Designation: C 426 – 07

Standard Test Method for Linear Drying Shrinkage of Concrete Masonry Units[1]

This standard is issued under the fixed designation C 426; 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.

1. Scope*

1.1 This test method covers a routine standardized procedure for determining the linear drying shrinkage of concrete masonry units or related concrete units under specified accelerated drying conditions.

1.2 The values stated in inch-pound 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:* [2]

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 1093 Practice for Accreditation of Testing Agencies for Unit Masonry

2.2 *ANSI Standard:*

B94.11M—1993 Twist Drills[3]

3. Terminology

3.1 *Definition:*

3.1.1 *linear drying shrinkage*—in this test method, the change in linear dimension of the test specimen due to drying from a saturated condition to an equilibrium weight and length under specified accelerated drying conditions.

4. Significance and Use

4.1 This test method is intended to evaluate the drying shrinkage characteristics of a given unit. The results of this laboratory method are considered in determining concrete masonry crack control provisions.

NOTE 1—The testing laboratory performing this test method should be evaluated in accordance with Practice C 1093.

5. Apparatus

5.1 *Strain Gauge*—The instruments for measuring linear drying shrinkage shall be so designed as to permit or provide the conditions described in 5.1.1 through 5.1.5.

NOTE 2—Strain gauges may be obtained with various gauge lengths. The 10-in. (254-mm) gauge length is recommended for use with regular concrete masonry units, however, particular sizes of products may require other lengths. The length of the shrinkage specimen shall not be less than required for a minimum gauge length (distance between gauge plugs) of 6 in. (152.4 mm).

5.1.1 A means of positive contact with the specimen that will ensure reproducible measurements of length.

5.1.2 Means for precise measurement, consisting of a dial micrometer or other measuring device graduated to read in 0.0001-in. (0.0025-mm) units, and accurate within 0.0001 in. (0.0025 mm) in any 0.0010-in. (0.025-mm) range, and within 0.0002 in. (0.0050-mm) in any 0.0100-in. (0.254-mm) range.

5.1.3 Sufficient range to allow for small variations in the gauge lengths.

NOTE 3—If the shrinkage reference points are set carefully to position, a dial micrometer with a travel of 0.2 or 0.3 in. (5.1 or 7.6 mm) provides ample range in the instrument.

5.1.4 Means for checking the strain gauge at regular intervals against a standard reference bar. The standard reference bar shall be protected from air currents by placing it inside a wooden box which should be closed except when the strain gauge is being checked against it.

NOTE 4—A standard reference bar shall be furnished by the manufacturer of the instrument. A standard bar of ordinary steel is satisfactory, but corrections must be made for variations in its length due to temperature changes. When a more nearly constant datum is desired, Invar is preferable because of its low coefficient of thermal expansion.

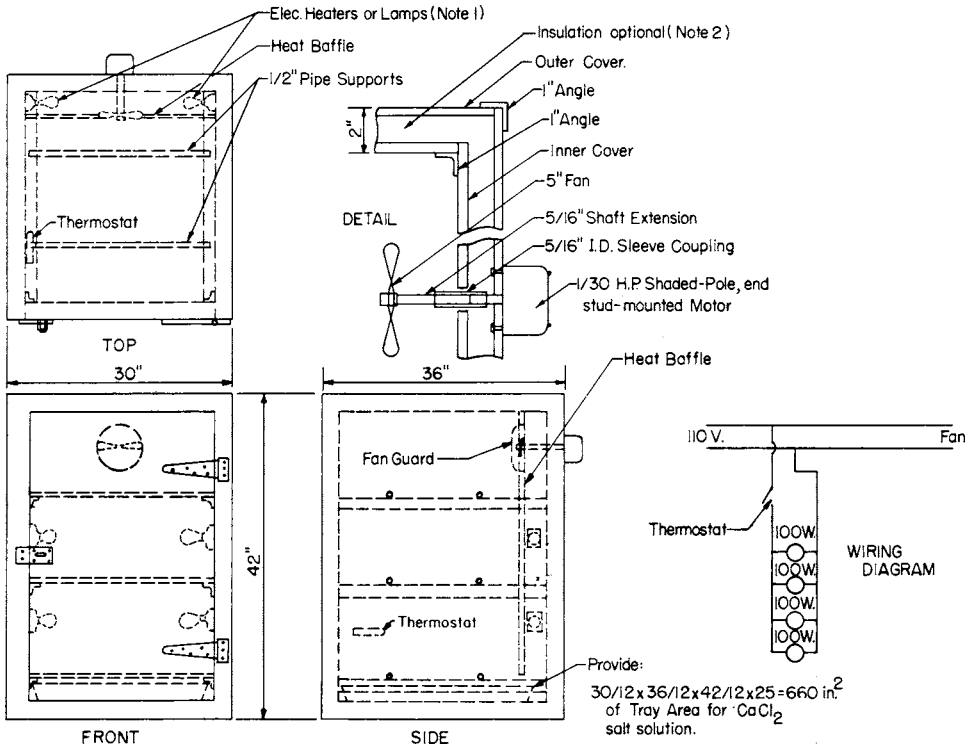
[1] This test method is under the jurisdiction of ASTM Committee C15 on Manufactured Masonry Units and is the direct responsibility of Subcommittee C15.03 on Concrete Masonry Units and Related Units.

Current edition approved June 1, 2007. Published June 2007. Originally approved in 1958. Last previous edition approved in 2006 as C 426 – 06.

[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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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



NOTE 1—Provide access to heaters.
NOTE 2—Insulating fill is recommended in cabinets having outer covers of sheet metal
NOTE 3—The following materials are required:

Quantity	Description
1	5-in. (127-mm) fan assembly, as shown
1	1/30-hp (25-W) shaded-pole, fan-cooled, stud-mounted electric motor
75 ft (22.9 m)	1-in. (25.4-mm) angle, steel or aluminum
60 ft^2(5.6 m^2)	Outer cover, ½-in. (12.7-mm) plywood or equivalent, faced with sheet metal or other material to provide a positive vapor barrier
60 ft^2(5.6 m^2)	Inner cover, ⅜-in. (9.5-mm) asbestos board or equivalent
1	Heat baffle, 25 by 34-in. (635 by 864-mm), sheet metal
16 ft (4.8 m)	½-in. iron pipe
4	100-W porcelain light fixtures
1	500-W thermostat
1	24 × 30 × 1½-in. (610 × 762 × 38-mm) tray, borosilicate glass or equivalent
1 pr	8-in. (203-mm) hinges and hasp

FIG. 1 Drying Oven Suitable for Determining Drying Shrinkage of Concrete Block

5.1.5 Convenient and rapid measurement of specimens.

5.2 *Comparator*—When desirable to measure specimens end to end, a comparator conforming to the requirements of Practice C 490 may be used as an alternative to the strain gauge for measuring linear drying shrinkage.

5.3 *Gauge Plugs*—The gauge plugs shall be made from metal that is resistant to corrosion. Plugs for use with strain gauges shall be ⅜ to ½ in. (9.5 to 12.7 mm) in diameter and ½ ± ⅛ (12.7 ± 3.2 mm) in thickness. Plugs for use with the comparator shall consist of ¼-in. (6.4-mm) diameter stainless steel gauge studs shown in Practice C 490.

5.4 *Drying Oven*—The oven shall be reasonably airtight and provide the features described in 5.4.1 through 5.4.4.

NOTE 5—One suggested oven construction is shown in Fig. 1.

5.4.1 A minimum storage capacity of three whole test specimens and a clearance of 1 in. (25.4 mm) on all sides of each test specimen.

5.4.2 A constant, uniform temperature of 122 ± 2°F (50 ± 0.9°C) throughout the insulated cabinet attained by means of an electrical heat source (Note 6).

NOTE 6—Direct heating of test specimens with the combustion products of gas or other carbonaceous fuels is not satisfactory due to the presence of carbon dioxide and water and their possible effect on the drying characteristics of portland cement products.

5.4.3 A means of drying specimens to a condition of equilibrium with a relative humidity of 17 ± 2 % (Note 7).

5.4.3.1 Calcium chloride ($CaCl_2$), if used for this purpose, shall be in flake form. Suitable dishes or trays shall be provided to give an exposed solution area of not less than 25 in.^{2} for each cubic foot (5800 cm^2 for each m^3) of oven volume. Dishes or trays shall contain sufficient solid calcium chloride so that the crystals will be exposed above the surface of the solution throughout the test. The calcium chloride solution shall be thoroughly stirred every 24 h, and more often if necessary, to prevent the formation of lumps and crusting over.

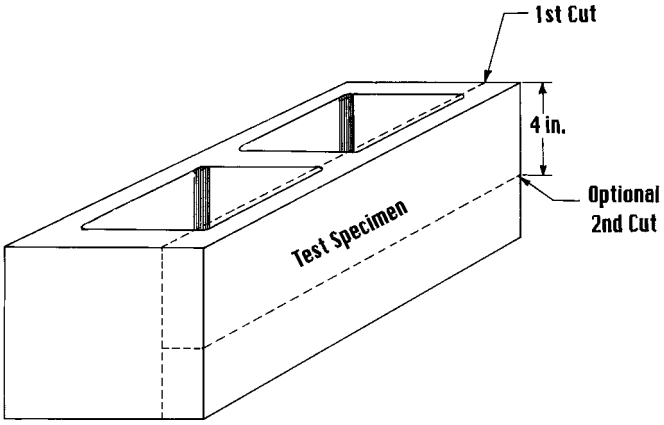


FIG. 2 View of Sawed Block Showing a Suggested Sequence of Cuts and Location of Half-Face Shell Specimens

NOTE 7—The air immediately above a saturated solution of calcium chloride ($CaCl_2$) at 122°F (50°C) is approximately 17 %.

5.4.4 Moderate circulation of air within the oven, over and around all test specimens and the drying agent.

5.5 *Cooling Chamber*—An airtight enclosure of sufficient capacity for cooling a minimum of three whole specimens to a temperature of 73.4 ± 2°F (23 ± 1.1°C).

5.6 *Immersion Tank*—A suitable container for completely immersing three whole test specimens in water maintained at 73.4 ± 2°F (23 ± 1.1°C).

5.7 *Balance or Scale*—The balance shall be sensitive to within 0.1 % of the weight of the smallest specimen tested.

6. Test Specimens

6.1 The test specimens selected shall be whole units, free of visible cracks or other structural defects, which shall be representative of the lot from which they are selected (Note 8). Portions of face shells (see 6.1.1) may be used for test in lieu of whole units providing they are cut lengthwise from hollow units at least 12 in. (304.8 mm) in length. Specimens to be used for testing shall not be exposed to external heat sources.

NOTE 8—In tests of short units such as concrete brick by this method, use of a 10-in. (254-mm) Whittemore strain gauge is reported to be feasible when two units are butted together and joined using an epoxy resin cement to form an extremely thin joint between the units. The abutting ends of the units should be ground to ensure intimate contact and a thin joint; these precautions are necessary to ensure the thinnest joints practicable and thereby avoid abnormal shrinkage indications. Some laboratories have obtained satisfactory results using a 10-in. Whittemore strain gauge on specimens joined with unfilled epoxy cements.

6.1.1 The number of specimens selected should consist of three whole units or three half face-shells. (See Fig. 2.)

6.1.2 The portions known as half face-shells should be at least 4 in. (101.6 mm) wide and should be of the same length as the face shell. Half face-shell specimens must be saw-cut from hollow units not less than 12 in. (304.8 mm) in length.

6.2 *Methods of Attaching Gauge Plugs to Specimens*:

6.2.1 *Gauge Plug Inserts for Use with Strain Gauges*—Place a pair of gauge plugs at or near, and parallel to, the center line in each of two opposite faces of the specimen. Drill plug holes with a drill that is slightly smaller in size than the plug diameter so as to provide a snug fit (Note 9). The depth of the holes shall be such that the exposed surface of the inserted gauge plug is approximately ⅛ in. (2.5 mm) below the surface of the specimen. Prior to setting of the plug, plug holes shall be dry and dust free. After the bonding material (Note 10) has been placed in the hole, insert the gauge plug and prick punch the plug to proper gauge length with the gauge bar provided. Wipe off excessive bonding material and allow the remainder to cure. After the bonding material is sufficiently hard, drill receiving holes for strain gauge points with a No. 56 to 60 twist drill.[4]

NOTE 9—A 5⁄16-in. (7.9-mm) diameter carbide-tipped masonry drill has been found satisfactory for gauge plugs ⅜ in. (9.5 mm) in diameter.

NOTE 10—A number of bonding agents have been reported satisfactory for setting gauge plugs. Tests to determine the effect of water immersion and subsequent drying on the bonding agent's adhesion should be made prior to use.

6.2.2 Drill receiving holes in gauge plugs for strain gauge points prior to attachment of gauge plugs. Attach gauge plugs with a bonding agent (Note 10) using the strain gauge punch bar or other convenient template to set gauge holes the proper distance apart.

6.3 *Inserts for Comparator Measurements*—On opposite ends of the test specimen, mount spherically shaped gauge plugs, for use with the comparator (see 5.2). Drill a shallow recess (Note 11) at the desired location using a drill slightly less in size than the plug diameter. Fill the recess with a bonding agent, and firmly press the plug into position, taking care that the bonding agent extends slightly above the level of the center of the sphere. After the bonding agent is sufficiently hard, clean excess material from the exposed portion of the gauge plug.

NOTE 11—Satisfactory results without a drilled recess have been reported with the use of quick-setting bonding agents. Aluminum putty has been demonstrated to perform well in this test as an adhesive to adhere gauge plugs to the surface of test specimens.

7. Procedure

7.1 Immerse specimens in water at 73.4 ± 2°F (23 ± 1.1°C) for 48± 2 h.

[4] Detailed requirements for these twist drills are given in the American National Standard for Twist Drills (ANSI B5.10).

7.2 Take the initial reading of specimen length, at saturation, with the unit positioned in the water tank so that its gauge line is about at the level of the water surface to avoid error due to cooling by evaporation. Take accompanying length readings of the standard reference bar. (See 8.1 and 8.2 for methods of adjusting and correcting length readings.) Record the temperature of the water as T_x.

7.3 Weigh and record the saturated surface-dry weight of the test specimen by draining the test specimen for 1 min ± 5 s over a ⅜-in. (9.5-mm) (or larger) mesh and removing visible surface water by blotting with a damp cloth.

7.4 Within 48 h after the specimens have been removed from the water, place them in the drying oven described in 5.4. During this period of up to 48 h, the specimens shall be stored continuously in air at a temperature of 75 ± 15°F (24 ± 8°C) and a relative humidity of less than 80 % (Note 12). To ensure uniformity of drying, the individual specimens should be rotated to different positions in the drying oven each time readings are taken.

NOTE 12—Reports have indicated that moisture is exuded faster by some masonry units during the early part of the drying period than can be absorbed by the calcium chloride solution, causing condensation to form on the interior surfaces of the oven.

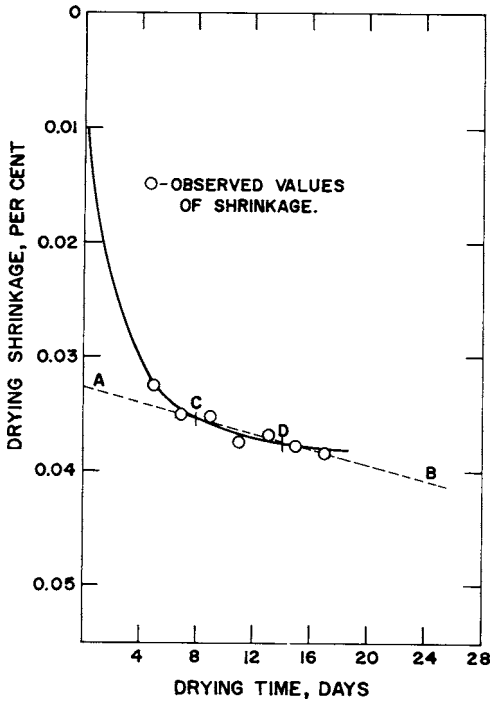
7.5 At the end of 5 days of drying, including any period of preliminary drying in air up to 48 h, remove shrinkage specimens from the drying oven and cool to 73.4 ± 2°F (23 ± 1.1°C) within 8 h (Note 13). Following cooling, record the temperature of the cooling chamber of T_x, remove each specimen from the cooling container and immediately take specimen length readings. Take accompanying length readings of the standard reference bar. Weigh the specimens. The air temperature of the laboratory at the time length readings are made on the specimens shall be 73.4 ± 5°F (23 ± 2.8°C).

NOTE 13—Use a cooling chamber consisting of a steel, drum-type container equipped with a ring-sealed, rubber-gasketed type cover. The drum cover should be equipped with a thermometer, the bulb of which is in the proximity of the uppermost test specimen. The drum must be stored in a temperature-controlled room in order that its final equilibrium temperature will be 73.4 ± 2°F (23 ± 1.1°C). Length measurements made at temperatures other than 73.4 ± 2°F (23 ± 1.1°C) shall be corrected as shown in 8.3.

7.6 Return test specimens to the drying oven for a second period of drying. The duration of the second, and subsequent, oven drying periods shall be 44 ± 4 h. Following the second period of drying, repeat cooling, length readings, and weight determinations as specified in 7.5.

7.7 Continue the periods of oven drying, followed by length and weight determinations after cooling under the specified conditions (Note 14) until the average length change of the test specimens is 0.002 %, or less, over a span of 6 days of drying, and when the average weight loss in 48 h of drying is 0.2 % or less compared to the last previously determined weight. For the purposes of this test method, equilibrium is considered to be achieved when these conditions are met.

NOTE 14—When uniform attainment of equilibrium length is not apparent in the tabular data, the value of equilibrium shrinkage may be obtained from shrinkage-time curves drawn through experimental points as illustrated in Fig. 3. The dotted line *AB* having a slope corresponding to the limiting value of rate of shrinkage (0.002 % in 6 days) is fitted to the experimental curve in such a manner that the points of intersection *C* and *D* span a time interval of 6 days; the corresponding shrinkage interval between point *C* and *D* is 0.002 %. The value of equilibrium shrinkage shall be taken as the shrinkage corresponding to point *D* expressed to the nearest 0.001 %. Data for which the rate of shrinkage is obviously within the prescribed limit need not be plotted, but the principle of selecting point *D* should be followed. That is, the final percent shrinkage is the greater of two values agreeing within 0.002 percentage points over a period of 6 days.



NOTE—The interval *CD* is 6 days on the time scale and % on the shrinkage scale. Point *D* defines equilibrium shrinkage value.

FIG. 3 Graphical Method of Determining Equilibrium Shrinkage

8. Calculations

8.1 *Method of Correcting Specimen Length Reading*—Correct specimen length readings taken at temperatures other than 73.4°F (23°C) as follows:

$$L_{x(73.4)} = L_x - (T_x - 73.4)GQ_c \quad (1)$$

where:

$L_{x\,(73.4)}$ = corrected specimen length reading, in. (mm),
L_x = specimen length reading taken at temperature T_x, in. (mm),
T_x = temperature of cooling chamber at the time specimens are removed for length measurements (Note 13), of °F (°C),
G = test specimen gauge length, in. (mm), and
Q_c = coefficient of thermal expansion of concrete specimen (Note 15), in./in.·°F (mm/mm·°C).

NOTE 15—If the coefficient Q for specimen is unknown, Q_c for concrete may be assumed to be 4.5×10^{-6} in./in. · °F (8.1×10^{16} mm/mm · °C).

8.2 *Method of Correcting Reference Bar Length Readings*—Correct reference bar length readings taken at temperatures other than 73.4°F (23°C) as follows:

$$R_{x(73.4)} = R_x - (T_x - 73.4)GQ_R \quad (2)$$

where:

$R_{x(73.4)}$ = corrected reference bar length reading, in. (mm),
R_x = reference bar length reading taken at temperature T_x, in. (mm),
T_x = temperature of reference bar at time of length reading, °F (°C),
G = test specimen gauge length, in. (mm), and
Q_R = coefficient of thermal expansion of reference bar (Note 15), in./in.·°F (mm/mm·°C).

NOTE 16—The coefficient Q_r for mild steel can be assumed to be 6.5×10^{-6} in./in. · °F (11.7×10^{-6} mm/mm·°C). The coefficient Q_R for lnvar can be assumed to be 0.7×10^{-6} in./in. · °F (1.3×10^{-6} mm/mm · °C).

8.3 *Method of Calculating Change in Specimen Length*—Adjust the reported change in linear dimension of the test specimen for variations in the reference bar readings that are due to causes other than temperature as follows:

$$\Delta L_x = (L_{I(73.4)} - R_{I(73.4)}) - (L_{x(73.4)} - R_{x(73.4)}) \quad (3)$$

where:

ΔL_x = change in the linear dimension of the specimen due to drying from a saturated to the length of the specimen at any time, x, in. (mm),
$L_{I\ (73.4)}$ = specimen length reading on saturated specimen, corrected for temperature (see 8.1), in. (mm),
$R_{I\ (73.4)}$ = accompanying reference bar length reading for L_I, in. (mm)
$L_{x\ (73.4)}$ = specimen length reading at any time x, corrected for temperature (see 8.1), in. (mm), and
$R_{x\ (73.4)}$ = accompanying reference bar reading for L_x, corrected for temperature, in. (mm).

8.4 *Method of Calculating Linear Drying Shrinkage*:

8.4.1 Calculate the linear drying shrinkage of the specimen at each reading as a percentage of the gauge length as follows:

$$S_x = (\Delta L_x/G) \times 100 \quad (4)$$

where:

S_x = linear drying shrinkage, at any time, x, %,
ΔL_x = change in the linear dimension of the specimen due to drying from a saturated condition to the length of the specimen at any time, x, in. (mm), and
G = test specimen gauge length, in. (mm).

8.4.2 Calculate the final linear drying shrinkage of the specimen, S, by averaging the drying shrinkage from each of the last three length measurements, with the final measurement considered to be that in which the equilibrium conditions for length and weight described in 7.7 are achieved.

NOTE 17—As an example, if length and weight equilibrium is first achieved on day 15 of the testing, $S = (S_{\text{day } 15} + S_{\text{day } 13} + S_{\text{day } 11})/3$.

9. Report

9.1 Report the following information:

9.1.1 Identification of product and number of specimens for each condition of test.

9.1.2 Source of specimens.

9.1.3 Age of specimens at start of shrinkage test.

9.1.4 Total length of drying period prior to each length measurement.

9.1.5 Weight of each test specimen, saturated, and at the time of each length measurement, including equilibrium.

9.1.6 Linear drying shrinkage, percent, for each test specimen from saturation to each length measurement, including the length measured at equilibrium.

9.1.7 Final linear drying shrinkage for each specimen and as an average of three specimens.

9.1.8 Any other information that may be pertinent.

10. Keywords

10.1 comparator; concrete brick; concrete masonry units; drying; drying oven; shrinkage; strain gauge

SUMMARY OF CHANGES

Committee C15 has identified the location of selected changes to this standard since the last issue (C 426 – 06) that may impact the use of this standard. (Approved June 1, 2007.)

(*1*) Limits on cooling time were added to subsection 7.5.
(*2*) Tolerances were added to oven drying periods in subsection 7.6.
(*3*) Statement of what is considered equilibrium was added to the end of subsection 7.7.

Committee C15 has identified the location of selected changes to this standard since the last issue (C 426 – 05) that may impact the use of this standard. (Approved Dec. 15, 2006.)

(*1*) Eq 4 and its legend were revised.
(*2*) A new subsection 8.4.2 and Note 17 were added to determine "final linear drying shrinkage." Related changes were made to Section 9 for reporting results.