Designation: C231/C231M − 22

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

This standard is issued under the fixed designation C231/C231M; 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 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 C173/C173M 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 test method 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 either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C172/C172M Practice for Sampling Freshly Mixed Concrete
C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C1758/C1758M Practice for Fabricating Test Specimens with Self-Consolidating Concrete

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 exist 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 C138/C138M and C173/C173M 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.

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[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] 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.

***A Summary of Changes section appears at the end of this standard**

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 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.

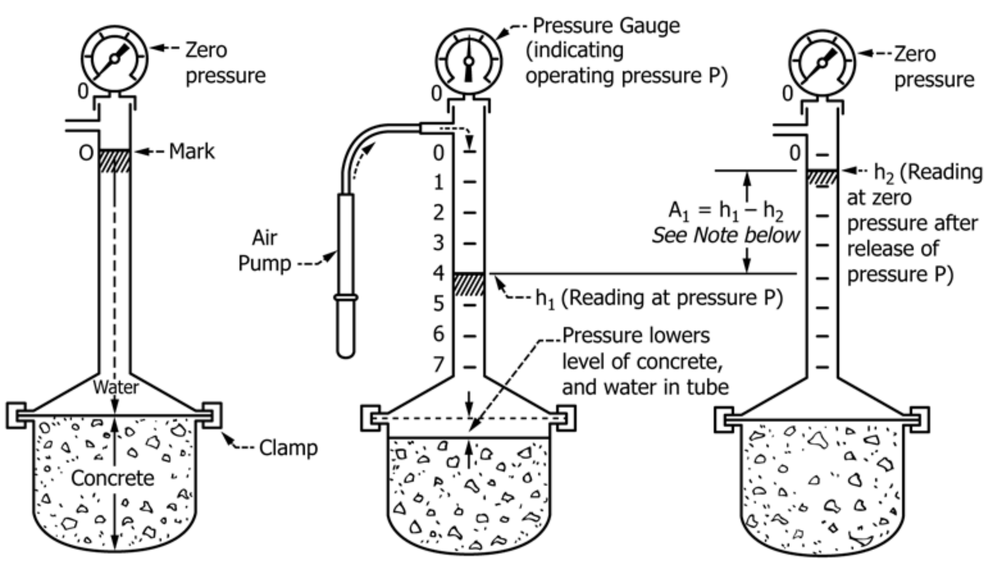
4.1.2 *Meter Type B*—An air meter consisting of a measuring bowl and cover assembly (see Fig. 2) conforming to the requirements of 4.2 and 4.3. The operational principle of this meter consists of equalizing a known volume of air at a known pressure in a sealed air chamber with the unknown volume of air in the concrete sample, the dial on the pressure gauge being calibrated in terms of percent air for the observed pressure at which equalization takes place. Working pressures of 50 kPa to 205 kPa [7.5 psi to 30.0 psi] 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 6.0 L [0.20 ft^3]. It shall be flanged or otherwise constructed to provide for a pressure tight fit between measuring bowl and cover assembly. The interior surfaces of the measuring 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 (Section A1.5) to not more than 0.1 % of air content on the indicator scale when under normal operating pressure.

4.3 *Cover Assembly:*

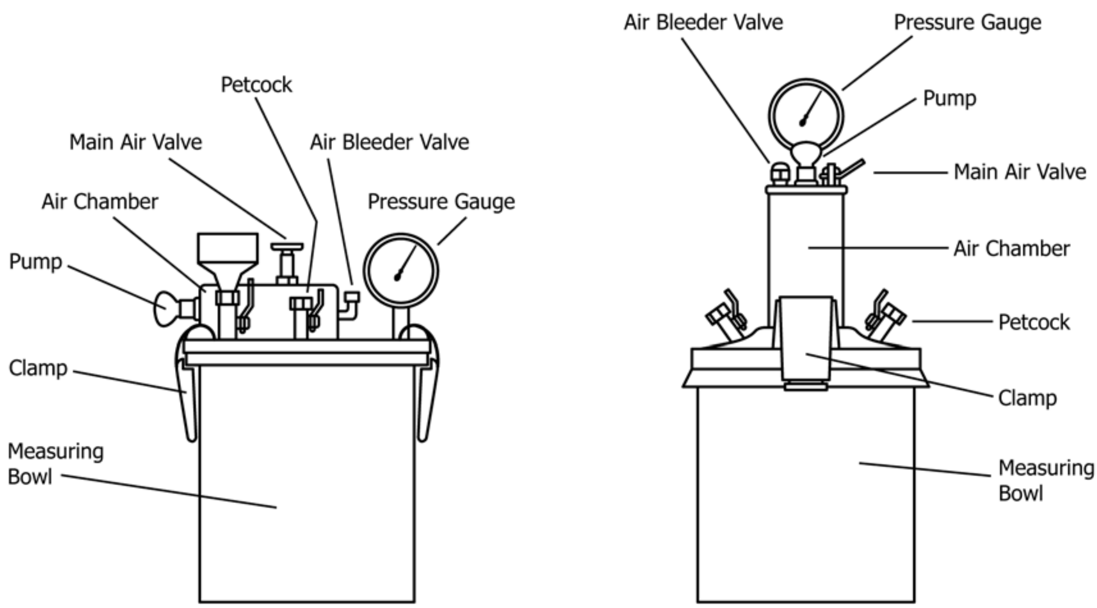
4.3.1 The cover assembly shall be made of steel, hard metal, or other hard material not readily attacked by the cement paste. It shall be flanged or otherwise constructed to provide for a pressure-tight fit between measuring bowl and cover assembly and shall have machined smooth interior surfaces contoured 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 gauge attached. In the Type B meter, the dial of the pressure gauge 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.



Note: $A_1 = h_1 - h_2$ when measuring bowl contains concrete as shown in this figure; when measuring 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



2a. Horizontal Air Chamber **2b.** Vertical Air Chamber

FIG. 2 Schematic Diagram—Type-B Meter

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 measuring bowl shall be provided to make a pressure-tight seal without entrapping air at the joint between the flanges of the cover and measuring 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.

NOTE 1—A satisfactory calibration vessel to place within the measuring bowl may be machined from No. 16 gauge brass tubing, of a diameter to provide the volume desired, to which a brass disk 13 mm [½ in.] in thickness is soldered to form an end. When design of the meter requires withdrawing of water from the water-filled measuring 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 air meters are such that they differ in operating techniques; 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*—A round, smooth, straight steel rod, with a 16 mm [⅝ in.] ± 2 mm [1⁄16 in.] diameter. The length of the tamping rod shall be at least 100 mm [4 in.] greater than the depth of the measuring bowl in which rodding is being performed, but not greater than 600 mm [24 in.] in overall length (see Note 2). The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 2—A rod length of 400 mm [16 in.] to 600 mm [24 in.] meets the requirements of the following: Practice C31/C31M, Test Method C138/C138M, Test Method C143/C143M, Test Method C173/C173M, and Test Method C231/C231M.

4.10 *Mallet*—A mallet (with a rubber or rawhide head) weighing approximately 0.60 kg ± 0.25 kg [1.25 lb ± 0.50 lb] for use with measures of 14 L [0.5 ft^3] or smaller, and a mallet weighing approximately 1.0 kg ± 0.25 kg [2.25 lb ± 0.50 lb] for use with measures larger than 14 L [0.5 ft^3].

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

4.12 *Strike-Off Plate*—A flat rectangular metal plate at least 6 mm [¼ in.] thick or a glass or acrylic plate at least 13 mm [½ in.] thick with a length and width at least 50 mm [2 in.] 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 1.5 mm [1⁄16 in.].

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 C192/C192M.

4.16 *Sieves,* 37.5 mm (1½ in.) with not less than 0.2 m^2 [2 ft^2] of sieving area.

4.17 *Scoop*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the measuring bowl.

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 Sections A1.2 – 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 gauge of the Type A meter as described in Section A1.7, or to determine the accuracy of the graduations indicating air content on the dial face of the pressure gauge of the Type B meter as described in Section A1.9. The steps in Sections A1.2 – 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 Sections A1.7 and A1.9, as applicable to the meter type being checked, must be made as frequently as necessary and at intervals not to exceed three months to ensure that the proper gauge pressure, *P*, is being used for the Type A meter or that the correct air contents are being indicated on the pressure gauge air content scale for the Type B meter. A change in elevation of more than 180 m [600 ft] from the location at which a Type A meter was last calibrated will require recalibration in accordance with Section A1.7.

5.2 *Calibration Records*—Information to be maintained in the records shall include determination of expansion factor; size of the calibration vessel used; and the reading of the meter at the calibration test point(s).

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

NOTE 3—The volume of concrete produced per batch can be determined in accordance with applicable provisions of Test Method C138/C138M.

NOTE 4—The term "weight" is temporarily used in this test method 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 measuring bowl and lightly rod the upper 25 mm [1 in.] 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 – 8.2.3. The aggregate correction factor, *G*, is equal to $h_1 - h_2$ (see Fig. 1) (Note 5).

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 measuring bowl. Remove the water in the manner described in Section 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 measuring bowl expressed as a percent of the volume of the measuring bowl (see Fig. 1).

NOTE 5—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 made easily. 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 C172/C172M. If the concrete contains coarse aggregate particles that would be retained on a 50 mm (2 in.) sieve, wet-sieve a sufficient amount of the representative sample over a 37.5 mm (1½ in.) sieve, as described in Practice C172/C172M, 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 Prepare the concrete as described in 7.1. Dampen the interior of the measuring bowl and place it on a flat, level, firm surface. Using the scoop described in 4.17, place the concrete in the measuring bowl in the number of layers required by the consolidation method (8.1.3 or 8.1.4). While placing the concrete in the bowl, move the scoop around the perimeter of the bowl opening to ensure an even distribution of the concrete with minimal segregation. Consolidate each layer by the rodding procedure (8.1.3) or by vibration (8.1.4). Strike-off the finally consolidated layer (8.1.5). Rod concretes with a slump greater than 75 mm [3 in.]. Rod or vibrate concrete with a slump of 25 mm to 75 mm [1 in. to 3 in.]. Consolidate concretes with a slump less than 25 mm [1 in.] by vibration.

8.1.2 *Self-Consolidating Concrete*—If self-consolidating concrete is being tested, follow the procedures in Practice C1758/C1758M for filling the measuring bowl instead of the procedure in 8.1.1. Upon completion of the filling process, proceed to 8.1.5.

8.1.3 *Rodding*—Place the concrete in the measuring bowl in three layers of approximately equal volume. Rod each layer 25 times uniformly over the cross section with the rounded end of the rod. Rod the bottom layer throughout its depth. In rodding this layer, use care not to damage the bottom of the measuring bowl. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 25 mm [1 in.]. After each layer is rodded, tap the sides of the measuring bowl 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. Add the final layer of concrete in a manner to avoid excessive overfilling (8.1.5).

8.1.4 *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 (8.1.5). In consolidating each layer, do not allow the vibrator to rest on or touch 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 6—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.

8.1.5 *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 measuring bowl must not contain an excess or deficiency of concrete. Removal of 3 mm [⅛ in.] during strike off is optimum. When a strike-off plate is used, strike off concrete as prescribed in Test Method C138/C138M.

NOTE 7—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 8—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.

8.1.6 *Application of Test Method*—Any portion of the test method not specifically designated as pertaining to Type A or Type B meter shall apply to both types.

8.2 *Procedure—Type A Meter:*

8.2.1 *Preparation for Test*—Thoroughly clean the flanges or rims of the measuring bowl and of the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus and add water over the concrete by means of the tube until it rises to about the halfway mark in the standpipe. Incline the apparatus assembly about 0.5 rad [30°] from vertical and, using the bottom of the measuring bowl as a pivot, describe several complete circles with the upper end of the column, simultaneously tapping the cover lightly to remove any entrapped air bubbles above the concrete sample. Return the apparatus assembly to a vertical position and fill the water column slightly above the zero mark, while lightly tapping the sides of the measuring bowl. Bring the water level to the zero mark of the graduated tube before closing the vent at the top of the water column (see Fig. 1 A).

NOTE 9—Some Type A meters have a calibrated starting fill mark above the zero mark. Generally, this starting mark should not be used since, as noted in 8.2.3, the apparent air content is the difference between the water level reading H, at pressure P and the water level h_2 at zero pressure after release of pressure P.

8.2.2 The internal surface of the cover assembly shall be kept clean and free from oil or grease; the surface shall be wet to prevent adherence of air bubbles that might be difficult to dislodge after assembly of the apparatus.

8.2.3 *Test Procedure*—Apply more than the desired test pressure, P, (about 1.4 kPa [0.2 psi] more) to the concrete by means of the small hand pump. To relieve local restraints, tap the sides of the measuring bowl sharply and, when the pressure gauge indicates the exact test pressure, P, as determined in accordance with Section A1.7, read the water level, h_1, and record to the nearest division or half-division on the graduated precision-bore tube or gauge glass of the standpipe (see Fig. 1

B). For extremely harsh mixes tap the measuring bowl vigorously until further tapping produces no change in the indicated air content. Gradually release the air pressure through the vent at the top of the water column and tap the sides of the measuring bowl lightly for about 1 min. Record the water level, h_2, to the nearest division or half-division (see Fig. 1 C). Calculate the apparent air content as follows:

$$A_1 = h_1 - h_2 \tag{3}$$

where:

A_1 = apparent air content,
h_1 = water level reading at pressure, P (see Note 10), and
h_2 = water level reading at zero pressure after release of pressure, P.

8.2.4 *Check Test*—Repeat the steps described in 8.2.3 without adding water to reestablish the water level at the zero mark. The two consecutive determinations of apparent air content should check within 0.2 % of air and shall be averaged to give the value A_1 to be used in calculating the air content, A_s, in accordance with Section 9.

8.2.5 In the event the air content exceeds the range of the meter when it is operated at the normal test pressure P, reduce the test pressure to the alternative test pressure P_1 and repeat the steps outlined in 8.2.2 and 8.2.3.

NOTE 10—See Section A1.7 for exact calibration procedures. An approximate value of the alternative pressure, P_1, such that the apparent air content will equal twice the meter reading can be computed from the following relationship:

$$P_1 = P_a P / (2P_a + P) \tag{4}$$

where:

P_1 = alternative test pressure, kPa or [psi],
P_a = atmospheric pressure, kPa or [psi], (approximately 100 kPa [14.7 psi] but will vary with altitude and weather conditions), and
P = normal test or operating gauge pressure, kPa or [psi].

8.3 *Procedure—Type B Meter:*

8.3.1 *Preparation for Test*—Thoroughly clean the flanges or rims of the measuring bowl and the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus. Close the main air valve between the air chamber and the measuring bowl and open both petcocks on the holes through the cover. Add water through one petcock until water emerges from the opposite petcock (Note 11). Jar the meter gently until all air is expelled from this same petcock.

NOTE 11—Gently squeezing water into the petcock using a bulb syringe or plastic wash bottle has been found to be satisfactory for adding water to the meter.

8.3.2 *Test Procedure*—Close the air bleeder valve on the air chamber and pump air into the air chamber until the gauge hand is on the initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gauge hand at the initial pressure line by pumping or bleeding-off air as necessary, tapping the gauge lightly by hand. Close both petcocks on the holes through the cover. Open the main air valve between the air chamber and the measuring bowl. Tap the sides of the measuring bowl smartly with the mallet to relieve local restraints. Lightly tap the pressure gauge by hand to stabilize the gauge hand. Read the percentage of air on the dial of the pressure gauge. Release the main air valve. Failure to close the main air valve before releasing the pressure from either the container or the air chamber will result in water being drawn into the air chamber, thus introducing error in subsequent measurements. In the event water enters the air chamber, it must be bled from the air chamber through the air bleeder valve followed by several strokes of the pump to blow out the last traces of water. Release the pressure by opening both petcocks (Fig. 2) before removing the cover.

9. Calculation

9.1 *Air Content of Sample Tested*—Calculate the air content of the concrete in the measuring bowl as follows:

$$A_s = A_1 - G \tag{5}$$

where:

A_s = air content of the sample tested, %,
A_1 = apparent air content of the sample tested, % (see 8.2.3 and 8.3.2), and
G = aggregate correction factor, % (Section 6).

9.2 *Air Content of Full Mixture*—When the sample tested represents that portion of the mixture that is obtained by wet sieving to remove aggregate particles larger than a 37.5 mm (1½ in.) sieve, the air content of the full mixture is calculated as follows:

$$A_t = 100 A_s V_c / (100 V_t - A_s V_a) \tag{6}$$

where (Note 12):

A_t = air content of the full mixture, %,
V_c = absolute volume of the ingredients of the mixture passing a 37.5-mm (1½-in.) sieve, airfree, as determined from the original batch weights, m^3 [ft^3],
V_t = absolute volume of all ingredients of the mixture, airfree, m^3 [ft^3], and
V_a = absolute volume of the aggregate in the mixture coarser than a 37.5-mm (1½-in.) sieve, as determined from original batch weights, m^3 [ft^3].

9.3 *Air Content of the Mortar Fraction*—When it is desired to know the air content of the mortar fraction of the mixture, calculate it as follows:

$$A_m = 100 A_s V_c / [100 V_m + A_s (V_c - V_m)] \tag{7}$$

where (Note 12):

A_m = air content of the mortar fraction, %, and
V_m = absolute volume of the ingredients of the mortar fraction of the mixture, airfree, m^3 [ft^3].

NOTE 12—The values for use in Eq 6 and Eq 7 are most conveniently obtained from data on the concrete mixture tabulated as follows for a batch of any size:

		Absolute Volume, m^3 [ft^3]		
Cement	______	} V_m	}	V_c
Water	______			
Fine aggregate	______			
Coarse aggregate (4.75-mm (No. 4) to 37.5-mm (1½-in.))	______			
Coarse aggregate (37.5-mm (1½-in.))	______	V_a		
Total	______	V_t		

10. Report

10.1 Report the following information:

10.1.1 The air content of the concrete sample to the nearest 0.1 % after subtracting the aggregate correction factor, unless the gauge reading of the meter exceeds 8 %, in which case the corrected reading shall be reported to the nearest ½ scale division on the dial.

10.1.2 The date and time of the test.

10.1.3 When requested, and when the absolute volume of the ingredients of the mortar fraction of the mixture can be determined, the air content of the mortar fraction of the mixture to the nearest ¼ %.

11. Precision and Bias

11.1 *Precision, Type A Meter:*

11.1.1 *Single-Operator Precision*—The single-operator standard deviation has not been established.

11.1.2 *Multilaboratory Precision*—The multilaboratory standard deviation has not been established.

11.1.3 *Multioperator Precision*—The multioperator standard deviation of a single test result has been found to be 0.28 % air by volume of concrete for Type A air meters as long as the air content does not exceed 7 %. Therefore results of two tests properly conducted by different operators but on the same material should not differ by more than 0.8 % air by volume of concrete.

NOTE 13—The number 0.8% represents the difference limit (d2s) as described in Practice C670. The precision statements are based on the variations in tests on three different concretes, each tested by eleven different operators.[4]

11.2 *Precision, Type B Meter:*

11.2.1 *Single-Operator Precision:*

11.2.1.1 *Air Content Less Than 3 %*—The maximum single-operator standard deviation was found to be 0.18 %. Therefore, the air contents from two properly conducted tests by the same operator on the same material are not expected to differ from each other by more than 0.5 %.[5]

11.2.1.2 *Air Content in the Range of 3 % to 8 %*—The single-operator standard deviation was found to increase with air content as shown in Table 1. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ from each other by more than the value shown in the last column of the upper half of Table 1.

TABLE 1 Indexes of Precision for Air Contents Between 3 and 8 %[A]

Air Content	Standard Deviation %	Acceptable Difference Between Two Results,[B] %
Single-operator precision:		
3 %	0.12	0.33
4 %	0.16	0.44
5 %	0.19	0.55
6 %	0.23	0.66
7 %	0.27	0.77
8 %	0.31	0.88
Multilaboratory precision:		
3 %	0.17	0.49
4 %	0.23	0.65
5 %	0.29	0.81
6 %	0.35	0.98
7 %	0.40	1.14
8 %	0.46	1.30

[A] Use interpolation to determine precision values for air contents between the values given in the table.

[B] These numbers represent the difference limits (d2s) as described in Practice C670.

11.2.2 *Multilaboratory Precision:*

11.2.2.1 *Air Content Less Than 3 %*—The maximum multilaboratory standard deviation was found to be 0.26 %. Therefore, the air contents from two properly conducted testes by different laboratories on the same material are not expected to differ from each other by more than 0.75 %.[5]

11.2.2.2 *Air Content in the Range of 3 % to 8 %*—The multilaboratory standard deviation was found to increase with air content as shown in Table 1. Therefore, results of two properly conducted tests by different laboratories on the same material are not expected to differ from each other by more than the value shown in the last column of the lower half of Table 1.

NOTE 14—These precision statements are based on an interlaboratory study that involved 16 operators, six values of air content ranging from 1.3 % to 7.6 %, and three replicate tests per operator. The results showed different precision performance for the two air contents less than 3 %, than for the 4 air contents above 3 %. Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1049. Contact ASTM Customer Service at service@astm.org.

11.3 *Bias*—This test method has no bias because the air content of freshly mixed concrete can only be defined in terms of the test methods.

12. Keywords

12.1 air content; calibration; concrete; correction factor; measuring bowl; meter; pressure; pump; unit weight

[4] Reidenour, D. R., and Howe, R. H., "Air Content of Plastic and Hardened Concrete," presented at the 2nd International Conference on" Durability of Building Materials and Components" Sept. 14–16, 1981. Reprints compiled by: G. Frohnsdorff and B. Horner, National Institute for Standards and Technology, Gaithersburg, MD 20899, formerly National Bureau of Standards, Washington, DC 20234.

[5] These numbers represent the difference limits (d2s) as described in Practice C670.