media remain 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 anthracite in a dual-media filter. Some intermixing usually occurs at the interface between the layers.

The term *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 that invariably is associated with hematite and magnetite, both iron oxides.

Properties of granular activated carbon when used as a filter medium are described in ANSI/AWWA B604, Standard for Granular Activated Carbon. Testing requirements for granular activated carbon vary from those for anthracite, silica and garnet. Refer to ANSI/AWWA B604, Standard for Granular Activated Carbon.

Properties of media used in precoat filters (such as diatomaceous earth) can be found in ANSI/AWWA B101, Precoat Filter Media. Synthetic media and membrane filters are 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, particle size, and particle density of each media layer to be used in any particular filter is the responsibility of the designer and should be done with careful consideration of raw water conditions, plant pretreatment facilities, and filter backwash system design.

If questions arise regarding the authenticity of the anthracite filter medium relative to the standard, the procedures and calculations for anthracite verification can be found in ASTM D388—Standard Classification of Coal by Rank. The results of the verification shall be reported as anthracite or nonanthracite.

II.C. *Particle Size Distribution.* There are two methods of classifying particle size distribution. The designer and end user are cautioned not to use both methods simultaneously. These methods are described in appendix C of this standard.

II.D. *Filter-Media Support.* If the openings in the underdrain system are larger than the filter media, a system of supporting material is required to prevent the filter media from entering and blocking the underdrain system and to help distribute backwash water evenly. This can be achieved by layers of gravel installed over the underdrain system or by use of proprietary media support systems provided by underdrain system manufacturers. When using gravel, the size and depth of the gravel layers must be selected to achieve the objectives of minimizing media loss through the underdrains, aid in evenly distributing backwash water, and minimizing displacement of the gravel by the rising backwash water and/or air scour supply. Guidance for selecting appropriate support gravel size and layer depths, along with examples, is included in appendix D. The use of air scour must also be considered in the proper selection of underdrain and media support systems. The user of this standard is urged to carefully consider several factors in determining the appropriate underdrain and filter-media support system for a particular application, including water quality, filter operating and backwash rates, whether air scour is provided, and type of treatment practiced at the facility (softening, biological filtration, etc.). Information and guidance to assist the user in proper selection of filter underdrains and media support systems are available in several of the references included in appendix A. In addition, advice and guidance can be solicited from underdrain system manufacturers and qualified consulting engineers.

II.E. *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.F. *Anthracite Quality Test.* ANSI/AWWA B100 defines *anthracite*, as used herein, as anthracite coal in accordance with ASTM D388. The intent of this reference and definition is to provide the capability to verify the specified filter media is anthracite coal and not bituminous coal.

II.G. *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 railcars are specified for hauling a bulk shipment of filter material, it is recommended that an impermeable plastic liner be used because the trucks or railcars 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, the media are 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 and a duplicate sample can be provided to the user if additional testing is required. If the purchaser requires sampling at the time of delivery, this requirement should be stated in the contract documents.

II.H. *Media Records.* Users are encouraged to maintain records of the physical characteristics and chemical composition of filter material installed in filters. For limits on undesirable impurities, refer to NSF/ANSI 61 and Sec. I.C in the foreword.

II.I. *Removal of Filter Material and Reuse.* Occasionally, there are circumstances, such as a filter media upset, an underdrain problem, or a header-lateral distribution system problem, that will cause the necessity for removal of filter material from the filter cell and replacement or reuse of the material. Unless the filter material is new or found by visual inspection to be in near-original condition, reuse is discouraged because the material will be worn to some degree, may be coated, may be damaged or contaminated during handling, and may create potential filtering problems if not properly combined with new material to obtain a desired gradation. In addition, removed material should not be installed in another filter plant without proper investigation of process and filter gradation requirements.

Removal may be performed hydraulically, pneumatically or by hand excavation. 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 in accordance with applicable regulations. 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 that 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 airborne contaminants. If any filter material becomes contaminated, it shall be replaced or cleaned to the user's satisfaction.

Disturbed filter-media support gravel should be replaced in its proper gradation prior to reuse and 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 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 size and specific gravity 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 user requirements.

Placement of the filter material in the filter cell, backwashing, and disinfection should be in accordance with procedures stated in this standard. This standard does not apply to reuse of GAC. See ANSI/AWWA B605, Granular Activated Carbon, for GAC reuse requirements.

II.J. *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. Filter backwashing, including surface wash, may be responsible for accelerating this action by removing loose or softened materials at the surface of the concrete in filter boxes. The purchaser 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. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* The following items should be covered by the purchaser:

1. Standard used—that is, ANSI/AWWA B100, Granular Filter Material, of latest revision.
2. Whether compliance with NSF/ANSI 61, Drinking Water System Components—Health Effects, is required.
3. Whether project includes providing filter material only or providing and placement of materials and preparation for service.
4. Whether an affidavit of compliance is required or whether the purchaser will select a representative to inspect supply for compliance with this standard (Sec. 6.3).
5. 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). For filter media sampling after

initial placement, the supplier, manufacturer, or constructor should supervise the transportation, handling, on-site storage, placement, and field preparation of the filter media for sampling. This includes backwashing of filter media prior to sampling. Sampling before delivery and/or after delivery prior to placement is recommended to verify compliance with the purchase documents. Sampling after placement is not a substitute for sampling after delivery prior to placement because of the effects of installation and the difficulties in collecting representative samples. Sampling for monitoring purposes after placement may help in documenting the installed conditions, the effectiveness of post-installation skimming and backwash, and any media fines retained following the installation. Testing results can form a benchmark for subsequent condition monitoring and filter condition records. Guidance is provided in appendix E.

6. Method of placing the material (Sec. 4.4.2).

7. Method of disinfecting (Sec. 4.5.3) and who will perform the disinfection procedure.

8. Sampling before delivery (Sec. 5.1) and after delivery prior to placement (Sec. 5.2).

9. Whether an affidavit of compliance is required (Sec. 6.3) or whether the purchaser will select a representative to inspect supply for compliance with this standard.

III.B. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided by the purchaser.

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

1. Sec. 4.1.1.4, added language highlighting that test procedures for granular activated carbon when used as a filtering material vary from those indicated in this standard for anthracite and can be found in AWWA B604.

2. Sec. 4.1.1.5, added language stating that when defining fine media effective size, a plus and minus tolerance range shall be allowed to account for sampling, testing, and test repeatability variances.

3. Sec. 5.1, added language stating that samples taken during the manufacturing process before delivery in accordance with this standard are more representative than samples taken after delivery prior to placement or after placement because of the effects of transportation, handling and installation, and difficulties in collecting representative samples in the field.

4. Sec. 5.3.4.3, modified language in accordance with latest revisions to ASTM E11 describing test sieves and procedures.

5. Appendix B, Table B.1, modified column 4, "Permissible Variation of Average Opening From Standard Sieve Designations," in accordance with revised ASTM E11

V. Comments. If you have any comments or questions about this standard, please call AWWA Engineering and Technical Services at 303.794.7711, FAX at 303.795.7603; write to the department at 6666 West Quincy Avenue, Denver, CO 80235-3098; or email at standards@awwa.org.

American Water Works Association

Dedicated to the World's Most Important Resource®

ANSI/AWWA B100-16
(Revision of ANSI/AWWA B100-09)

AWWA Standard

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 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 then 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.

ANSI*/AWWA B604—Granular Activated Carbon.

ANSI/AWWA B605—Reactivation of Granular Activated Carbon.

ANSI/AWWA C653—Disinfection of Water Treatment Plants.

ASTM† C40/C40M-11—Standard Test Method for Organic Impurities in Fine Aggregates for Concrete.

ASTM C114-15—Standard Test Method for Chemical Analysis of Hydraulic Cement.

ASTM C117-13—Standard Test Method for Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing.

ASTM C123/C123M-14—Standard Test Method for Lightweight Particles in Aggregate.

ASTM C127-15—Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate.

ASTM C128-15—Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate.

ASTM C136/C136M-14—Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

ASTM C653-97—Standard Guide for Determination of the Thermal Resistance of Low-Density Blanket-Type Mineral Fiber Insulation.

ASTM C702/C702-11—Standard Practice for Reducing Samples of Aggregate to Testing Size.

ASTM D75/D75M-14—Standard Practice for Sampling Aggregates.

ASTM D388-15—Standard Classification of Coal by Rank.

ASTM E11-15—Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves.

MIL-STD-105E‡ (1989)—Sampling Procedures and Tables for Inspection by Attributes, Washington, D.C.: Department of Defense.

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.
‡ MIL-STD=Military Standard.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Anthracite:* A classification of coal by rank in accordance with ASTM D388.

2. *Bag:* A plastic, paper, or woven container generally containing approximately 1 ft^3 (0.03 m^3) or less of filter material.

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

4. *Effective size (ES):* The size opening that will just pass 10 percent (by dry weight) of a representative sample of the filter material. For example, 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.

5. *Filter bed:* One or more layers of filter media plus any filter-media support gravel layers (if used) that are installed in the filter cell.

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

7. *Filter media:* 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. *Filter-media support 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.

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

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

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

12. *Semibulk container:* A large plastic or woven bulk container generally containing approximately 2,000 lb (910 kg) or more of filter material. These are commonly referred to as *sacks*.

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

14. *Uniformity coefficient (UC):* 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 nonanthracite material to meet any portion of this standard is not acceptable.

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

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 percent minus No. 200 (0.074 mm) material by washing, as determined by ASTM C117; and (2) a maximum of 0.5 percent organic impurities, such as wood timber, roots, or twigs, as determined by ASTM C123 for lightweight pieces in aggregate (except dry basis is used, not saturated surface dry, and the float is removed immediately) using a liquid with a 1.0 specific gravity.

4.1.1.2 Silica sand.

1. Silica sand shall consist of hard, durable, dense grains that will resist degradation during handling and use.

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

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.

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.

4.1.1.3 High-density sand.

1. High-density sand shall consist of hard, durable, 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.

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 Granular activated carbon.

1. Properties of granular activated carbon when used as a filter medium are described in ANSI/AWWA B604.

2. Testing requirements for granular activated carbon vary from those for anthracite, silica, and garnet (refer to ANSI/AWWA B604 and B605).

3. Specific gravity and acid solubility are not standard test methods performed on GAC. Testing that is recommended for GAC can be found in ANSI/AWWA B604 and B605.

4.1.1.5 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. These methods are further described in appendix C. Only one of the following shall be used:

a. The effective size as defined in Section 3, item 4, and the uniformity coefficient as described in Section 3, item 14, shall be as required in the purchase document. When defining fine media effective size, a plus and minus tolerance range shall be allowed to account for sampling, testing, and test repeatability variances.

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

4.1.2 *Filter-media support gravel.*

4.1.2.1 Silica gravel.

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 (see Sec. 5.3.2).

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

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

Note: Testing for clay, shale, or organic impurities is normally not necessary. However, if deleterious materials are noticeable, the gravel shall be within the following limits: (1) a maximum of 1 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.

4.1.2.2 High-density filter-media support gravel.

1. High-density filter-media support 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 specific gravity requirement.

2. High-density filter-media support 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 two 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 (see Sec. 5.3.2).

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

NOTE: Testing for clay, shale, or organic impurities is normally not necessary. However, if deleterious materials are noticeable, the gravel shall be within the following limits: (1) a maximum of 1 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.

4.1.2.3 Gravel size. Filter-media support gravel shall be provided in the particle size ranges as required in the purchase documents. For each required size range of gravel, 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 five 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 1.0 in. (25.4 mm), and 25 percent for sizes 1.0 in. (25.4 mm) 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

4.2.1 *Filter media.*

4.2.1.1 Silica sand. The silicon dioxide content of silica sand shall be at least 85 percent and determined in accordance with ASTM C114.

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 (Sec. I.C in the foreword).

Sec. 4.4 Placing Filter Media

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. Debris, dirt, dust, and any other foreign substances shall be removed from the underdrain plenum (which may need to be vacuumed), filter underdrain system, piping, washwater troughs, walls, and any other filter cell component. Each cell shall be kept clean throughout placement operations. After cleaning, the underdrain system, washwater troughs, and any air or surface wash piping shall be checked to ensure they are level, undamaged, and complete within the requirements of the purchase documents. Underdrain mechanical connections to the filter cell (if applicable) shall be secure and tightened to manufacturer's tolerances, and underdrain grout (if applicable) shall be in place, cured, and free of defects. Deficiencies shall be corrected before 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 operational testing of the backwash system, including air and/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 project 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,

Table 2 Appropriate fluidization backwash rates

Water Temperature		Fluidization Backwash Rate (gpm/ft^2)	
°F	(°C)	Sand ($d_{60\%}$ size of 0.7 mm)	Anthracite Coal ($d_{60\%}$ size of 1.5 mm)
41	5	12.0	15.0
50	10	13.5	16.5
59	15	15.0	18.0
68	20	16.5	20.0
77	25	18.0	22.0
86	30	20.0	24.0

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.

except for 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 agreed to by the 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 filter-media support gravel shall be carefully placed to avoid damaging the filter underdrain system. Workers shall not stand or walk directly on the filter-media support gravel or the filter media. Workers 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 leveled. 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 ft (0.9 m). Each lift should be backwashed, scraped, and sampled, if required, prior to placement of the next lift. For placement of GAC, see ANSI/AWWA B604.

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 within the filter from which they may be distributed with a hand shovel. Vertical dropping of the material into filters is unacceptable, as it may damage the material. Alternatively, bulk materials may be placed hydraulically by an ejector or a pump without an impeller. In any case, care shall be taken not to damage the underdrain system.

For filter sand, anthracite, or GAC placed using the wet method, the materials shall be added through the water and then backwashed for leveling. Pneumatic handling of filter media is unacceptable.

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. Any layers already in place shall not be disturbed. 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 procedure, the additional 10 percent or other amount necessary to reach the finished elevation shall be added. For placement of GAC, see ANSI/AWWA B604.

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. (±13 mm) 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 filter-media support gravel layer. After the filter-media support gravel is placed and before any filter sand, anthracite, or GAC is placed, the filter should be washed for 5 minutes 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 3 minutes. 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 required in the purchase documents 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 filter materials have been placed, washwater 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 required in the purchase document to saturate the filter material before initial wash. This period shall not be less than 12 hours 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 2.0 gpm/ft^2 of filter area. The backwash rate shall then be increased gradually over a period of 3 minutes to the rate that achieves fluidization and maintained at that rate for not less than 5 minutes. Table 2 presents fluidization backwash rate guidelines for commonly used filter media. These fluidization rates should be adjusted for filter media of different sizes and will vary with water temperature. 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.

For backwashing GAC, see ANSI/AWWA B604.

4.5.2 *Scraping.* Scraping is required after placement of each lift of fluidizable filter media and before placing another media above. After the initial wash of each layer, the filter shall be partially drained and a layer of fine material approximately 3⁄16-in. (5-mm) thick shall be removed from the surface of the filter by scraping. Scraping is not normally required for GAC media but can be performed if head loss is a concern and/or as required in the purchase documents.

4.5.2.1 Repetitions. The scraping operation shall be repeated as many times as necessary to remove fine material (these fines will be visible, giving a smooth appearance rather than the desired rough surface texture), to remove organic particles, such as wood, timber, roots, and twigs, and, in addition in the case of anthracite, to remove 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 minutes and shall be at an appropriate rate as listed in Table 2 or as recommended by the filter media producer and underdrain manufacturer.

4.5.2.3 Additional filter media. If additional filter media are 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.

4.5.3 *Disinfecting.* After work related to placement of filter media has been completed and before the filter is placed in service, the entire filter, excluding GAC media if applicable, shall be disinfected by chlorination in accordance with ANSI/AWWA C653 or as required in the purchaser documents. Chlorine is rapidly removed by GAC through an oxidation–reduction reaction. Thus, a residual chlorine concentration will not be maintained through the filter if GAC is present.

Sec. 4.6 Replenishing Filter Media in Existing Filter Bed

4.6.1 *Sampling and testing.* Before 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. 4.1.1.5 to determine its effective size and uniformity coefficient.

4.6.2 *New filter media sizing.* The effective size and uniformity coefficient of new filter media shall be determined by the media purchaser, 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 purchaser requirements, 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 the applicable sections of Sec. 4.4 and then backwashed, scraped, and leveled at least two times in accordance with Sec. 4.5. If in-place sampling is to be performed for monitoring, it shall be performed after the last backwash and scraping in accordance with Sec. 4.4.2.4.

4.6.4 *Disinfection.* Before 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 required in the purchase documents, a representative sample of each size of filter material shall be submitted 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 purchaser approval of the samples, the shipments shall comply with the requirements or acceptance criteria. Site samples shall meet the requirements of Sec. 5.2. Samples taken during the manufacturing process before delivery in accordance with this standard are more representative than samples taken after delivery prior to placement or after placement because of the effects of transportation, handling, and installation and difficulties in collecting representative samples in the field. However, samples taken after delivery can be important to the owner or user.

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. If, however, bulk shipment is required, representative filter material samples shall be obtained at either the production site or loading point. When a truck or railcar 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

Table 3 Minimum size of composite sample

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

Note: Refer to ANSI/AWWA B604 for GAC sampling.

Table 4 Sampling of bagged filter material*‡

Lot Size† (number of bags)		Minimum Sample Sizes (number of bags)
More than	Less than or equal to	
2	8	2
8	15	3
15	25	5
25	50	8
50	90	13
90	150	20
150	280	32
280	500	50
500	1,200	80
1,200	3,200	125
3,200	10,000	200
10,000	35,000	315
35,000	150,000	500

* Refer to Military Standard MIL-STD-105E (1989).
† Lot size at the producer's plant is the number of bags produced in a batch. Lot size at the jobsite is the number of bags of a particular production batch delivered to the project site.
‡ Refer to ANSI/AWWA B604 for GAC sampling.

a loading site, the composite sample shall be taken as each railcar, barge, or truck is filled. It is not recommended that filter materials be sampled on receipt at the jobsite because of segregation during shipment. When required in the purchase documents, sampling on receipt requires that samples shall be taken from 10 locations in the railcar, barge, or truck. The railcar, barge, or truck shall be sampled near, but not in, each corner, at the center, and in five other random locations.

5.2.2 *Bag shipments.* While bags are being filled at the production site, sampling across a cross section of the material being loaded for each lot is recommended. When filter material is shipped to the jobsite in bags and jobsite 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. 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 a 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 Jobsite sampling of filter material shipped in semibulk containers. When jobsite sampling is required in the purchase documents in addition to production-site sampling, filter material shall be sampled upon arrival at the jobsite and before placement in the filter by either the method described in Sec. 5.2.3.1.1 or the method in Sec. 5.2.3.1.2. A 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 An expedient method of obtaining samples upon delivery consists of using a "thief" made of approximately 2 in. (51 mm) of thin-walled tubing approximately 48-in. (1,200-mm) long, or a brass seed sampler consisting of two nested tubes containing slotted openings. First, the top of the sack is opened and 2 in. (50 mm) of material is pushed to the outside, forming a depression in the center. The sampler is then pushed into the center as far as possible and extracted with the sample, which is then removed to the compositing container. The sampler shall not be forced into the sack with a hammer or hard rotating force on the tube, as this may cause attrition of the material being sampled. At least three stabs are made, each angling off in a different direction. For GAC sampling, see ANSI/AWWA B604.

Note: If the material is too dry to stay in the sampler, water may be poured down the tube after it has been inserted. If the materials are too large for this method, the method described in Sec. 5.2.3.1.2 is recommended.

5.2.3.1.2 For situations where expedient field sampling methods have resulted in mixed, conflicting, or disputed results or where a more representative sample is required, the following method is recommended. An open-top box at least 1-ft (0.3-m) deep with at least 40 ft^2 (3.7 m^2) of area (i.e., a 40-ft^3 [1.1 m^3] shallow-depth container) shall be provided at the jobsite. 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. (0.3-m) 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 and test methods indicated in ANSI/AWWA B604 for GAC. Samples shall be tested by the methods indicated in Sec. 5.3.

Sec. 5.3 Test Procedures—General

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 (HCl) (made by combining equal volumes of 1.18 specific gravity HCl and H_2O) until the acid-soluble materials are dissolved and then determining the weight loss of the material. The minimum sample size and the minimum quantity of concentrated HCl 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. The sample shall be washed in distilled water and dried at 230°F ±9°F (110°C ±5°C) to constant weight.

2. The sample shall be allowed to cool in a desiccator. The dried sample shall be weighed to the nearest 0.1 percent of the weight of the sample.

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

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

3. The sample shall be placed in a beaker and enough 1:1 HCl added to immerse the sample completely but not less than the quantity indicated in Table 5.

4. The sample shall be allowed to stand, with occasional stirring, at room temperature for 30 minutes after effervescence ceases.

5. The sample shall be washed several times in distilled water and dried at 230°F ±9°F (110°C ±5°C) to a constant weight.

6. The sample shall be allowed to cool in a desiccator and weighed to the nearest 0.1 percent of the weight of the sample.

7. The loss in weight shall be reported 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, two additional tests shall be made and the four determinations averaged.

5.3.2 *Filter-media support gravel shape.* The following definitions and tests shall be used in identifying fractured, flat, or elongated pieces of filter-media support 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 occupies 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 flat and 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 silica filter-media support 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 filter-media support 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. When reporting the specific gravity of filter anthracite, it is recommended that all specific gravity and absorption values obtained

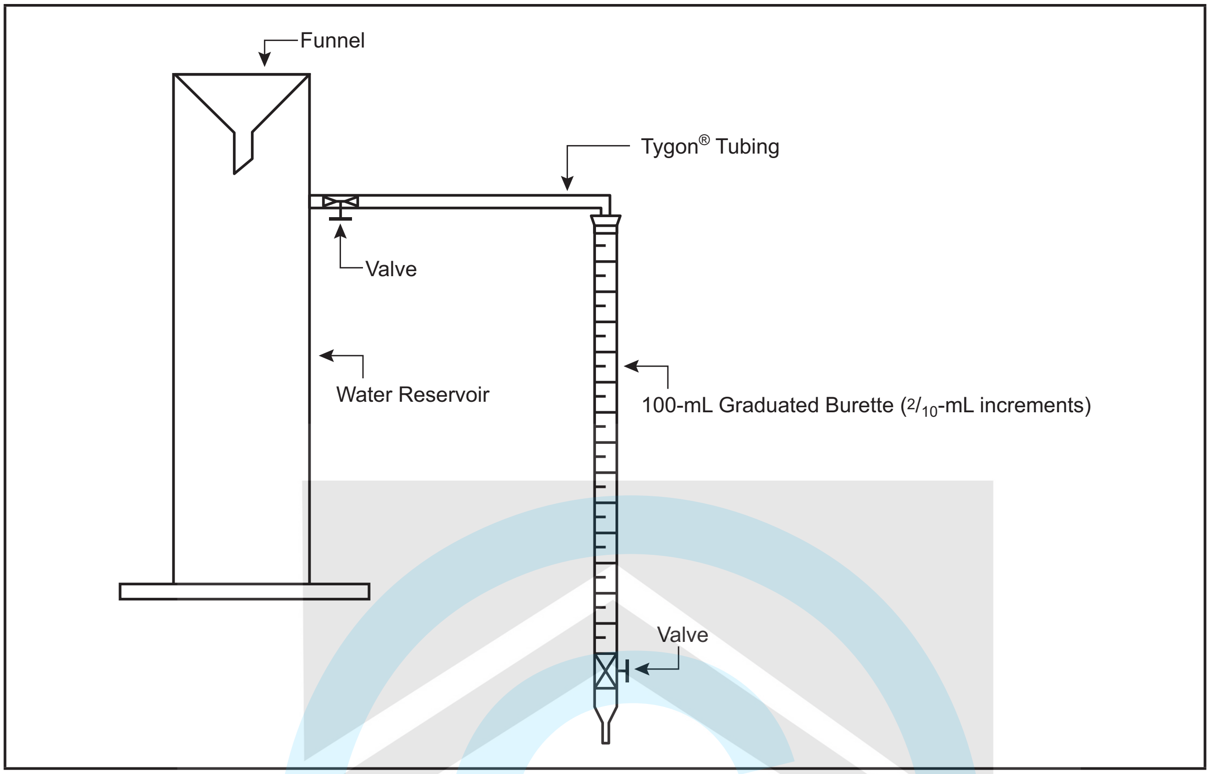

Figure 1 Specific gravity test apparatus

in ASTM C128 be reported. The report should include at a minimum the oven-dry (OD), saturated-surface-dry (SSD), apparent (APP) specific gravity, and absorption value.

5.3.3.1 Noble large aggregate test procedure (see Figure 1).

1. The sample shall be soaked in water at room temperature (approximately 73°F or 23°C) for 24 hours.

2. The water reservoir shall be placed on a level surface with the cylinder valve closed.

3. The reservoir shall be filled with room-temperature water to a depth where the valve opening is totally submerged.

4. After 5 minutes, the valve shall be opened and the excess water allowed to drain. The valve shall be closed after the last drop has drained.

5. The presoaked sample shall be removed from the water and patted dry with dry cloth or paper towels to an SSD condition.

6. The sample shall be immediately weighed to nearest 0.1 g.

7. Using a funnel or by hand, the preweighed sample shall be carefully dropped into the water reservoir. The sample shall be submerged for 15 minutes, and tapping on the sides of the reservoir and stirring shall be used to free entrapped air.

8. The graduated burette (with valve closed) shall be placed under the Tygon® tubing. The cylinder valve shall be opened to allow the displaced water to drain into the graduated burette to its last drop. The burette tip shall be allowed to fill before taking final volume reading.

9. The water volume shall be read in milliliters.

10. Calculation.

$$\text{bulk specific gravity (SSD)} = \frac{\text{weight of sample (g)}}{\text{volume of drained water (mL)}} \quad \text{(Eq 2)}$$

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. When the maximum size of particles in the samples is No. 8 sieve (2.36 mm) or less, the maximum size of the sample to be tested shall not exceed 0.3 lb (150 g). The maximum allowable quantity of material retained on an individual sieve shall be as indicated in Table 7.

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 minutes ±0.5 minutes for sand or gravel and 5 minutes ±0.5 minutes for anthracite. Standard sieves used for

Table 6 Minimum sample size for sieve analyses

Maximum Size of Particle in Sample		Minimum Sample Weight	
in.	*(mm)*	*lb*	*(kg)*
2½	63.00	77.00	35.0
2	50.00	45.00	20.0
1½	37.50	33.00	15.0
1	25.40	22.00	10.0
¾	19.00	11.00	5.0
½	12.50	4.00	2.0
⅜	9.50	2.00	1.0
No. 4 sieve	4.80	0.66	300.0 g
No. 8 sieve or less	2.36 or less	0.17	75.0 g*

* Maximum sample weight not to exceed 0.3 lb (150 g).

Table 7 Maximum allowable quantity of material retained on an individual sieve

Sieve Designation		8-in. Diameter Sieve		18-in. × 24-in. Sieve	
in.	*(mm)*	*lb*	*(kg)*	*lb*	*(kg)*
2½	63.00			104.83	47.55
2	50.00	7.85	3.560	82.20	37.74
1½	37.50	5.89	2.670	62.41	28.31
1	25.40	3.92	1.780	41.60	18.87
¾	19.00	2.98	1.350	31.61	14.34
½	12.50	1.96	0.890	20.81	9.44
⅜	9.50	1.48	0.670	15.81	7.17
No. 4 sieve	4.75	0.73	0.330	7.91	3.59
No. 8 sieve or less	2.36 or less	0.17	0.077		

testing filter material shall conform to the tolerances required in ASTM E11. The test sieves can be supplied as compliance (66 percent confidence level), inspection (99 percent), and calibration (99.74 percent). If questions of compliance arise during testing, when nominal standard sieve openings are used, standard reference materials (SRM) glass spheres certified by the National Institute of Standards and Technology should be used to more accurately determine the effective sieve opening size. The confidence level of compliance sieves that are calibrated with SRM glass spheres shall be increased from 66 percent to 95 percent. If non-SRM calibrated compliance sieves are used, the data shall be replotted using both the maximum and minimum permissible ± Y variation for 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 requirements in the purchase documents.

In situations where precision of sieve apertures is necessary, it is recommended that inspection sieves or calibration sieves be employed. When compliance sieves (with SRM calibration), inspection sieves, and calibration sieves are used in testing, the test reports shall include the test sieve serial number, type of sieve, calibrated sieve opening, and the date of certification or calibration. Proof of certification or calibration shall be made available upon request.

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 (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 a minimum of six sieves, with the largest sieve not retaining more than 5 percent of the grains by weight. If the filter media requirement 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. The particle size corresponding to the 10 percent size, which is the effective size in millimeters, shall be read from the curve. The ratio of the 60 percent size divided by the 10 percent size, as read from the curve, is the uniformity coefficient.

5.3.5 *Mohs' hardness scale.* There is no ASTM test method for Mohs' hardness.* The test is a subjective one, 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. The steps between the numbers are not of equal value. The difference in hardness, for example, between 9 and 10 is much greater than the difference between 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 lies 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' hardness is recorded as "greater than (the number of the last standard rock that can be scratched)."

5.3.5.1 When 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, each sample is scratched on the standard samples in increasing order of hardness, using a firm, constant-pressure stroke. The last number of the standard sample rock that the anthracite scratched is recorded for each test sample. The 15 test numbers shall be summed and the sum divided by 15 to obtain the average hardness of the total test sample. The Mohs' hardness shall be recorded as "greater than the average number" (e.g., >2.8).

* Geology for Engineers (Trefethen 1959), referenced in appendix A, presents Mohs' hardness–scale numbers for known geological rocks.

5.3.5.2 The Mohs' hardness test is a subjective test. It should only be performed by commercial laboratories that regularly perform filter media Mohs' hardness scale 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 disputed material before removal.

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

5.3.6.2 Alternative to removal. The constructor (or manufacturer or supplier) may, with the purchaser's agreement and control, reprocess rejected material at the jobsite to meet the applicable requirements.

SECTION 6: DELIVERY

Sec. 6.1 Marking

6.1.1 *Required.* Each package and container shall have the name of the material, gradation, filling date, net weight of the contents, name of the manufacturer, lot number, and brand name (if any) legibly marked. These markings shall be indelibly stenciled on bags. Each package shall bear other markings as 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 ANSI/AWWA B100, Granular Filter Material," provided that the requirements of this standard are met and that the material is not of a different quality in separate agreement between the manufacturer, or supplier, or constructor and purchaser.

Sec. 6.2 Packaging and Shipping

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

6.2.1 *Bags.* When required in the purchase documents, shipment shall be made in suitable new and unused heavy-duty cloth, paper, woven polypropylene, or polyethylene bags that contain ultraviolet (UV) light inhibitors, and which contain not more than 1 ft^3 (0.03 m^3) of material. Each bag shall be marked in an appropriate manner so that its contents are identified.

6.2.2 *Semibulk containers.* When required in the purchase documents, shipment shall be made in suitable new and unused heavy-duty woven polypropylene semibulk containers, treated with UV light inhibitors and having a safety factor of at least five. Each container shall hold 1 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 material segregation caused by vibration during transit. This latter event creates size gradation problems if the load is placed in two or more filter cells or vessels.

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 (82°C) 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 required in the purchase documents, shipment shall be made in cars washed with 180°F (82°C) 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 (or supplier or manufacturer) shall notify the purchaser of the railcar 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 required in the purchase documents, the manufacturer shall provide an affidavit of compliance stating that the filter material provided complies with the applicable provisions of this standard.

APPENDIX A

Bibliography

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

Amburgey, J.E., A. Amirtharajah, B.M. Brouckaert, and N.C. Spivey. 2003. An Enhanced Backwashing Technique for Improved Filter Ripening. *Jour. AWWA*, 95(12):81–94.

American Water Works Association (AWWA); Edzwald, J.K., ed. 2011. *Water Quality and Treatment*. 6th ed. New York: McGraw-Hill.

American Water Works Association and EWRI of American Society of Civil Engineers; Randtke, S.J., and M.B. Horsley, eds. 2012. *Water Treatment Plant Design*. 5th ed. New York: AWWA, ASCE, and McGraw-Hill.

Amirtharajah, A. 1993. Optimum Backwashing of Filters With Air Scour: A Review. *Water Science and Technology*, 27(10):195–211.

Amirtharajah, A., and J.L. Cleasby. 1972. Predicting Expansion of Filters During Backwash. *Jour. AWWA*, 64(1):52–59.

Amirtharajah, A., and D.P. Wetstein. 1980. Initial Degradation of Effluent Quality During Filtration. *Jour. AWWA*, 72(9):518–524.

Amirtharajah, A., N. McNelly, G. Page, and J. McLeod. 1991. *Optimum Backwash of Dual Media Filters and GAC Filter-Adsorbers With Air Scour*. Denver, CO: AWWA Research Foundation and American Water Works Association.

ASTM International. 2016. *Concrete and Aggregates*. Vol. 04.02 of *Annual Book of ASTM Standards*. West Conshohocken, PA: ASTM International.

Baylis, J.R. 1960. Discussion of Conley and Pitman. *Jour. AWWA*, 52(2):214.

Baylis, J.R. 1960. Two Layer Filter Media. *Jour. AWWA*, 52(2):215.

Beverly, R.P. 2012. *Filter Troubleshooting and Design Handbook*, 2nd ed. Denver, Colo.: American Water Works Association.

Brown, M.P., C.S.B. Fitzpatrick, and J. Murrer. 1995. Stratification in Triple Media Filters. *Jour. of Water Supply Research and Technology—Aqua*, 45(5):244.

Camp, T.R. 1961. Discussion of Conley—Experiences With Anthracite Filters. *Jour. AWWA*, 53(12):1478.

Chang, M., R.R. Trussell, V. Guzman, J. Martinez, and C.K. Delaney. 1999. Laboratory Studies on the Clean Bed Headloss of Filter Media. *Jour. of Water Supply Research and Technology—Aqua*, 48(4):137.

Cleasby, J.L., and K. Fan. 1981. Predicting Fluidization and Expansion of Filter Media. *Jour. ASCE*, 107(3):455–471.

Cleasby, J.L., and G.D. Sejkora. 1975. Effect of Intermixing on Dual Media Filtration. *Jour. ASCE*, 101(4):503–516.

Cleasby, J.L., and C.F. Woods. 1975. Intermixing on Dual Media and Multi-media Granular Filters. *Jour. AWWA*, 67(4):197.

Cleasby, J.L., G.L. Sindt, D.A. Watson, and E.R. Baumann. 1992. *Design and Operation Guidelines for Optimization of the High-Rate Filtration Process: Plant Demonstration Studies*. Denver, CO: Awwa Research Foundation and American Water Works Association.

Conley, W.R. 1961. Experiences With Anthracite-Sand Filters. *Jour. AWWA*, 53(12):1473.

Conley, W.R., and R.W. Pitman. 1960. Test Program for Filter Evaluation at Hanford. *Jour. AWWA*, 52(2):205.

Dostal, K.A., and G.G. Robeck. 1966. Studies of Modifications in Treatment of Lake Erie Water. *Jour. AWWA*, 58(11):1489.

Emelko, M.B., P.M. Huck, B.M. Coffey, and E.F. Smith. 2006. Effects of Media, Backwash, and Temperature on Full-Scale Biological Filtration. *Jour. AWWA*, 98(12):61–73.

Fair, G.M., J.C. Geyer, and D.A. Okun. 1968. Water Purification and Wastewater Treatment and Disposal. Vol. 2 of *Water and Wastewater Engineering*. New York: John Wiley & Sons.

Graese, S.L., V.L. Snoeyink, and R.G. Lee. 1987. *GAC Filter-Adsorbers*. Denver, CO: Awwa Research Foundation and American Water Works Association.

Great Lakes Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers. 2012. *Recommended Standards for Water Works*. Albany, NY: Health Research Inc.

Grens, B.K., and C.J. Werth. 2001. Durability of Wood Based Versus Coal Based GAC. *Jour. AWWA*, 93(4):175–181.

Hendricks, D., J.M. Barrett, J. Bryck, M.R. Collins, B.A. Janonis, and G.S. Logsdon. 1991. *Manual of Design for Slow Sand Filtration*. Denver, CO: Awwa Research Foundation.

Ives, K.J. 1990. Testing of Filter Media. *Jour. of Water Supply Research and Technology—Aqua*, 39(3):144–151.

Ives, K.J., and I. Sholji. 1965. Research on Variables Affecting Filtration. *ASCE Sanitary Engineering Division Jour.*, 91:SA4:1.

Kawamura, S. 1996. Optimization of Basic Water Treatment Processes—Design and Operation: Sedimentation and Filtration. *Jour. of Water Supply Research and Technology—Aqua*, 45(3):130–142.

Kawamura, S. 2000. *Integrated Design and Operation of Water Treatment Facilities*. 2nd ed. New York: John Wiley and Sons.

Kawamura, S. 2001. Design and Operation of Filters with Granular Media. In *Proc.: International Conference on Advances in Rapid Granular Filtration in Water Treatment*, 4–6 April 2001, 149–159. London: Chartered Institution of Water and Environmental Management.

Krumbein, W.C. 1941. Measurement and Geological Significance of Shape and Roundness of Sedimentary Particles. *Jour. of Sedimentary Petrology*, 11(2):64.

Krumbein, W.C., and L.L. Sloss. 1970. *Stratigraphy and Sedimentation*. 2nd rev. ed. San Francisco, CA: Freeman and Co. (Fig. 5.1, Chart for Visual Estimation of Sphericity and Roundness).

Logsdon, G.S., ed. 1991. *Slow Sand Filtration: A Report Proposed by the Task Committee on Slow Sand Filtration*. New York: American Society of Civil Engineers.

Logsdon, G.S., and J.M. Symons. 1977. Removal of Asbestiform Fibers by Water Filtration. *Jour. AWWA*, 69(9):499.

Logsdon, G.S., A.F. Hess, M.J. Chipps, and A.J. Rachwal. 2002. *Filter Maintenance and Operations Guidance Manual*. Denver, CO: Awwa Research Foundation and American Water Works Association.

Logsdon, G.S., V.C. Thurman, E.S. Frindt, and J.G. Stoecker. 1985. Evaluating Sedimentation and Various Filter Media for Removal of *Giardia* Cysts. *Jour. AWWA*, 77(2):61.

MacPhee, M.J., and W.C. Becker. 1999. Filter Backwashing: When and How. *Opflow*, 25(3):10–12.

McBride, D.G., R.C. Siemak, C.H. Tate, and R.R. Trussell. 1977. Pilot Plant Investigations for Treatment of Owens River Water. In *Proc. of the American Water Works Association Annual Conference, Anaheim, Calif.* Denver, CO: American Water Works Association.

Monk, R.D.G. 1987. Design Options for Water Filtration. *Jour. AWWA*, 79(9):93.

Montgomery Watson Harza. 2012. *MWH's Water Treatment: Principles and Design*. 3rd ed. Hoboken, NJ: John Wiley and Sons.

Nix, D.K., and J.S. Taylor. *Filter Evaluation Procedures for Granular Media*. Denver, CO: American Water Works Association.

Portland Cement Association; Kerkhoff, B. 2007. *Effects of Substances on Concrete and Guide to Protective Treatments*. 11th ed. Skokie, IL: Portland Cement Association.

Qureshi, N. 1982. The Effect of Backwashing Rate on Filter Performance. *Jour. AWWA*, 74(5):242–248.

Robeck, G.A., K.A. Dostal, and R.L. Woodward. 1964. Studies of Modifications in Water Filtration. *Jour. AWWA*, 56(2):198.

Swertfeger, J., D.H. Metz, J. DeMarco, A. Braghetta, and J.G. Jacangelo. 1999. Effect of Filter Media on Cyst and Oocyst Removal. *Jour. AWWA*, 91(9):90.

Trefethen, J.M. 1959 (reprinted 2015). *Geology for Engineers*. 2nd ed. Princeton, NJ: Van Nostrand Co. Inc. (Mohs' hardness scale is presented in this reference).

Trussell, R.R., and M. Chang. 1999. Review of Flow Through Porous Media as Applied to Head Loss in Water Filters. *Jour. of Environmental Engineering*, 125(11):998.

Trussell, R.R., M.M. Chang, J.S. Lang, and W. E. Hodges Jr. 1999. Estimating the Porosity of a Full-Scale Anthracite Filter Bed. *Jour. AWWA*, 91(12):54.

Trussell, R.R., A.R. Trussell, J.S. Lang, and C.H. Tate. 1980. Recent Developments in Filtration System Design. *Jour. AWWA*, 72(12):705.

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, sieves should be calibrated annually according to procedures in ASTM* E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves, and such calibrated effective size openings are to be utilized in performing sieve analysis. (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 purchase documents. Glass spheres for sieve calibration may be obtained from the National Institute of Standards and Technology.† 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.

* ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

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

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

Sieve Designation: Standard†	Sieve Designation: Alternative	Nominal Sieve Opening *in.*‡	Permissible Variation of Average Opening From the Standard Sieve Designation§	Opening Dimension Exceeded by Not More Than 5 Percent of the Openings	Maximum Individual Opening§	Nominal Wire Diameter *mm*¶
125 mm	5 in.	5	±3.66 mm	130.0 mm	129.51 mm	8.00
106 mm	4.24 in.	4.24	±3.12 mm	110.2 mm	109.99 mm	6.30
100 mm**	4 in.††	4	±2.94 mm	104.0 mm	103.82 mm	6.30
90 mm	3½ in.	3.5	±2.65 mm	93.6 mm	93.53 mm	6.30
75 mm	3 in.	3	±2.22 mm	78.1 mm	78.09 mm	6.30
63 mm	2½ in.	2.5	±1.87 mm	65.6 mm	65.71 mm	5.60
53 mm	2.12 in.	2.12	±1.58 mm	55.2 mm	55.39 mm	5.00
50 mm**	2 in.††	2	±1.49 mm	52.1 mm	52.29 mm	5.00
45 mm	1¾in.	1.75	±1.35 mm	46.9 mm	47.12 mm	4.50
37.5 mm	1½ in.	1.5	±1.13 mm	39.1 mm	39.35 mm	4.50
31.5 mm	1¼ in.	1.25	±0.95 mm	32.9 mm	33.13 mm	4.00
26.5 mm	1.06 in.	1.06	±0.802 mm	27.7 mm	27.94 mm	3.55
25.0 mm**	1.00 in.††	1	±0.758 mm	26.1 mm	26.38 mm	3.55
22.4 mm	7/8 in.	0.875	±0.681 mm	23.4 mm	23.67 mm	3.55
19.0 mm	¾ in.	0.750	±0.579 mm	19.9 mm	20.13 mm	3.15
16.0 mm	⅝ in.	0.625	±0.490 mm	16.7 mm	16.99 mm	3.15
13.2 mm	0.530 in.	0.530	±0.406 mm	13.83 mm	14.06 mm	2.80
12.5 mm**	½ in.††	0.500	±0.385 mm	13.10 mm	13.33 mm	2.50
11.2 mm	7⁄16 in.	0.438	±0.346 mm	11.75 mm	11.97 mm	2.50
9.5 mm	⅜ in.	0.375	±0.295 mm	9.97 mm	10.18 mm	2.24
8.0 mm	5⁄16 in.	0.312	±0.249 mm	8.41 mm	8.60 mm	2.00

* Reprinted, with permission, from ASTM E11-13, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.
† 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.
§ Table information is from ASTM E11-13.
¶ The average diameter of the wires in the *x* and *y* directions, measured separately, of any wire cloth shall not deviate from the nominal values by more than ±15 percent.
** These sieves are not in the standard series, but they have been included because they are in common usage.
†† These numbers (3½ to 635) are the approximate number of openings per linear inch, but it is preferred that the sieve be identified by the standard designation in millimeters or micrometers.

(Table continued next page)

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

Sieve Designation: Standard†	Sieve Designation: Alternative	Nominal Sieve Opening *in.*‡	Permissible Variation of Average Opening From the Standard Sieve Designation§	Opening Dimension Exceeded by Not More Than 5 Percent of the Openings	Maximum Individual Opening§	Nominal Wire Diameter *mm*¶
6.7 mm	0.265 in.	0.265	±0.210 mm	7.05 mm	7.23 mm	1.80
6.3 mm**	¼ in.††	0.250	±0.197 mm	6.64 mm	6.81 mm	1.80
5.6 mm	No. 3½††	0.223	±0.176 mm	5.90 mm	6.07 mm	1.60
4.75 mm	No. 4	0.187	±0.150 mm	5.02 mm	5.16 mm	1.60
4.00 mm	No. 5	0.157	±0.127 mm	4.23 mm	4.37 mm	1.40
3.35 mm	No. 6	0.132	±0.107 mm	3.55 mm	3.67 mm	1.25
2.80 mm	No. 7	0.110	±0.090 mm	2.975 mm	3.09 mm	1.12
2.36 mm	No. 8	0.0937	±0.076 mm	2.515 mm	2.61 mm	1.00
2.00 mm	No. 10	0.0787	±0.065 mm	2.135 mm	2.23 mm	0.900
1.70 mm	No. 12††	0.0661	±0.056 mm	1.820 mm	1.90 mm	0.800
1.40 mm	No. 14	0.0555	±0.046 mm	1.505 mm	1.58 mm	0.710
1.18 mm	No. 16	0.0469	±0.040 mm	1.270 mm	1.34 mm	0.630
1.00 mm	No. 18	0.0394	±0.034 mm	1.080 mm	1.14 mm	0.560
850 µm**	No. 20	0.0331	±29.1 µm	925 µm	977 µm	0.500
710 µm	No. 25	0.0278	±24.7 µm	775 µm	822 µm	0.450
600 µm	No. 30	0.0234	±21.2 µm	660 µm	701 µm	0.400
500 µm	No. 35	0.0197	±18.0 µm	550 µm	589 µm	0.315
425 µm	No. 40	0.0165	±15.5 µm	471 µm	506 µm	0.280
355 µm	No. 45	0.0139	±13.3 µm	396 µm	427 µm	0.224
300 µm	No. 50	0.0117	±11.5 µm	337 µm	365 µm	0.200
250 µm	No. 60	0.0098	±9.9 µm	283 µm	308 µm	0.160

* Reprinted, with permission, from ASTM E11-13, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

† 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.

§ Table information is from ASTM E11-13.

¶ The average diameter of the wires in the *x* and *y* directions, measured separately, of any wire cloth shall not deviate from the nominal values by more than ±15 percent.

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

†† These numbers (3½ to 635) are the approximate number of openings per linear inch, but it is preferred that the sieve be identified by the standard designation in millimeters or micrometers.

(Table continued next page)

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

Sieve Designation		Nominal Sieve Opening *in.*‡	Permissible Variation of Average Opening From the Standard Sieve Designation§	Opening Dimension Exceeded by Not More Than 5 Percent of the Openings	Maximum Individual Opening§	Nominal Wire Diameter *mm*¶
Standard†	Alternative					
212 μm	No. 70	0.0083	±8.7 μm	242 μm	264 μm	0.140
180 μm	No. 80	0.0070	±7.6 μm	207 μm	227 μm	0.125
150 μm	No. 100	0.0059	±6.6 μm	174 μm	193 μm	0.100
125 μm	No. 120	0.0049	±5.8 μm	147 μm	163 μm	0.090
106 μm	No. 140	0.0041	±5.2 μm	126 μm	141 μm	0.071
90 μm	No. 170	0.0035	±4.6 μm	108 μm	122 μm	0.063
75 μm	No. 200	0.0029	±4.1 μm	91 μm	104 μm	0.050
63 μm	No. 230	0.0025	±3.7 μm	77 μm	89 μm	0.045
53 μm	No. 270	0.0021	±3.4 μm	66 μm	77 μm	0.036
45 μm	No. 325	0.0017	±3.1 μm	57 μm	67 μm	0.032
38 μm	No. 400	0.0015	±2.9 μm	48 μm	58 μm	0.030
32 μm	No. 450	0.0012	±2.7 μm	42 μm	50 μm	0.028
25 μm**	No. 500	0.0010	±2.5 μm	34 μm	41 μm	0.025
20 μm**	No. 635	0.0008	±2.3 μm	29 μm	35 μm	0.020

* Reprinted, with permission, from ASTM E11-13, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

† 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.

§ Table information is from ASTM E11-13.

¶ The average diameter of the wires in the *x* and *y* directions, measured separately, of any wire cloth shall not deviate from the nominal values by more than ±15 percent.

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

†† These numbers (3½ to 635) are the approximate number of openings per linear inch, but it is preferred that the sieve be identified by the standard designation in millimeters or micrometers.

APPENDIX C

Particle Sizes

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

SECTION C.1: PARTICLE SIZE DISTRIBUTION

Sec. C.1.1 Particle Size Distribution

C.1.1.1 *Particle size distribution.* There are two methods of classifying particle size distribution. Either method may be used. The designer and end user are cautioned not to use both methods simultaneously. 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, arithmetic graph paper, or comparable computer programs.

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.

As an alternative to classifying particle size distribution as described above, media gradation also may be described in terms of effective size and uniformity coefficient as defined in Section 3, item 4, and Section 3, item 14, respectively, of ANSI/AWWA B100. 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 defining 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 require media size by both techniques may result in requiring a particle size distribution that cannot be attained by media producers.

C.1.1.2 *Anthracite sizes.* Effective sizes of anthracite generally range from 0.6 mm to 1.6 mm, and uniformity coefficients are generally 1.7 or lower.

C.1.1.3 *Silica sand sizes.* Effective sizes of silica sand generally range from 0.35 mm to 0.65 mm, and uniformity coefficients are generally 1.7 or lower.

C.1.1.4 *High-density sand sizes.* Effective sizes for high-density sand generally range from 0.18 mm to 0.60 mm, and uniformity coefficients are generally 2.2 or lower.

Lower and more specific uniformity coefficients are commonly specified by the purchaser, with consideration for the specific gravities of the media, to achieve proper stratification, minimize intermixing, and prevent carryover during backwash.

C.1.1.5 *Granular activated carbon.* GAC is suitable for use as a filter medium either alone or as a dual media with sand. GAC, when used as a filter medium, may have effective sizes that range from 0.5 to 1.5 mm. GAC is commonly manufactured with ranges in effective size from 0.35 to 2.0 mm. See ANSI/AWWA B604 for GAC filter medium information, including properties, sampling, testing, shipping, placement, and preparation for service.

APPENDIX D

Filter-Media Support Gravel Size and Layer Depth

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

The following guidelines can be used to select the sizes and depths of gravel layers for a conventional filter-media support 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 two. The minimum particle size of the top layer of fine gravel should be 4.0 to 4.5 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 4.0 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 filter-media support gravel should be at least three times the maximum particle size of the gravel in the layer, but not less than 3.0 in. (76 mm) in any case, except for gravel larger than 1.0 in. (25 mm), 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 D.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

Table D.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 to 0.50 mm Underdrain Orifice Size 0.25 in. (6.35 mm)			Fine Filter Media Effective Size 0.50 mm to 0.60 mm Underdrain Orifice Size 0.5 in. (12.7 mm)		
	Gradation of Gravel† Larger Than	but Smaller Than	Thickness of Layer	Gradation of Gravel† Larger Than	but Smaller Than	Thickness of Layer
1st‡	3.350 mm	1.700 mm	76 mm	4.750 mm	2.360 mm	76 mm
	(No. 6	No. 12)	(3 in.)	(No. 4	No. 8)	(3 in.)
2nd	6.300 mm	3.350 mm	76 mm	9.500 mm	4.750 mm	76 mm
	(0.250 in.	No. 6)	(3 in.)	(0.375 in.	No. 4)	(3 in.)
3rd	12.500 mm	6.300 mm	76 mm	19.000 mm	9.500 mm	76 mm
	(0.500 in.	0.250 in.)	(3 in.)	(0.750 in.	0.375 in.)	(3 in.)
4th	25.000 mm	16.000 mm	76 mm to 102 mm	37.500 mm	19.000 mm	76 mm to 127 mm
	(1.000 in.	0.675 in.)§	(3 in. to 4 in.)	(1.500 in.	0.750 in.)	(3 in. to 5 in.)
5th	None			63.000 mm	37.500 mm	127 mm to 203 mm
				(2.500 in.	1.500 in.)	(5 in. to 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.
§ 0.75 in. to 0.50 in. may be considered as an alternative size.

no more than 8 percent by dry weight shall pass through a No. 10 sieve. The layer thickness normally ranges between 2.0 in. and 4.0 in. (51 mm and 102 mm).

For triple-media filters with a layer of high-density sand, an additional layer of high-density gravel may be required to satisfy the 4.0 to 4.5 ratio of the media effective size and the top gravel layer.

For special applications, high-density gravels are available for 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, but are found in several of the references listed in appendix A.

This page intentionally blank.

APPENDIX E

In-Place Sampling and Testing of Existing Filter Media

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

If in-place samples of existing filter media are required, composite samples shall be prepared from each of the filters or 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. (50-mm) diameter core sampler. The sampler 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 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.

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. The bottle shall be filled to within 1 in. of the top with clean water.

c. The bottle shall be capped and shaken for 2 minutes using two or three forward and backward motions per second.

d. The filter media shall be allowed to settle, and then the supernatant liquid shall be decanted into a clean container.

e. Steps b through d shall be repeated until supernatant is clean.

f. If coal or granular activated carbon is used as the top layer, that filter media shall be separated from the sand using 1.95 specific gravity liquid as indicated in ASTM C123.

4. Testing. Samples shall be tested in accordance with Sec. 5.3.

This page intentionally blank.

This page intentionally blank.

American Water Works Association

6666 West Quincy Avenue
Denver, CO 80235-3098
T 800.926.7337
www.awwa.org

Dedicated to the world's most important resource, AWWA sets the standard for water knowledge, management, and informed public policy. AWWA members provide solutions to improve public health, protect the environment, strengthen the economy, and enhance our quality of life.

ISBN 978-1-62576-153-8

9 781625 761538

1P–2M 42100-2016 (04/16) IW

Printed on Recycled Paper