

AWWA Standard for Granular Activated Carbon

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Prepared by AWWA Standards Committee on Activated Carbon

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Foreword

This foreword is for information only and is not a part of AWWA B604.

I. — Purpose of Standard

The purpose of AWWA Standard B604 is to provide a specification for the purchase of granular activated carbon used as an adsorption media for treatment of municipal and industrial water supplies.

The purchase of powdered activated carbon is covered in AWWA Standard B600.

This standard does not cover the design of carbon handling facilities or adsorption processes. Design information may be found in the JOURNAL AWWA and in other publications, some of which are listed in an appendix to this standard.

II. — Introductory Information

II-1. *Description.* Activated carbon is a form of carbon that is activated by a carefully controlled oxidation process to develop a porous carbon structure with a large surface area. This large surface area gives the activated carbon a high capacity to adsorb dissolved organic materials, many of which are taste- and odor-causing substances in water.

The major raw materials used in the manufacture of granular activated carbons are petroleum coke, bituminous coal, and lignite. After preliminary processing prior to firing in a furnace, these materials are heated to a high temperature and reacted with steam to develop the extensive internal pore structure required for adsorption. Subsequent processing includes crushing, grading, screening, and packaging.

The raw material and activating conditions used affect adsorption and physical properties of the carbons produced. As a general rule, granular carbons that are made from petroleum coke have the smallest average pore size and consequently have the greatest surface area and a high bulk density; those from lignite have the largest average pore size, least surface area, and lowest bulk density; those from bituminous coal have a bulk density about equal to that of petroleum coke carbons and average pore size and surface area somewhere in between those of petroleum coke's and lignite-based carbons'. Although it is known that pore size distribution and surface area affect the adsorptive capacity of granular carbon, their relationship to removal of various taste- and odor-causing substances is not well defined.

Water treatment with granular acti-

vated carbon is usually accomplished by percolating the water to be treated through fixed adsorption beds. The granular carbon may be crushed and screened to any particle size, but typical sizes used for water treatment range between No. 8 and No. 40 US Standard Sieve size.

II-2. *Source of supply.* Activated carbon to be used in water treatment should be obtained from sources regularly engaged in the production of activated carbon found satisfactory for this service.

II-3. *Caution in handling and storage.* 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.

In storing activated carbon, precautions must be taken to avoid direct contact with strong oxidizing agents, such as chlorine, hypochlorites, potassium permanganate, ozone, and peroxide.

Mixing of carbon with hydrocarbons (oils, gasoline, diesel fuel, grease, paint thinners, etc.) may cause spontaneous combustion. Therefore, activated carbon must be kept separated from hydrocarbon storage or spills.

II-4. *Particle size distribution.* Granular activated carbons extending over a wide range of size distributions have given satisfactory results. The proper size distribution for a particular application cannot be specified without consideration of the nature of the water to be treated, the particular treatment process in question, and other controlling factors.

In general, coarser particle-size distributions will permit higher hydraulic loading and backwash rates but will exhibit somewhat lower adsorption rates.

The particle size distribution for a particular grade of carbon is usually specified by particle size range, effective size range, and maximum uniformity coefficient. Commonly manufactured particle size ranges for granular activated carbons, expressed in limiting US Standard Sieve sizes, include 8×16 , 8×30 , 10×30 , 12×40 , 14×40 , and 20×40 , with effective sizes ranging from 0.55 mm to 1.30 mm. The purchaser should specify a particular size range and effective size range meeting his particular requirements, which may include one or more of the

manufactured size ranges previously enumerated. In general, the uniformity coefficient for granular activated carbon should not exceed 2.1.

II-5. *Abrasion resistance.* Granular activated carbons used for municipal water treatment are exposed to a variety of external forces during shipping, loading into adsorption beds, and backwashing. These forces can cause carbon granule crushing on impact, granule to granule abrasion, and the generation of undesirable fines. Because of difficulty in devising a test that simulates the various handling conditions that may be encountered, the industry has not agreed upon any one standard test for predicting carbon durability.

Two tests, the stirring abrasion test and the Ro-Tap abrasion test, have been included in this standard for measuring granular carbon durability. It is recognized that differences in bulk density and other physical properties of the various manufactured 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 based granular carbons, the Ro-Tap abrasion test for bituminous based granular carbons, and either test for petroleum coke based granular carbons.

II-6. *Adsorptive capacity.* The optimum method for determining the effectiveness of a granular carbon is by using water from the particular plant in question for the test. Various other tests have been developed which give an indication of a granular activated carbon's performance under specific conditions. These tests use a very high concentration of adsorbate to reduce the time required to run the test. Various producers of activated carbon suggest different adsorbates to give an index of a carbon's performance. Examples are phenol, tannin, iodine, and molasses. Phenol adsorption is an index of a carbon's ability to remove chemical taste and odor; tannin is representative of organic compounds added to water by decayed vegetation; and iodine adsorption is an index of the total surface area of a carbon. Iodine and molasses adsorption may be used to show if a carbon is activated. An iodine adsorption test is included in this standard. Information on other adsorptive capacity tests may be found in an appendix to this standard.

III. — Information Regarding Use of This Standard

When purchasing activated carbon under the provisions of this standard, the purchaser should provide supplementary specifications covering the following:

III-1. Standard used; that is, AWWA B604-74.

III-2. Quantity of granular activated carbon to be purchased in cubic feet, backwashed, drained, and in

place—or by weight; carbon intended for immediate placement in an adsorption bed is typically purchased by volume, backwashed, drained, and in place; makeup carbon or other carbon intended for subsequent placement is purchased on a volume or weight basis.

III-3. Whether an affidavit of compliance is required (Sec. 1.3).

III-4. Reference sample and acceptance method (Sec. 1.4).

III-5. Particle size range, effective size, and uniformity coefficient, if other

than that specified (Sec. 2.4).

III-6. Special adsorptive capacity tests (footnote under Sec. 2.6).

III-7. Provisions for reaching agreement on sampling technique (Sec. 3.1.1).

III-8. Method of shipping and packing (Sec. 3.2).

III-9. If shipment is to be in bulk: type of freight car, hopper car, or truck (Sec. 3.2.4); and whether bulk shipments are to be accompanied by weight certificates or certified weighers (Sec. 3.2.5).

AWWA Standard for Granular Activated Carbon AWWA B604-74 (First Edition)

Section 1 — General

Sec. 1.1 — Scope

This standard covers granular activated carbon for use as an adsorption media in the treatment of municipal and industrial water supplies.

Sec. 1.2 — Definitions

1.2.1 *Purchaser.* A person, firm, corporation, or governmental agency purchasing activated carbon under an agreement that references this standard.

1.2.2 *Contractor.* A person, firm, or corporation that manufactures or supplies activated carbon and agrees to furnish material as described in this standard.

Sec. 1.3 — Affidavit of Compliance

When specified by the purchaser, the contractor shall provide an affidavit of compliance stating that the activated carbon furnished complies with the applicable provisions of this standard.

Sec. 1.4 — Basis for Shipment, Acceptance and Rejection

1.4.1 *Reference sample.* When specified, a representative sample of the granular activated carbon shall be submitted to the purchaser for approval before shipment. The sample must be submitted in clean vaporproof containers, plainly marked with the address of the contractor, and identified as to the lot number of the contents.

A duplicate sample shall be tested by the contractor and a certified test report shall be submitted to the purchaser with his sample, showing compliance with the requirements of the purchaser's specifications, along with a statement certifying that the material for shipment is equal in quality to the sample submitted.

1.4.2 *Authorization for shipment.* The purchaser may authorize shipment on the basis of the contractor's certification of quality, or he may test the reference sample submitted to confirm compliance before shipment is authorized.

1.4.3 *Sampling and testing after delivery of shipment.* The purchaser may elect to collect a representative sample of the material after delivery. The procedure used shall be in accordance with Sec. 3.1. One of the three sample portions taken may be tested to determine compliance with his specifications.

1.4.4 *Acceptance.* The purchaser may elect to accept the material on the basis of (1) the contractor's certified test report and accompanying certification as to the quality of the material to be shipped; (2) his own tests of the reference sample submitted by the contractor and the certification as to the quality of the material in the shipment; or (3) his own tests of the representative sample, collected in accordance with Sec. 3.1 after receipt of

shipment, showing compliance with the specifications.

1.4.5 *Rejection.* If the tests of the material received reveal that it does not comply with the specifications, the purchaser shall so notify the contractor within twelve days after receipt of shipment. The results of the purchaser's test shall prevail unless the contractor notifies the purchaser within five working days of the notice of complaint that he desires a retest. Upon receipt of the request for a retest, the purchaser shall forward to the contractor one of the sealed samples taken in accordance with Sec. 3.1. In the event that the results obtained by the contractor, upon retesting, do not agree with the results obtained by the purchaser, the other sealed sample shall be forwarded, unopened, to a referee laboratory agreed upon by both parties for analysis. The results of the referee's analysis shall be accepted as final. The cost of the referee's analysis shall be paid by the contractor if the referee's analysis shows that the material does not meet this standard and by the purchaser if it does meet this standard.

1.4.6 *Removal or price adjustment.* If the material does not meet the requirements of the purchase agreement under this standard, the contractor shall remove it from the premises of the purchaser, unless a price adjustment is agreed upon by the contractor and the purchaser.

Section 2 — Materials

Sec. 2.1 — Impurities

The granular activated carbon shall contain no soluble inorganic or organic substances in quantities capable of producing deleterious or injurious effects upon the health of those consuming the

water or that would otherwise render the water that has been treated properly with activated carbon unfit for public use. The carbon shall not impart to the water any contaminant that exceeds the limits as defined by the US Public Health Service Drinking Water Stan-

dards.

Sec. 2.2 — Moisture

The moisture content of granular activated carbon shall not exceed 8 per cent by weight of the listed container contents, as packed or at the

time of shipment by the contractor in the case of a bulk shipment. The moisture content shall be determined in accordance with Sec. 4.3.

Sec. 2.3 — Apparent Density

The apparent density of the activated carbon shall be not less than 0.36 g/ml as determined in accordance with Sec. 4.4.

Sec. 2.4. — Particle Size Distribution

Particle size distribution shall be determined in accordance with Sec. 4.5.

2.4.1 *Particle size range.* The particle size range of the granular activated carbon shall be as specified by

the purchaser. Not greater than 15 per cent of the carbon shall be retained on the maximum size sieve, and not greater than 5 per cent of the carbon shall pass the minimum size sieve.

2.4.2 *Effective size.* The effective size of the granular activated carbon shall be within the limits specified by the purchaser.

2.4.3 *Uniformity coefficient.* Unless otherwise specified by the purchaser, granular activated carbon shall have a uniformity coefficient not greater than 2.1.

Sec. 2.5 — Abrasion Resistance

The retention of average particle size

of granular activated carbon shall not be less than 70 per cent as determined by either the stirring abrasion test or the Ro-Tap abrasion test, in accordance with Sec. 4.6.

Sec. 2.6 — Adsorptive Capacity

2.6.1 *Iodine number.* The iodine number of the granular activated carbon shall not be less than 500 as determined in accordance with Sec. 4.7.

See Foreword, II-6, for discussion of other tests to determine special adsorptive characteristics for color, taste, and odor, and specific organics removal. These special procedures should be specified if deemed advisable.

Section 3 — Sampling, Inspection, Packing, and Marking

Sec. 3.1 — Sampling

3.1.1 If the purchaser elects to accept the material on the basis specified in Sec. 1.4.4(3), samples shall be taken at the point of destination. The technique of sample collection shall be agreed upon by both the contractor and the purchaser prior to shipment.

3.1.2 If the granular activated carbon is handled by conveyor or elevator or shipped in bulk, a mechanical sampling arrangement may be used.

3.1.3 If the material is packaged, 5 per cent of the packages shall be sampled. No sample shall be taken from a broken package. If the packaged material is shipped in carload quantities, one package from each lot number should be selected for sampling, with a minimum of twenty bags being sampled per carload.

3.1.4 Carbon may be sampled, by the use of a sampling tube of at least $\frac{3}{4}$ -in. dia., from carload shipments in bulk or from packages. When taking samples from packages, the sampling tube shall be extended the full length of the package to obtain a representative sample. It should be noted that it is virtually impossible to avoid particle fracture when using a sampling tube. Extreme care should be taken to minimize the effect of this on particle size distribution.

3.1.5 The gross sample, weighing 5-6 lb, shall be mixed thoroughly and quartered to provide three 1-lb samples. These shall be sealed in airtight, moistureproof glass containers. Each sample container shall be labeled to identify it, and the label shall be signed by the sampler.

Sec. 3.2 — Packing and Shipping

3.2.1 Granular activated carbon shall be in packages acceptable to the Interstate Commerce Commission and shall contain from 35 to 150 lb each.

3.2.2 Paper bags used in shipments of carbon in less than carload lots shall be protected by an outer package of a resistant nature, to avoid tearing the bags, if required by the purchaser's supplementary specifications. Complete protection from weather shall be provided for the individual packages or by the conveyance.

3.2.3 The net dry weight of the packages shall not deviate from the recorded weight by more than 5 per cent, plus or minus. Objections to the weight of the material received shall be based on a certified unit weight of not less than 10 per cent of the packages shipped, selected at random from the entire shipment.

3.2.4 Shipments of activated carbon in bulk shall be in clean cars or trucks with tight closures to avoid loss and contamination of material in transit. Shipments in open-top hopper bottom cars will be acceptable with adequate provision for covering the material and keeping it contained and protected in shipment. The type of freight car or hopper car shall be agreed upon by the supplier and the user prior to shipment. The important factors are the type of handling equipment and unloading facilities at the destination.

3.2.5 Bulk shipments shall be accompanied by weight certificates of certified weighers, if specified by the purchaser; or the weights may be checked by certified weighers for the purchaser upon delivery.

Sec. 3.3 — Marking

Each shipment of the material shall carry with it some means of identification. In the case of packaged material, each package shall have marked legibly thereon the net weight of the contents, the name of the manufacturer, and a brand name, if any. Identifying production numbers shall be marked on each bag.

Section 4 — Testing Methods

Sec. 4.1 — Samples

If the purchaser elects to accept the material on the basis specified in Sec. 1.4.4(3), samples shall be taken from each shipment of granular activated carbon in accordance with Sec. 3.1. The sample delivered to the laboratory shall be quartered to approximately 1 lb. After thorough mixing, this sample

should be stored in an airtight glass container and weighed out of it rapidly to avoid change in moisture content.

Sec. 4.2 — Testing Period

The laboratory examination of a sample shall be complete in time to meet the requirements of Sec. 1.4.5 for notification of the contractor if the tests reveal that the material does not com-

ply with the specifications.

Sec. 4.3 — Moisture

4.3.1 *Procedure.* Weigh exactly, in a tared weighing bottle, approximately 2 g of the sample. Dry in a drying oven at 140C for 2 hr or 110C for 3 hr; then cool in a desiccator and weigh rapidly.

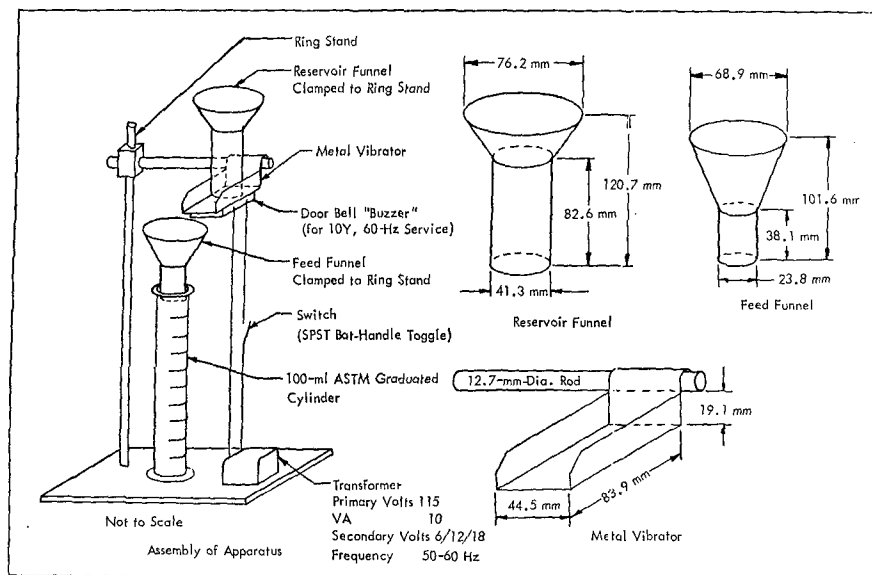


Fig. 1. Apparent-Density Test Apparatus

4.3.2. Calculation.

$$\frac{\text{Loss of weight}}{\text{Weight of sample}} \times 100 = \text{Percentage moisture}$$

Apparent density

$$= \frac{(\text{Weight of carbon}) \times (100 - \text{Percentage moisture})}{10\,000}$$

Sec. 4.4 – Apparent Density

4.4.1 *General.* The apparent density of a carbon is the weight in grams of 1 ml of the carbon in air. Carbons should have the density determined on an "as-received" basis with corrections made for moisture content.

4.4.2 *Apparatus.* Testing apparatus shall be as shown in Fig. 1. Reservoir and feed funnels are glass or metal. The metal vibrator is 26-gage galvanized sheet metal. A balance having a sensitivity of 0.1 g will be required.

4.4.3 Procedure.

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

(b) Add the sample to the cylinder by the vibrator feeder at a uniform rate not less than 0.75 ml/s nor greater than 1.0 ml/s 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.

(c) Transfer the contents from the cylinder to a balance pan and weigh to the nearest 0.1 g.

4.4.4 Calculations.

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

Sec. 4.5 – Particle Size Distribution

4.5.1 *General.* Determine the particle size distribution of granular carbon 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.

4.5.2 Apparatus.

(a) Sample splitter—similar to Jones Riffler.

(b) Sieve shaker, electrically driven, equipped with automatic timer similar to Ro-Tap.

(c) Sieves—US Standard Sieves, 8 in. in dia. and 2 in. high.

(d) Bottom receiver pan—8-in. dia., full height.

(e) Top sieve cover—8-in. dia.

(f) Balance—top loader with sensitivity of 0.1 g.

(g) Brush—soft brass-wire brush.

4.5.3 Procedure.

(a) Assemble the sieves to be used on the bottom receiver pan in order of increasing sieve opening from bottom to top. The smallest and largest open-

ing size sieves should correspond to the limiting sizes for the grade of carbon specified; e.g., for 12 × 40 carbon, use sieve numbers 12, 14, 16, 20, 30, and 40. US Standard Sieves and opening sizes are tabulated in Table 1.

(b) Mix the sample by passing the material through the riffle and recombining twice.

(c) 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 carbon may be added or taken from the test sample without additional riffing.

(d) Transfer the weighed sample to the top sieve. Install the sieve cover and sieve shaker cover and place the assembly on the sieve shaker.

(e) Allow the sieve assembly to shake for $3 \text{ min} \pm 3 \text{ s}$ with the hammer operating.

(f) Remove the sieve assembly from the sieve shaker and quantitatively transfer the carbon 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.

(g) Add the weights of each sieve fraction and, if the sum deviates more than 2.0 g from the test sample weight, repeat the analyses.

4.5.4 *Percentage retained on each sieve.*

$$\frac{(\text{Sieve fraction weight}) (100)}{(\text{Sum of sieve fraction weights})}$$

= Percentage retained on each sieve

4.5.5 *Effective size and uniformity coefficient.*

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

(b) On probability × logarithmic paper or semilogarithmic paper, 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.

(c) The effective size is the sieve opening in millimeters at which 10 per cent of the material passes on the cumulative percentage passing scale.

(d) The uniformity coefficient is determined by dividing the millimeter opening at which 60 per cent passes by the millimeter opening at which 10 per cent passes.

TABLE 1

US Standard Sieves and Opening Sizes

US Standard Sieve Number	Sieve Opening mm
8	2.36
10	2.00
12	1.70
14	1.40
16	1.18
20	0.850
30	0.600
40	0.425

Sec. 4.6 — Abrasion Resistance

4.6.1 *General.* Determine abrasion resistance either by the stirring abrasion test or by the Ro-Tap abrasion test as follows.

4.6.2 *Stirring abrasion test.* The stirring abrasion test measures percentage retention of the average particle size in the carbon after abrading the carbon by the action of a T-shaped stirrer in a specially fabricated abrasion unit. This test is used to measure abrasion resistance of lignite- and petroleum-coke base granular activated carbons.

4.6.2.1 *Sieving apparatus—stirring abrasion test.*

(a) Sieve shaker, electrically driven, equipped with automatic timer—similar to Ro-Tap.

(b) Sieves—US Standard Sieves, 8 in. in dia. and 2 in. high; Table 2 indicates sieves that are required:

TABLE 2
Sieving Apparatus Required for Stirring Abrasion Test

US Standard Sieve Number	Sieve Opening mm	Average Opening mm (D _i)
8	2.36	—
12	1.70	2.03
16	1.18	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

(c) Bottom receiver pan—8-in.-dia., full height.

(d) Top sieve cover—8-in. dia.

(e) Balance—top loader with sensitivity of 0.1 g.

(f) Brush—soft brass-wire brush.

4.6.2.2 *Stirring abrasion unit.* The abrasion unit is detailed in Fig. 2. The apparatus includes a T-shaped

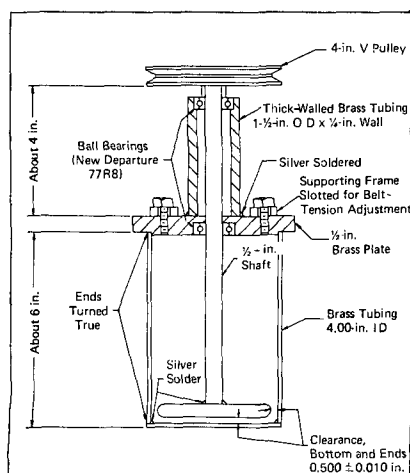


Fig. 2. Stirring Abrasion Unit

stirrer made from 1/2-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 designed size or when the hemispherical ends show signs of serious wear; that is, more than 0.025 in. from designed size. Such wear will show on the leading edge.

4.6.2.3 *Procedure—stirring abrasion test.*

(a) Place a No. 8 sieve above a No. 70 sieve on the sieve shaker. Screen sufficient granular carbon sample to obtain 250–300 ml of 8 × 70-mesh carbon by shaking portions of the carbon on the sieve shaker for exactly 3 min ± 2 s with the hammer operating. Discard the material retained on the No. 8 sieve and the material passing the No. 70 sieve.

(b) Place the 250–300-ml portion of granular carbon on the top screen of a nest of US Standard Sieves, Nos. 12, 16, 20, 40, 50, and 70, and shake on the sieve shaker for 15 min ± 10 s, with the hammer operating.

(c) Remove the sieve assembly from the sieve shaker and quantitatively transfer the carbon 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 carbon recovered.

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

(e) Remove the carbon from the abrasion unit and repeat the screening on a nest of US Standard Sieves, Nos. 12, 16, 20, 40, 50, and 70, as in (b) previously. 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 carbon recovered.

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

$$D_{avg} = \frac{\text{Summation of } (W_i \times D_i)}{\text{Summation of } (W_i)}$$

Where D_{avg} is the average particle size in millimeters, W_i is the weight of a sieve fraction in grams, and D_i is the opening in millimeters that corresponds to the average of the openings in the two sieves that enclose that mesh fraction. (See Table 2.)

Calculate the percentage retention of average particle size, adjusted to 1 mm original particle size, by using the following equation:

Percentage retention/mm

$$= (100) \left[1 - \frac{(\text{Original } D_{avg} - \text{Final } D_{avg})}{(\text{Original } D_{avg})^2} \right]$$

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

4.6.3 *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 bituminous coal and petroleum-coke base granular activated carbons.

4.6.3.1 *Sieving apparatus—Ro-Tap abrasion test.*

(a) Sample splitter—similar to Jones Riffler.

(b) Ro-Tap—sieve shaker, electrically driven, equipped with automatic timer.

(c) Sieves—US Standard Sieves, 8 in. in dia. and 2 in. high.

(d) Bottom receiver pan—8-in.-dia. full height.

(e) Top sieve cover—8-in. dia.

(f) Balance—top loader with sensitivity of 0.1 g.

(g) Brush—soft brass-wire brush.

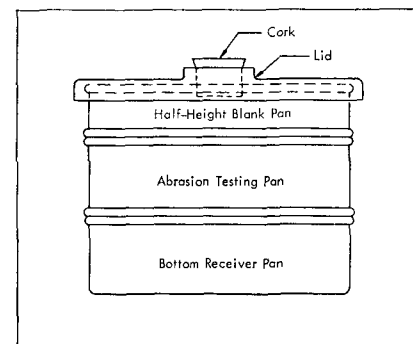


Fig. 3. Testing Pan Assembly for Ro-Tap Abrasion Test (No Scale)

4.6.3.2 *Testing pan assembly.* The abrasion pan assembly is detailed in Fig. 3. The assembly consists of a Ro-Tap lid with cork insert, a half-height blank pan, a specially fabricated

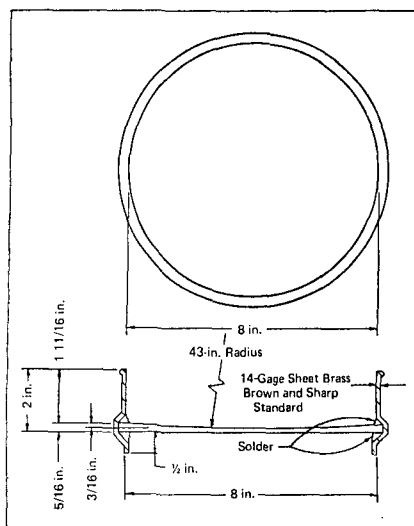


Fig. 4. Abrasion Testing Pan for Ro-Tap Abrasion Test (No Scale)

abrasion testing pan, and a bottom receiver pan. The abrasion testing pan is detailed in Fig. 4. Ten $\frac{1}{2}$ -in.-dia. and ten $\frac{3}{4}$ -in.-dia. smooth steel balls will also be required. The steel balls will be placed in the testing pan, together with the carbon sample to be tested, for the abrasion test.

4.6.3.3 Procedure—Ro-Tap abrasion test.

(a) 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 3:

TABLE 3
Recommended Sieve Sizes

Particle Size Range	US Standard Sieve Sizes
8 × 16	8, 12, 16, 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

(b) Mix the sample by passing the material through the riffle and recombining twice.

(c) 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 carbon without additional riffing.

(d) Transfer the weighed sample to the top sieve.

(e) Install the sieve cover and Ro-Tap cover and place the assembly on the Ro-Tap sieve shaker.

(f) Allow the sieve assembly to shake for $10 \text{ min} \pm 10 \text{ s}$ with the hammer operating.

(g) Prepare the abrasion testing

pan and count the steel balls to ensure that ten $\frac{1}{2}$ -in. and ten $\frac{3}{4}$ -in.-dia. smooth steel balls are contained in the pan.

(h) Remove the sieve assembly from the Ro-Tap and quantitatively transfer the carbon retained on the top sieve to a tared balance pan and weigh to the nearest 0.1 g; then transfer 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 carbon recovered.

(i) 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.

(j) Allow the testing pan assembly to shake for $20 \text{ min} \pm 2 \text{ s}$ with the hammer operating. The time is critical, and if the automatic timer is not capable of the specified accuracy, the sieve shaker should be manually controlled and timed with a stopwatch.

(k) 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 carbon, or the balls may be removed by hand.

(l) Repeat steps (e), (f), and (h), 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.

4.6.3.4 Calculations—Ro-Tap abrasion test.

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

$$D_{\text{avg}} = \frac{\text{Summation of } (W_i \times D_i)}{\text{Summation of } (W_i)}$$

Where: D_{avg} is the average particle size in millimeters, W_i is the weight of a sieve fraction in grams, and D_i is the opening in millimeters that corresponds to the average of the openings in the two sieves that enclose that mesh fraction. Material caught on the pan is not considered in calculating the average particle diameter. Values for D_i are given in Table 4.

(b) Calculate average particle size; example calculation using a 12×30

mesh material

U.S. Std. Sieve No.	Retained per cent	Avg. Opening D_i ml	Avg.*
+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
	100.0		106.3

$$D_{\text{avg}} = \frac{106.3}{100.0} = 1.063$$

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

$$\text{Retention, \%} = \frac{\text{Final } D_{\text{avg}}}{\text{Original } D_{\text{avg}}} \times 100$$

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

Sec. 4.7 — Iodine Number

4.7.1 Definition. The iodine number is defined as the milligrams of

TABLE 4
 D_i Values for Ro-Tap Abrasion Test

US Standard Sieve Numbers	Average Opening (D_i)—mm
6 × 8	2.86
8 × 10	2.18
8 × 12	2.03
10 × 12	1.85
12 × 14	1.55
12 × 16	1.44
14 × 16	1.29
16 × 20	1.02
20 × 30	0.725
30 × 40	0.513

iodine adsorbed by 1 g of carbon when the iodine concentration of the residual filtrate is 0.02 N.

4.7.2 Reagents and equipment.

(a) Hydrochloric acid, 5 per cent weight—To 550 ml of distilled water add 70 ml of reagent-grade concentrated hydrochloric acid (HCl).

(b) Sodium thiosulfate, 0.1 N—Dissolve 25 g of reagent-grade sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) in 1 l of freshly boiled distilled water. Add a few drops of chloroform to minimize bacterial decomposition of the thiosulfate solution. Standardize the thiosulfate solution against 0.100 N potassium biniodate [$\text{KH}(\text{IO}_3)_2$]. Prepare the 0.100 N potassium biniodate using primary standard quality potassium biniodate, which has dried overnight at 105C and cooled in a desiccator. Weigh 3.249 g potassium biniodate and make

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

up to exactly 1 l in a volumetric flask with distilled water. Store in a glass-stoppered bottle.

To 80 ml of distilled water add, with constant stirring, 1 ml of concentrated sulfuric acid (H_2SO_4), 10 ml of 0.100 *N* potassium biniodate solution, and approximately 1 g of potassium iodide (KI). Titrate the mixture immediately with the thiosulfate solution adding 2–3 drops of starch when the iodine fades to a light yellow color. Continue the titration by adding the thiosulfate solution dropwise until a drop produces a colorless solution. Record the volume of titrate used.

Normality of sodium thiosulfate

$$= \frac{1.000}{\text{ml of } Na_2S_2O_3 \text{ consumed}}$$

(c) Iodine solution—dissolve 12.7 g of reagent-grade iodine (I_2) and 19.1 g of potassium iodide in a small quantity, approximately 25 ml, of distilled water. Dilute to 1 l in a volumetric flask with distilled water. Store in a glass-stoppered bottle in a dark place or use a dark bottle. To standardize the iodine solution, pipette 25.0 ml into a 250 ml Erlenmeyer flask and immediately titrate with the 0.1 *N* thiosulfate solution. Add 2–3 drops of starch near the endpoint and continue titrating until solution is colorless. Record the volume of titrant used.

Normality of iodine solution

$$= \frac{\text{Milliliters of } Na_2S_2O_3 \text{ used} \times \text{Normality } Na_2S_2O_3}{25}$$

(d) Starch solution—To 2.5 g starch (potato, arrowroot, or soluble) add a little cold water and grind in a mortar to a thin paste. Pour into 1 l of boiling distilled water, stir, and allow to settle. Use the clear supernatant. Preserve with 1.25 g salicylic acid per one liter of starch solution.

(e) Filter paper—Whatman Folded No. 2V, 18.5 cm, or equivalent.

(f) Pipet, volumetric, 10.0, 25.0, 50.0, and 100.0 TD.

4.7.3 Procedure.

(a) Grind a representative sample of carbon until 95 per cent or more will pass through a No. 325 US Standard Sieve. The fineness of the carbon should be determined by a wet sieve analysis.

(b) Dry an adequate sample of the pulverized carbon at 140C for 2 hr or 110C for 3 hr.

(c) Depending on the carbon used, weigh 1.000–1.600 g of the dried pulverized carbon (see “Notes on

Procedure”) and transfer the weighed sample into a dry, glass-stoppered, 250-ml Erlenmeyer flask.

(d) To the flask, add 10 ml of 5 per cent by weight HCl and swirl until the carbon is wetted.

(e) Place the flask on a hotplate, bring the contents to a boil, and allow to boil for exactly 30 s.

(f) After allowing flask and contents to cool to room temperature, add by pipet 100 ml of standardized 0.1 *N* iodine solution to the flask.

(g) Immediately stopper flask and shake contents vigorously for 30 s.

(h) Filter by gravity immediately after the 30-s shaking period through Whatman No. 2V filter paper.

(i) Discard the first 20 or 30 ml of filtrate and collect the remainder in a clean beaker.

(j) Mix the filtrate in the beaker with a stirring rod and pipette 50 ml of the filtrate into a 250-ml Erlenmeyer flask.

(k) Titrate the 50-ml sample with standardized 0.1 *N* sodium thiosulfate solution until the yellow color has almost disappeared. Add about 1 ml of starch solution and continue titration until the blue indicator color just disappears. Record the volume of sodium thiosulfate solution used.

Notes on procedure. The capacity of a carbon for any adsorbate is dependent on the concentration of the adsorbate in the medium contacting the carbon. Thus, the concentration of the

residual filtrate must be specified or known so that appropriate factors may be applied to correct the concentration to agree with the definition.

The amount of sample to be used in the determination is governed by the activity of the carbon. If the residual filtrate normality *C* is not within the range 0.008*N*–0.0334*N* given in Table 5, the procedure should be repeated using a different weight of sample.

It is important to the test that the potassium iodide-to-iodine weight ratio is 1.5:1 of the standard iodine solution.

4.7.4 *Calculations.* Calculate the iodine number of the carbon by using the following equation:

$$\text{Iodine number} = \frac{X}{m} D$$

Where:

$$\frac{X}{m} = \frac{A - (2.2 B \times \text{ml of thiosulfate solution used})}{\text{Weight of sample (grams)}}$$

$$C = \frac{N_2 \times \text{ml of thiosulfate solution used}}{50}$$

X/m = milligrams iodine adsorbed per gram of carbon

*N*₁ = normality of iodine solution

*N*₂ = normality of sodium thiosulfate solution

A = *N*₁ × 12 693.0

B = *N*₂ × 126.93

C = Residual filtrate normality

D = Correction factor (obtained from Table 5).

TABLE 5

Correction Factor *D* for Iodine Number Test

Residual Filtrate Normality <i>C</i>	0.0000	0.0001	0.0002	0.0003	0.0004	0.0005	0.0006	0.0007	0.0008	0.0009
0.0080	1.1625	1.1613	1.1600	1.1575	1.1550	1.1538	1.1513	1.1500	1.1475	1.1463
0.0090	1.1438	1.1425	1.1400	1.1375	1.1363	1.1350	1.1325	1.1300	1.1288	1.1275
0.0100	1.1250	1.1238	1.1225	1.1213	1.1200	1.1175	1.1163	1.1150	1.1138	1.1113
0.0110	1.1100	1.1088	1.1075	1.1063	1.1038	1.1025	1.1000	1.0988	1.0975	1.0963
0.0120	1.0950	1.0938	1.0925	1.0900	1.0888	1.0875	1.0863	1.0850	1.0838	1.0825
0.0130	1.0800	1.0788	1.0775	1.0763	1.0750	1.0738	1.0725	1.0713	1.0700	1.0688
0.0140	1.0675	1.0663	1.0650	1.0625	1.0613	1.0600	1.0588	1.0575	1.0563	1.0550
0.0150	1.0538	1.0525	1.0513	1.0500	1.0488	1.0475	1.0463	1.0450	1.0438	1.0425
0.0160	1.0413	1.0400	1.0388	1.0375	1.0375	1.0363	1.0350	1.0333	1.0325	1.0313
0.0170	1.0300	1.0288	1.0275	1.0263	1.0250	1.0245	1.0238	1.0225	1.0208	1.0200
0.0180	1.0200	1.0188	1.0175	1.0163	1.0150	1.0144	1.0138	1.0125	1.0125	1.0113
0.0190	1.0100	1.0088	1.0075	1.0075	1.0063	1.0050	1.0050	1.0038	1.0025	1.0025
0.0200	1.0013	1.0000	1.0000	0.9988	0.9975	0.9975	0.9963	0.9950	0.9950	0.9938
0.0210	0.9938	0.9925	0.9925	0.9913	0.9900	0.9900	0.9888	0.9875	0.9875	0.9863
0.0220	0.9863	0.9850	0.9850	0.9838	0.9825	0.9825	0.9813	0.9813	0.9800	0.9788
0.0230	0.9788	0.9775	0.9775	0.9763	0.9763	0.9750	0.9750	0.9738	0.9738	0.9725
0.0240	0.9725	0.9708	0.9700	0.9700	0.9688	0.9688	0.9675	0.9675	0.9663	0.9663
0.0250	0.9650	0.9650	0.9638	0.9638	0.9625	0.9625	0.9613	0.9613	0.9606	0.9600
0.0260	0.9600	0.9588	0.9588	0.9575	0.9575	0.9563	0.9563	0.9550	0.9550	0.9538
0.0270	0.9538	0.9525	0.9525	0.9519	0.9513	0.9513	0.9506	0.9500	0.9500	0.9488
0.0280	0.9488	0.9475	0.9475	0.9463	0.9463	0.9463	0.9450	0.9450	0.9438	0.9438
0.0290	0.9425	0.9425	0.9425	0.9413	0.9413	0.9400	0.9400	0.9394	0.9388	0.9388
0.0300	0.9375	0.9375	0.9375	0.9363	0.9363	0.9363	0.9363	0.9350	0.9350	0.9346
0.0310	0.9333	0.9333	0.9325	0.9325	0.9325	0.9319	0.9313	0.9213	0.9300	0.9300
0.0320	0.9300	0.9294	0.9288	0.9288	0.9280	0.9275	0.9275	0.9275	0.9270	0.9270
0.0330	0.9263	0.9263	0.9257	0.9250	0.9250					

Appendix A – Adsorptive Capacity Tests

This appendix is for information only and is not a part of AWWA B604-74.

These tests were added because they are referred to in Sec. II-6 of the Foreword and appear to have utility in analysis of granular carbon used for water treatment.

Sec. A1 – Tannin Adsorption Test

A1.1 Stock tannic acid solution—500 mg/l

Dissolve exactly 1.00 g of NF grade tannic acid in distilled water and dilute to 2 l in a volumetric flask. Use tannic acid similar to Merck & Co., NF Catalog No. 04541.

A1.2 Test Procedure

A piece of 0.75-in-ID tubing* (glass or acrylic) about 7-in. long is fitted at the bottom with a one-hole rubber stopper, a short piece of rubber tubing, and an adjustable hose clamp. A piece of 80-mesh screen is used in the bottom of the tube to support the carbon. The tube is marked to indicate a carbon volume of 32 ml. A weighed amount of granular carbon is added to the tube to about the 32-ml mark, then gently washed upflow to remove any fines. If needed, additional carbon is added to the 32-ml mark, and the column is backwashed again. After backwashing, the water level is allowed to fill to the top of the carbon bed. Care should be taken so the carbon in the column is completely submerged at all times; otherwise channeling will occur through the center of the bed.

One liter of 500 mg/l tannic acid solution is passed downflow through the column at the rate of 15 ml/min (assuming 0.75-in. tubing is used, and the entire effluent is collected in a receiving flask. If a suitable pump is not available, the tannic acid solution can be fed from a separatory funnel held above the column by adjusting the

stopcock to give a flow of 15 ml/min.

The effluent is mixed and the concentration of tannin remaining is determined by either UV absorbance at 275 m μ m by evaporation of a portion of the mixed filtrate or by the standard AWWA color method for the tannin analysis.

A1.3 Determination of Tannin in Effluent

A1.3.1 UV absorbance.

A sample of mixed effluent and of the original 5 000-mg/l tannin feed is read on a UV spectrophotometer at 275 m μ m (maximum absorbance peak). Samples are diluted with distilled water until a direct instrument scale reading can be obtained and corrected for dilution. A standard curve is prepared by diluting the 500-mg/l tannin feed as follows:

TABLE A.1
Standard Curve of Tannin Dilution

Tannin—mg/l	500 mg/l Tannin—ml	Dist. Water ml
5	1	99
25	5	95
50	10	90
100	20	80
200	40	60
300	60	40
400	80	20

The optical density of each above dilution at 275 m μ m is plotted against mg/l tannin. From the standard curve the mg/l tannin in each effluent sample is determined.

Calculation

Percentage tannin adsorbed

$$= 100 \left[1 - \frac{\text{Effluent tannin (in milligrams per liter)}}{\text{Influent tannin (in milligrams per liter)}} \right]$$

Weight tannin adsorbed (in grams)

100 g carbon

$$= \frac{\text{Percentage tannin adsorbed} \times 5\text{g} \times \text{Liters used}}{\text{Weight carbon in column (in grams)}} \times 100$$

* A larger diameter tube can be used with appropriate adjustments of carbon volume, flow rate, and total volume of tannic acid solution used.

A1.3.2 Evaporation of mixed effluent.

Exactly 200 g of mixed effluent and a 200-g feed sample are evaporated in

a 100C convection oven to dryness and each residue weighed on an analytical balance to nearest milligram.

Calculation

Percentage tannin adsorbed = 100

$$\left[1 - \frac{\text{Effluent residue (in grams)}}{\text{Influent residue (in grams)}} \right]$$

Weight tannin adsorbed (in grams) =
100 g carbon

Percentage tannin adsorbed
 $\times 5\text{g} \times \text{Liters used}$

Weight carbon in column (in grams)
 $\times 100$

A1.3.3 AWWA-APHA-WPCF

Method

The residual mg/l tannin is determined colorimetrically for the mixed effluent and feed using the AWWA-APHA-WPCF method for tannin and lignin. Reagents and apparatus required are given in *Standard Methods for Examination of Water and Wastewater*. Calculations are made in the same manner as previously described.

Sec. A2 – Phenol Adsorption Test

A2.1 Reagents

(a) Stock phenol solution—5 000 mg/l. Dissolve 5.0 g reagent-grade phenol in distilled water and dilute to 1 l. Phenol should be weighed in a glass weighing dish. Rinse the dish several times with distilled water to ensure transfer of all phenol from the dish into the solution. Standardize. If the concentration of phenol is more than ± 200 mg/l, either dilute with distilled water or add more phenol to get the desired concentration. After two weeks this solution should be discarded and a fresh one prepared. (Reagent-grade phenol should be stored in a refrigerator.)

(b) Sodium thiosulfate solution—0.1 N. Dissolve 25.0 g reagent-grade sodium thiosulfate and 1.0 g reagent-grade sodium carbonate (as a preservative) in boiled distilled water and make up to 1 l. Store in a brown bottle. Standardize.

(c) Potassium bromate—bromide solution—0.1 *N*. Dissolve 2.784 g of reagent-grade potassium bromate and 10.0 g reagent-grade potassium bromide (bromate free) in distilled water and make up to 1 l. Store in a brown bottle.

(d) Potassium biniodate solution—0.1 *N*. Dissolve 3.2499 g potassium biniodate, primary standard, in distilled water and make up to 1 l.

(e) Potassium iodide solution—12.5 per cent. Dissolve 25 g reagent-grade potassium iodide in 175 ml distilled water. Store in a brown bottle. (Discard when it develops a yellow color.)

(f) Starch solution. Dissolve 5.0 g soluble potato powder starch and 1.25 g reagent-grade salicylic acid in 50 ml distilled water. Add the dissolved starch and salicylic acid slowly, with stirring, to 950 ml boiling distilled water. Rinse the beaker with some of the hot starch solution to ensure removal of all the starch.

A.2.2 Standardization of reagents.

(a) Sodium thiosulfate solution. Add 100 ml distilled water; 4 ml concentrated, reagent-grade hydrochloric acid; and 8 ml, 12.5 per cent potassium iodide solution to a 500-ml iodine flask and mix. Rinse down sides of the flask with distilled water. Using a transfer pipet, add 25 ml 0.1 *N* potassium binodate solution to the flask. Mix and allow to stand for 3 min. Titrate with the 0.1 *N* sodium thiosulfate solution using starch solution as the indicator.

Calculation

$$\begin{aligned} \text{Phenol conc. (in grams per liter)} = \\ \frac{[(\text{Millilitres bromate-bromide} \times \text{NF}) \\ - (\text{Millilitres thiosulfate} \times \text{NF})]}{\text{Millilitres phenol solution titrated}} \\ \times 15.685 \end{aligned}$$

(b) Stock phenol solution. Pipet 25 ml stock phenol solution into a 500-ml iodine flask and add 15 ml concentrated, reagent-grade hydrochloric acid. Titrate with the potassium bromate-bromide solution to a slight yellow color. (For 5 000 mg/l phenol concentration, it will require about 80–90 ml of solution to produce the yellow color.) Shake the flask and allow to stand for 3 min. Add 8 ml 12.5 per cent potassium iodide solution, shake, and allow to stand for 3 min. Titrate the liberated iodine with the standardized 0.1 *N* sodium thiosulfate solution, using the starch solution as indicator.

Calculation

Normality sodium thiosulfate solution

$$\begin{aligned} \text{Millilitres potassium biniodate} \\ \times \text{NF biniodate} \\ = \frac{\text{Millilitres sodium thiosulfate}}{\text{solution used}} \end{aligned}$$

Percentage phenol adsorbed

$$= 100 \left[1 - \frac{\text{Effluent phenol (in milligrams per liter)}}{\text{Influent phenol (in milligrams per liter)}} \right]$$

Weight phenol adsorbed (in grams)
100 g carbon

$$= \frac{\text{Percentage phenol adsorbed} \times 5\text{g} \times \text{Liters used} \times 100}{\text{Weight carbon in column (in grams)}}$$

A.2.3 Test procedure.

(a) Phenol adsorption. A piece of 0.75-in.-ID tubing (glass or acrylic) about 7 in. long is fitted at the bottom with a one-hole rubber stopper, a short piece of rubber tubing, and an adjustable hose clamp. A piece of 80-mesh screen is used in the bottom of the tube to support the carbon. The tube is marked at such a height as to indicate a carbon volume of 32 ml. The granular carbon is added to the tube to about the 32-ml mark, then gently washed upflow to remove any fines. If needed, additional carbon is added to the 32-ml mark, and the column is backwashed again. After backwashing, the water level is allowed to fall to the top of the carbon bed.

One liter of phenol solution at 5 000 mg/l is passed downflow through the column at the rate of 15 ml/min, and the entire effluent is collected in a receiving flask.

The effluent is mixed and the concentration of phenol determined.

(b) Determination of phenol in effluent. A 25-ml aliquot of the mixed effluent is placed in a 500-ml iodine flask and carried through the same procedure and calculation used to determine the concentration of the stock solution in A.2.2(b).

Calculation.

Appendix B — Bibliography

This appendix is for information only and is not a part of AWWA B604-74.

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