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(Revision of ANSI/AWWA B604-12)

American Water Works Association
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AWWA Standard

Granular Activated Carbon

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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 from water.

The major raw materials used in the manufacture of granular activated carbon (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 dual-media/multimedia filters whereby the top layer is GAC and/or 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, June 23, 1996, Jan. 16, 2005, and Jan. 22, 2012. This edition was approved by the AWWA Board of Directors on Jan. 20, 2018.

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 granular activated carbon is covered in ANSI/AWWA B605, and other filtering materials including anthracite coal are covered in ANSI/AWWA B100.

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

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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 Water Research Foundation (formerly AwwaRF) 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. Specific policies of the state or local agency.

2. 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.

3. 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 regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines

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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.

‡ 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, NW, Washington, DC 20418.

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(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 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

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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, test work should be completed using water from the particular plant in question for tests. Rapid small-scale column tests (RSSCTs) are the most widely accepted method for comparing the performance of activated carbon with the actual water to be treated (Crittenden et al. 1986,* 1987; Summers et al. 1995, 2014). If the contaminant(s) of interest are not present at the time of testing, they can be added so that a breakthrough curve (effluent concentration as a function of time) can be developed. Although RSSCTs may overpredict GAC performance (Summers et al. 1989; Crittenden et al. 1991), the relative ranking of performance is expected to remain the same. Test methods may include testing for removal of a specific challenge compound, such as for taste and odors caused by geosmin or 2-methylisoborneol present in the water to be treated (MacKenzie et al. 2005). 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. As stated in ASTM† D4607, iodine number is the relative indicator of porosity in an activated carbon. It does not necessarily provide a measure of the carbon's ability to adsorb another species. However, any relationship between surface area and iodine number cannot be generalized. This relationship varies with changes in carbon raw material, processing conditions, and pore volume distribution. 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. The same can be said for acetoxime number as for iodine number; the number cannot be generalized and should be reviewed and/or tested for each individual application. This value may not be applicable for every

* Sources cited within the foreword may be found at the end of Appendix A, Bibliography, or in Sec. 2, References.

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

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drinking water system. 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 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, and, therefore, it is highly encouraged that GAC users follow the Water Research Foundation's* (formerly AwwaRF's) *Standardized Protocol for the Evaluation of GAC* (Summers et al. 1992).

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 and anthracite coal, and filter media support, such as gravel, are 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. 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 restratification 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

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

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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 required 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 required. 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-media 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 based on the desired backwash properties. The relative size depends on the density and shape of the media, as well as on particle size. Intermixing sand with GAC may introduce reactivation problems and reduce 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.

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

Standard US Mesh Size	Uniformity Coefficient	Effective Size *mm*	Apparent Density *lb/ft³*	Apparent Density *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.

Two tests, the stirring abrasion test and the Ro-Tap abrasion test, have been included in this standard for measuring GAC durability. 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. Thus, 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.

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II.G. *Nonwettable*. 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.

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. Details of other federal, state or provincial, and local requirements (Sec. 4.1).
7. The particle-size range and effective size (Sec. 4.2.3 and 4.2.4).
8. The uniformity coefficient requirement (Sec. 4.2.5).
9. The iodine number requirement (Sec. 4.2.9).

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10. Adsorptive capacity tests, if necessary (Sec. 4.2.10).

11. 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 purchase documents 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. 5.1.1 after receipt of shipment, showing compliance with this standard and the purchase documents.

12. Whether the purchaser will reject a product from containers or packaging with missing or damaged seals. The purchaser may reject a 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.

13. Provisions for reaching agreement on sampling technique (Sec. 5.1.2). The technique of sample collection shall be agreed on between the supplier and the purchaser before shipment.

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 quantities as agreed on by the purchaser and supplier.

18. If shipment is 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.

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

21. 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. Additional guidance added to Sec. II.C., Adsorptive Performance.
2. Added references to Appendix A, Bibliography.
3. In Section 3, revised definition of *uniformity coefficient*.

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.

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ANSI/AWWA B604-18
(Revision of ANSI/AWWA B604-12)

American Water Works Association
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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 only to GAC used in water supply service applications.

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SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, these documents form a part of this standard to the extent required 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.

APHA,† AWWA, and WEF‡—*Standard Methods for the Examination of Water and Wastewater*. Washington, DC: APHA, AWWA, and WEF.

ASTM§ D2854—Standard Test Method for Apparent Density of Activated Carbon.

ASTM D2862—Standard Test Method for Particle Size Distribution of Granular Activated Carbon.

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

ASTM D6781—Standard Guide for Carbon Reactivation.

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

ASTM E300—Standard Practice for Sampling Industrial Chemicals.

MIL-STD-105D, Military Standard—Sampling Procedures and Tables for Inspection by Attributes.

National Academy of Sciences—*Food Chemicals Codex.* Washington, DC: National Academy of Sciences.

NSF¶/ANSI 60, Drinking Water System Chemicals—Health Effects.

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

Summers, R.S.; Cummings, L.; DeMarco, J.; Hartman, D.J.; Metz, D.H.; Howe, E.W.; MacLeod, B.; Simpson, M., 1992. *Standardized Protocol for the Evaluation of GAC.* Denver, CO: Water Research Foundation and AWWA.

* American National Standards Institute, 25 West 43rd Street., Fourth Floor, New York, NY 10036.
† American Public Health Association, 800 I Street., NW, Washington, DC 20005.
‡ Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314.
§ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.
¶ NSF International, 789 North Dixboro Road, Ann Arbor, MI 48113.

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