Designation: F2170 – 19a

Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes[1]

This standard is issued under the fixed designation F2170; 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 quantitative determination of percent relative humidity in concrete slabs for field or laboratory tests.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific warnings are given in Section 7, 10.3.2, and 10.4.4.

1.4 *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:*[2]

E104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

F710 Practice for Preparing Concrete Floors to Receive Resilient Flooring

2.2 *OSHA Standard:*[3]

§1926.1153 Respirable crystalline silica

3. Terminology

3.1 *Definitions:*

3.1.1 *relative humidity, n*—ratio of the amount of water vapor actually in the air compared to the amount of water vapor required for saturation at that particular temperature and pressure, expressed as a percentage.

3.1.2 *service temperature and relative humidity, n*—average ambient air temperature and relative humidity that typically will be found in a building's occupied spaces during normal use.

4. Summary of Test Method

4.1 This test method comprises two procedures for forming holes in concrete into which a relative humidity probe is placed. Procedure A for hardened concrete involves drilling a cylindrical hole in concrete with a rotary hammerdrill, then placing a hollow sleeve to line the hole. Procedure B is an alternative procedure for fresh concrete, which involves forming a cylindrical hole in concrete by placing a hollow cylindrical tube in the formwork, then placing and consolidating concrete around the tube. The liner or tube permits measurement of RH at a specific, well-defined depth in the concrete.

4.2 Methods of probe calibration and factors affecting equilibration are described in Section 8.

5. Significance and Use

5.1 Excessive moisture in floor slabs after floor covering has been installed can cause floor covering system failures such as debonding, peaking and deterioration of finish flooring and coatings and microbial growth.

5.2 Manufacturers of such systems generally require moisture testing to be performed before installation on concrete. Internal relative humidity testing is one such method.

5.3 Moisture test results indicate the moisture condition of the slab only at the time of the test and in the specific locations tested.

6. Apparatus

6.1 *Hole Liner,* made of plastic or non-corroding metal. The liner shall have the shape of a hollow right circular cylinder and shall be between 0.37 to 0.75-in. (10 to 20 mm) outside diameter.

[1] This test method is under the jurisdiction of ASTM Committee F06 on Resilient Floor Coverings and is the direct responsibility of Subcommittee F06.40 on Practices.

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

[3] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, http://www.osha.gov.

6.1.1 The liner shall have a solid sidewall that is open only at the bottom and at the top. Slots, holes, or other penetrations in the sidewall of the liner are not permitted. Two or more deformable circumferential fins located around the exterior circumference near the bottom of the liner shall be provided to create a positive seal against the concrete. The liner shall be of sufficient length to extend from the bottom diameter of the hole to the surface of the concrete. See Fig. 1.

NOTE 1—The purpose of the liner is to isolate the probe from the sidewall of the hole so that moisture only enters into the sensor from a specific depth at the bottom of the hole. The specified diameter range will usually permit the hole to intersect a sufficient volume of cement paste to provide adequate moisture interaction with the sensor for accurate measurement. Smaller diameter holes may intersect only a single aggregate particle at the bottom of the hole and therefore produce inaccurate results. If the user observes that the bottom of the hole is occupied by a single aggregate particle, do not use that hole.

6.2 *Humidity Probe and Digital Meter*—Relative humidity and temperature sensors in cylindrical probe, designed such that when the probe is installed to its full depth within the hole liner, the following geometrical considerations shall be met:

6.2.1 The sensing elements of the probe shall be located within 0.625 ± 0.125 in. (15.9 ± 3 mm) of the base of the liner and the probe sealed or gasketed within itself and the liner such that the volume of air being measured cannot escape upward beyond 0.625 ± 0.125 in. (15.9 ± 3 mm) within the probe itself or the liner. See Fig. 2.

6.2.2 Obtain probes from a manufacturer with NIST traceable calibration equal to or better than ±2 % relative humidity at 50 % relative humidity and ±2 % relative humidity at 90 % relative humidity.

NOTE 2—Calibration by end-users using saturated salt solutions in accordance with Practice E104 is not recommended due to the technical difficulties of maintaining sufficiently accurate reference standards. Checking with salt solutions is an acceptable method of assessing probe performance.

7. Hazards

7.1 *Silica and Asbestos Warning*—Do not sand, dry sweep, dry scrape, drill, saw, beadblast, or mechanically chip or pulverize existing resilient flooring, backing, lining felt, paint, asphaltic cutback adhesives, or other adhesives. These products may contain asbestos fibers or crystalline silica. (See OSHA §1926.1153 for latest OSHA requirements). Avoid creating dust. Use of dust collection equipment and appropriate personal protective equipment such as an approved respirator may be required to control worker exposure to respirable crystalline silica produced from drilling concrete. Inhalation of such dust is a cancer and respiratory tract hazard. Smoking by individuals exposed to asbestos fibers greatly increases the risk of serious bodily harm. Unless positively certain that the product is a nonasbestos-containing material, presume that it contain asbestos. Regulations may require that the material be tested to determine asbestos content. The Resilient Floor Covering Institute's (RFCI) recommended work practices for removal of existing resilient floor coverings should be consulted for a defined set of instructions addressed to the task of removing all resilient floor covering structures.[4]

7.2 *Lead Warning*—Certain paints may contain lead. Exposure to excessive amounts of lead dust presents a health hazard. Refer to applicable federal, state, and local laws and guidelines for hazard identification and abatement of lead-based paint published by the U.S. Department of Housing and Urban Development regarding appropriate methods for identifying lead-based paint and removing such paint, and any licensing, certification, and training requirements for persons performing lead abatement work.[5]

7.3 *Wet Concrete Warning*—Contact with wet (unhardened) concrete, mortar, cement, or cement mixtures can cause skin irritation, severe chemical burns, or serious eye damage. Wear waterproof gloves, a long-sleeved shirt, full-length trousers, and proper eye protection when working with these materials. If you have to stand in wet concrete, use waterproof boots that are high enough to keep concrete from flowing into them. Wash wet concrete, mortar, cement, or cement mixtures from your skin immediately after contact. Indirect contact through clothing can be as serious as direct contact, so promptly rinse out wet concrete, mortar, cement, or cement mixtures from clothing. Seek immediate medical attention if you have persistent or severe discomfort.

8. Calibration

8.1 Recalibrate probes at least annually or more frequently if exposed to environmental conditions that affect measurement accuracy.

8.2 Check probe calibration within 30 days before use by the following procedure:

[4] *Recommended Work Practices for Removal of Resilient Floor Coverings*, Resilient Floor Covering Institute, 115 Broad St., Suite 201, La Grange, GA 30240, rfci.com.

[5] *Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing*, U.S. Department of Housing and Urban Development, NTIS Order Number PB91-144311. Available online from www.fedworld.gov.

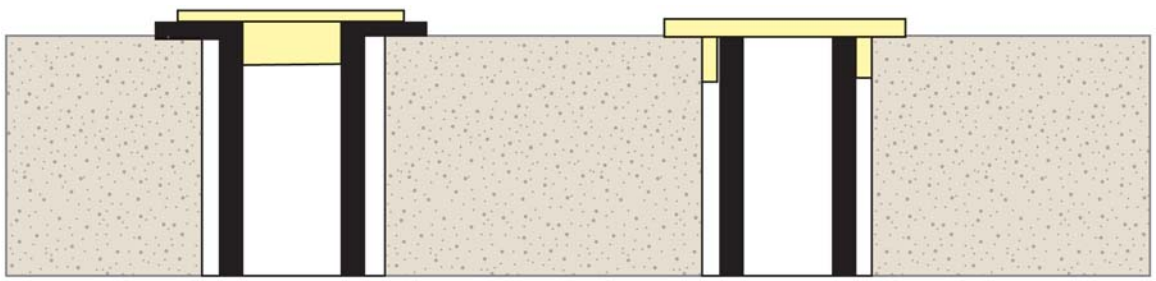

FIG. 1 Example Hole with Liner

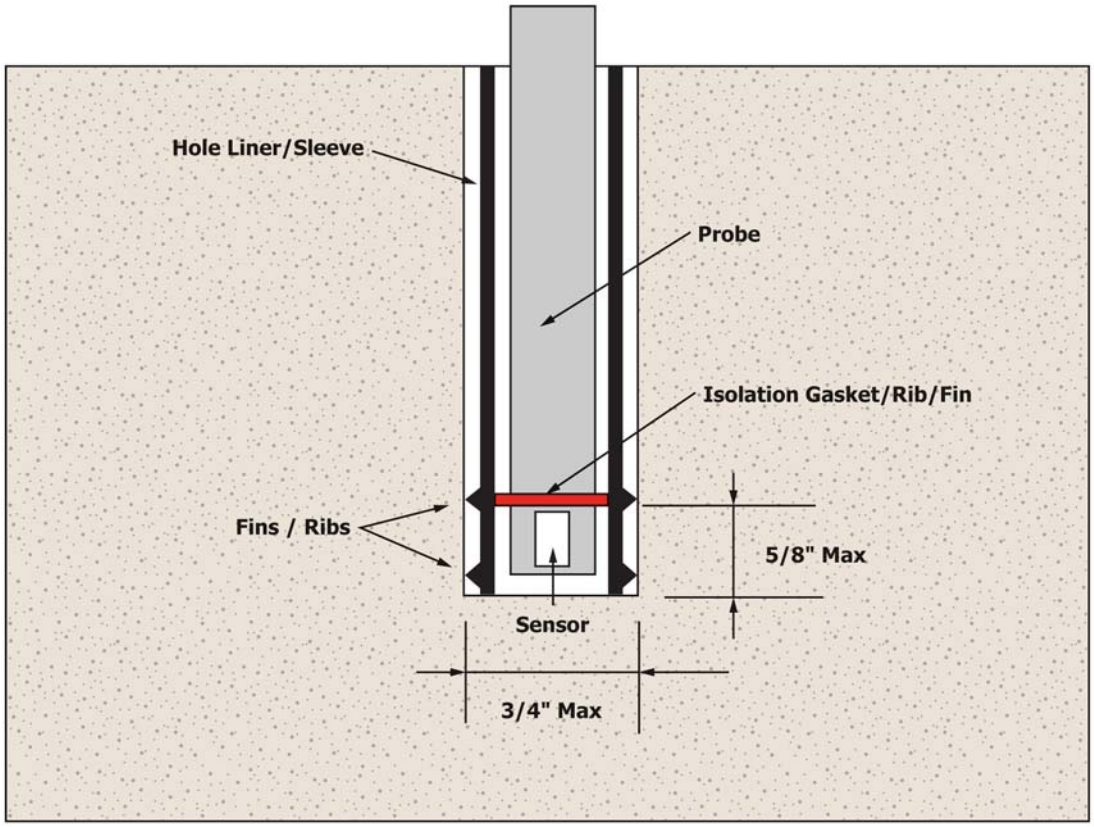

FIG. 2 Example % RH - Probe Element Position

8.2.1 *Calibration Check Procedure, Saturated Salt Solutions*—Prepare saturated salt solutions in accordance with Practice E104. Follow probe manufacturer's recommended procedure for exposing probes. Check probes at relative humidity (RH) equal to or greater than 75 % RH. Record the as-found relative humidity of the probe and the nominal relative humidity of the salt solutions. If the as-found relative humidity differs from the nominal relative humidity by more than 2 % RH (below 90 % relative humidity) or by more than 3 % RH (from 90 to 100 % relative humidity), recalibrate the probe before use or discard.

9. Conditioning

9.1 Concrete floor slabs shall be at service temperature and the occupied air space above the floor slab shall be at service temperature and service relative humidity for at least 48 h before making relative humidity measurements in the concrete slab.

10. Procedure

10.1 *Number of Tests and Locations:*

10.1.1 Perform three tests for the first 1000 ft^2 (100 m^2) and at least one additional test for each additional 1000 ft^2 (100 m^2).

10.1.2 Select test locations to provide information about moisture distribution across the entire concrete floor slab, especially areas of potential high moisture. Include a test location within 3 ft (1 m) of each exterior wall.

10.2 Determine the appropriate depth for probe holes from the following table:

Drying Conditions	Drill-to Depth from Top of Slab
Slab drying from top only (Example: slab on ground with vapor retarder below, or slab on metal deck)	40 % (Example: 1.6 in. (41 mm) deep in 4-in. (102-mm) thick slab)
Slab drying from top and bottom (Example: elevated structural slab not in metal deck)	20 % (Example: 0.8 in. (20 mm) deep in 4-in. (102-mm) thick slab)
Fluted Metal Deck (Composite)	40 % of maximum slab thickness (Example: 2.4 in. (61 mm) deep in a 3-6 in. (76-152 mm) thick fluted deck slab)

NOTE 3—Testing at these depths will indicate the potential equilibrium relative humidity that will be established within the concrete slab after a low-permeability floor covering is applied.

10.2.1 Drilled hole depth shall be calculated using the established concrete slab thickness of the concrete slab.

10.3 *Procedure A—Drilled Holes:*

10.3.1 Use a rotary hammerdrill with a carbide-tipped drill bit to drill holes to required depth. Drill bit diameter shall not exceed 0.04 in. (1 mm) larger than the external diameter of the hole liner. Hole shall be drilled dry. Do not use water for cooling or lubrication; do not wet-core test hole.

10.3.2 Remove dust from the hole using a vacuum cleaner. (**Warning**—Avoid blowing dust from the hole that might

become respirable. Wear respiratory protection if necessary to avoid breathing concrete dust while drilling and cleaning holes.)

10.3.2.1 After cleaning, measure drilled hole depth at bottom outside edge (circumference) to ensure appropriate depth has been reached in accordance with 10.2. Drilled hole depth shall not be less than the appropriate calculated value as listed in the table in 10.2.

10.3.3 Record drilled hole depth measured at the bottom outside edge (circumference) after cleaning.

10.3.4 Insert hole liner to bottom of hole. Cap or seal open end of hole liner and any open gaps at the top of the liner per manufacturer's instructions.

NOTE 4—Care should be taken to protect the hole from the intrusion of any dust and debris after installation of the sleeve.

10.3.5 Allow 24 h to achieve moisture equilibrium within the hole before making relative humidity measurements.

10.3.6 Continue the determination of relative humidity in accordance with 10.5.

NOTE 5—Measurement of relative humidity on concrete powder collected from a drilled hole does not produce results of sufficient accuracy to meet the purposes described in Significance and Use.

10.4 *Alternative Procedure B—Cast Holes:*

10.4.1 Before placing concrete, secure liner tube to formwork or steel reinforcement to avoid displacement of tubes during concrete placement, consolidation, and finishing.

10.4.2 Secure a solid rod slightly smaller than the inner diameter of the liner into the liner so that the bottom end of the rod is flush with the bottom end of the liner at measurement depth and the top end protrudes above the top of the liner. This rod will exclude fresh concrete from entering the liner during concrete placement and consolidation.

10.4.3 Place, consolidate, and finish the concrete, ensuring the liner remains at required depth. Remove the inner solid rod after the concrete hardens and place a rubber stopper into the upper end of the liner. Record the installed hole liner depth.

10.4.4 Holes formed by casting liners in fresh concrete can be used to measure relative humidity as soon as the concrete hardens. (**Warning**—Holes formed in fresh concrete might contain highly alkaline solution (pH>12) that must be removed before placing probes. This solution can cause chemical burns on exposed skin. Remove solution from a hole using a sponge or rag. Wear protective eyewear and gloves. Handle soaked rags or sponges with care. Do not use compressed air to blow solution out of holes.)

10.5 *Measurement:*

10.5.1 Remove the rubber stopper at the top of the liner and insert probe. Seal the probe lead wire to the liner where the wire emerges from the top of the liner. Connect the probe lead wire to the meter, turn on the meter and allow it to warm up as indicated by the manufacturer's instructions.

10.5.2 Allow probe to reach temperature equilibrium before measuring relative humidity. Probe shall be at the same temperature as the concrete before reading. Even a small difference in temperature will produce a significant error in relative humidity measurement.

10.5.3 Check for drift. Meter reading must not drift more than 1 % relative humidity over 5 min. Equilibration may take several hours to several days depending on factors such as the initial temperature difference between probe and concrete. The meter can be turned off and disconnected from the probe while the probe equilibrates with the concrete.

10.5.4 Record the in-situ, concrete relative humidity to the nearest percent and the in-situ, concrete temperature to the nearest degree Fahrenheit (Celsius). Also record the location of the hole within the structure, established slab thickness and drilled hole depth in accordance with 10.3.3.

10.5.5 Use a relative humidity probe to measure the ambient air temperature and relative humidity above the slab in the vicinity of the hole. Record the relative humidity to the nearest percent, and temperature to the nearest degree Fahrenheit (Celsius).

10.6 Remove the hole liner and fill the hole with a cementitious patching compound to produce a surface finish in accordance with Practice F710, in Paragraph 4.5 under General Guidelines. Use a patching compound rated by its manufacturer as suitable for the depth of patch.

11. Report

11.1 Report the following information:

11.1.1 Name and address of the structure.

11.1.2 Date and time holes were drilled, time in hours that probes equilibrated in holes, and date and time when measurements were made.

11.1.3 Name, title, and affiliation of worker performing the measurements.

11.1.4 Locations, established slab thickness, and depths of probe holes within the structure.

11.1.5 Relative humidity in each probe hole, to the nearest percent relative humidity.

11.1.6 Temperature in each probe hole, to the nearest degree Celsius (Fahrenheit).

11.1.7 Ambient air temperature, to the nearest degree Celsius (Fahrenheit) and relative humidity (to the nearest percent relative humidity) above each probe hole.

11.1.8 Make, model, and last calibration date of the instrument used to make the measurements.

11.2 Report any observations that might affect the interpretation of individual measurements such as standing water on the slab, wet coring operations, weather, or ventilating system operations.

12. Precision and Bias

12.1 The precision of this test method is based on an interlaboratory study of Test Method F2170, conducted in March 2014. Six analysts participated in the study, testing randomly spaced locations on two concrete slabs. Each analyst was asked to report eighteen test results for this study. Practice E691 was followed for the study design; the details are given in an ASTM Research Report.[6]

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F06-1011. Contact ASTM Customer Service at service@astm.org.

12.1.1 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same property, obtained by the same operator using the same equipment on the same day in the same laboratory.

12.1.1.1 Repeatability limits are listed in Table 1.

12.1.2 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same property, obtained by different operators using different equipment in different laboratories.

12.1.2.1 Reproducibility limits are listed in Table 1.

12.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

12.1.4 Any judgment in accordance with 12.1.1 and 12.1.2 would have an approximate 95 % probability of being correct.

12.2 *Bias*—At the time of the study, no accepted certified reference material was analyzed by the participating laboratories, therefore no quantitative statement on bias is being made. Bias is affected by accuracy of probe calibration and can be strongly affected by equilibration of probes in the concrete. Measurements made too soon after placing a probe in a drilled hole may be significantly higher or lower than measurements made under equilibrium conditions.

12.3 The precision statement was determined through statistical examination of 1080 results, from a total of five analysts, over a 72-h span.

13. Keywords

13.1 concrete; flooring; floors; moisture; relative humidity

TABLE 1 Relative Humidity (%)[A]

	Average[B] $\bar{x}$	Repeatability Standard Deviation S_r	Reproducibility Standard Deviation S_R	Repeatability Limit r	Reproducibility Limit R
1 h – open	81.85	2.17	3.80	6.09	10.64
1 h – sealed	84.75	1.77	3.64	4.96	10.20
2 h – open	81.37	2.07	3.60	5.81	10.07
2 h – sealed	85.20	1.56	3.45	4.38	9.65
4 h – open	80.45	1.85	3.24	5.17	9.08
4 h – sealed	85.48	1.38	3.06	3.85	8.57
24 h – open	77.84	1.30	1.84	3.63	5.16
24 h – sealed	85.91	0.95	1.85	2.67	5.19
48 h – open	77.23	1.29	1.60	3.61	4.48
48 h – sealed	85.65	0.93	1.37	2.60	3.84
72 h – open	77.07	1.31	1.69	3.66	4.72
72 h – sealed	85.60	1.02	1.33	2.86	3.73

[A] "Open" refers to a concrete slab that was exposed to air before and during moisture measurements, therefore having a gradient of moisture throughout the vertical section of the concrete similar to concrete slabs in buildings. "Sealed" refers to a concrete slab that was covered on its upper surface so that the moisture was effectively uniform throughout the vertical section of the concrete, similar to a concrete slab with floor covering in place.
[B] The average of the laboratories' calculated averages.

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE REPORT FORM

REPORT OF RELATIVE HUMIDITY IN CONCRETE

Name and address of structure	*Identify Floor*

Test Location (use room numbers or building grid)	Depth from top of slab, in.	Relative Humidity in concrete, %	Temperature in concrete, °F	Air Temperature, °F	Air Relative Humidity, %	Notes

Instrument Used

Make, Model, Serial number	Last calibration date

Tests performed by

Name	Date
Company name, address	

RELATED MATERIAL

BS5325:1996, *Code of Practice for Installation of Textile Floor Coverings*.

BS8203:1996, *Code of Practice for Installation of Resilient Floor Coverings*.

Hedenblad, G., "Drying on Construction Water in Concrete," T9:1997, Swedish Council for Building Research, 1997. (Available from Svensk Byggtjanst, Stockholm.)

Molina, L., *Measurement of High Humidity in Cementitious Material at an Early Age*, CBI Report 3:90, Swedish Cement and Concrete Research Institute, 1990.

New Zealand Federation of Master Flooring Contractors and New Zealand Concrete Research Association, *Manual of Practices and Conditions for the New Zealand Flooring Industry: Concrete Floor Construction*, Wellington, NZ, 1984.

Nordtest Method NT BUILD 439, *Concrete Hardened: Relative Humidity Measured in Drilled Holes*.