Designation: C 231 – 97 ε1

Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method[1]

This standard is issued under the fixed designation C 231; 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.

This standard has been approved for use by agencies of the Department of Defense.

ε1 NOTE—Section 1.4 was updated editorially in April 1999.

1. Scope

1.1 This test method covers determination of the air content of freshly mixed concrete from observation of the change in volume of concrete with a change in pressure.

1.2 This test method is intended for use with concretes and mortars made with relatively dense aggregates for which the aggregate correction factor can be satisfactorily determined by the technique described in Section 6. It is not applicable to concretes made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity. In these cases, Test Method C 173 should be used. This test method is also not applicable to nonplastic concrete such as is commonly used in the manufacture of pipe and concrete masonry units.

1.3 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

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

1.5 *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.* See Note A1.7 for a specific caution statement.

2. Referenced Documents

2.1 *ASTM Standards:*

C 138 Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete[2]

C 172 Practice for Sampling Freshly Mixed Concrete[2]

C 173 Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method[2]

C 192 Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods of Construction Materials[2]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[3]

3. Significance and Use

3.1 This test method covers the determination of the air content of freshly mixed concrete. The test determines the air content of freshly mixed concrete exclusive of any air that may be inside voids within aggregate particles. For this reason, it is applicable to concrete made with relatively dense aggregate particles and requires determination of the aggregate correction factor (see 6.1 and 9.1).

3.2 This test method and Test Method C 138 and C 173 provide pressure, gravimetric, and volumetric procedures, respectively, for determining the air content of freshly mixed concrete. The pressure procedure of this test method gives substantially the same air contents as the other two test methods for concretes made with dense aggregates.

3.3 The air content of hardened concrete may be either higher or lower than that determined by this test method. This depends upon the methods and amount of consolidation effort applied to the concrete from which the hardened concrete specimen is taken; uniformity and stability of the air bubbles in the fresh and hardened concrete; accuracy of the microscopic examination, if used; time of comparison; environmental exposure; stage in the delivery, placement and consolidation processes at which the air content of the unhardened concrete is determined, that is, before or after the concrete goes through a pump; and other factors.

4. Apparatus

4.1 *Air Meters*—There are available satisfactory apparatus of two basic operational designs employing the principle of

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

Boyle's law. For purposes of reference herein these are designated Meter Type A and Meter Type B.

4.1.1 *Meter Type A*—An air meter consisting of a measuring bowl and cover assembly (see Fig. 1) conforming to the requirements of 4.2 and 4.3. The operational principle of this meter consists of introducing water to a predetermined height above a sample of concrete of known volume, and the application of a predetermined air pressure over the water. The determination consists of the reduction in volume of the air in the concrete sample by observing the amount the water level is lowered under the applied pressure, the latter amount being calibrated in terms of percent of air in the concrete sample.

4.1.2 *Meter Type B*—An air meter consisting of a measuring bowl and cover assembly (see Fig. 2) conforming to the requirements of 4.2 and 4.3. The operational principle of this meter consists of equalizing a known volume of air at a known pressure in a sealed air chamber with the unknown volume of air in the concrete sample, the dial on the pressure gage being calibrated in terms of percent air for the observed pressure at which equalization takes place. Working pressures of 7.5 to 30.0 psi (51 to 207 kPa) have been used satisfactorily.

4.2 *Measuring Bowl*—The measuring bowl shall be essentially cylindrical in shape, made of steel, hard metal, or other hard material not readily attacked by the cement paste, having a minimum diameter equal to 0.75 to 1.25 times the height, and a capacity of at least 0.20 ft^3 (0.006 m^3). It shall be flanged or otherwise constructed to provide for a pressure tight fit between bowl and cover assembly. The interior surfaces of the bowl and surfaces of rims, flanges, and other component fitted parts shall be machined smooth. The measuring bowl and cover assembly shall be sufficiently rigid to limit the expansion factor, *D*, of the apparatus assembly (Annex A1.5) to not more than 0.1 % of air content on the indicator scale when under normal operating pressure.

4.3 *Cover Assembly*:

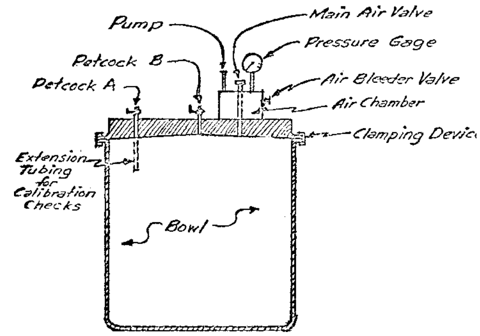
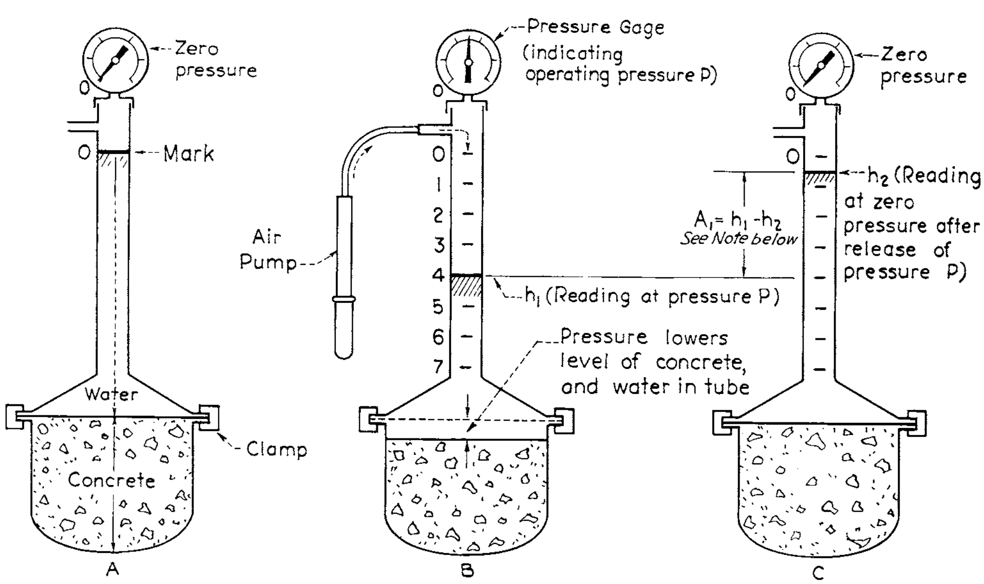


FIG. 2 Schematic Diagram—Type-B Meter

4.3.1 The cover assembly shall be made of steel, hard metal, or other hard material not readily attacked by the cement paste. It shall be flanged or otherwise constructed to provide for a pressure-tight fit between bowl and cover assembly and shall have machined smooth interior surfaces contoured to provide an air space above the level of the top of the measuring bowl. The cover shall be sufficiently rigid to limit the expansion factor of the apparatus assembly as prescribed in 4.2.

4.3.2 The cover assembly shall be fitted with a means of direct reading of the air content. The cover for the Type A meter shall be fitted with a standpipe, made of a transparent graduated tube or a metal tube of uniform bore with a glass water gage attached. In the Type B meter, the dial of the pressure gage shall be calibrated to indicate the percent of air. Graduations shall be provided for a range in air content of at least 8 % readable to 0.1 % as determined by the proper air pressure calibration test.

4.3.3 The cover assembly shall be fitted with air valves, air bleeder valves, and petcocks for bleeding off or through which water may be introduced as necessary for the particular meter design. Suitable means for clamping the cover to the bowl shall



Note: $A_1 = h_1 - h_2$ when bowl contains concrete as shown in this figure; when bowl contains only aggregate and water, $h_1 - h_2 = G$ (aggregate correction factor). $A_1 - G = A$ (entrained air content of concrete)

FIG. 1 Illustration of the Pressure Method for Air Content—Type-A Meter

be provided to make a pressure-tight seal without entrapping air at the joint between the flanges of the cover and bowl. A suitable hand pump shall be provided with the cover either as an attachment or as an accessory.

4.4 *Calibration Vessel*—A measure having an internal volume equal to a percent of the volume of the measuring bowl corresponding to the approximate percent of air in the concrete to be tested; or, if smaller, it shall be possible to check calibration of the meter indicator at the approximate percent of air in the concrete to be tested by repeated filling of the measure. When the design of the meter requires placing the calibration vessel within the measuring bowl to check calibration, the measure shall be cylindrical in shape and of an inside depth ½ in. (13 mm) less than that of the bowl.

NOTE 1—A satisfactory calibration vessel to place within the measure bowl may be machined from No. 16 gage brass tubing, of a diameter to provide the volume desired, to which a brass disk ½in. in thickness is soldered to form an end. When design of the meter requires withdrawing of water from the water-filled bowl and cover assembly to check calibration, the measure may be an integral part of the cover assembly or may be a separate cylindrical measure similar to the above described cylinder.

4.5 The designs of various available types of airmeters are such that they differ in operating techniques and therefore, all of the items described in 4.6-4.16 may not be required. The items required shall be those necessary for use with the particular design of apparatus used to satisfactorily determine air content in accordance with the procedures prescribed herein.

4.6 *Coil Spring or Other Device for Holding Calibration Cylinder in Place*.

4.7 *Spray Tube*—A brass tube of appropriate diameter, which may be an integral part of the cover assembly or which may be provided separately. It shall be so constructed that when water is added to the container, it is sprayed to the walls of the cover in such a manner as to flow down the sides causing a minimum of disturbance to the concrete.

4.8 *Trowel*—A standard brick mason's trowel.

4.9 *Tamping Rod*—The tamping rod shall be a round straight steel rod ⅝in. (16 mm) in diameter and not less than 16 in. (400 mm) in length, having the tamping end rounded to a hemispherical tip the diameter of which is ⅝ in. (16 mm).

4.10 *Mallet*—A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb (0.57 ± 0.23 kg) for use with measures of 0.5ft^3 (14 dm^3) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb (1.02± 0.23 kg) for use with measures larger than 0.5 ft^3.

4.11 *Strike-Off Bar*—A flat straight bar of steel or other suitable metal at least ⅛ in. (3 mm) thick and ¾in. (20 mm) wide by 12 in. (300 mm) long.

4.12 *Strike-Off Plate*—A flat rectangular metal plate at least ¼ in. (6 mm) thick or a glass or acrylic plate at least ½ in. (12 mm) thick with a length and width at least 2 in. (50 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1⁄16 in. (1.5 mm).

4.13 *Funnel*, with the spout fitting into spray tube.

4.14 *Measure for Water*, having the necessary capacity to fill the indicator with water from the top of the concrete to the zero mark.

4.15 *Vibrator*, as described in Practice C 192.

4.16 *Sieves*, 1½-in. (37.5-mm) with not less than 2 ft^2 (0.19 m^2) of sieving area.

5. Calibration of Apparatus

5.1 Make calibration tests in accordance with procedures prescribed in the annex. Rough handling will affect the calibration of both Types A and B meters. Changes in barometric pressure will affect the calibration of Type A meter but not Type B meter. The steps described A1.2 to A1.6, as applicable to the meter type under consideration, are prerequisites for the final calibration test to determine the operating pressure, *P*, on the pressure gage of the Type A meter as described in A1.7, or to determine the accuracy of the graduations indicating air content on the dial face of the pressure gage of the Type B meter. The steps in A1.2 to A1.6 need be made only once (at the time of initial calibration), or only occasionally to check volume constancy of the calibration cylinder and measuring bowl. The calibration test described in A1.7 and A1.9, as applicable to the meter type being checked, must be made as frequently as necessary to ensure that the proper gage pressure, *P*, is being used for the Type A meter or that the correct air contents are being indicated on the pressure gage air content scale for the Type B meter. A change in elevation of more than 600 ft (183 m) from the location at which a Type-A meter was last calibrated will require recalibration in accordance with A1.7.

6. Determination of Aggregate Correction Factor

6.1 *Procedure*—Determine the aggregate correction factor on a combined sample of fine and coarse aggregate as directed in 6.2 to 6.4. It is determined independently by applying the calibrated pressure to a sample of inundated fine and coarse aggregate in approximately the same moisture condition, amount, and proportions occurring in the concrete sample under test.

6.2 *Aggregate Sample Size*—Calculate the weights of fine and coarse aggregate present in the sample of fresh concrete whose air content is to be determined, as follows:

$$F_s = (S/B) \times F_b \quad (1)$$

$$C_s = (S/B) \times C_b \quad (2)$$

where:

F_s = weight of fine aggregate in concrete sample under test, lb (kg),
S = volume of concrete sample (same as volume of measuring bowl), ft^3 (m^3),
B = volume of concrete produced per batch (Note 1), ft^3 (m^3),
F_b = total weight of fine aggregate in the moisture condition used in batch, lb (kg),
C_s = weight of coarse aggregate in concrete sample under test, lb (kg), and
C_b = total weight of coarse aggregate in the moisture condition used in batch, lb (kg).

NOTE 2—The volume of concrete produced per batch can be determined in accordance with applicable provisions of Test Method C 138.

NOTE 3—The term "weight" is temporarily used in this standard because of established trade usage. The word is used to mean both "force" and "mass," and care must be taken to determine which is meant in each case (SI unit for force = newton and for mass = kilogram).

6.3 *Placement of Aggregate in Measuring Bowl*—Mix representative samples of fine aggregate F_s and coarse aggregate C_s, and place in the measuring bowl filled one-third full with water. Place the mixed aggregate, a small amount at a time, into the measuring bowl; if necessary, add additional water so as to inundate all of the aggregate. Add each scoopful in a manner that will entrap as little air as possible and remove accumulations of foam promptly. Tap the sides of the bowl and lightly rod the upper 1 in. (25 mm) of the aggregate eight to twelve times. Stir after each addition of aggregate to eliminate entrapped air.

6.4 *Aggregate Correction Factor Determination*:

6.4.1 *Initial Procedure for Types A and B Meters*—When all of the aggregate has been placed in the measuring bowl, remove excess foam and keep the aggregate inundated for a period of time approximately equal to the time between introduction of the water into the mixer and the time of performing the test for air content before proceeding with the determination as directed in 6.4.2 or 6.4.3.

6.4.2 *Type A Meter*—Complete the test as described in 8.2.1 and 8.2.2. The aggregate correction factor, G, is equal to $h_1 - h_2$ (see Fig. 1) (Note 4).

6.4.3 *Type B Meter*—Perform the procedures as described in 8.3.1. Remove a volume of water from the assembled and filled apparatus approximately equivalent to the volume of air that would be contained in a typical concrete sample of a size equal to the volume of the bowl. Remove the water in the manner described in A1.9 for the calibration tests. Complete the test as described in 8.3.2. The aggregate correction factor, G, is equal to the reading on the air-content scale minus the volume of water removed from the bowl expressed as a percent of the volume of the bowl (see Fig. 1).

NOTE 4—The aggregate correction factor will vary with different aggregates. It can be determined only by test, since apparently it is not directly related to absorption of the particles. The test can be easily made and must not be ignored. Ordinarily the factor will remain reasonably constant for given aggregates, but an occasional check test is recommended.

7. Preparation of Concrete Test Sample

7.1 Obtain the sample of freshly mixed concrete in accordance with applicable procedures of Practice C 172. If the concrete contains coarse aggregate particles that would be retained on a 2-in. (50-mm) sieve, wet-sieve a sufficient amount of the representative sample over a 1½-in. (37.5-mm) sieve, as described in Practice C 172, to yield sufficient material to completely fill the measuring bowl of the size selected for use. Carry out the wet-sieving operation with the minimum practicable disturbance of the mortar. Make no attempt to wipe adhering mortar from coarse aggregate particles retained on the sieve.

8. Procedure for Determining Air Content of Concrete

8.1 *Placement and Consolidation of Sample*:

8.1.1 Dampen the interior of the measuring bowl and place it on a flat, level, firm surface. Place a representative sample of the concrete, prepared as described in Section 7, in the measuring bowl in equal layers. Consolidate each layer by the rodding procedure (8.1.2) or by vibration (8.1.3). Strike-off the finally consolidated layer (8.1.4). Rod concretes with a slump greater than 3 in. (75 mm). Rod or vibrate concrete with a slump of 1 to 3 in. (25 to 75 mm). Consolidate concretes with a slump less than 1 in. (25 mm) by vibration.

8.1.2 *Rodding*—Place the concrete in the measuring bowl in three layers of approximately equal volume. Consolidate each layer of concrete by 25 strokes of the tamping rod evenly distributed over the cross section. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Rod the bottom layer throughout its depth, but the rod shall not forcibly strike the bottom of the measure. In rodding the second and final layers, use only enough force to cause the rod to penetrate the surface of the previous layer about 1 in. (25 mm). Add the final layer of concrete in a manner to avoid excessive overfilling (8.1.4).

8.1.3 *Vibration*—Place the concrete in the measuring bowl in two layers of approximately equal volume. Place all of the concrete for each layer before starting vibration of that layer. Consolidate each layer by three insertions of the vibrator evenly distributed over the cross section. Add the final layer in a manner to avoid excessive overfilling (8.1.4). In consolidating the bottom layer, do not allow the vibrator to rest on or touch the bottom or sides of the measuring bowl. Take care in withdrawing the vibrator to ensure that no air pockets are left in the specimen. Observe a standard duration of vibration for the particular kind of concrete, vibrator, and measuring bowl involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Continue vibration until the concrete is properly consolidated. Never continue vibration long enough to cause escape of froth from the sample.

NOTE 5—Overvibration may cause segregation and loss of intentionally entrained air. Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth and has a glazed appearance.

8.1.4 *Strike Off*—After consolidation of the concrete, strike off the top surface by sliding the strike-off bar across the top flange or rim of the measuring bowl with a sawing motion until the bowl is just level full. On completion of consolidation, the bowl must not contain an excess or deficiency of concrete. Removal of ⅛ in. (3 mm) during strike off is optimum. When a strike-off plate is used, strike off concrete as prescribed in Test Method C 138.

NOTE 6—A small quantity of representative concrete may be added to correct a deficiency. If the measure contains a great excess, remove a representative portion of concrete with a trowel or scoop before the measure is struck off.

NOTE 7—The use of the strike-off plate on cast aluminum or other relatively soft metal air meter bases may cause rapid wear of the rim and require frequent maintenance, calibration, and ultimately, replacement.