Designation: E688 – 94 (Reapproved 2011)

Standard Test Methods for Waste Glass as a Raw Material for Glass Manufacturing[1]

1. Scope

1.1 These test methods give the various tests for assessing the compliance of glass recovered from wastes for use as a raw material for glass manufacturing.

1.2 The test methods combine visual examinations with both chemical and physical tests. A flow chart of the testing sequence is included in this test method (see Fig. 1).

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3.1 *Exception*—The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For hazard statements, see 5.3, 5.5, Section 6, 11.1.1 and 12.3.2.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C169 Test Methods for Chemical Analysis of Soda-Lime and Borosilicate Glass
C566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying
C702 Practice for Reducing Samples of Aggregate to Testing Size
C729 Test Method for Density of Glass by the Sink-Float Comparator
D1068 Test Methods for Iron in Water
D1193 Specification for Reagent Water
D2576 Method of Test for Metals in Water and Waste Water by Atomic Absorption Spectrophotometry (Withdrawn 1979)[3]
D4129 Test Method for Total and Organic Carbon in Water by High Temperature Oxidation and by Coulometric Detection
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E105 Practice for Probability Sampling of Materials
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

3. Significance and Use

3.1 These test methods provide a means for determining whether waste glass is suitable for use as a raw material for glass manufacturing.

4. Apparatus

4.1 The following various items of equipment required may be purchased from most laboratory supply houses:

4.1.1 *Aspirator.*
4.1.2 *Balance.*
4.1.3 *Burner,* Fisher (Meker) type.
4.1.4 *Crucible,* porcelain or other ceramic.
4.1.5 *Crucible,* platinum.
4.1.6 *Flask,* filtering, with side tube, 2000-ml.
4.1.7 *Funnel,* Büchner, approximately 171 mm in diameter.
4.1.8 *Funnel,* approximately 150 mm in diameter, filtering.
4.1.9 *Furnace,* 540°C or 1000°F.
4.1.10 *Clamps,* tubing, screw compressor.
4.1.11 *Magnet,* C-shaped, Alnico.
4.1.12 *Magnifier,* 5×, 10×.
4.1.13 *Oven,* 110°C or 230°F.
4.1.14 *Scales,* triple-beam.
4.1.15 *Sieves, U.S. Standard Series*—50 mm (2 in.), 6.3 mm (¼ in.), 1.18 mm (No. 16), 850 µm (No. 20), 425 µm (No. 40), 250 µm (No. 60), 106 µm (No. 140), conforming to Specification E11.
4.1.16 *Sink-Float Standard,* sp gr 2.65.
4.1.17 *Triangle,* platinum.

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[1] These test methods are under the jurisdiction of ASTM Committee D34 on Waste Management and are the direct responsibility of Subcommittee D34.03 on Treatment, Recovery and Reuse.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

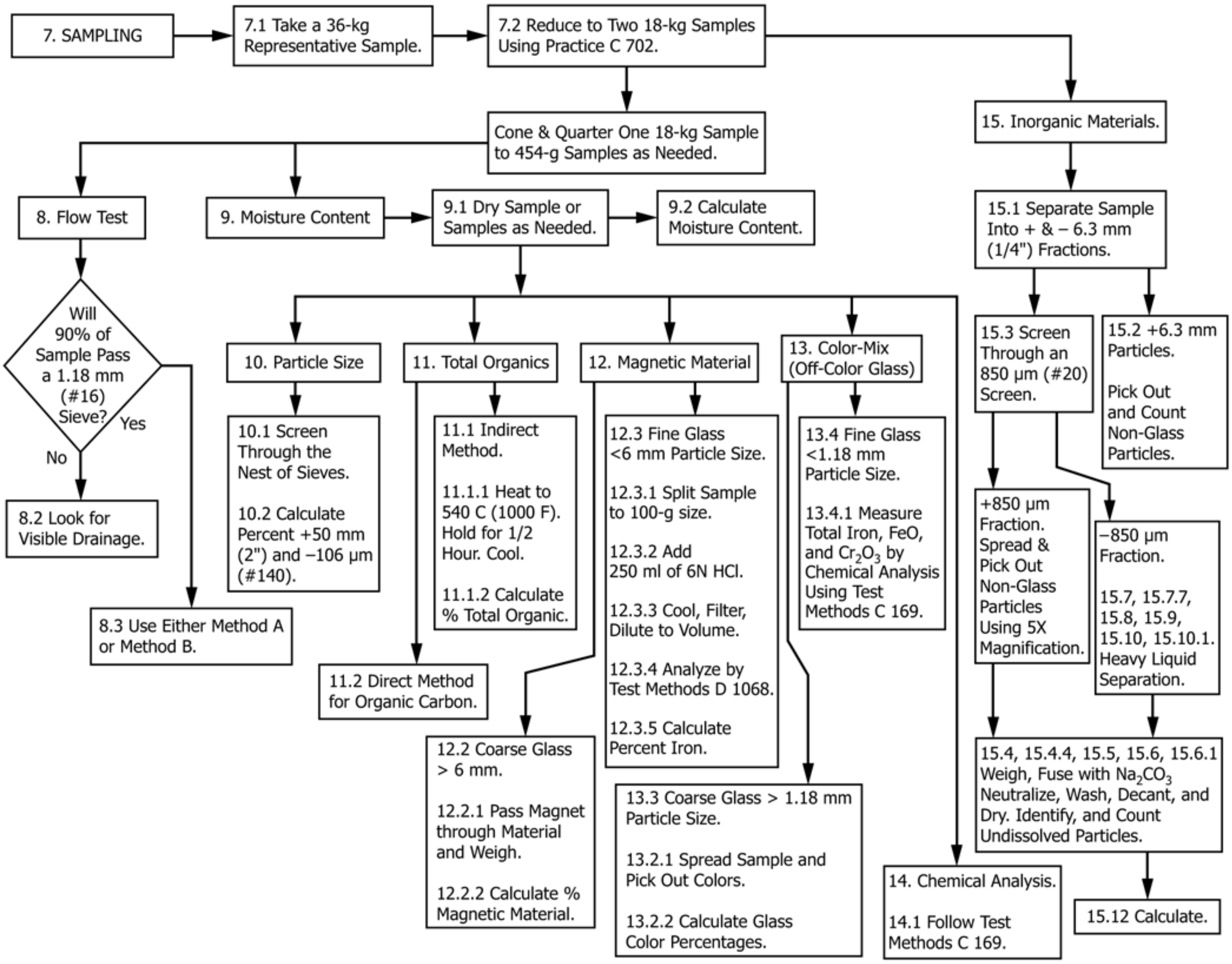

FIG. 1 Simplified Testing Flow Chart

4.1.18 *Tubing,* vinyl.[4]

4.1.19 Other ancillary laboratory equipment.

5. Reagents and Materials

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[5] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Purity of Water*— Unless otherwise indicated, references to water shall be understood to mean reagent water, Type II, as defined in Specification D1193.

5.3 *Warning—Acetone* (*see* 15.5)—This substance is highly flammable (Class B) and must not be used in the vicinity of open flames or other ignition sources. Vapors should not be inhaled, since they can cause skin and membrane irritation.

5.4 *Ethyl Alcohol,* denatured.

5.5 *Hydrochloric Acid (3 N and 6 N) (see 12.3.2/15.11)*—Prepare 3 *N* acid by diluting 1 part of concentrated hydrochloric acid (HCl, sp gr 1.19) with 3 parts of water. Prepare 6 *N* acid by diluting 1 part of concentrated HCl with 1 part of water. (**Warning** —These materials are corrosive and injurious to the skin as well as irritating to the eyes and mucous membranes.)

5.6 *Potassium Hydroxide, Saturated Solution*—Add 100 g of potassium hydroxide (KOH) slowly, while stirring, to 100 ml water. Store this solution in a polyethylene bottle. This solution is corrosive and injurious to the skin.

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[4] Tygon plastic tubing, available from Norton Co., Plastics and Synthetics Div., Dept TR2, 12 East Ave., Tallmadge, OH 44278, or equivalent, has been found suitable for this purpose.

[5] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

5.7 *Sodium Carbonate* (Na_2CO_3).

5.8 *sym-Tetrabromoethane (Acetylene Tetrabromide)* (*sp gr 2.964*)—This substance has a threshold limit value (8 h time-weighted average exposure) of 1 ppm and a short time exposure limit (15 min) of 1.25 ppm. It must be used in a hood or under conditions of ensured ventilation.

6. Hazards

6.1 The analyst should be aware of good laboratory practices. Adequate ventilation is necessary, particularly for handling sym-tetrabromoethane and the density liquids used in 15.7.1 – 15.10.1. The flammability of acetone must be considered when it is used in 15.5.

6.2 Due to the origins of glass samples in municipal wastes destined for disposal, common sense dictates that some precautions should be observed when conducting tests on the samples. Recommended hygienic practices include using gloves when handling waste glass and washing hands before eating or smoking.

7. Sampling

7.1 *Gross Sample*—Take a grab sample weighing 36 kg (80 lb) in such a manner that it will be representative of the lot as described in Practices E105 and E122.

7.2 *Test Sample Preparation*—Reduce the gross sample to two samples, each weighing 18 kg (40 lb) by a method as described in Practice C702. Use one sample for testing for inorganic material. Reduce the other sample by coning and quartering to produce at least seven samples, each weighing 454 g (1 lb), to be used for the remaining tests described in Sections 8 – 14.

7.3 *Sample Preservation*—Store the gross sample and subsequent samples in such a manner as to prevent not only the loss of contaminants but to prevent further contamination, until the necessary tests can be performed. It is recommended that samples be stored in sealed plastic bags (75 µm or 3 mil) or other airtight containers in order to avoid gain or loss of moisture.

8. Flow Test[6]

8.1 This test is used to ensure that the sample of glass shows no drainage, is noncaking, and free flowing.

8.2 If the sample is 90 % larger than will pass through a 1.18-mm (No. 16) sieve, the requirements will be met if the sample shows no drainage of water.

8.3 *Method A*—If the sample contains in excess of 10 % through a 1.18-mm (No. 16) sieve, screen a sample through the 1.18-mm sieve, 454 g (1 lb) of this material must flow out of the funnel as follows: Fit a powder funnel having a uniform internal stem diameter of 18 mm, a stem length of 30 mm, and a top of 80 mm, in a rack, and close off the bottom by the palm of a hand. Pour the sample to be tested into the funnel until the funnel is full. When the hand over the opening is removed, glass meeting the requirements will flow out of the funnel. One or two light taps on the funnel may be used to begin or aid flow. If the glass fails to flow out of the specified funnel and both producers and users agree, a second funnel test (Method B) may be performed; this test will measure the flow properties of a somewhat more sticky glass.

8.4 *Method B*—Use the same procedure as in Method A except that the dimensions of the second funnel shall be: stem internal diameter, 38 mm; stem length, 48 mm; top diameter, 170 mm.

9. Moisture Content

9.1 *Procedure*—Dry five 454-g (1-lb) test samples (see 7.2) to constant weight in accordance with Test Method C566. Drying time may be in the order of 2 h at 110°C (230°F). Record the dry weight of at least one sample for use in 9.2. Use the remaining dry samples for testing according to Sections 10 – 14.

9.2 *Calculation*— Calculate the moisture content as follows:

$$Moisture,\ \% = \frac{(\text{original weight} - \text{dry weight}) \times 100}{\text{original weight}} \tag{1}$$

10. Particle Size

10.1 *Procedure*—Screen a sample from 9.1 on a 50-mm (2-in.) sieve. Weigh the material remaining on the sieve. Screen the material passing the sieve on a 106-µm (No. 140) sieve. An intervening sieve, such as a 212 µm (No. 70) may be used merely to reduce the amount presented to the test sieve. Weigh material passing through the 106-µm sieve. Shake all sieves mechanically for 10 min or by hand to achieve equivalent results. Other intervening screen sizes may be utilized.

10.2 *Calculations*—Calculate the percent of plus 50-mm and minus 106-µm material as follows:

$$Plus\ 50 - \text{mm material},\ \% = (A/W) \times 100 \tag{2}$$

$$Minus\ 106 - \mu\text{m material},\ \% = (B/W) \times 100 \tag{3}$$

where:

A = weight of material on 50-mm sieve,
B = weight of material through 106-µm sieve, and
W = dry weight of sample.

11. Total Organics (Paper, Plastic, and Other Combustibles)

11.1 *Indirect Method:*

11.1.1 *Procedure*—Using a sample from 9.1, place the sample in an uncovered ceramic crucible(s) and heat to 540°C (1000°F). Maintain this temperature for ½ h or until all flame and smoke have ceased. (**Warning**—Overheating can cause the glass particles to fuse together. Allow the sample to cool to room temperature, weigh, and calculate the percent total organics. Reserve the sample or use an alternative dry sample for subsequent tests.)

11.1.2 *Calculation*—Calculate the percent total organics as follows:

$$Total\ organics,\ \% = 100 - \frac{\text{weight after ignition} \times 100}{\text{dry weight of sample}} \tag{4}$$

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[6] More detailed testing procedures and the effect of compaction are discussed by Carson, J. W., in *International Journal of Powder Metallurgy and Powder Technology*, vol. 11, 1975, pp. 233–239.

11.2 *Direct Method for Organic Carbon*—Organic carbon can only be inferred from the method in 11.1. Organic carbon can be determined directly by the method in this section.

11.2.1 *Procedure*—Organic carbon can be determined directly by an instrumental method such as coulometrics.[7] Test Method D4129 uses this instrumentation for total and organic carbon in water. The instrument can be readily adapted to solid materials such as waste glass.

12. Magnetic Material (Iron Contamination)

12.1 The method of testing for iron contamination will depend on the particle size of the sample.

12.2 *Determination of Iron Contamination in Coarse Glass (Larger Than 6 mm in Size):*

12.2.1 *Procedure*—Using the sample from 9.1 or from a replicate dry sample, spread a portion of the sample over a clean, dry surface in such a manner as not to have any piles over three particles deep. Cover the poles of a C-shaped Alnico magnet or its equivalent with a piece of paper or plastic film. Draw the magnet slowly through the glass particles so as to collect any magnetic material present. Transfer the magnetic material to an appropriate container by removing the cover from the magnet, while holding it over the container. Continue this process until all of the sample has been exposed to the magnet. Screen at 6.3 mm (¼ in.); then combine the magnetic material from all portions of the sample, weigh, and calculate the percent magnetic material. Reserve all portions of the sample, or from a replicate sample for subsequent tests.

12.2.2 *Calculation*—Calculate the percent magnetic material as follows:

$$Magnetic\ material,\ \% = \frac{\text{weight of tramp iron} \times 100}{\text{dry weight of sample}} \quad (5)$$

12.3 *Determination of Iron Contamination in Fine Glass (Smaller than 6 mm Size):*

12.3.1 Weigh 100 g from the sample from 11.1 or from a replicate.

12.3.2 Add 250 ml of 6 *N* hydrochloric acid (HCl) and slowly heat to a vigorous boil. Stir while boiling. (**Warning**—Rapid heating may cause "bumping.")

12.3.3 Cool the sample and filter through a medium filter paper. Catch the filtrate in a 500-ml volumetric flask and wash the insolvable sample at least five times with warm distilled water. Wash water should not exceed 500 ml. Allow the flask and its contents to cool to room temperature and dilute to volume with distilled water.

12.3.4 Transfer an appropriate sized aliquot to a 200-ml volumetric flask and analyze for iron, by either Test Methods D1068 or Test Method D2576.

12.3.5 *Calculation*—Calculate the percent iron as follows:

$$Iron,\ \% = \frac{\text{weight of iron } (Fe^{++}) \times 100}{\text{dry weight of sample}} \quad (6)$$

To report results as % Fe_2O_3, multiply by 1.43.

13. Off-Color Glass

13.1 This test is used to test for off-color glass in color-sorted glass used by the container industry. Glass samples that are plus 1.18-mm (No. 16 sieve) particle size can be tested by visual means. Glass samples that are minus 1.18-mm particle size cannot be tested by visual means but must be chemically analyzed.

13.2 *Coarse Material*—Plus 1.18-mm.

13.2.1 *Procedure*—Spread the dry sample from 9.1 on a clean, dry surface that is illuminated to at least 2150 lx (200 fc). Visually pick out the off-color glass particles. The off-color particles should be segregated into amber, green (emerald green and Georgia green should be segregated when examining a flint glass because emerald green has a chromium content ten times that of Georgia green), flint, and other glass fractions. Georgia green can be visually distinguished from emerald green, since Georgia green is lighter in color. Other glass colors are those other than the colors listed. Save the fractions.

13.2.2 *Calculation*— Calculate the percent off-color glass as follows:

$$Off - \text{color glass},\ \% = \frac{\text{weight of off} - \text{color glass} \times 100}{\text{dry weight of sample}} \quad (7)$$

13.3 *Examples*—The following examples are used to demonstrate the method of calculating the off-color fraction:

13.3.1 *Example 1:*

Given: A flint glass analytical sample with a dry weight of 447.8 g.

Off-Color Fractions:

$$Amber = 13.4\text{ g}$$
$$Georgia\ green = 21.9\text{ g}$$
$$Emerald\ green = 2.2\text{ g}$$
$$Other = 2.2\text{ g}$$

Then:

$$Amber,\ \% = \frac{13.4 \times 100}{447.8} = 3.0$$

$$Georgia\ green,\ \% = \frac{21.9 \times 100}{447.8} = 4.9$$

$$Emerald\ green,\ \% = \frac{2.2 \times 100}{447.8} = 0.5$$

$$Equivalent\ emerald\ green,\ \% = 0.5 + \frac{4.9}{10} = 1.0$$

$$Other,\ \% = \frac{2.2 \times 100}{447.8} = 0.5$$

$$Flint,\ \% = 100 - (3.0 + 1.0 + 0.5) = 95.5$$

13.3.2 *Example 2:*

Given: An amber glass analytical sample with a dry weight of 446 g.

Off-Color Fractions:

[A] Emerald and Georgia green need not be segregated for amber glass determination.

Then:

$$Flint,\ \% = \frac{19.9 \times 100}{446} = 4.5$$

$$Green,\ \% = \frac{17.8 \times 100}{446} = 4.0$$

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[7] Model 5010 Coulometer, available from Coulometrics Inc., a subsidiary of UIC Inc., P.O. Box 563, Joliet, IL 60434.

$$Other, \% = \frac{4.5 \times 100}{446} = 1.0$$

$$Amber, \% = 100 - (4.5\% + 4.0 + 1.0) = 90.5$$

13.4 *Fine Material*—Minus 1.18 mm.

13.4.1 *Procedure*—Chemically analyze a representative sample of the glass in accordance with procedures found in Test Method C169. Test for: (*1*) Cr_2O_3; (*2*) Fe_2O_3; (*3*) FeO, and (*4*) any other coloring species of interest.

13.4.2 Color is an indicator of the oxidation state of cullet. The buyers and sellers of cullet may agree to limits on the concentration of coloring species because changes in oxidation state can affect heat transfer in the melt, cause the release of dissolved gases, and thus change furnace efficiency and glass quality. Limits on coloring species may be expressed through the REDOX NUMBER as follows, where

$$Redox\ number = \frac{Fe^{++}}{Fe^{+++}} = \tag{8}$$

$$\frac{\%FeO \times 0.7779}{(\%Fe_2O_3 \times 0.6994) - (\%FeO \times 0.7779)}$$

An increasing Redox number indicates a more reduced state of the material.

14. Chemical Analysis

14.1 A chemical analysis may be necessary to establish the acceptability of a glass sample. Chemical analysis of glass samples shall be done in accordance with procedures for routine analysis found in Test Methods C169 or to procedures mutually agreeable to the parties involved.

15. Inorganic Material (Nonmagnetic Metal, Refractories, and Other Solid Inorganics)

15.1 *Sample Preparation*—Using the 18-kg (40-lb) sample from 7.2, screen through a 6.3-mm (¼-in.) sieve or screen. If the sample is not dry, the material on the screen or sieve must be washed on the screen or sieve with a flowing stream of water to remove adhering particles. Reserve the minus 6.3-mm material for 15.3 and dry if necessary.

15.2 *For Material Remaining on the Screen*—Pick out non-glass particles and determine if any are of magnetic metal, nonmagnetic metal or other inorganic materials. Count the number of such particles. Discard any of the remaining particles and reserve the rest for calculating total inorganic materials. From the remaining glass material, pick any pieces that appear to be coated with a painted or foil paper label or other coating. Save these for subsequent test for the presence of free metals. Discard the remaining plus 6.3-mm material.

15.3 Screen the dry minus 6.3-mm material from 15.1 through a 850-µm (No. 20) sieve. Reserve the minus 850-µm material for 15.7. Spread the plus 850-µm material on a clean dry surface that is illuminated to 2150 lx (200 fc) and visually pick out the non-glass particles using 5× magnification. Discard any particles attracted to a magnet and all organic material. Weigh the remaining inorganic particles and reserve the weight for calculating total inorganic material. Pick out and count the nonmagnetic metal particles. In addition, from the remaining glass material, pick any pieces that appear to be coated with a painted or foil paper label or other coating. Save these for subsequent test for the presence of free metals. Reserve the remaining inorganic particles for 15.4.

15.4 Weigh the inorganic particles from 15.3. If the sample weighs more than 1 g, split the sample into aliquots so that not more than 1 g will be fused at one time in a single crucible. Weigh out seven times as much sodium carbonate (Na_2CO_3) as the weight of the sample(s). Mix the sample(s) with its charge of sodium carbonate and add to the crucible(s). Platinum crucibles are preferred but certain metals may destroy the crucible. Porcelain crucibles with covers may be substituted. Heat the mixture on a Meker-type laboratory burner and fuse the mixture for 10 min at the maximum heat attainable.

15.4.1 The purpose of the fusion is to eliminate particles that are obviously not refractory so as to facilitate the inspection of the remaining particles. The particles remaining after fusion may not necessarily be refractory in glass furnaces so must be evaluated individually.

15.5 Place the cooled crucible in a 250-ml beaker. Neutralize the fused material with 3 *N* hydrochloric acid (HCl). Rinse the particles from the crucible. Dilute the solution with water, decant and dispose of the spent liquid. Wash the residue with water. If the presence of a residue obscures the particles, add a few millilitres of concentrated potassium hydroxide (KOH) solution and warm to dissolve. Again dilute the solution with water, decant, discard the spent liquid, and wash the residue with water. Rinse the particles with acetone and allow to air dry.

15.6 Examine the particles remaining. Particles that remain nondriable when probed with a needle and appear unaltered except for possible reduction in size will be reserved for routine examination by a petrographic microscope or subjected to a standard glass melt test, or both. Questionable particles can be examined by other means (for example, X-ray diffraction, emission spectroscopy, or microchemistry). Record the number of particles.

15.6.1 These materials are shown to be refractory in glass furnaces when they exist as particles of 250 µm or larger: corundum, mullite, zircon, chromite, spinel, sillimanite, andalusite, kyanite, and cassiterite.

15.7 Weigh the minus 250-µm material from 15.3. If the sample weight exceeds 450 g, take a representative sample weighing 450 g; otherwise use the whole sample. Separate the heavy inorganic particles from the glass using a dense liquid of 2.65 sp gr.

15.7.1 A dense liquid of 2.65 sp gr may be prepared by slowly adding denatured ethyl alcohol while stirring to *sym*-tetrabromoethane until a 2.65 sp gr density standard is no longer buoyant. Other liquids of 2.65 sp gr may be used.

15.8 Construct a separatory apparatus by slipping a 100-mm piece of vinyl tubing about 15 mm in diameter on the stem of a large filtering funnel. Install two screw compression-type tubing clamps on the tubing about 50 mm apart. Tighten the lower clamp to completely close off the tubing and adjust the upper clamp merely tight enough to remain in place. Add enough dense liquid to fill the separatory apparatus about half full.

15.9 Add the sample from 15.7 and enough dense liquid to nearly fill the separatory apparatus. Stir the sample periodically, and allow sufficient intervals between the stirring to permit the materials to separate. Should the accumulation of heavy particles in the tubing tend to fill up the upper clamp, close off the upper clamp, place a 100-ml beaker under the tubing, open the lower clamp, and flush the particles into the beaker. Close off the lower clamp and open the upper clamp as before. Continue stirring for a total of ten times. It may be necessary to repeat the removal of particles between stirrings and after the final stirring. Allow the particles to settle in the beaker, and decant the excess heavy liquid back into the separatory apparatus.

15.10 After the final decantation into the separatory apparatus, dilute the remaining heavy liquid in the beaker with acetone, allow the particles to settle, and decant the dilute heavy liquid into the evaporating dish. (See 15.10.1) Wash the heavy particles with acetone, decant, and discard the liquid. Allow the heavy particles to dry and weigh. Reserve this material for calculating total inorganic materials. If the heavy particles exceed 1 g, screen through a 250-µm sieve and reserve the plus 250-µm heavy particles for 15.11. Discard the minus 250-µm particles.

15.10.1 The heavy liquid containing glass and other light particles may be conserved by filtering the liquid through a Büchner funnel, using a rapid filter paper and vacuum. Transfer the filtered liquid to a storage reservoir, which should be covered to retard evaporation of alcohol. Rinse the particles remaining on the filter with acetone to remove additional heavy liquid. Transfer the dilute heavy liquid to the evaporating reservoir, and allow the acetone to evaporate. Periodically test the density of the dilute liquid with a 2.65 sp gr sink-float density standard (see Test Method C729). When the liquid exceeds the 2.65 sp gr, filter and transfer to the storage reservoir for reuse. Discard the glass and other light particles.

15.11 Test the heavy particle sample from 15.10 in the same manner as found in 15.4 and 15.5 by fusion with sodium carbonate and dissolution of the fusion with 3 *N* HCl. If a platinum crucible is used, be sure all metals have been removed. After drying, screen the particles through the 425-µm and 250-µm sieves. Particles that remain nonfriable when probed with a needle and appear unaltered except for possible reduction in size will be considered potential refractories. Record the number of potential refractory particles found on each sieve. As in 15.6 these particles may be examined further.

15.12 *Calculations:*

15.12.1 Calculate the percent weight of inorganic materials larger than 6.3 mm (¼ in.), W_i (+ 6.3 mm), as follows:

$$W_i\ (+6.3\ \text{mm}) = \frac{100\ W}{18} \tag{9}$$

where W is the weight of +6.3 mm inorganic material reserved from 15.2.

15.12.2 Calculate the percent weight of inorganic materials, between 6.3 mm and 850 µm (¼ in. and No. 20) W_i(+850 µm), as follows:

$$W_i\ (+850\ \mu\text{m}) = \frac{100\ W_2}{18} \tag{10}$$

where W_2 is the weight of 6.3 mm – 850 µm inorganic material reserved from 15.3.

15.12.3 Calculate the percent weight of inorganic materials, smaller than 850 µm (No. 20), W_i (–850 µm), as follows:

$$W_i\ (-850\ \mu\text{m}) = \frac{100\ W_3}{18} \tag{11}$$

where W_3 is the weight of – 850 µm inorganic material reserved from 15.10.

15.12.4 Calculate the percent weight of total inorganic materials, W_t, as follows:

$$W_t = W_i\ (+6.3\ \text{mm}) + W_i\ (+850\ \mu\text{m}) + W_i\ (-850\ \mu\text{m}). \tag{12}$$

15.13 *Test for Presence of Free-Metals*—After following the calculation procedures in 15.12, gather the inorganic material particles from 15.2, 15.3, 15.6, and 15.10 along with the pieces of coated glass from 15.3 and 15.4.

15.13.1 *Procedure*—Place the inorganic particles in a 15-mL or other appropriate sized test tube. Add a sufficient amount of a 1 % alcoholic solution of o-dinitrobenzene to half cover the particles in each test tube. Add 0.5 N NaOH to each test tube until the particles are covered (this will constitute a 1:1 mixture). Suspend the test tubes in boiling water. The development of a violet color indicates the presence of aluminum, zinc, lead, or tin metal, or a combination thereof.

NOTE 1—This test is effective even if these metals have an oxide surface coating.

15.14 *Chemical Analysis*—This procedure does not separate or identify any inorganic materials other than glass smaller than 850 µm in size and having a specific gravity less than 2.65. If such material is suspected to be present, the methods cited in Section 14 should be used.

16. Precision and Bias

16.1 The precision and bias of these methods have not yet been established.

17. Flow Chart

17.1 The accompanying flow chart (see Fig. 1) is included to clarify the complex sequence of tests to be carried out in accordance with Sections 7 – 15.

18. Keywords

18.1 chemical tests; glass; glass cullet; glass manufacturing; glass recovery; inorganic contaminants; metallic contaminants; off-color glass; organic contaminants; physical tests; refractory contaminants; test methods; waste glass

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