American Water Works Association

Erratum to
ANSI/AWWA B604-05
Standard
for

Granular Activated Carbon

(December 2008)

1. A new Coconut Shell-Based GAC section was added to Table F.1 to read as follows:

Table F.1 Typical characteristics for a range of GAC products*

Standard US Mesh Size	Uniformity Coefficient	Effective Size *(mm)*	Apparent Density *lb/ft³*
Coconut Shell-Based GAC			
20 × 50	≤1.6	0.3–0.5	28–38
12 × 40	≤1.9	0.55–0.75	28–35
12 × 30	≤2.1	0.6–0.85	28–35
10 × 30	≤1.6	0.7–0.9	28–35
8 × 30	≤2.1	0.7–1.0	28–35
8 × 16	≤1.5	1.2–1.5	29–39

ANSI/AWWA B604-05
(Revision of ANSI/AWWA B604-96)

American Water Works Association

The Authoritative Resource on Safe Water℠

AWWA Standard

Granular Activated Carbon

ANSI American National Standards Institute

Effective date: March 1, 2006.
First edition approved by AWWA Board of Directors Jan. 28, 1974.
This edition approved Jan. 16, 2005.
Approved by American National Standards Institute May 19, 2005.

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AWWA Standard

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AWWA unites the entire water community by developing and distributing authoritative scientific and technological knowledge. Through its members, AWWA develops industry standards for products and processes that advance public health and safety. AWWA also provides quality improvement programs for water and wastewater utilities.

Committee Personnel

The Subcommittee on Granular Activated Carbon as a Filter Medium, which assisted in developing this revision, had the following personnel at the time:

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*Alternate

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 B604.

I. Introduction.

I.A. *Background.* Activated carbon is a crude form of graphite that is produced by a carefully controlled oxidation process to develop a porous carbon structure with a large internal surface area greater than 500 m^2/g. This surface area gives the activated carbon the capacity to adsorb dissolved organic materials, many of which are taste- and odor-causing substances in water.

The major raw materials used in the manufacture of granular activated carbons (GAC) include, but are not limited to, peat, bituminous coal, coconut shells, wood, and lignite. During activation, the raw materials are either reacted at high temperatures in the presence of steam, or at more moderate temperatures in the presence of activation chemicals. The activation process first drives off volatile components from the raw material, creating a fine porous structure, and then enlarges the pores, which creates the extensive internal pore structure required to obtain appreciable adsorption of organic chemicals.

Water treatment with GAC is accomplished by percolating the water to be treated through fixed-bed adsorbers containing GAC. The GAC may be crushed and screened to any particle size, but typical sizes used for water treatment range from No. 8 to No. 50 US standard sieve sizes.

I.A.1. Source of supply. Virgin activated carbon used for water treatment should be obtained from manufacturers regularly engaged in the production of activated carbon found to be satisfactory for service in the water treatment field.

I.B. *History.* The first edition of ANSI/AWWA B604, Granular Activated Carbon, was approved by the AWWA Board of Directors on Jan. 28, 1974. Subsequent revisions to ANSI/AWWA B604 were prepared by the AWWA Standards Committee and approved by the AWWA Board of Directors June 17, 1990, and June 23, 1996. This fourth edition of B604 was approved by the AWWA Board of Directors on Jan. 16, 2005.

ANSI/AWWA B604 provides information on preparing documents for the purchase of virgin GAC to be used as an adsorption medium and filtration/adsorption medium for the treatment of municipal and industrial water supplies. Powdered activated carbon is covered in ANSI/AWWA B600, reactivated carbon is

covered in ANSI/AWWA B605, and other filtering materials are covered in ANSI/AWWA B100.

This standard does not cover the design of activated carbon handling facilities or adsorption processes. Design information may be found in *Journal AWWA* and in other publications, some of which are listed in the bibliography (Appendix A) to this standard.

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 American Water Works Association Research Foundation (AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

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

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state or local agency.
3. Two standards developed under the direction of NSF, 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.

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*Persons outside the US should contact the appropriate authority having jurisdiction.

†NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

‡American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

§Both publications available from National Academy of Sciences, 500 Fifth Street, N.W., Washington, DC 20001.

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 jurisdiction. 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 B604 does not address additives requirements. 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. *Handling and storage.* The following safety precautions should be exercised to minimize or eliminate hazards when handling and storing GAC. Wet activated carbon will readily adsorb oxygen from the air, creating an acute oxygen depletion hazard in confined areas. Appropriate safety measures for oxygen-deficient atmospheres should be strictly adhered to when entering enclosed or partially enclosed areas containing activated carbon.

GAC should be stored in a building or compartment that is as fire resistant as possible. Bags of GAC should be stacked in rows with aisles between them so that each bag may be easily removed in case of fire. Nothing else should be stored in the same building or compartment with activated carbon. Strict precautions must be taken to avoid GAC contacting strong oxidizing agents such as chlorine, hypochlorites, potassium permanganate, ozone, and peroxide. Mixing activated carbon with hydrocarbons (such as oils, gasoline, diesel fuel, grease, paint thinners, and so forth) may cause spontaneous combustion. Therefore, activated carbon must be kept separate from hydrocarbon storage or spills.

In case of an activated carbon fire, the safest procedure, if possible, is to place the smoldering material in a metal container and remove it from the building. An

activated carbon fire may also be smothered by means of a very fine spray or mist of water from a hose or by a foam-type chemical extinguisher. A direct stream of water should not be used, as it will cause the smoldering particles to fly into the air and spread the fire.

II.B. *Activated carbon dust.* Respiratory protection should be worn when bags of activated carbon or dry bulk material are unloaded or otherwise handled. Excessive dusting and inhalation of activated carbon dust should be avoided. Activated carbon dusts are classified as "nuisance particulates" and the applicable Threshold Limit Values should be followed.

Activated carbon is an electrical conductor and should not be allowed to accumulate as dust near or on open electrical circuits. Electrical outlets, lights, and motors in dry-activated-carbon feed and storage rooms should be watertight to preclude the entrance of activated carbon dust.

II.C. *Adsorptive performance.* To accurately assess the effectiveness of a GAC treatment, testwork should be completed using water from the particular plant in question for tests. Test methods may include testing for removal of a specific challenge compound, such as for taste and odors caused by Geosmin or 2 methyl-isoborneol present in the water to be treated. It is strongly recommended that activated carbon users follow this approach, as tests will reflect the actual conditions under which the activated carbon will be used.

Various surrogate tests have been developed that give an indication of a GAC's performance under specific conditions. The tests use a specific adsorbate at a high concentration to reduce the amount of time required to run the test. These tests are of limited versatility and are not necessarily indicative of an activated carbon's performance for a given application. Examples of these tests are the iodine number, tannin value, and acetoxime adsorption tests. Iodine number is indicative of the total surface area of a carbon. Acetoxime number is used as an index of activated carbon's ability to remove some low molecular weight organic compounds, such as volatile organic carbons. Tannin value is used as an index of a carbon's ability to remove high molecular weight impurities, such as natural organic matter from decaying vegetation. The test method for iodine number can be found in ASTM D4607. Information on tannin value and acetoxime adsorption tests may be found in Appendix B to this standard for those purchasers who want to include these requirements in their documents. Please note that the use of these surrogates may not model adsorption of actual water contaminants. An American Water Works

Association Research Foundation (AwwaRF) protocol has also been developed for the evaluation of GACs.*

II.D. *Filter media.* Filter media are those portions of the filter bed that remove particulate matter from the water during the filtration process. This standard covers GAC, which serves as both an adsorbent and filter medium. Properties of other filter media such as sand, anthracite, and filter media support such as gravel are contained in ANSI/AWWA B100.

II.E. *GAC size distribution.* The selection of the type, size, and bed depth of GAC in any particular application is site specific and depends on the raw water quality, pretreatment provided, and water quality objectives. These are site-specific design criteria and must be determined by the design engineer.

In general, for a given pretreatment of raw water and a given filtration rate, coarse media will permit longer filtration runs, but the rate of adsorption is slower. The organic removal and filtration efficiency will normally decrease as the particle size is increased. However, the head loss will also increase with decreasing particle size, and, as a result, the filter runs may be shorter. The uniformity coefficient (UC) of GAC used as a filter medium may be less than the UC of GAC used as an adsorbent. Experience indicates that a more uniform media results in greater filtration efficiency.

Dual- or multimedia GAC filters have been used in lieu of a single medium in standard filter-adsorbers for water treatment. The dual or multimedia are selected to provide a coarse layer of GAC in the upper filter with the smaller and more dense sand in the lower layers. This coarse-to-fine grading combines longer filter runs with the superior filtration characteristics of finer media. Obviously, the larger media must be lighter than the smaller media to provide the desired gradation, and the relative sizes of the various media should be selected on the basis of the desired backwash properties. Therefore, the relative size depends on the density and shape of the media, as well as particle size. It should also be noted that intermixing sand with GAC may introduce reactivation problems.

Because GAC is normally used as a filter medium due to the adsorption characteristics, the adsorption properties of the material must be considered. Efficient adsorption requires that the adsorption wave front of the GAC be maintained during the backwash–filtration cycle. Excessive intermixing of the GAC will reduce the

*R.S. Summers, et al. 1992. Standardized Protocol for the Evaluation of GAC. Denver, Colo.: AwwaRF and AWWA.

adsorption capacity of the filter bed material and increase the cost of operation. Maintaining a stratified bed is more difficult with GAC than with other media, such as sand or anthracite. As the activated carbon granules in the upper portion of the bed adsorb organic materials, the density increases and the particles settle to a lower portion of the bed. To assist in the maintenance of bed stratification, the adsorption wave front, and efficient adsorption, GAC is typically produced to be as nonuniform as possible. That is, the GAC is produced as nonuniform as possible without reaching the transport velocity of the smallest particles prior to achieving expansion of the largest fraction. This normally occurs at a uniformity coefficient of approximately 2.1. Where filtration is the primary function of the GAC, more uniform carbons may be warranted. The design engineer must balance the adsorption performance with the filtration requirements.

In specifying the size of GAC, it is normal to express the effective size of the particle and maximum allowable uniformity coefficient, or the average particle size and maximum uniformity coefficient. An oversize and undersize allowance may also be specified on the mesh sizes that incorporate the desired carbon gradation. For example, when specifying an 8 × 30 mesh size, the maximum amount that is retained on the 8 mesh (oversize) and the maximum percent that passes the 30-mesh screen (undersize) may also be specified. Commonly manufactured size ranges for GAC are expressed in US standard sieve sizes that include, but are not limited to, 8 × 16, 8 × 20, 8 × 30, 10 × 30, 12 × 40, 14 × 40, 20 × 40, and 20 × 50, with effective size ranges from 0.35 mm to 2.0 mm. Extruded carbons are also produced in various size ranges. The typical properties of the more standard GAC products are shown in Table F.1.

II.F. *Abrasion resistance.* GACs used for municipal water treatment are exposed to a variety of external forces during shipping, loading into adsorption beds, backwashing, and reactivation. These forces can cause activated carbon granule crushing on impact, granule-to-granule abrasion, and the generation of undesirable fines. Because of the difficulty in devising a test that simulates the various handling conditions that may be encountered, the industry has not yet agreed on any one standard test for predicting activated carbon durability.

Two tests, the stirring abrasion test and the Ro-Tap abrasion test, have been included in this standard for measuring GAC durability. It is recognized that differences in bulk density and other physical properties of the various manufactured activated carbons, which might not be related to durability, influence the results obtained in

Table F.1 Typical characteristics for a range of GAC products*

Standard US Mesh Size	Uniformity Coefficient	Effective Size (*mm*)	Apparent Density *lb/ft*^{3}
Bituminous Coal-Based GAC			
12 × 40	≤1.9	0.55–0.75	27–41
10 × 20	≤1.6	0.8–1.1	28–39
8 × 30	≤2.1	0.7–1.0	28–41
8 × 20	≤1.5	1.0–1.2	29–39
8 × 16	≤1.5	1.2–1.5	29–39
6 × 14	≤1.5	1.7–1.9	31–39
Lignite Coal-Based GACs			
20 × 50	≤1.6	0.3–0.5	22–26
20 × 40	≤1.5	0.45–0.65	22–26
12 × 40	≤1.8	0.55–0.8	22–26
10 × 30	≤1.6	0.7–0.9	22–26
12 × 20	≤1.7	0.7–1.0	22–26
8 × 30	≤1.8	0.7–1.0	22–26
8 × 16	≤1.5	1.2–1.5	22–26
Wood-Based GACs			
14 × 35	≤1.5	0.6–0.8	16–19
10 × 25	≤1.5	1.0–1.3	15–18
4 × 14	≤1.5	1.6–2.0	14–17

* The characteristics shown represent a range of GAC products and not a specific grade and mesh size. Manufacturer's product data bulletins should be consulted for information on specific grades and particle sizes.

using these tests. For this reason, it is current practice to use the stirring abrasion test for lignite-based GACs and the Ro-Tap abrasion test for bituminous-based GACs.

II.G. *Nonwettable.* In order for GAC to be effective as a filtration medium, the carbon particles must wet and settle into a filter bed. Some fraction of the activated carbon, due to some manufacturing processes, may not entirely wet and submerge. This can result in loss of activated carbon following initial placement in a

filter. If losses are sufficient, there can be a change in the particle size distribution that may lead to poor filtration performance. A test method to measure how much material will wet and sink is included in this standard.

II.H. *Reactivation.* The reactivation of GAC for municipal drinking water is covered in separate standards, ANSI/AWWA B605 and ASTM D6781.

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 provided by the purchaser:

1. Standard used—that is, ANSI/AWWA B604, GAC, of latest revision.
2. Whether compliance with NSF/ANSI 61 Drinking Water System Components—Health Effects, is required, in addition to the requirements of the Safe Drinking Water Act.
3. Quantity of GAC to be purchased. Activated carbon intended for immediate placement in an adsorption bed is typically purchased by volume and is backwashed and drained in place. Makeup activated carbon or activated carbon intended for subsequent placement is purchased on a volume or weight basis.
4. When requested, a representative sample of the GAC shall be submitted to the purchaser for acceptance before shipment. The sample must be submitted in clean, vapor-proof containers, clearly marked with the address of the supplier, and identified with the lot number of the contents. A duplicate sample shall be tested by the supplier and a certified test report shall be submitted to the purchaser with the purchaser's sample, showing compliance with the requirements of the purchaser, along with a statement certifying that the material for shipment is equal in quality to the sample submitted.
5. Name of the manufacturer whose product will be furnished by the supplier.
6. The purchaser may authorize shipment on the basis of the supplier's certification of quality or may test the reference sample submitted by the supplier to confirm compliance before shipment is authorized.
7. Details of other federal, state, local, and provincial requirements (Sec. 4.1).
8. Particle-size range, effective size, and uniformity coefficient, if other than that specified (Sec. 4.2.3).
9. Additional adsorptive capacity tests (Sec. 4.2.9 and Sec. 4.2.10).

10. The purchaser may elect to accept the GAC on the basis of (1) the supplier's certified test report and an accompanying affidavit of compliance indicating the product proposed for use complies with this standard and with the purchasers with no exceptions; (2) the supplier's certified test report completed by a qualified third-party testing laboratory approved by the purchaser and an accompanying affidavit of compliance; (3) the purchaser's own testing of the reference sample submitted by the supplier and the required affidavit of compliance; or (4) the purchaser's own testing of the representative sample, collected according to Sec. 5.1 after receipt of shipment, showing compliance with this standard and the purchase documents.

11. Provisions for reaching agreement on sampling technique (Sec. 5.1).

12. The purchaser may elect to collect a representative sample of the material after delivery. The procedure used shall be in accordance with Sec. 5.1. One of the three sample portions taken may be tested to determine compliance with the purchase documents.

13. Marking (6.1).

14. Method of packaging and shipping (Sec. 6.2).

15. If shipment is to be in bulk: type of railcar or hopper truck (Sec. 6.2.4); and whether bulk shipments are to be accompanied by weight certificates of certified weighers (Sec. 6.2.5).

16. Whether an affidavit of compliance is required (Sec. 6.3).

17. Whether this is a supply contract or a supply and installation contract (Sec. 7).

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

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

1. Additional recommended storage and safe handling requirements were added to Sec. II, including use of respiratory protection when handling bagged or bulk material.

2. Sec. II.G Nonwettable material was added to the Foreword and to Sec. 4, Requirements.

3. The Nonwettable materials test was added to Sec. 5, Verification.

4. The Tannin Absorption Test and Phenol Adsorption Test were removed from Appendix B and replaced with Tannin Value and Acetoxime Number Tests.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer and Technical Support Group at (303) 794-7711, FAX at (303) 795-7603, write to the group at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail at standards@awwa.org.

ANSI/AWWA B604-05
(Revision of ANSI/AWWA B604-96)

American Water Works Association

AWWA Standard

Granular Activated Carbon

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes virgin granular and extruded activated carbons for use as a filter medium and adsorbent in water treatment. It involves the selection, placement, and use of granular activated carbon (GAC) in filter-adsorbers where the GAC must function as both a filter medium and adsorbent, as well as those systems where the primary function is adsorption.

Sec. 1.2 Purpose

The main purpose of this standard is to provide the minimum requirements for GAC, including physical, testing, packing, and shipping requirements.

Sec. 1.3 Application

This standard can be referenced in documents for purchasing and receiving GAC and can be used as a guide for testing the physical properties of GAC samples. The stipulations of this standard apply when this document has been referenced and then only to GAC used in water supply service applications.