American Water Works Association

The Authoritative Resource on Safe Water®

ANSI/AWWA B604-12
(Revision of ANSI/AWWA B604-05)

AWWA Standard

Granular Activated Carbon

STANDARD
Since 1881

Approved American National Standard
ANSI

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AWWA Standard

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA B604-12.*

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 from 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.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 on June 17, 1990, and June 23, 1996. The fourth edition of B604 was approved on Jan. 16, 2005. This edition was approved by the AWWA Board of Directors on Jan. 22, 2012.

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 including anthracite coal are covered in ANSI/AWWA B100.

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

This standard does not cover the design of activated carbon handling facilities or adsorption processes. Design information may be found in *Journal - American Water Works Association* 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, now Water Research Foundation) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association 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.

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

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* Persons outside the United States should contact the appropriate authority having jurisdiction.

† NSF International, 789 North Dixboro Road, Ann Arbor, MI 48113.

‡ Both publications available from National Academy of Sciences, 500 Fifth Street N.W., Washington, DC 20418.

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. *Storage and Handling Precautions.* 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. Packaged GAC should be stacked in rows with aisles between them so that each package 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-methylisoborneol (MIB) 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 chemicals from groundwater. The Acetoxime Test's applicability for evaluating activated carbon for use in surface water applications has not been demonstrated. Tannin value is used as an index of a carbon's ability to remove high molecular weight impurities, such as natural organic matter. 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 ANSI/AWWA B604 for those purchasers who want to include these requirements in their documents. Please note that the use of these surrogates may not appropriately model adsorption of actual water contaminants. The Water Research Foundation's† *Standardized Protocol for the Evaluation of GAC* has 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 coal, and filter media support, such as gravel are

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

† Water Research Foundation, 6666 West Quincy Avenue, Denver, CO 80235.

contained in ANSI/AWWA B100. Information pertaining to the placement of GAC filter material can be located in appendix C.

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 filter medium results in greater filtration efficiency. With GAC, the UC is typically larger than for conventional filter media to promote re-stratification of the filter after backwash and to minimize disruption of the adsorption wave front (mass transfer zone).

GAC is normally used as a filter medium because of its adsorption characteristics. Efficient adsorption requires that the adsorption wave front be maintained during the backwash–filtration cycle. Excessive intermixing of the GAC during the backwash cycle will reduce the adsorption capacity of the filter bed material and increase the cost of operation. Maintaining a stratified bed is more important 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, their density increases and the particles settle to a lower portion of the bed. To assist in the maintenance of bed stratification, and the adsorption wave front, and to achieve efficient adsorption, GAC is typically produced as nonuniform in particle size distribution as possible. Of the GAC used, the smallest particles should not reach transport velocity before expansion of the largest fraction is achieved. 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 × 25, 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.

Dual- or multimedia GAC filters have been used in lieu of a single medium in standard filter-adsorbers for water treatment. In such filters, media are selected to provide a coarse layer of GAC above the smaller and denser sand layer. This coarse-to-fine grading combines longer filter runs with the superior filtration characteristics of finer media. 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. The relative size depends on the density and shape of the media, as well as particle size. It should be noted that intermixing sand with GAC may introduce reactivation problems, in addition to reducing filtration efficiency.

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

II.G. *Non-wettable.* For GAC to be effective as a filtration medium, the carbon particles must wet and settle into a filter bed. Because of some manufacturing processes, some fraction of the activated carbon 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.

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})	(*g/cc*)
		Bituminous Coal-Based GAC		
12 × 40	≤1.9	0.55–0.75	27–41	0.43–0.66
10 × 20	≤1.6	0.80–1.10	28–39	0.45–0.62
8 × 30	≤2.1	0.70–1.00	28–41	0.45–0.66
8 × 20	≤1.5	1.00–1.20	29–39	0.46–0.62
8 × 16	≤1.5	1.20–1.50	29–39	0.46–0.62
6 × 14	≤1.5	1.70–1.90	31–39	0.50–0.62
		Lignite Coal-Based GAC		
20 × 50	≤2.1	0.30–0.50	22–26	0.35–0.42
20 × 40	≤1.5	0.45–0.65	22–26	0.35–0.42
12 × 40	≤2.1	0.55–0.80	22–26	0.35–0.42
10 × 30	≤1.6	0.70–0.90	22–26	0.35–0.42
12 × 20	≤1.7	0.70–1.00	22–26	0.35–0.42
8 × 30	≤1.8	0.70–1.00	22–26	0.35–0.42
8 × 16	≤1.5	1.20–1.50	22–26	0.35–0.42
8 × 20	<1.5	1.00–1.20	22–26	0.35–0.42
		Wood-Based GAC		
6 × 18	≤2.0	1.30–1.60	13–18	0.21–0.29
8 × 25	≤2.0	0.90–1.10	13–18	0.21–0.29
8 × 30	≤2.1	0.60–0.80	18–22	0.29–0.35
12 × 40	≤2.1	0.60–0.80	18–22	0.29–0.35
		Coconut-Based GAC		
8 × 20	≤1.5	1.00–1.20	29–35	0.46–0.56
8 × 30	<2.1	0.80–1.10	28–33	0.45–0.53
12 × 30	<2.0	0.60-0.90	28–33	0.45–0.53

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

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, Granular Activated Carbon, 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. The particle-size range, effective size, and uniformity coefficient requirements (Sec. 4.2.3, 4.2.4, 4.2.5).
9. The uniformity coefficient requirement (Sec. 4.2.5)
10. The Iodine Number requirement (Sec. 4.2.9)
11. Additional adsorptive capacity test requirements (Sec. 4.2.10).
12. 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.

13. Provisions for reaching agreement on sampling technique (Sec. 5.1.2).

14. Required sample technique (Sec. 5.1.2). 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.

15. If remainder of the gross composite sample should be retained or returned to the package (Sec. 5.1.6, item 2).

16. Additional marking requirements (Sec. 6.1).

17. Method of packaging and shipping. Individual bags, boxes, or fiber drums may contain from 35 lb (16 kg) to 200 lb (91 kg) each and semibulk containers may contain 500 lb (363 kg) to 2,000 lb (908 kg) or other quantity as agreed on by the purchaser and supplier.

18. If shipment is to be in bulk: list type of railcar or hopper truck and adequately describe the GAC receiving structures (pressure vessels, gravity contactors, etc.) and conveyance (Sec. 6.2.4); and whether bulk shipments are to be accompanied by weight certificates of certified weighers (Sec. 6.2.5).

19. Whether alternative security measures have been adopted to replace or augment the security measures set out in Sec. 6.2.6.

20. Whether the purchaser will reject product from containers or packaging with missing or damaged seals. The purchaser may reject product from bulk containers or packages with missing or damaged seals unless the purchaser's tests of representative samples, conducted in accordance with Sec. 5.1 and 5.2 demonstrate that the product meets specifications. Failure to meet specifications or the absence of, or irregularities in, seals may be sufficient cause to reject the shipment.

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

22. Whether this is a supply contract or a supply and installation contract.

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. Added an alternative procedure for determination of percent moisture (Sec. 5.2.3.3)
2. Added security requirements for bulk shipments (Sec. 6.2.6)
3. Added a mandatory requirement for delivery of Affidavit of Compliance (Sec. 6.3)
4. Filter Material and Placing and Preparation was moved to appendix C.

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 e-mail at standards@awwa.org.

ANSI/AWWA B604-12
(Revision of ANSI/AWWA B604-05)

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 filter medium and adsorbent, as well as in those systems where the primary function is adsorption.

Sec. 1.2 Purpose

The 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.

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 this standard. In any case of conflict, the requirements of this standard shall prevail.

ANSI[*]/AWWA B100—Granular Filter Material.

ANSI/AWWA B600—Powdered Activated Carbon.

ANSI/AWWA B605—Reactivation of Granular Activated Carbon.

ANSI/AWWA C653—Disinfection of Water Treatment Plants.

ASTM[†] D4607—Standard Test Method for Determination of Iodine Number of Activated Carbon.

ASTM D6781—Standard Guide for Carbon Reactivation.

ASTM E300—Standard Practice for Sampling Industrial Chemicals

NSF[‡]/ANSI 60—Drinking Water System Chemicals–Health Effects.

NSF/ANSI 61—Drinking Water System Components–Health Effects.

Standardized Protocol for the Evaluation of GAC. AwwaRF (now Water Research Foundation), Denver, Colo.

Standard Methods for the Examination of Water and Wastewater. APHA,[§] AWWA, WEF,[¶] Washington, D.C.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Activated carbon:* A family of carbonaceous substances manufactured by processes that develop internal porosity, thereby creating adsorptive properties.

2. *Adsorption:* A process in which molecules are concentrated on a surface by chemical forces, physical forces, or both.

3. *Bag:* A plastic, paper, or woven container that may contain approximately 2.0 ft^3 of GAC.

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

[†] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

[‡] NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48113.

[§] American Public Health Association, 800 I St., N.W., Washington, DC 20005.

[¶] Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314.

4. *Bulk containers:* These are typically specially constructed trucks that may contain 20,000 lb to 40,000 lb of GAC.

5. *Day:* A day is defined as a 24-hr period.

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

7. *Extruded activated carbon:* A form of GAC in which the particles are uniform cylinders or cylindrical pellets. Effective size and uniformity coefficient are not applicable for extruded carbons. The diameter is normally specified.

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

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

10. *Reclaimed water:* Wastewater that becomes suitable for beneficial use as a result of treatment.

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

12. *Semibulk container:* A large plastic or woven bulk container that may contain 500 lb to 2,000 lb of GAC.

13. *Support media:* For the definitions and shipment requirements of gravel, sand, and associated support media, please refer to ANSI/AWWA B100.

14. *Uniformity coefficient:* A measure of the size range of media. The uniformity coefficient is the ratio between d60 (diameter from sieve analysis at which 60 percent of the grains are smaller by weight) and the effective size (defined above). UC = d60/effective size.

15. *Wastewater:* A combination of the liquid and water-carried waste from residences, commercial buildings, industrial plants, and institutions, together with any groundwater, surface water, and stormwater that may be present.

SECTION 4: REQUIREMENTS

Sec. 4.1 Materials

Materials shall comply with the requirements of the Safe Drinking Water Act and other federal regulations for water, wastewater, and reclaimed water systems as applicable.

Sec. 4.2 Characteristics

4.2.1 *Moisture.* The moisture content of GAC shall not exceed 8 percent, by weight, of the listed container contents as packaged, or at the time of shipment by the supplier, in the case of a bulk shipment. The moisture content shall be determined according to Sec. 5.2.3.

NOTE: Because ambient conditions may be beyond the control of the supplier, the moisture content of activated carbon may increase during bulk shipment. A moisture content exceeding 8 percent is permitted in the reference sample that is collected after receipt of shipment (Sec. III.A, 5.1 and 5.2).

4.2.2 *Apparent density.* The apparent density of the activated carbon shall be not less than 0.20 g/mL, as determined according to Sec. 5.2.4.

4.2.3 *Particle-size distribution.* Particle-size distribution shall be determined in accordance with Sec. 5.2.5. Not more than 15 percent of the activated carbon shall be retained on the maximum-size sieve,* and not more than 5 percent of the activated carbon shall pass the minimum-size sieve.

4.2.4 *Effective size.* The effective size of the GAC shall be from 0.30 mm to 2.0 mm as determined in accordance with Sec. 5.2.5.5. This parameter does not apply to extruded carbons where the cylindrical diameter is typically specified.

4.2.5 *Uniformity coefficient.* GAC shall have a uniformity coefficient not greater than 2.1 as determined in accordance with Sec. 5.2.5.5. This parameter does not apply to extruded carbons. More uniform carbons may be specified where desirable for filtration performance.

4.2.6 *Abrasion resistance.* The retention of average particle size of GAC shall not be less than 70 percent, as determined by either the stirring abrasion test or the Ro-Tap abrasion test, according to Sec. 5.2.6.

4.2.7 *Water-extractable ash.* The water-extractable ash shall not exceed 4 percent, as determined according to Sec. 5.2.7.

4.2.8 *Non-wettable materials.* The non-wettable materials should not exceed 5 percent by weight. Non-wettable materials shall be determined according to Sec. 5.2.8.

4.2.9 *Iodine number.* The iodine number of the GAC shall not be less than 500 mg/g carbon, as determined according to Sec. 5.2.9. If desired, a higher iodine number may be specified. (See Foreword, Sec. II.C, for discussion of other

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* Sieve numbers referred to in this standard are US Standard Sieve Series numbers, as specified in the ASTM International Standard Designation E11, Specification for Wire-Cloth Sieves for Testing Purposes, available from ASTM, 100 Barr Harbor Dr., West Conshohocken, PA 19428.

tests to determine special adsorptive characteristics for specific organics removal. These special test procedures should be specified, if deemed advisable, and the purchaser requirements should allow adequate time to complete testing and confirmation analysis.)

4.2.10 *Representative samples for additional tests.* If the purchaser desires to use additional tests to measure adsorptive capacity, the purchaser shall notify the supplier of the need for a representative sample. The purchaser's requirements should allow adequate time to complete testing and confirm analysis.

Sec. 4.3 Impurities

4.3.1 *General impurities.* The GAC 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 GAC.

SECTION 5: VERIFICATION

Sec. 5.1 Sampling

5.1.1 *Sampling location.* Should the manufacturer's product certification or the representative samples collected during product manufacturing not be the agreed basis for acceptance, samples shall be taken at the point of destination.

5.1.1.1 Sampling in the field. Care should be exercised in sampling materials after shipment due to the inherent challenges of obtaining a representative sample from bulk shipping containers.

5.1.1.1.1 Samples taken during the manufacturing process should be considered to be more representative of the produce than samples taken in the field.

5.1.1.1.2 The customer shall maintain the right to observe sampling processes during product manufacturing or in the field.

5.1.2 *Technique.* The technique of sample collection should be decided before shipment.

5.1.2.1 Damaging sample. Care shall be taken during sampling to minimize particle fracturing or alteration of any of the other material requirements of this standard.

5.1.2.2 Collecting representative samples. Refer to ASTM E300 and ANSI/AWWA B100.

Table 1 Sampling of bagged media*

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

*Refer to Military Standard MIL-STD-105D Sampling Procedures for Inspection by Attributes.

5.1.3 *Mechanical sampling.* If the GAC is handled by conveyor or elevator or shipped in bulk, a mechanical sampling arrangement may be used.

5.1.4 *Package sampling.* When material is shipped to the jobsite in bags, or semibulk containers, representative samples shall be collected using a core sampler. The representative samples from each bag shall be combined to produce the required composite sample. The minimum-sized composite sample shall be 10 lb (4.5 kg), and the number of packages to be sampled is indicated in Table 1.

5.1.5 *Sampling tube.* Activated carbon may be sampled, from bulk carload shipments or from packages by the use of a sampling tube of at least ¾ in. (19 mm)* diameter. When taking samples from packages, the sampling tube shall be extended the full length of the package to obtain a representative sample.

5.1.6 *Sample size.* The representative gross composite sample of approximately 10 lb shall be sealed in vapor-proof containers. Each sample container shall be labeled to identify it, and the label shall be signed by the sampler. The gross composite sample shall be divided using one of the following methods:

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* Metric conversions given in this standard are soft conversions of US customary units and are not those specified in International Organization for Standardization (ISO) standards.

1. Mix thoroughly and divide the sample to provide three 1-lb (0.45-kg) samples. The remainder of the gross composite may be either retained or returned to the package, approximately 7 lb (3.15 kg).

2. Pour through a sample riffler. Repeat as necessary using the split portions to provide three 1-lb (0.45-kg) samples. The remainder of the gross composite may be either retained or returned to the package, approximately 7 lb (3.15 kg).

Sec. 5.2 Test Procedures

5.2.1 *Samples.* If the purchaser elects to accept the material on the basis specified in Sec. III.A, samples shall be taken from each shipment of GAC according to Sec. 5.1. After thorough mixing, the sample shall be weighed immediately and then stored in an airtight vapor-proof container to avoid moisture pickup.

5.2.2 *Testing period.* The laboratory examination of a sample shall be completed in time to meet the requirements of Sec. 5.3.1 for notification of the supplier in the event that tests reveal that the material does not comply with this standard or the purchaser's requirements.

5.2.3 *Moisture.*

5.2.3.1 Procedure. In a tared weighing bottle, accurately weigh approximately 2 g of the sample. Dry in a drying oven at 140°C (284°F) for 2 hr or 110°C (230°F) for 3 hr; then cool in a desiccator and weigh rapidly.

5.2.3.2 Calculation.

$$\frac{\text{loss of weight}}{\text{weight of sample}} \times 100 = \%\ \text{moisture} \qquad \text{(Eq 1)}$$

5.2.3.3 Alternative procedure using a moisture balance. A moisture balance utilizes a thermo gravimetric method to measure the water content on the carbon. A heat source set to 110°C is used to dry the carbon sample until a constant weight is measured. The moisture is displayed as a percent of the wet sample weight. The end point should be less than 0.1 percent change in weight for 5 min. Sample size is 10 g.

5.2.4 *Apparent density.*[*]

5.2.4.1 General. The apparent density of GAC is the weight in grams per milliliter (g/mL) of the GAC in air with the density determined on an "as-received" basis with corrections made for moisture content.

5.2.4.2 Apparatus. The testing apparatus shall be as shown in Figure 1. Reservoir and feed funnels are glass or metal. The metal vibrator is 26-gauge

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[*] ASTM D2854 may also be used as a method for the determination of apparent density.

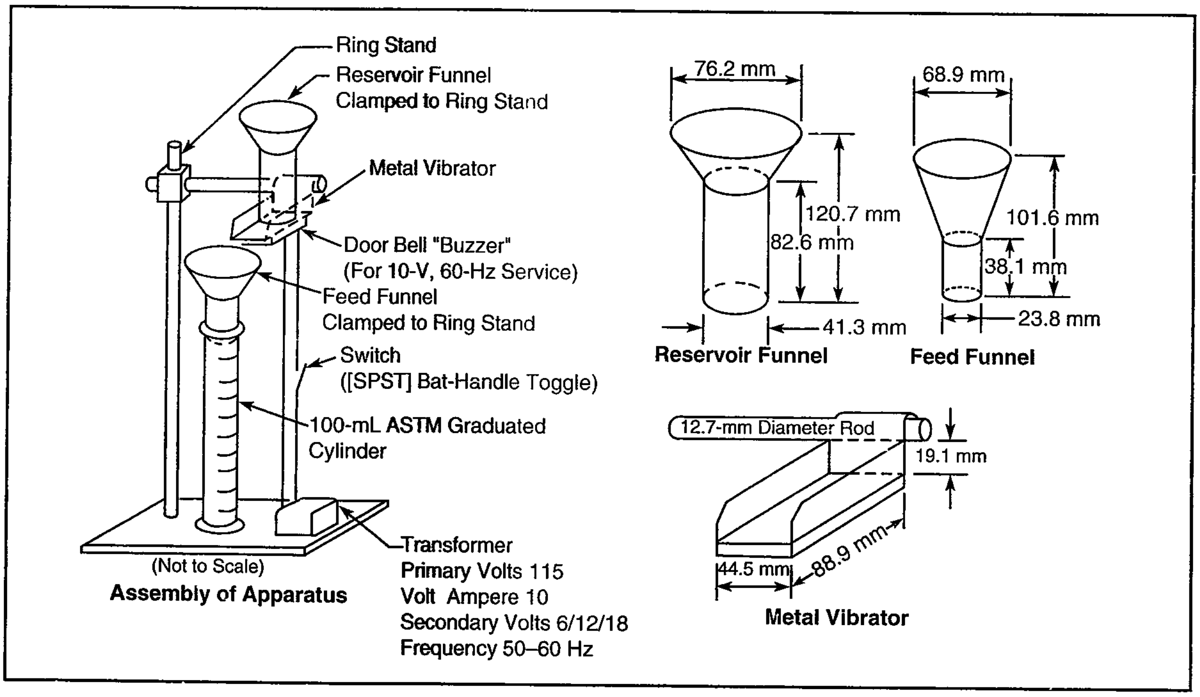

Figure 1 Apparent density apparatus

galvanized sheet metal. Commercial vibratory feeders are available. A balance with a sensitivity of 0.1 g is required.

5.2.4.3 Procedure.

1. Carefully place a representative sample of the GAC into the reservoir funnel. If the material prematurely flows into the graduated cylinder, return the material to the reservoir funnel.

2. Add the sample to the cylinder by the vibrator feeder at a uniform rate of not less than 0.75 mL/sec nor greater than 1.0 mL/sec up to the 100-mL mark. Adjust the rate by changing the slope of the metal vibrator or raising or lowering the reservoir funnel, or both, or by using a variable autotransformer to vary the current to the buzzer transformer.

3. Transfer the contents from the cylinder to a balance pan and weigh to the nearest 0.1 g.

5.2.4.4 Calculation. Calculate the apparent density in grams/milliliter on the dry basis:

$$\text{apparent density} = \frac{(\text{weight of sample, in grams}) \times (100 - \%\ \text{moisture})}{(\text{volume of sample, in cubic centimeters} \times 100)} \qquad \text{(Eq 2)}$$

5.2.5 *Particle-size distribution.**

5.2.5.1 General. Determine the particle-size distribution of GAC by mechanically shaking a weighed amount of material through a series of US standard sieves and then determining the quantity retained on or passing through each sieve.

5.2.5.2 Apparatus.

- Sample splitter—similar to Jones riffler
- Sieve shaker, electrically driven, equipped with automatic timer similar to Ro-Tap
- Sieves—US standard sieves, 8-in. diameter and 2 in. high
- Bottom receiver pan—8-in. diameter and 2 in. high
- Top sieve cover—8-in. diameter
- Balance—top loader with sensitivity of 0.1 g
- Brush—soft brass-wire brush

5.2.5.3 Procedure.

1. Assemble the sieves to be used on the bottom receiver pan in order of increasing sieve opening size from bottom to top. The smallest- and largest-opening size sieves should correspond to the limiting sizes for the grade of carbon specified; for example, for 12 × 40 GAC, use sieve numbers 12, 14, 16, 20, 30, and 40. US standard sieves and opening sizes are tabulated in Table 2.

2. Mix the sample by passing the material through the riffle and recombining twice.

3. Carefully reduce the mixed sample by repeated passes through the riffle to obtain a test sample of 100 ± 5 g. No more than 5.0 g of GAC may be added or taken from the test sample without additional riffling.

4. Transfer the weighed sample to the top sieve. Install the sieve cover and sieve shaker cover and place the assembly on the sieve shaker.

5. Allow the sieve assembly to shake for 3 min ± 3 sec with the hammer operating.

6. Remove the sieve assembly from the sieve shaker and quantitatively transfer the GAC retained on the top sieve to a tared balance pan and weigh to the nearest 0.1 g. Repeat this procedure for material retained on each subsequent sieve and the bottom receiver pan. Lightly brush the material from each sieve to free particles held in the screen.

7. Add the weights of each sieve fraction; if the sum deviates more than 2.0 g from the test sample weight, repeat the analysis.

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* ASTM D2862 may be used as a method for the determination of particle size distribution.

Table 2 US standard sieves and opening sizes

US Standard Sieve Number	Sieve Opening *mm*
6	3.360
8	2.380
10	2.000
12	1.700
14	1.400
16	1.180
18	1.000
20	0.850
25	0.710
30	0.600
35	0.500
40	0.425
45	0.355
50	0.300

5.2.5.4 Percentage retained on each sieve.

$$\frac{\text{(sieve fraction weight)(100)}}{\text{(sum of sieve fraction weights)}} = \text{\% retained on each sieve} \qquad \text{(Eq 3)}$$

5.2.5.5 Effective size and uniformity coefficient.

1. From the percentage retained on each sieve, calculate the cumulative percentage passing each sieve. The cumulative percentage passing a sieve is the sum of the percentages retained on subsequent (smaller) sieves plus the percentage retained on the pan.

2. Using logarithmic paper or graphing software, plot the sieve opening in millimeters on the ordinate, or vertical, scale versus the cumulative percentage passing each sieve on the abscissa or horizontal scale.

3. The effective size is the sieve opening in millimeters at which 10 percent of the material passes on the cumulative percentage passing scale.

4. The uniformity coefficient is determined by dividing the millimeter opening at which 60 percent passes by the millimeter opening at which 10 percent passes.

Table 3 Sieving apparatus required for stirring abrasion test

US Standard Sieve Number	Sieve Opening *mm*	Average Opening *mm* (D_i)
8	2.360	—
12	1.700	2.03
16	1.180	1.44
20	0.850	1.02
40	0.425	0.64
50	0.300	0.36
70	0.212	0.26
pan	—	0.15

5.2.6 *Abrasion resistance.*

5.2.6.1 General. Determine abrasion resistance either by stirring abrasion or Ro-Tap abrasion tests as follows.

5.2.6.2 Stirring abrasion test. The stirring abrasion test measures percentage retention of the average particle size of the GAC after abrading the GAC by the action of a T-shaped stirrer in a specially fabricated abrasion unit. This test is used to measure abrasion resistance of wood-, lignite-and petroleum-coke-based GAC.

5.2.6.2.1 Apparatus.

- Sieving apparatus—stirring abrasion test
- Sieve shaker, electrically driven, equipped with automatic timer—similar to Ro-Tap
- Sieves—US standard sieves, 8-in. diameter and 2 in. high; Table 3 indicates sieves that are required
- Bottom receiver pan—8-in. diameter, full height
- Top sieve cover—8-in. diameter
- Balance—top loader with sensitivity of 0.1 g
- Brush—soft brass-wire brush

5.2.6.2.2 Stirring abrasion unit. The abrasion unit is detailed in Figure 2. The apparatus includes a T-shaped stirrer made from ½-in. metal rod that is driven at 855 ± 15 rpm. The stirrer and cylinder may be made of any suitable material; for example, steel, stainless steel, or brass. The absence of burrs and rough welds is absolutely necessary. The T-bar stirrer should be replaced when the length of the cross bar is 0.02 in. less than the designed size or when the hemispherical ends show signs of

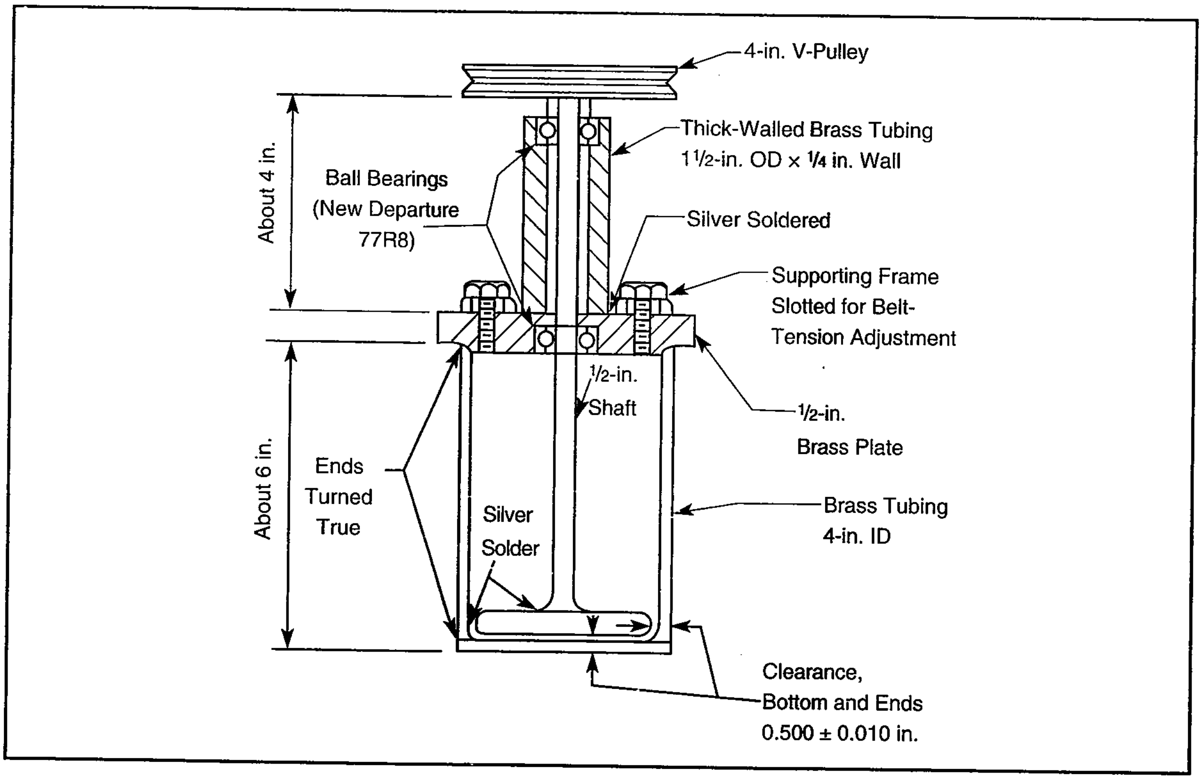

Figure 2 Stirring abrasion unit

serious wear; that is, when the length of the cross bar is more than 0.025 in. from the designed size. Such wear will show on the leading edge of the T-bar stirrer.

5.2.6.2.3 Procedure—stirring abrasion test.

1. Place a No. 8 sieve on top of a No. 70 sieve on the sieve shaker. Screen sufficient GAC sample to obtain 250 mL to 300 mL of 8 × 70 mesh by shaking portions of the GAC on the sieve shaker for exactly 3 min ± 2 sec with the hammer operating. Discard the material retained on the No. 8 sieve and the material passing the No. 70 sieve.
2. Place the 250-mL to 300-mL portion of GAC on the top screen of a nest of US standard sieves, numbers 12, 16, 20, 40, 50, and 70, and shake on the sieve shaker for 15 min ± 10 sec with the hammer operating.
3. Remove the sieve assembly from the sieve shaker and quantitatively transfer the GAC retained on the top sieve to a tared balance pan and weigh to the nearest 0.1 g. Repeat this procedure for material retained on each subsequent sieve and the bottom receiver pan. The material should be lightly brushed from each sieve to free particles held in the screen. Record the weight of each sieve fraction and the total weight of GAC recovered.

4. Recombine and blend by tumbling the sieve fractions very gently in a quart fruit jar or similar container and place the GAC in the abrasion unit. Operate the abrasion unit for 1 hr ± 1 min.

5. Remove the GAC from the abrasion unit and repeat the screening on a nest of US standard sieves, numbers 12, 16, 20, 40, 50, and 70, as in step 2. Use the same sieve shaker as was used for the initial sieve analysis. Record the weight of each sieve fraction and the total weight of GAC recovered.

5.2.6.2.4 Calculations—stirring abrasion test. Calculate the average particle size before and after stirring by using the following equation:

$$D_{\text{avg}} = \frac{\text{summation of } (W_i \times D_i)}{\text{summation of } (W_i)} \qquad \text{(Eq 4)}$$

Where:

D_{avg} = the average particle size, in millimeters

W_i = the weight of a sieve fraction, in grams

D_i = the opening in millimeters that corresponds to the average of the openings in the two sieves that enclose that mesh fraction (see Table 3)

Calculate the percentage retention of average particle size; adjust to 1-mm original particle size by using the following equation:

$$\% \text{ retention/millimeter} = (100)\left[1 - \frac{(\text{original } D_{\text{avg}} - \text{final } D_{\text{avg}})}{(\text{original } D_{\text{avg}})^2}\right] \qquad \text{(Eq 5)}$$

Report the value obtained as the percentage retention of particle size from the stirring abrasion test.

5.2.6.3 Ro-Tap abrasion test. The Ro-Tap abrasion test measures the percentage retention of original average particle size by the resistance of the particles to the action of steel balls in the Ro-Tap machine. This test is used to measure abrasion resistance of coconut-, bituminous-, and petroleum-coke-based GAC.

5.2.6.3.1 Sieving apparatus—Ro-Tap abrasion test.

- Sample splitter—similar to Jones riffler
- Ro-Tap—sieve shaker, electrically driven, equipped with automatic timer
- Sieves—US standard sieves, 8-in. diameter and 2-in. high
- Bottom receiver pan—8-in. diameter, full height
- Top sieve cover—8-in. diameter
- Balance—top loader with sensitivity of 0.1 g
- Brush—soft brass-wire brush

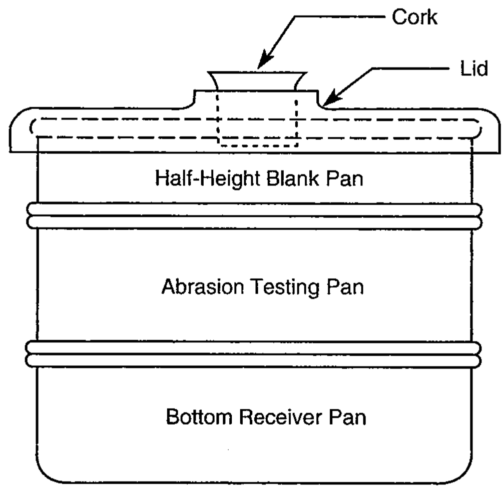

Figure 3 Testing pan assembly for Ro-Tap abrasion test (not to scale)

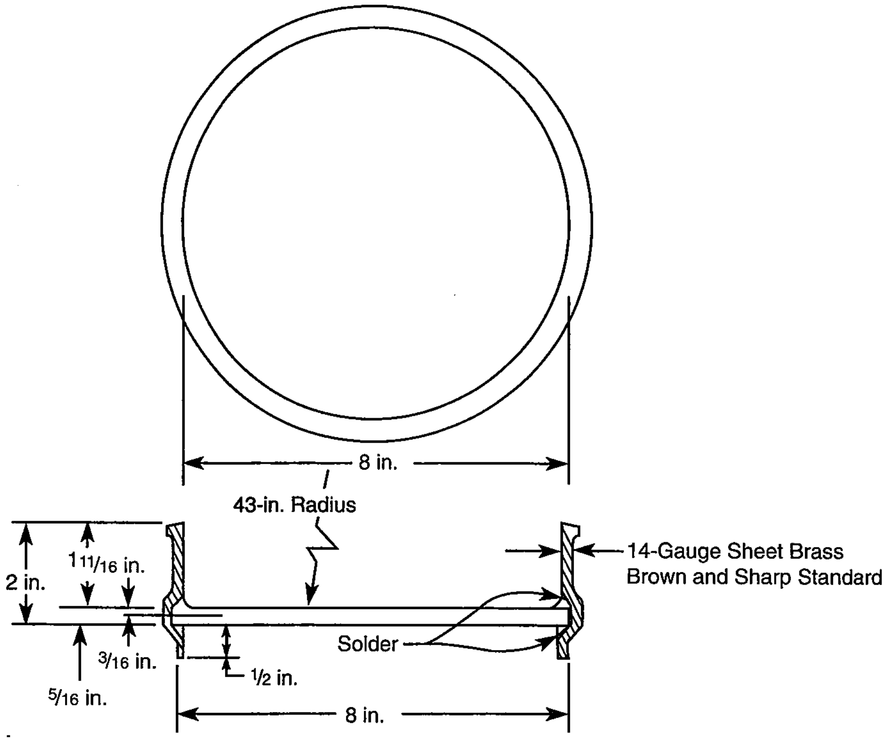

Figure 4 Abrasion testing pan for Ro-Tap abrasion test (not to scale)

5.2.6.3.2 Testing pan assembly. The abrasion pan assembly is detailed in Figure 3. The assembly consists of a Ro-Tap lid with cork insert, a half-height blank pan, a specially fabricated abrasion testing pan, and a bottom receiver pan. The abrasion testing pan is detailed in Figure 4. Ten ½-in. (12.7-mm) diameter

Table 4 Recommended particle sieve sizes

Particle-Size Range	US Standard Sieve Sizes
8 × 16	8, 12, 16 pan
8 × 20	8, 12, 16, 20 pan
8 × 30	8, 12, 16, 20, 30 pan
10 × 30	10, 12, 16, 20, 30 pan
12 × 40	12, 16, 20, 30, 40 pan
14 × 40	14, 16, 20, 30, 40 pan
20 × 40	20, 30, 40 pan
20 × 50	20, 30, 40, 50 pan

and ten ¾-in. (19-mm) diameter smooth steel balls will also be required. The steel balls will be placed in the testing pan together with the GAC sample to be tested for the abrasion test.

5.2.6.3.3 Procedure—Ro-Tap abrasion test.

1. Assemble the sieves to be used on the bottom receiver pan in order of increasing sieve opening from bottom to top. Suggested sieve sizes to be used with various particle-size ranges are given in Table 4.
2. Mix the sample by passing the material through the riffle and recombining twice.
3. Carefully reduce the mixed sample by repeated passes through the riffle so as to obtain a test sample of 100 ± 5 g. Do not add to or take from the sample more than 5.0 g of GAC without additional riffling.
4. Transfer the weighed sample to the top sieve.
5. Install the sieve cover and Ro-Tap cover and place the assembly on the Ro-Tap sieve shaker.
6. Allow the sieve assembly to shake for 10 min ± 10 sec with the hammer operating.
7. Prepare the abrasion testing pan and count the steel balls to ensure that ten ½-in. (12.7-mm) and ten ¾-in. (19-mm) diameter smooth steel balls are contained in the pan.
8. Remove the sieve assembly from the Ro-Tap and quantitatively transfer the GAC retained on the top sieve to a tared balance pan. Weigh the GAC to the nearest 0.1 g, then transfer it to the abrasion testing pan. Repeat this procedure for material retained on each subsequent sieve and the bottom receiver pan. The material should

be lightly brushed from each sieve to free particles held in the screen. Record the weight of each sieve fraction and the total weight of GAC recovered.

9. After the sieve fractions have been weighed and recombined in the abrasion testing pan, place the testing pan assembly on the Ro-Tap sieve shaker. The testing pan assembly must be level and fit snugly on the Ro-Tap.

10. Allow the testing pan assembly to shake for 20 min ± 2 sec with the hammer operating. The time is critical; if the automatic timer is not capable of the specified accuracy, the sieve shaker should be manually controlled and timed with a stopwatch.

11. Remove the abrasion pan from the Ro-Tap and quantitatively transfer the contents to the original set of sieves. A large-opening sieve may be temporarily nested into the top sieve to remove the steel balls from the GAC, or the balls may be removed by hand.

12. Repeat steps 5, 6, and 8 in Sec. 5.2.6.3.3 using the same Ro-Tap as was used for the initial sieve analysis. However, after this second sieve analysis, discard the individual screen fractions after weighing. Repeat the analysis if the sum of either sieve analysis deviates by more than 2.0 g from the test sample weight.

5.2.6.3.4 Calculations—Ro-Tap abrasion test.

(a) Calculate the original and final average particle size by using the following equation:

$$D_{\text{avg}} = \frac{\text{summation of } (W_i \times D_i)}{\text{summation of } (W_i)} \qquad \text{(Eq 6)}$$

Where:

D_{avg} = the average particle size, in millimeters

W_i = the weight of a sieve fraction, in grams

D_i = the opening in millimeters that corresponds to the average of the openings in the two sieves that enclose that mesh fraction.

NOTE: Material caught on the pan is not considered in calculating the average particle diameter. Values for D_i are given in Table 5.

(b) Calculate average particle size; example calculation using a 12 × 30 mesh material given in Table 6.

$$D_{\text{avg}} = \frac{106.3}{100.0} = 1.063 \qquad \text{(Eq 7)}$$

(c) Calculate the percentage retention of average particle size by using the following equation:

$$\text{retention, percentage} = \frac{\text{final } D_{\text{avg}}}{\text{original } D_{\text{avg}}} \times 100 \qquad \text{(Eq 8)}$$

Table 5 D_i **values for Ro-Tap abrasion test**

US Standard Sieve Numbers	Sieve Opening Size *mm × mm*	Average Opening (D_i) *mm*
6 × 8	3.360 × 2.360	2.860
8 × 10	2.360 × 2.000	2.180
8 × 12	2.360 × 1.700	2.030
10 × 12	2.000 × 1.700	1.850
12 × 14	1.700 × 1.400	1.550
12 × 16	1.700 × 1.180	1.440
14 × 16	1.400 × 1.180	1.290
16 × 20	1.180 × 0.850	1.020
20 × 30	0.850 × 0.600	0.725
30 × 40	0.600 × 0.425	0.513
40 × 50	0.425 × 0.300	0.360

Table 6 Example Ro-Tap abrasion test

US Standard Sieve No.	Retained W_i *grams*	Average Opening (D_i) *mm*	$W_i \times D_i$
+12	1.5	2.03*	3.0
12 × 16	25.0	1.44	36.0
16 × 20	50.0	1.02	51.0
20 × 30	22.5	0.725	16.3
+30	1.0	0.00	0.0
Summation	100.0		106.3

*The 2.03 factor was used for material remaining on the No. 12 sieve because it was assumed that this material would pass through a No. 8 sieve (generally the next larger sieve in the square root of two series).

Report the value obtained as the percentage retention of average particle size from the Ro-Tap abrasion test.

5.2.7 *Water extractables test.* The method used for determining the water extractable content of GAC is found in the *Food Chemicals Codex* procedures, under the category of Carbon, Activated.

5.2.8 *Non-wettable materials test.*

5.2.8.1 General. A known weight of activated carbon is mixed with water. Floating material is collected, dried, and weighed.

5.2.8.2 Apparatus.

- Sample splitter—similar to Jones riffler
- Drying oven
- Desiccator and desiccant
- Balance
- ½ – 1-in. Teflon stir bars
- 500-mL glass beaker
- Straining spoon

5.2.8.3 Procedure

1. Mix the sample by passing through the riffle and recombining twice.
2. Carefully reduce the mixed sample by repeated passes through the riffle to obtain a sample between 25 and 30 grams.
3. Dry the sample for 2 hr at 150°C.
4. Cool the sample in a desiccator to ambient temperature.
5. Weigh 20 gram ± 0.01 gram and place into 500 mL beaker. Record this value as Sample Weight.
6. Slowly add 400 mL tap water into the beaker on top of the GAC.
7. Place the beaker on a magnetic stirrer and place the Teflon stir bar into the beaker.
8. Stir for 5 min ± 10 sec at a speed to just put the GAC into suspension.
9. Allow the sample to sit without stirring for a minimum of 10 min.
10. Remove floating (buoyant) material using straining spoon and place in a container suitable for drying. Discard the remaining GAC/water mixture.
11. Dry the GAC removed in step 10 for 3 hr at 150°C.
12. Cool material in desiccator to ambient temperature.
13. Weigh dried, cooled GAC to the nearest 0.01 g. Record this value as the *Wt. of Non-wettable Material.*

5.2.8.4 Calculations

$$\text{non-wettable materials (\%)} = \frac{\text{weight of non-wettable material}}{\text{sample weight}} \times 100 \qquad \text{(Eq 9)}$$

5.2.9 *Test method for iodine number.* The procedure for determining the iodine number of GAC is ASTM D4607.

Sec. 5.3 Notice of Nonconformance

5.3.1 *Notice of nonconformance.* If the GAC delivered does not meet the requirements of this standard or the purchaser's requirements, a notice of nonconformance must be provided by the purchaser to the supplier within 30 days after receipt of the shipment at the point of destination. The results of the purchaser's test shall prevail unless the supplier notifies the purchaser within five days of the notice of nonconformance that a retest is desired. On receipt of the request for a retest, the purchaser shall forward to the supplier one of the sealed samples taken according to Sec. 5.1. In the event that the results obtained by the supplier on retesting do not agree with the results obtained by the purchaser, the other sealed sample shall be forwarded, unopened, for analysis to a referee laboratory agreed on by both parties. The results of the referee's analysis shall be accepted as final.

SECTION 6: DELIVERY

Sec. 6.1 Marking

6.1.1 *Packaged material.* Each container of GAC shall have marked legibly on it the net weight of the contents, the name of the manufacturer, country of origin,* the lot number, a brand name, if any, and shall bear other markings as required by applicable regulations and laws.†

6.1.2 *Bulk material.* When shipped in bulk, the information required in Sec. 6.1.1 for packaged material shall accompany the bill of lading.

6.1.3 *Conformance with standard (optional).* Containers may bear the statement: "Guaranteed by (name of supplier or manufacturer) to meet the requirements of ANSI/AWWA B604, Standard for Granular Activated Carbon," provided that the requirements of this standard are met.

Sec. 6.2 Packaging and Shipping

6.2.1 *Containers.* GAC shall be shipped in packages in accordance with the applicable local, state or provincial, and federal regulations.

6.2.2 *Package shipments.* Paper-bag packages used in shipments of GAC in less than carload lots shall be protected by an outer package of a resistant nature, to avoid tearing the bags. Complete protection from weather shall be provided for the individual packages or by the conveyance.

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* Governmental marking, packaging, and shipping references reflect US requirements. Users of ANSI/AWWA B604 outside the US should verify applicable local and national regulatory requirements.

† Because of frequent changes in these regulations, their specific provisions should not be included in the purchaser's requirements.

6.2.3 *Tolerances.* The net dry weight of the packages shall not deviate from the recorded weight by more than ± 5 percent. Objections to the weight of the material received shall be based on a certified unit weight of not less than 10 percent of the packages shipped, which are selected at random from the entire shipment.

6.2.4 *Bulk shipments.* Bulk shipments of GAC shall be in clean cars or trucks with tight closures to avoid loss and contamination of the material in transit. The interior of the cars or trucks shall be clean and free from dirt, corrosion scale, and other sources of contamination. Shipments in open-top, hopper-bottom cars are acceptable only with adequate provisions for covering the material and keeping it contained and protected during shipment. The criteria for choosing a car or truck are the type of handling equipment and the unloading facilities at the destination. Caution is advised in unloading bulk containers because particle stratification may occur during shipment. If the entire bulk shipment is used to fill a single contactor or filter, no special precautions are required. Where the bulk shipment will be divided between or among contactors or filters, different bays should be used to fill the various units, or GAC additions should be rotated among various contactors or filters. In order to ensure accurate and comparable bids from suppliers, the purchaser should adequately describe the GAC receiving structures (pressure vessels, gravity contactors, etc.) and conveyance measures that exist on-site and that are available for the suppliers' use during delivery. Purchaser should also itemize equipment that should be provided by the GAC supplier and its subcontractors, such as type of delivery (bulk truckload, sacks, etc.), eductor system, amount of hose or pipe that is needed, types of hose connections necessary to connect with the utility's existing conveyance system (if any), types of hose connections necessary to connect to the conveyance water supply, available pressure and flow of the conveyance water supply, any other necessary accommodations, allowable hours of work, and so forth.

6.2.5 *Weight certification (bulk).* Bulk shipments shall be accompanied by weight certificates of certified weighers, or the weights may be checked by certified weighers for the purchaser on delivery.

6.2.6 *Security requirements for bulk shipments.* Bulk quantities of product shall be secured employing one of the following security measures (or a combination of measures):

6.2.6.1 Seals. Bulk quantities of product must be sealed with a uniquely numbered tamper evident seal(s). The seal numbers shall be recorded and disclosed on shipping documents such as the Bill of Lading. Seals shall be inspected upon receipt of product by the purchaser and evidence of tampering or removal should be reported to the carrier and supplier.

6.2.6.2 Chain of custody. A continuous chain of custody must be maintained between the manufacturer and the purchaser during storage and shipment.

6.2.6.3 Alternative Method. An alternative method or methods must be used that provide reasonable assurance of protection against tampering.

Sec. 6.3 Affidavit of Compliance

The purchaser may require an affidavit from the manufacturer or supplier that the granular activated carbon provided complies with applicable requirements of this standard.

APPENDIX A

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This appendix is for information only and is not a part of ANSI/AWWA B604.

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APPENDIX B

Surrogate Tests

This appendix is for information only and is not a part of ANSI/AWWA B604.

SECTION B.1: TANNIN VALUE

Tannin Value Test

This tannin value test procedure is taken from appendix B of ANSI/AWWA B600. The tannin value of the representative sample collected after delivery of shipment shall not be more than 10 percent greater than that of the reference sample. The tannin value is defined as the concentration of GAC in milligrams per liter required to reduce the standard tannic acid concentration from 20 mg/L to 2 mg/L.

Procedure

B.1.1.1 *Reagents.*

1. Buffer solution. Dissolve exactly 133 g of Na_2HPO_4 in distilled water and make up to 12 L. Slowly add sufficient concentrated phosphoric acid to bring pH to 6.5 ± 0.1 (this should require approximately 17 mL of acid).

2. Tannic acid test solution (20 mg/L). Dissolve exactly 0.20 g of tannic acid (Merck National Formulary) into a 1-L portion of buffer solution. Blend the solution thoroughly with 9 L of buffer solution (giving 10 L total). The solution should be prepared fresh daily.

B.1.1.2 *Activated carbon dosage.*

1. Weigh out 80 mg, 160 mg, 240 mg, and 320 mg of "as received" GAC. Place in 1,000-mL beakers and add 800 mL of 20-mg/L tannic acid test solution.

2. Place the beakers on a paddle gang stirrer using an 800-mL portion of tannic acid test solution without GAC as a control. Stir samples at a uniform speed sufficient to keep GAC in suspension through the mixing period. Flat-type paddle mixers with an area of approximately 2 $in.^2$ (1,290 mm^2) will require a speed of at least 100 rpm. Small propeller-type paddles require speeds of 100 rpm to 200 rpm, depending on the size of the paddle. Stir for 1 hr.

3. Remove beakers from stirrer. Immediately vacuum filter 200 mL of each sample through one sheet of 0.8-mm Millipore paper or equivalent for analyses.

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3. Remove beakers from stirrer. Immediately vacuum filter 200 mL of each sample through one sheet of 0.8-mm Millipore paper or equivalent for analyses.

Filtration equipment that is used should be cleaned thoroughly and rinsed with distilled water prior to use.

B.1.1.3 *Residual tannin determination.* Determine the residual tannin concentration for each GAC-treated filtrate by either the ultraviolet (UV) absorbance method or the colorimetric method according to the following procedures:

1. UV absorbance method. Tannic acid can be determined by UV absorbance at 254 mm. A 1-cm silica cell should be used for the control and for lower GAC dosages. A 5-cm cell length should be used for higher dosages or, if absorbance in a 1-cm cell is less than 0.1, a 5-cm cell should be used. Each reading should be made with buffer solution in the reference cell. The concentration of tannic acid in the GAC-treated samples is determined by using a standard curve made by diluting 10 mL, 20 mL, 40 mL, and 70 mL of the original tannic acid test solution to 100 mL with buffer solution.

2. Colorimetric method. Tannin lignin reagent. Dissolve 100 g of sodium tungstate dehydrate, $Na_2WO_4{\cdot}2H_2O$; 20 g of molybdic phosphoric acid (also called physphomolybdic acid), $20MoO_3{\cdot}2H_3PO_4{\cdot}48H_2O$; and 50 mL of 85 percent phosphoric acid, H_3PO_4, in 750 mL distilled water. Boil the liquid under reflux for 2 hr; cool and make up to 1 L with distilled water.

Sodium carbonate solution. Dissolve 200 g of Na_2CO_3 in 500 mL of warm distilled water and dilute to 1 L to form a saturated solution. Store in a rubber stoppered bottle. Add 2 mL of tannin lignin reagent to 50 mL of clear sample and mix well. After 5 min, add 10 mL of sodium carbonate solution and mix thoroughly. Wait 10 min for color development. Determine tannin acid concentration using a standard curve made by diluting 10 mL, 20 mL, 40 mL, and 70 mL of the original tannic acid test solution to 100 mL with buffer solution. Use the following guide for the instrumental measurements at 600 m wavelength:

Tannic acid in 62-mL final volume—*μg*	Light path—*cm*
50–600	1
10–150	5

If a suitable colorimeter is not available, the tannic acid concentration can be estimated visually using 100-mL matched, tall-form Nessler tubes. Determine the color intensity of the treated samples in the Nessler tubes with that of known concentrations of tannic acid prepared by dilution of the control with buffer solution. The tubes are viewed lengthwise from the top against a white background.

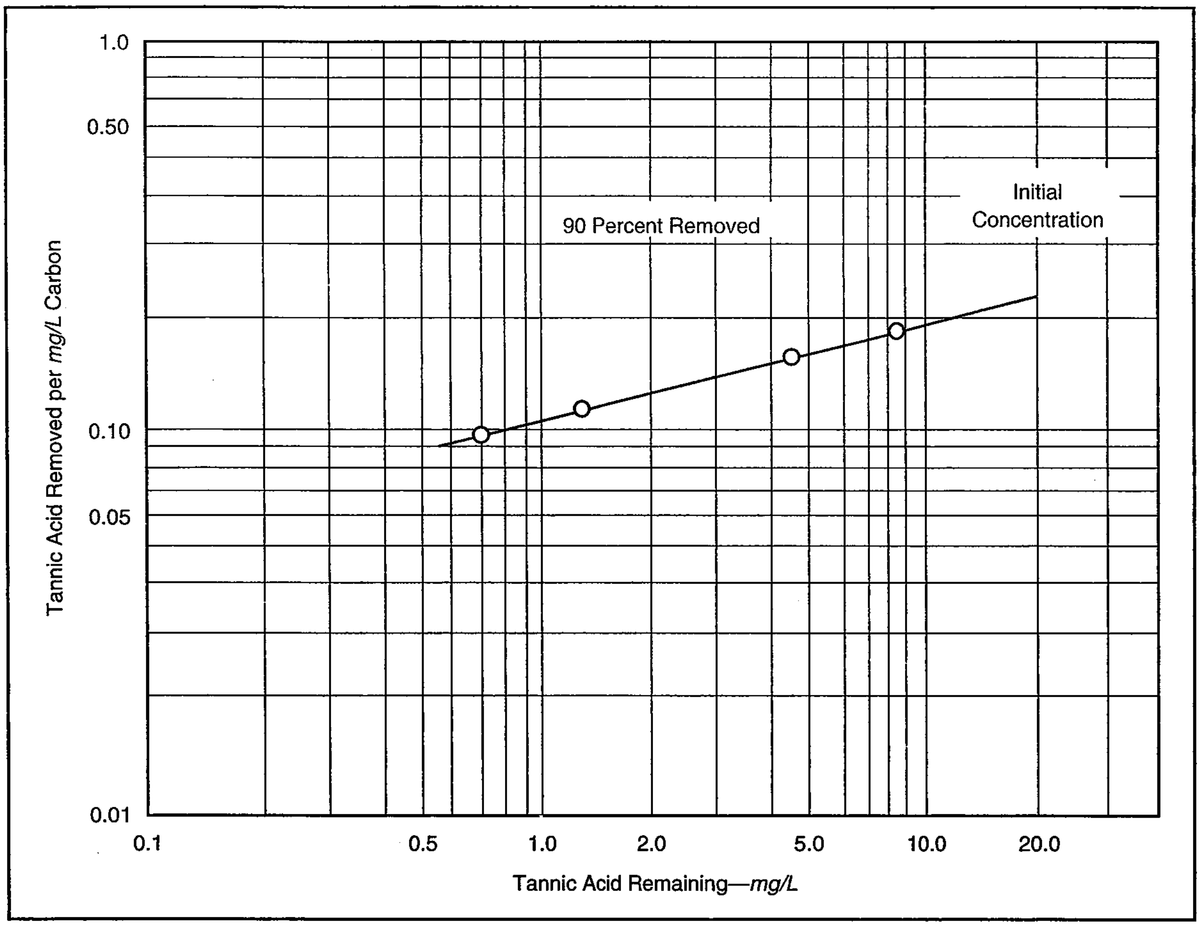

Figure B.1 Sample determination of tannin extract by carbon adsorption

B.1.1.4 *Calculations.*

1. A data table is prepared giving the mg/L GAC, mg/L tannic acid remaining, and mg/L tannic acid removed. The mg/L removed per mg/L GAC (*X/M*) for each sample is calculated.

2. Plot the results on double logarithmic paper (2 x 2 cycles) to establish the relationship between the GAC dosage and the total amount of tannic acid remaining for each sample of the previous series. A straight-line plot will be obtained by plotting the total amount of tannic acid removed in mg/L per mg/L of GAC at each GAC dosage as the ordinate and the corresponding mg/L of original tannic acid remaining as the abscissa. When plotting the line between points, the "least squares" method should be used to establish the correct position of the line (see Figure B.1).

3. The effectiveness of the GAC for tannic acid removal is obtained from the plot by determining the adsorption value of the GAC (the total amount of

tannic acid removed per unit weight of GAC) corresponding to the 2 mg/L tannic acid residual (90 percent removal), and dividing it into the total amount of tannic acid removed (18 mg/L tannic acid). This computed value is known as the "tannin value" of the GAC.

SECTION B.2: DETERMINATION OF ACETOXIME NUMBER

Sec. B.2.1 General

Determine carbon capacity at 30 mg/L residual acetoxime concentration, which is indicative of the trace adsorption capacity of the GAC.

Sec. B.2.2 Apparatus

- Balance capable of weighing to 0.0001 g
- Oven capable of maintaining 150°C
- Desiccator with calcium chloride desiccant
- Weighing paper
- Spatula
- Magnetic stirrer and stir bars
- Thermometer, glass, –1 to 101°C in 10/10°C graduations
- Timer/stopwatch count-up/countdown capability
- Flasks, 125-mL culture media screw cap, Fisher 10-093A, or equivalent, volumetric—50/1,000/2,000 mL, class A, Fisher 10-210-5B, 5G, and 5H or equivalent
- Graduated cylinder 100 mL, class A "To Deliver"
- Vinyl-covered lead weight ring
- Volumetric pipettes, class A, 10 and 25 mL
- Mohr pipettes, 5 mL with 0.1 mL subdivision
- Disposable syringe, 20 cc, slip tip without needle
- Acrodisc syringe filter disk, 25-mm diameter × 0.8-mm pore size
- 2-oz filtrate collection bottles, plastic or glass
- Water bath, 10-L capacity
- Spectrophotometer capable of absorbance readings at 220 nm with 1-cm cuvettes
- Quartz 1-cm size, 10-mm path-length spectrophotometer cuvettes

Sec. B.2.3 Reagents

- Acetone oxime (Acetoxime), crystalline, 98 percent pure
- Deionized water
- KH_2PO_4, certified ACS
- NaOH, ACS
- pH 7 buffer

Sec. B.2.4 Procedure

1. Prepare 5.0 L of pH 7 buffer by weighing out 34.02 g KH_2PO_4 and 5.82 g NaOH and dilute with 5.0 L deionized water. After mixing, adjust pH to 7.00 ± 0.05, as measured by a calibrated pH meter, by additions of NaOH or KH_2PO_4 solutions.
2. Prepare 200 ppm acetoxime test solution—weigh exactly 0.2000 ± 0.002 g acetoxime into 1,000 mL volumetric flask and dilute to line with pH 7 buffer. Prepare fresh test solution daily.
3. Pulverize the GAC to 95 percent—325 mesh.
4. Oven dry sample at 150°C for 3 hr. Cool in dessicator.
5. Set water bath to 25°C. Place volumetric flask containing acetoxime test solution into water bath.
6. Weigh 0.25, 0.5, and 1.0 gram of pulverized GAC into 125-mL labeled culture media flasks to the nearest 0.0004 g. Record exact weights.
7. Transfer 100 mL of acetoxime solution into each flask using a graduated cylinder. Pour solution down sides of flask to wash any GAC off the walls. Gently swirl the flask to wet carbon.
8. Add a magnetic stir bar to each flask and place each flask on a stir plate. Start stirring action for all 3 flasks and tie for 10 min for all 3 flasks.
9. After 10 min stir time, remove each flask from the stir plate.
10. Allow flasks to settle for 5 min to make filtration easier.
11. Place syringe filter disc on the end of a disposable filter syringe. Fill syringe with solution, reattach plunger and place assembly on top of a labeled filtrate collection bottle. Push plunger and collect approximately 20 mL of filtrate.
12. Prepare "control" sample with each new batch of acetoxime test solution, following steps 7–11 above, without GAC. (It is also recommended that a "standard" GAC be run to verify the method and operator precision.)
13. Set spectrophotometer wavelength to 220 nm. Allow instrument to warm up 30 min or until stable.
14. Prepare acetoxime calibration curve daily from acetoxime solution.

a. Pipette the following 4 volumes, using volumetric or mohr pipettes, into 50-mL volumetric flasks: 6.3, 12.5, 25.0, and 37.5 mL (this will correspond to concentrations of 25, 50, 100, and 150 mg/L, respectively). Dilute to the mark with pH 7 buffer solution.

b. Zero the spectrophotometer with DI or MilliQ water. Measure the absorbance of each sample including the buffer solution alone, which corresponds to "0" for the calibration curve.

c. Plot absorbance vs. concentration to obtain the calibration curve. (Calibration curve can be a graph paper plot or a spreadsheet can be used to manipulate the data).

15. Read the absorbance for each filtrate sample and determine residual concentration (R) from calibration curve.

16. Calculate mg acetoxime adsorbed (*X*) by subtracting (*R*) from the initial concentration of the solution (C_0).

17. Calculate loading by dividing (*X*) by the respective weight of carbon (*M*) for the sample.

18. Plot log (*R*) vs. log (*X/M*). Perform a "least squares" fit to the data. If the correlation coefficient is less than 0.9, repeat the test.

19. From the straight line, determine the *X/M* value at an acetoxime residual concentration (*R*) of 30 mg/L. This is the acetoxime number.

APPENDIX C

Filter Material Placing and Preparation

This appendix is for information only and is not a part of ANSI/AWWA B604.

SECTION C.1: PLACING GAC FILTER MATERIAL

Sec. C.1.1 Preparation

1. Cleaning. Each filter cell shall be cleaned thoroughly before any filter materials are placed. Each cell shall be kept clean throughout placement operations.

2. Marking each layer. Before any materials are placed, the top elevation of each layer shall be marked by a level line on the inside of the filter cell.

3. Storage and handling of materials. Filter materials shall be kept clean. Bulk materials shall be stored on a clean, hard, dry surface and covered to prevent contamination during storage. Materials shipped in bags or semibulk containers shall be covered with a durable, opaque material to block sunlight and provide protection from weather. Bags and semibulk containers shall be stored separately. When materials are shipped in bags or sem bulk containers, under no circumstances shall the material be removed from the bags or semibulk containers prior to placement in the filter, except for sampling.

Sec. C.1.2 Placement of Support Media

1. Caution in installing material. The bottom layer of gravel shall be carefully placed to avoid damage to the filter underdrain system. For materials smaller than ½ in., workers shall not stand or walk directly on the gravel but shall walk on boards or plywood that will support their weight without displacing the material.

2. Placement of layers. Each layer shall be completed before beginning placement of the layer above. Each layer of filter material shall be deposited in a uniform thickness, with the top surface screened and brought to a true level plane using backwash water. Care shall be exercised in placing each layer to avoid disturbing the surface of the layer beneath.

3. Alternate material placement. Bulk materials may be placed dry by using a chute or conveyor to discharge the materials onto a platform, from which

they may be distributed with a hand shovel. Alternatively, bulk materials may be placed hydraulically by pump or ejector. For filter sand placed using the wet method, the materials shall be added through the water and then backwashed for leveling.

4. Placement of materials 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. To provide for an initial expansion of the bed because of segregation of particle sizes, the elevation of the top surface, before the initial washing, shall be approximately 10 percent of the final bed thickness below the finish elevation.

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.

6. Washing gravel layer. After filter gravel is placed, and before any filter sand and GAC are placed, the filter should be washed for 5 min at the maximum available rate, not to exceed 25 gpm/ft of filter area. This step may be eliminated if fines or contaminants are not apparent to the purchaser. Any gravel that becomes intermixed after placement with another material or size shall be removed and replaced with clean material of the proper type and size.

7. Washing other material. With a dual- or multiple-media filter bed, each filter material shall be washed and scraped or skimmed as deemed necessary to remove excess fine materials before the next material is installed.

8. Disinfection of filter. Prior to installation of GAC, the filter shall be disinfected with chlorine according to ANSI/AWWA C653 or as otherwise specified. Disinfection shall be performed after the filter underdrain has been added and the support gravel and sand have been added and leveled. Microbial testing should be conducted after the filter support has been disinfected and prior to GAC installation.

Sec. C.1.3 Placement of GAC

1. Slurry transport. To avoid dust in the filter area, it is recommended that GAC be added hydraulically through an eductor, slurry pump, blow case, or directly from specially built bulk trucks. Where bags, bulk boxes, or other bulk containers are used, the construction of an eduction system is recommended. While the volatiles have been removed from the GAC during the activation step and the carbon dust is not an explosive hazard, it is a nuisance dust and should be

prevented or precluded by a slurry addition. This will also provide an opportunity for the GAC to become wetted. Since GAC is filled with internal pores, it is vitally important for it to become thoroughly wetted before backwashing to prevent the undue loss of materials.

2. Placing GAC. The filter box should be filled with water prior to adding GAC. The water level should be approximately one third of the GAC filter medium volume. In filling the filter box with GAC, care should be taken to avoid disruption of the supporting gravel or sand layer. The GAC slurry delivery hose should be directed to various locations in the filter to provide as uniform a distribution as possible. If the delivery is made in large bulk trucks, it is also advisable to rotate the addition of GAC among filters to avoid any differences in particle size that may result from the stratification of the media during transport. Any graded media can stratify during bulk transport and care must be taken to ensure that the materials placed in the filter beds are uniform.

3. GAC should be added to the filter box to bring the level to approximately 85 percent of the final volume. A permanent expansion of approximately 15 percent will occur due to stratification of the bed after the GAC medium is backwashed. Since the uniformity coefficient of GAC is typically larger than that of sand or anthracite, the permanent expansion will be greater. The actual amount of the permanent expansion will depend on the uniformity of the GAC, the effectiveness of the backwash system, and the control of the backwash sequence.

4. Backwashing and leveling. After placing GAC into the filter box to provide approximately 85 percent of the filter volume, the carbon should be leveled by backwashing. If the GAC was added via a slurry transport system, backwashing may be accomplished at a controlled rate within 4 hr. If the GAC was placed dry, the bed should be allowed to set for approximately 24 hr in a completely submerged condition to allow the GAC pores to fill with water. Otherwise, the reduced density of the GAC attributable to air in the pores may result in excessive backwash losses.

5. After ensuring that the GAC is completely wetted, it should be backwashed at a reduced rate (<5 gpm/ft) to remove the fines. As the fines are removed and the granular medium is clearly visible, the backwash rate should be increased to provide at least 30 percent expansion for approximately 10 min to allow the GAC bed to thoroughly stratify by particle size. The bed should be backwashed twice to ensure the particles are completely stratified. The bed level should then be noted and additional GAC added with subsequent backwashing to reach the final

desired level. Bags and bulk containers of GAC can be added to control the final fill elevation. Care should be taken to avoid overfilling the filter. The removal of material from the top of a GAC bed to achieve the final depth will remove the top layer and change the particle size distribution in the filter. Neither air backwash nor surface sweeps should be operated during this filling procedure. The backwash curves provided by the supplier should be used as guidance, if available.

Sec. C.1.4 Top Surface Elevation

GAC should be added with periodic backwashing until the final surface elevation is achieved after a normal backwash cycle and the bed is allowed to settle. It should be noted that any graded filter media, including GAC, will compact during the filtration cycle causing the surface elevation to be reduced. The surface of GAC should not be scraped.

Sec. C.1.5 Contamination

GAC is manufactured at high temperatures and packaged or stored directly following production. Therefore, it should be free from contamination and care should be exercised to ensure that it does not become contaminated during transport, filling, or the backwash process. Should contamination occur, the contaminated materials should be removed and replaced with virgin GAC.

SECTION C.2: PREPARATION OF FILTER FOR SERVICE

Sec. C.2.1 Backwashing

1. Backwash controls. Since GAC serves as both a filter medium and adsorbent in filtration systems, it is imperative that an effective backwash system be in place. This should include a backwash control system that gradually increases the backwash rate to provide for the expulsion of entrapped air and ensures that the filter expands from the top downward. Surface sweeps and air backwash systems should be turned off before backwash water reaches the bottom of the overflow trough to avoid loss of GAC. Air scour should be turned off as the water level reaches the bottom of the trough to allow air to be purged prior to overflow. To promote stratification of the GAC bed and improve adsorption efficiency, the backwash rate should be decreased gradually over a period of 3 min to 5 min at the end of the backwash cycle. The backwash rate can be calibrated by comparing the rise rate in the filter box with the recorded flow rate.

2. Backwash procedures. When the GAC filter is initially placed in service, or after it has been idle, it should be backwashed before being placed in operation. The water level in filters should be maintained above the GAC level when the filters are out of service to prevent oxygen adsorption, and new beds should be flooded to ensure wetting for 24 hr unless the GAC has just been hydraulically transported. The backwash shall then be commenced at an initial flow rate not to exceed 5 gpm/ft. The flow rate should be gradually increased to provide the desired expansion.

3. Backwash rate. During each backwash, the water shall be applied in an upward direction at an initial rate not to exceed 5 gpm/ft. The up-flow rate should then be increased gradually over a period of several minutes until the desired expansion is achieved. The expansion and backwash rate should be based on the manufacturer's recommendations and the backwash rate should be adjusted to compensate for changes in temperature. The density and viscosity of water can have a significant influence on the expansion properties of GAC and losses because both vary with temperature. Surface sweeps and air washes should be turned off before the backwash water begins to flow over the wash water trough to prevent GAC losses.

4. GAC filter bed stratification. Since the maintenance of a stratified bed and adsorption wave front is vital to providing an efficient adsorption process, the backwash flow should always be turned off gradually. This will promote stratification and adsorption efficiency. Quick opening or quick closing valves should not be used on any granular media filter, including GAC adsorption systems.

Sec. C.2.2 Scraping

GAC filters should not be scraped because (1) the fines will be removed during the extended backwash period; (2) the materials as manufactured are clean, and since GAC cannot be disinfected with chlorine, it is advisable to not risk contamination by working on the surface; (3) GAC is friable, and movement on the surface can generate more fines while fines are being removed. However, should undue head loss develop as a result of fines, the filters can be scraped to restore capacity.

Sec. C.2.3 Disinfection

Chlorine is rapidly removed by GAC through an oxidation-reduction reaction. Thus, a residual chlorine concentration will not be maintained through the filter. Therefore, chlorine disinfection is not effective and should not be practiced.

However, backwashing with a chlorinated backwash water will assist in controlling biological growth, although it will not disinfect the filter. Microbial testing of a new filter should be conducted before placing the filter in service.

Sec. C.2.4 Cleaning

GAC systems will remove dirt and debris similar to other filter media and must be periodically cleaned. This can be accomplished by backwashing the GAC bed with water or an air–water wash. The particle density of GAC is appreciably less than sand, so care must be exercised during the backwash procedure. In addition, the water backwash should be slowly increased when initiating the backwash to prevent the GAC from rising as a plug and should be turned off slowly at the conclusion of the backwash cycle to promote GAC bed stratification, improve the adsorption process, and reduce operating costs.

Sec. C.2.5 Safety

1. Fire. Although activated carbon is not an explosive hazard, it does burn and will react with strong oxidizing agents. Therefore, it should be stored away from oxidizing agents and potential sources of heat and ignition.

2. Oxygen depletion. Wet GAC will rapidly adsorb oxygen and create an oxygen deficient condition. Idle filters should be covered with water and workers should follow safety precautions when entering enclosed spaces containing wet activated carbon.

3. Proper disposal. The only two spent GACs specifically listed as hazardous are those GACs used in the treatment of munitions waste and those used in veterinary medicines. However, any spent GAC can be hazardous if it meets certain criteria under the Toxic Substance Control Act (TSCA). Therefore, the user should refer to TSCA, the Resource Conservation and Recovery Act (RCRA), and other applicable federal, state, local, and provincial regulations before disposing of any spent GACs. Manufacturers will often accept spent GAC for regeneration and reuse.

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