Designation: C 1446 – 99

Standard Test Method for Measuring Consistency and Working Time of Self-Flowing Castable Refractories[1]

This standard is issued under the fixed designation C 1446; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the consistency (degree of self-flow) and working time of self-flowing castable refractories.

1.2 The values stated in inch-lb. units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 71 Terminology Relating to Refractories[2]

C 230 Specification for Flow Table for Use in Tests of Hydraulic Cement[3]

C 860 Practices for Determining the Consistency of Refractory Castable Using the Ball-in-Hand Test[2]

C 862 Practice for Preparing Refractory Concrete Specimens by Casting[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *consistency of self-flowing castable refractories*—the degree of mobility (self-flow) of the refractory castable under its own weight as described in this test method at the specified times after adding liquid to the mixer.

3.1.2 *working time of self-flowing castable refractories*—the elapsed time from the first addition of liquid during mixing until the mix will only achieve 25 % self-flow using the procedure described in this test method.

4. Summary of Test Method

4.1 The castable refractory is mixed with a tempering liquid and the percentage of self-flow is measured at specified time intervals until self-flow is determined to be less than 25 %. Self-flow is the percent increase in the diameter of the sample after removing the Specification C 230 cone mold and allowing the specimen to flow (spread) under it own weight for 60 s. Graph paper, or a functionally equivalent method, is used to interpolate between the last reading greater than 25 % self-flow and the first reading less than 25 % self-flow. Interpolation should be done assuming decay is linear between these two readings. The interpolated elapsed time from the first addition of liquid to the mixer to 25 % self-flow is the working time. If working time is not of interest, consistency at 10 min after adding liquid to the mixer is the only self-flow to be measured.

5. Significance and Use

5.1 This test method is used to measure the consistency (degree of self-flow) that a castable refractory demonstrates at a given level of tempering liquid at specified time intervals after the liquid is added. A self-flow of 25 % has been selected as the minimum at which a mix can be poured into typical molds or forms in normal practice.

5.2 Castable refractories which are self-flowing at one level of tempering liquid will require vibration for placement at some lower level of tempering liquid. At the tempering liquid levels which require vibration or tamping for placement, the castable refractory should be characterized using test methods which are appropriate for castable refractories designed for vibration placement.

5.3 This test method is not appropriate for determining the pumpability of castable refractories.

6. Interferences (Factors Known to Affect Results)

6.1 During method development, a ruggedness evaluation was performed using a 5 % cement, 17 % reactive alumina, and 78 % tabular alumina castable. Several factors were found to cause statistically significant effects on the measured results. See ASTM Research Report Number (to be added when available).

6.1.1 *Amount of Mixing Liquid*—The amount of mixing liquid affects the measured results for typical self-flowing castable refractories unless added by weight to within ± 0.002 lb (± 1 g) of the target weight for a 16.52–lb (7500-g) sample weight. The target liquid level is a percentage of the dry weight of the batch.

6.1.2 *Temperature*—During ruggedness testing the effect of temperature was evaluated. The test mix, tempering liquid, and room temperature were controlled to the same targets. When

[1] This test method is under the jurisdiction of ASTM Committee C-8 on Refractories and is the direct responsibility of Subcommittee

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[2] *Annual Book of ASTM Standards*, Vol 15.01.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

the temperature was raised by 3.5°F (70.3 to 73.8°F) working time was found to be reduced by an average of 10 min. While the degree of this effect may be castable-formulation-dependent, it is accepted that temperature will affect the working time for all typical self-flowing castables.

6.1.3 *Mold Filling Level*—During ruggedness testing it was found that filling the mold to a level of 1⁄32 in. below the top of the mold reduced the measured flow at 10 min after adding liquid to the mixer by approximately 5.5 % for a mix with an average flow of approximately 115 % at this elapsed time.

6.1.4 *Mold Lifting Technique*—During ruggedness testing it was found that the technique for lifting the mold from the sample affected the results. The techniques compared were lifting the mold straight up and twisting the mold approximately 45° as it was lifted off the sample. Twisting the mold while lifting resulted in an appropriate 4.5 % increase in the measured self-flow at 10 min after adding liquid to the mixer.

6.1.5 *Extended Flow Time*—During ruggedness testing it was found that a probable effect on measured percent self-flow existed when the measurement was made at 70 s after lifting the mold from the sample as compared to the specified 60 s after lifting the cone off the sample.

6.2 Factors which were found to be rugged during method development for percentage self-flow at 10 min after adding tempering liquid to the mixer were (*1*) ambient temperature when varied from 70°F to 74°F, (*2*) tempering liquid when varied by 0.1 %, (*3*) time allowed to flow when varied from 60 to 70 s, (*4*) holding time from filling the mold to lifting the mold when varied from 20 to 60 s, and (*5*) lubricating the flow surface and wiping clean prior to placing the specimen on the flow surface as compared to no lubrication on a clean metal surface.

6.3 Factors which were found to be rugged during method development for working time were (*1*) time allowed to flow when varied from 60 to 70 s, (*2*) holding time from filling the mold to lifting the mold when varied from 20 to 60 s, (*3*) lubricating the flow surface and wiping clean prior to placing the specimen on the flow surface as compared to no lubrication on a clean metal surface, (*4*) returning the castable to the storage container after each flow measurement when compared to discarding the castable used for each flow measurement, and (*5*) storing the castable in a covered mixing bowl when compared to storing in a sealed container.

7. Apparatus

7.1 *Cone Mold*—The mold used to form the specimen is in accordance with Specification C 230.

7.2 *Measuring Caliper*—Either a caliper in accordance with Specification C 230 which reads directly in percent flow or a standard caliper that can be read to within ± 0.004 in. (± 0.1-mm) accuracy can be used

7.3 *Flow Surface*—A metal plate shall be used as the flow surface for the sample. It shall be thick enough to remain flat in use, 1⁄8-in. thickness is recommended. It shall have a smooth mill finish with any minor imperfections ground smooth. The surface shall not have any circumferential markings, either permanent or temporary. Radial lines scribed lightly at 45° intervals are recommended to aid in measuring the sample after flow. The surface must be kept clean and free from oxidation. A galvanized or stainless steel or other nonoxidizing metal is recommended. If the flow surface is an oxidizing metal, a lightweight oil can be used to prevent oxidation. The surface must be wiped clean prior to use with an absorbent cloth or clean sponge.

7.4 *Mixed Castable Storage Container*—The mixed castable may either be stored in the mixer bowl between flow intervals or transferred to a container for storage. Independent of the storage container used, it must be sealed airtight to prevent evaporation and must be constructed of a nonporous material. The container size should minimize the air space volume above the stored mixed castable. No more than double the volume of the stored castable is recommended.

7.5 *Castable Mixer*—The castable mixing equipment shall be in accordance with Practice C 862. Care must be exercised to ensure the appropriate size mixing bowl is chosen. A motor-driven mixer is highly recommended as many self-flowing castable refractories require high-energy mixing to achieve their self-flowing consistency at the specified liquid levels.

7.6 *Stopwatch/Timer*, capable of being read to 1 s.

7.7 *Balance*, accurate to 0.002 lb (1 g).

7.8 *Light Mold Release Oil or Vegetable Oil Cooking Spray*.

7.9 *Absorbent Cloth or Clean Sponge*.

8. Procedure

8.1 All times, amounts, and conditions are to be in accordance with this practice unless others are specified by the castable manufacturer/mix provider. Any deviations will be included in the test report, see Section 10.

8.2 Ensure all materials and testing equipment that come in contact with the castable are within 2°F (1°C) of the ambient temperature. During the test, the ambient temperature should not be allowed to change more than 2°F. (see 6.1.2). Whenever possible, the ambient temperature during the test should be in the 68 to 75°F (20 to 24°C) range. Record the actual ambient, dry castable, and mixing liquid temperatures.

8.3 Ensure all equipment is clean and dry. Remove any oxidation from the flow plate; lightly lubricate and wipe dry the flow plate and flow mold. Lubricate with a light lubricating oil or a vegetable oil cooking spray. No further lubrication of the flow plate shall be done until the testing is completed for the day.

8.4 Weigh out the mixing liquid to within ±0.002 lb (± 1 g) of that specified (see 6.1.1).

8.5 Dry mix the batch for 30 s.

8.6 Start the timer/stopwatch and add all mixing liquid within 10 s while the mixer is running. Use care that none of the liquid or dry mix is lost. Mix for 5 min after adding the liquid. After 1 min of wet mixing, stop the mixer, check for dry material in the bottom of the bowl, stir in any dry material by hand if needed, and resume mixing. All mixing is to be done at the low speed (Speed 1 for a Hobart mixer) setting.

8.7 At the end of wet mixing, place the mixed castable sample in the storage container and measure the castable temperature. The mixed castable may be stored in either the mixer bowl or another container. The mixed castable sample must be protected from moisture loss by sealing the storage container. See 7.4.

8.8 Approximately 1 min prior to each self-flow determination, place the cone mold on the center of the flow plate with the large end down. Hand-mix the stored castable sample lightly with a spatula and pour into the mold. Do not vibrate the material into the mold. The mold must be filled flush with the top. Either overfilling or underfilling will affect the percent flow results (see 6.1.3). If any material is spilled onto the flow plate, clean and wipe the plate dry.

8.9 At the scheduled time, lift the mold from the specimen using care not to twist or pull the mold to the side (see 6.1.4). Wipe any castable adhering to the mold with a finger and place it gently in the middle of the sample. Rubber or latex gloves should be worn when handling the castable to minimize the loss of fines which adhere to hands. Record the actual stored castable temperature at each flow interval.

8.10 Allow the specimen to flow for 60 s then measure and record the sample patty diameter or the percentage self-flow (see 8.11). The flow should be measured quickly as self-flow with some castables may still be proceeding. Measure the flow at 10, 20, and 30 min after adding liquid to the mixer and then every 15 min until less than 25 % self-flow is reached.

8.11 Measure the diameter of the specimen at 4 places approximately 45° apart. If there are localized irregularities in the specimen diameter, the measurement may be taken in an adjacent area which better represents the average flow diameter. If the Specification C 230 caliper is used for measurement, record the four individual readings. The sum of the four individual readings is the percent flow. If a standard caliper is used, record the four individual measurements. Calculate and record the average diameter from the 4 measurements (see 9.1).

8.12 As soon as the flow readings are recorded, return the castable to the storage container and mix into the remaining castable sample with a spatula. Wash the flow plate clean and wipe dry.

8.13 Continue running and recording the remaining self-flow checks (see 8.10) until the result is found to be less than 25 % self-flow. Dispose of the castable and clean all equipment.

8.14 If appropriate, lightly lubricate the flow surface to prevent oxidation.

9. Calculation

9.1 *Percentage Self-Flow*—When a standard caliper is used to measure the sample patty, use the following formula to calculate percent self-flow.

DF = final average diameter
Di = initial diameter (4 in. for the Specification C 230 mold)

$$\text{Percent self flow} = [D_f - D_i]^* \, 100/D_i \quad (1)$$

$$= [D_f - 4]^* \, 100/4 \quad (2)$$

9.2 *Working Time Calculation*—Plot the percentage self-flow as the y scale on graph paper versus the elapsed time after adding liquid to the mixer as the x scale. Both the y and the x scales are linear. Connect each of the sequential points on the time scale with a straight line. Where the line crosses the 25 % flow scale, draw a vertical line down to the time scale. Record this point as the working time of the castable refractory.

9.3 See Table 1 and Fig. 1 as examples of the flow readings recorded and the calculation of working time from those readings.

TABLE 1 Recorded Flow Readings

Minutes	% Flow
10	119.0
20	120.0
30	120.5
45	124.5
60	123.5
75	96.0
90	16.5

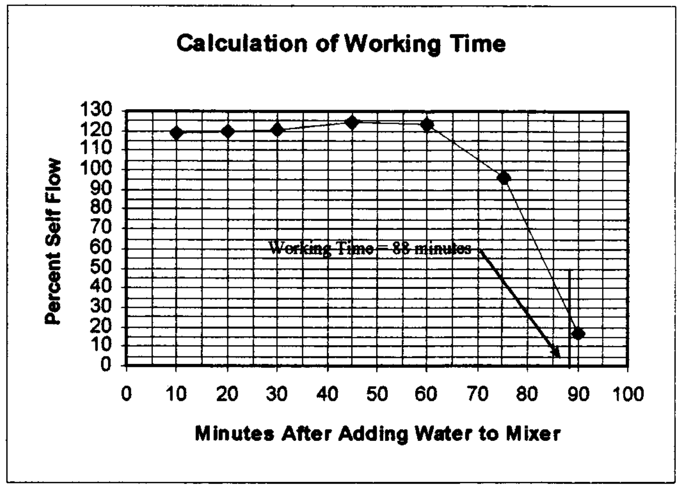

FIG. 1 Calculation of Working Time

10. Report

10.1 Report the following information in the test results:

10.1.1 Date test was run,

10.1.2 Castable/product name or other description of the castable tested,

10.1.3 The dry batch weight for the test, lb (g)

10.1.4 Identification and amount of any additives used (optional),

10.1.5 Mixing liquid used as a percent of the dry sample weight, (%)

10.1.6 Mixing liquid range specified as being acceptable for the product/castable tested (optional),

10.1.7 Mixing liquid type (potable, deionized, distilled/deionized, other),

10.1.8 Mixing time (minutes),

10.1.9 Ambient temperature at the time of mixing, dry mix temperature, and liquid temperature, °F (°C),

10.1.10 Final castable temperature,°F (°C),

10.1.11 Description of the container used to store the castable between self-flow intervals,

10.1.12 Percent self-flow at each interval evaluated (%),

10.1.13 Ambient temperature at the time when each self-flow was evaluated,°F (°C),

10.1.14 Working time as calculated in 9.2 (minutes),

10.1.15 Any deviations from Practice D 862 in mixing the castable other than those specified in this method. Deviations of particular interest are mixing time, mixing method, and use of materials (liquid, dry castable components, and so forth) at

other than room temperature, and
Any deviations from conditions specified in this practice.

11. Precision and Bias

11.1 *Ruggedness Evaluation and Interlaboratory Test Program*—No interlaboratory study has been performed for this test method as it is newly developed. The study will be performed when sufficient laboratories have adequate experience in its use to give meaningful results. A ruggedness evaluation was performed during the method development (ASTM Research Report No. C08–1016). The within-laboratory precision reported is based on that ruggedness study.

11.2 The precision information given as follows for initial consistency (percent self-flow at 10 min after adding liquid to the mixer) is given as a percentage of the percent self-flow determined. This assumes that the random within-laboratory variability is proportional to the percent self-flow.

11.3 *Precision for Consistency (% self-flow at 10 min after adding liquid to the mixer)*:

Average test value for consistency	115.8 %
95 % repeatability limit (within laboratory - raw)	10 %
95 % repeatability limit (within laboratory - as a percent of consistency)	9 %
95 % reproducibility limit (between laboratory - raw)	not available
95 % reproducibility limit (between laboratory - as a percent of consistency	not available

11.4 *Precision for Working Time*:

Average test value for working time (minutes)	87.1
95 % repeatability limit (within laboratory - raw)	22 min
95 % repeatability limit (within laboratory - as a percent of the working time)	26 %
95 % reproducibility limit (between laboratory - raw)	not available
95 % reproducibility limit (between laboratory - as a percent of the working time)	not available

11.5 *Bias*—This test method has no bias because consistency and working time for self-flow castables is defined only in terms of this test method.

11.5.1 A ruggedness study (ASTM Research Report No. C08–1016) showed that working time test results are temperature dependent. Therefore, if the test temperature cannot be maintained within the specified limits, either determine the temperature dependence for the castable being tested and correct test results accordingly or report prominently the deviation and its expected effect on the results.

12. Keywords

12.1 castable; consistency; refractories; self-flowing; self leveling; working time