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Standard Specification for Cold-Weather Admixture Systems[1]

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1. Scope

1.1 This specification covers cold-weather admixture systems to be added to hydraulic-cement concrete when the temperature of the concrete immediately after placement will be as low as 23.0 °F [-5.0 °C].

1.2 This specification stipulates tests of the cold-weather admixture system with suitable materials as described in 11.1-11.3 or with materials proposed for specific work (See 11.5). Unless otherwise requested by the purchaser, tests shall be made using suitable concreting materials as described in 11.1-11.3.

NOTE 1—Whenever practicable, tests should be made using the concreting materials, the mixture proportions, and batching sequence proposed for the specific work (See 11.5) because the time of setting, compressive strength gain, and other properties may vary.

1.3 This specification provides three levels of testing.

1.3.1 *Level 1*—During the initial approval stage, proof of compliance with the performance requirements defined in Table 1 demonstrates that the cold-weather admixture system meets the requirements of this specification. Uniformity and equivalence tests (See Section 6) shall be carried out to provide results against which later comparisons can be made.

1.3.2 *Level 2*—Limited retesting is described in 5.2, 5.2.1, and 5.2.2. Proof of compliance with the requirements of Table 1 demonstrates conformity of the admixture system with the requirements of this specification.

1.3.3 *Level 3*—For acceptance of a lot or for measuring uniformity within or between lots, when specified by the purchaser, uniformity and equivalence tests (See Section 6) shall be used.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 The text of this standard references notes and footnotes, which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.6 The following precautionary caveat pertains to the test methods portion, Sections 11-18, of this specification. *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.* **WARNING**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 33 Specification for Concrete Aggregates

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 150 Specification for Portland Cement

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement, Mortar, and Concrete

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C 09.23 on Chemical Admixtures.

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[2] Section on Safety Precautions, Manual of Aggregates 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.

TABLE 1 Performance Requirements for Cold-Weather Admixture[A]

Time of Initial Setting, maximum % of control	200
Compressive Strength. minimum % of control[B]	
7 days[C]	40
28 days	80
90 days	90
Length Change, Maximum Shrinkage (alternative requirements)[D]	
Percent of Control	135
Increase over control, percentage points	0.010
Relative Durability Factor, Minimum % of control[E]	80

[A]The values in the table include allowance for normal variation in test results

[B]The compressive strength of the concrete containing the cold-weather admixture shall not be less than 90 % of that attained at the previous test age. The objective of this limit is to require that the compressive strength of the cold-weather admixture concrete shall not decrease with age.

[C]Because the test specimens will be cool and damp for the 7d compressive test, it will be necessary to use unbonded caps as described in Practice C 1231/C 1231M.

[D]Alternative requirements, see 17.1.2: Percent of control applies when shrinkage of control concrete is 0.030 % or greater; the increase over control limit applies when shrinkage of control concrete is 0.030 % or less.

[E]This requirement is applicable only when the cold-weather admixture is to be used in air-entrained concrete that may be exposed to freezing and thawing while wet.

C 260 Specification for Air-Entraining Admixtures for Concrete

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C 1064/C 1064M Test Method for Temperature of Freshly Mixed Portland Cement Concrete

C 1231/C 1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

D 1193 Specification for Reagent Water

2.2 *American Concrete Institute Standard:*[4]

ACI 211.1 Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

3. Terminology

3.1 *Definitions of Terms:*

3.1.1 For definitions of terms used in this specification, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cold-weather admixture system*, *n*—an admixture or group of admixtures that depresses the freezing point of mixing water and increases the hydration rate of cement in concrete.

3.2.2 *control concrete mixture*, *n*—a concrete mixture without the cold-weather admixture system.

3.2.3 *dummy concrete specimen*, *n*—additional concrete specimen instrumented with a temperature sensing device to estimate the temperature of test concrete specimens.

3.2.4 *replicate concrete specimen*, *n*—additional time-of-setting specimen exposed to the same temperature regimen as the test concrete specimen.

3.2.5 *test concrete mixture*, *n*—a concrete mixture with the cold weather admixture system.

4. Apparatus

4.1 *Low Temperature Environment*—A chamber of sufficient size to subject the test specimens to the specified low temperature and that allows access for laboratory personnel to conduct appropriate tests. The chamber or chambers shall be capable of cooling numerous specimens from their initial temperature to 23.0 ± 2.0 °F [-5.0 ± 1 °C] within the specified elapsed time and maintain them at that temperature for the specified time period.

4.2 *Temperature Measuring Equipment*—The temperature measuring equipment shall be capable of measuring and recording the temperature at the center of the dummy specimens to ± 2.0 °F [± 1.0 °C] at least every ½ h for 7 days.

4.3 *Tools*—Molds and tools for preparing test specimens as described in Practice C 192/C 192M. Molds shall have lids to provide for sealed conditions.

5. General Requirements

5.1 For initial compliance with this specification, the concrete shall be tested with the cold-weather admixture system for conformance with the requirements in Table 1.

5.2 The purchaser is permitted to require limited retesting to confirm current compliance of the admixture system to specification requirements. The limited retesting includes measurements of physical and performance properties of the admixture system as described in 5.2.1 and 5.2.2.

5.2.1 The physical properties retesting consists of uniformity and equivalence tests of the admixture system for infrared absorption spectrum and relative density.

5.2.2 The performance properties retesting consists of time of initial setting and compressive strength of concrete at 7 and 28 days. Purchasers having special requirements are permitted to require additional tests.

5.3 At the request of the purchaser, the manufacturer shall state in writing that the admixture system supplied for use in the work is equivalent in all essential respects, including concentration, to the admixture system tested under this specification.

5.4 At the request of the purchaser, the manufacturer shall state in writing the chloride content of the admixture system.

5.5 Tests for uniformity and equivalence, as indicated in Section 6, shall be made on the initial sample and the results retained for reference and comparison with the results of samples taken elsewhere within the lot or subsequent lots of admixture supplied to the work.

6. Uniformity and Equivalence Tests

6.1 When specified by the purchaser, the uniformity of a lot, or equivalence of multiple lots from the same source shall be established by the following requirements:

[4] Available from the American Concrete Institute, 38899 Country Club Drive, Farmington Hills, MI. 48333.

6.1.1 *Infrared Analysis*—The absorption spectra of the initial sample and the test sample, obtained as specified in Section 18, shall exhibit the same pattern of absorption bands in terms of frequency and intensity.

6.1.2 *Relative Density (Liquid Admixture)*—When tested as specified in Section 18, the relative density (specific gravity) of subsequent test samples shall not differ from the relative density of the initial sample by more than 10 % of the difference between the relative density of the initial sample and reagent water at the same temperature. Reagent water conforming to Specification D 1193, Type III or IV, and prepared by distillation, ion exchange, reverse osmosis, or a combination of these procedures, is acceptable (See Note 2).

6.2 When the nature of the admixture system or analytical capability of the purchaser make these procedures unsuitable, other requirements for uniformity and equivalence from lot to lot or within a lot shall be established by agreement between the purchaser and the manufacturer.

NOTE 2—Oven drying methods are not appropriate for measuring the oven-dried residue content for cold-weather admixture system because water, present in the form of bound water of hydration, is released slowly upon drying, and can often lead to highly variable results. Relative density is an acceptable indication of lot-to-lot uniformity.

7. Packaging and Marking

7.1 When the cold-weather admixture system is delivered in packages or containers, the proprietary name of the individual admixtures in the system, the designation of this specification, and the net mass or volume shall be plainly marked thereon. Similar information shall be provided in the shipping information accompanying packages or bulk shipments of admixture.

8. Storage

8.1 Store the cold-weather admixture system to permit easy access for proper inspection and identification of each shipment, and in a suitable building that will protect the admixture from moisture absorption if it is a dry admixture or from freezing if it is a liquid admixture.

9. Sampling and Testing

9.1 Every facility shall be provided to the purchaser for sampling and inspection, either at the point of manufacture or at the site of the work, as specified by the purchaser.

9.2 Samples shall be either “grab” or “composite” samples as specified by this specification. A grab sample is one obtained in a single operation. A composite sample is one obtained by combining three or more grab samples.

9.3 For the purpose of this specification, it is recognized that samples will be taken for two reasons:

9.3.1 *Compliance Tests*—A sample taken for evaluating compliance of a source or lot of cold-weather admixture system shall meet the applicable requirements of this specification. Samples used to determine conformance with this specification shall be composites of grab samples taken from different locations so that the composite sample will be representative of the lot.

9.3.2 *Uniformity and Equivalence Tests*—When specified by the purchaser, a sample taken for evaluating the uniformity of a single lot or equivalence of multiple lots from one source shall be tested as provided in Section 6. When uniformity of a single lot is being determined, grab samples shall be used. When uniformity of multiple lots from the same source is being determined, composite samples from individual lots shall be used.

9.4 *Liquid Admixtures*—Liquid admixtures shall be agitated immediately prior to sampling. Grab samples taken for quality or uniformity tests shall represent a unit shipment or a single production lot. Each grab sample shall be at least 1 qt [1 L]. At least three grab samples of equal portions shall be taken. Composite samples shall be prepared by mixing the grab samples and the resultant mixture shall provide at least 3 qt [3 L] for compliance tests. Grab samples shall be taken from different locations distributed throughout the quantity to be represented.

9.4.1 Admixtures in bulk storage tanks shall be sampled equally from the upper, intermediate, and lower levels by means of drain cocks in the sides of the tanks or a weighted sampling bottle fitted with a stopper that can be removed after the bottle is lowered to the desired depth.

9.4.2 Samples shall be stored in impermeable containers that are resistant to attack by the admixture.

9.5 *Nonliquid Admixtures*—Grab samples taken for compliance or uniformity tests shall be at least 2 lb [1kg]. At least four grab samples of equal portions shall be taken from not more than 2 tons [2 Mg] of admixture. Prepare composite samples by mixing the grab samples and sampling the resultant mixture to provide at least 5 lb [2.5 kg] for the composite sample. Take grab samples from different locations distributed throughout the quantity to be represented.

9.5.1 Obtain samples of packaged admixtures by means of a sampler as described in Practice C 183.

9.5.2 Samples shall be stored in moisture-proof, airtight containers.

9.6 Mix samples before testing to ensure uniformity. When recommended by the manufacturer, dissolve the entire sample of non-liquid admixture in water prior to testing.

10. Rejection

10.1 For initial compliance testing, the purchaser is permitted to reject the cold-weather admixture system if it fails to meet any of the requirements of this specification.

10.2 For the initial retesting, the purchaser is permitted to reject the admixture if it fails to meet any of the requirements of Section 6 and applicable parts of Table 1, as defined in 5.2.2.

10.3 If, after completion of tests, an admixture has been stored at the point of manufacture for more than 6 months prior to shipment, or an admixture has been in local storage in the hands of a vendor for more than 6 months, it shall be retested before use when requested by the purchaser and is permitted to be rejected if it fails to conform to this specification.

10.4 Packages and containers varying more than 5 % from the specified mass or volume are permitted to be rejected. If the average mass or volume of 50 packages taken at random is less than that specified, the entire shipment is permitted to be rejected.

10.5 When the admixture is for a specific use in non-air-entrained concrete, it is permitted to be rejected if the test concrete containing it has an air content greater than 3.5 % at

the dosage used to meet this specification. When the admixture is to be used in air-entrained concrete, it is permitted to be rejected if the test concrete containing it has an air content greater than 7.5 % at the dosage used to meet this specification.

11. Materials

11.1 *Concrete Not for Specific Use*—The materials in 11.2-11.4 are for compliance testing using a concrete mixture not for a specific use.

11.2 *Cementitious Materials*—The cementitious materials shall be a Type I or Type II portland cement conforming to Specification C 150, or a blend of two or more of these cements from different sources.

11.3 *Aggregates*—Except when tests are made in accordance with 11.4 using the aggregates for a specific use, the fine and coarse aggregates used in any series of tests shall come from single lots of materials that conform to the requirement of Specification C 33, except that the grading shall conform to the following requirements:

11.3.1 *Fine Aggregate Grading:*

Sieve	Percent Passing by Mass
4.75 mm [No. 4]	100
1.18 mm [No. 16]	65 to 75
300 µm [No. 50]	12 to 20
150 µm [No. 100]	2 to 5

11.3.2 *Coarse Aggregate Grading*—The coarse aggregate grading shall meet the Size 57 grading requirements of Specification C 33. Take care in loading and delivery to avoid segregation.

11.3.3 Coarse aggregate used for control concrete and test concrete shall be essentially the same. Provide sufficient coarse aggregate for the control concrete, the test concrete, and for grading analysis.

11.3.3.1 Prepare required quantities of coarse aggregate (See Note 3) as follows: Fill tared containers, one for sieve analysis, one for a batch of control concrete, and one for a batch of test concrete, to the required mass from the aggregate stockpile. Accomplish this by placing equal quantities into each container, successively, and repeat the procedure until all the containers have their required mass.

NOTE 3—Refer to the section on Sampling Aggregates in the Manual of Aggregate and Concrete Testing for guidance on sampling from stockpiles.

11.3.4 Perform sieve analyses on the coarse aggregate prepared in 11.3.3.1 by Test Method C 136. Discard any prepared quantity of aggregate that deviates from the specified percent passing by more than the amount shown in column 3 below.

Sieve	Specification C 33, No. 57 Percent Passing by Mass	Maximum Variation from Percent Passing
37.5 mm [1 ½ in.]	100	0.0
25.0 mm [1 in.]	95 to 100	1.0
12.5 mm [½ in.]	25 to 60	4.0
4.75 mm [No. 4]	0 to 10	4.0
2.36 mm [No. 8]	0 to 5	1.0

11.4 *Air-Entraining Admixture*—Except when tests are made in accordance with 11.5 using an air-entraining admixture proposed for specific work, the air-entraining admixture used in the concrete mixtures specified in Section 12 shall be a material such that, when used to entrain the specified amount of air in the concrete mixture, will give concrete of satisfactory resistance to freezing and thawing. The air-entraining admixture shall conform to Specification C 260.

11.5 *Concrete for Specific Use*—The materials in this section are for specific use, such as for testing the cold-weather admixture system in simulated job concrete mixtures. To test the cold-weather admixture system for use in specific work, the cementitious materials, aggregates (See 11.3), other chemical admixtures, and air-entraining admixture used shall be representative of those used in the work. Add the cold-weather admixture system in the same manner and at the same time during the batching and mixing sequence as it will be added on the job. Proportion the concrete mixture to be similar to that used in the work. If the maximum size of coarse aggregate in the job concrete is greater than 25.0 mm [1 in.], screen the fresh concrete over a 25.0 mm [1 in.] sieve prior to fabricating the specimens to be tested.

12. Proportioning Concrete Mixtures

12.1 *Preparation and Batching*—Prepare all materials and make all weighing as prescribed in Practice C 192/ C 192M. Prepare all materials so that the test concrete temperature, at the time of specimen casting, shall be 57 ± 3 °F [14 ± 2 °C]. Prepare all control concrete materials according to 14.6.1.

12.2 *Proportions*—Concrete mixtures not for specific uses shall be proportioned using ACI 211.1 (See Note 4). After evaluation of trial mixtures, aggregate proportions shall be adjusted as needed to obtain workable, cohesive mixtures with the correct yield. Unless otherwise specified, the cold-weather admixture system shall be added with the second increment of mixing water added to the mixer.

12.2.1 The cementitious materials content shall be 600 ± 5 lb/yd^3 [357 ± 3 kg/m^3]

12.2.2 For the first trial mixture, refer to the table on volume of coarse aggregate in ACI 211.1 for guidance on amount of coarse aggregate to use for the fineness modulus of the fine aggregate being used.

NOTE 4—Values in the referenced table of ACI 211.1 are intended to ensure workable mixtures with the least favorable combinations of aggregates used. It is suggested, therefore, that for a closer approximation of the proportions required for this test, the volume of coarse aggregate (in the dry-rodded condition) per unit volume of concrete selected from ACI 211.1 be increased by about 0.07 for the first trial mixture.

12.2.3 The target air content of air-entrained concrete shall be 6 %.

12.2.4 Adjust the water content to obtain a slump of 6 ± ½ n. [150 ± 15 mm].

The workability of the control concrete mixture shall be suitable for consolidation by hand rodding and the concrete mixture shall have the lowest water content possible. Achieve these conditions by final adjustment in the amount of fine aggregate or in the amount of total aggregate, or both, while maintaining yield and slump.

12.3 *Specimens*—Prepare concrete mixtures with and without the cold-weather admixture system. Control concrete specimens shall be cured in above-freezing conditions and test concrete specimens in below-freezing conditions as specified

in Section 14 and Section 16. Add the cold-weather admixture system in a manner recommended by the manufacturer and in an amount necessary to comply with Table 1.

12.4 *Non-Air-Entrained Concrete*—When the cold-weather admixture system is to be tested in non-air-entrained concrete, the air content of both the control and test mixtures shall be 3.5 % or less, and the difference between the air contents of the two mixtures shall not exceed 1.0 percentage point. If necessary, air-entraining admixture shall be added to the control mixture to achieve the same air content as the test concrete. Tests for freezing and thawing are not required.

12.5 *Air-Entrained Concrete*—When the cold-weather admixture system is to be tested in air-entrained concrete, the air-entraining admixture shall be added to the control concrete and, if necessary, to the test concrete mixtures in sufficient amounts to produce air contents of 6 ± 1.5 % when measured according to Test Method C 231. The difference between the air content of the control concrete mixture and that of the test concrete mixture shall not exceed 0.5 percentage point. Tests for freezing and thawing are required.

13. Mixing

13.1 Machine mix the concrete as prescribed in Practice C 192/C 192M.

NOTE 5—Tests in Sections 14-18 are based on arbitrary stipulations, which make possible highly standardized testing in the laboratory, and are not intended to simulate actual job conditions.

14. Test and Properties of Freshly Mixed Concrete

14.1 Samples of freshly mixed concrete from at least three separate batches for each control and test concrete mixture shall be tested according to 14.2-14.6.

14.2 *Slump*—Test Method C 143/C 143M.

14.3 *Density*—Test Method C 138/C 138M

14.4 *Air Content*—Test Method C 231.

14.5 *Temperature of Freshly Mixed Concrete*—Test Method C 1064/C 1064M.

14.6 *Time of Initial Setting*—Test Method C 403/C 403M with the following exceptions:

14.6.1 *Control Concrete:* Condition concrete ingredients at 68 to 77 °F [20 to 25 °C] prior to mixing. Mix the concrete, prepare test specimens, and measure penetration resistance at this temperature. Make the initial penetration measurement 3 to 4 h after initial contact of the cement with the water.

14.6.2 *Test Concrete:* Measurements are made in a low-temperature environment. Unless otherwise specified, make the initial penetration measurement 3 to 5 h after initial contact of the cement with the water. Prepare three specimens: one for measuring setting time at low temperature; a dummy specimen for measuring temperature history; and a replicate specimen for verifying that freezing did not occur. Place the specimens into the low-temperature environment within 40 min after the start of mixing so that, within 8 h, the temperature at the center of the specimen is at 23.0 ± 2.0 °F [-5.0 ± 1 °C] (See Note 6). Record the initial temperature of the dummy specimen, its temperature history every ½ h while in the low-temperature environment, and the time required to cool it from its initial temperature to the required temperature range.

NOTE 6—It may be desirable to use a series of baths, each at a different temperature, for cooling specimens to target temperature within the specified period.

14.6.2.1 To make certain that the test specimen did not freeze during the test, a replicate specimen (See Table 2) shall be removed from the low-temperature room and placed at 68 to 77 °F [20 to 25 °C] at the time the test specimen reaches initial setting. Penetration readings shall be made on the replicate specimen every 15 min for 2 h. If the penetration resistance continues to increase, the test specimen is considered not to have frozen. Conversely, if a decrease in penetration resistance is observed during the 2 h period, the test specimen is considered to have frozen and the admixture system fails to meet this specification. The results of this testing of the replicate specimen, including the thermal history of the dummy specimen recorded every ½ h, shall be included in the final report.

14.6.3 Calculate the average time of initial setting from the results of each batch of concrete. Calculate relative initial setting time by dividing the average time of initial setting of the test concrete by the average time of initial setting of the control concrete and multiplying by 100.

14.7 *Water-Cementitious Materials Ratio and Water Content*:

14.7.1 Determine the water-cementitious materials ratio of concrete as follows: Determine the amount of total water in the batch as the mass of water added to the batch, water occurring as free moisture on the aggregates, and water introduced by the admixtures. Determine the water-cementitious materials ratio as the mass of the total water divided by the mass of the cementitious materials. Calculate the volume of concrete from the total batch quantities and density in accordance with Test Method C 138/C 138M. Determine the water content as the

TABLE 2 Minimum Number of Specimens for each test.

Test	Tests Ages	Test Specimens		Dummy Specimens		Batches per test age		Total Specimens	
		Control	Test	Control	Test	Control	Test	Control	Test
Setting	[A]	1	2	–	1[B]	3	3	3	9[C]
Compressive Strength	3	2	2		1	3	3	18	19
Freezing and Thawing	1	3	3	–	–	3	3	9	9
Length Change	1	3	3	–	–	3	3	9	9

[A] See 14.6.
[B] For measurement of the thermal history of each batch of test concrete.
[C] Includes one replicate specimen per batch of test concrete.

mass of total water divided by the volume of the concrete batch. Determine the cementitious materials content as mass of cementitious materials divided by the volume of the concrete batch.

14.7.2 Calculate the relative water content of the test concrete as follows: Divide the average water content of all batches of test concrete by the average water content of all batches of the control concrete and multiply the quotient by 100.

15. Preparation of Test Specimens

15.1 Make sufficient number of specimens representing each test from at least three separate batches. The minimum numbers of specimens are shown in Table 2 (See Note 7). It is permitted to complete specimen fabrication in one, two, or three days of mixing provided control concrete specimens are made each day.

NOTE 7—It is recommended that more than the minimum number of specimens be prepared so that replacements are available in case some specimens are faulty.

15.2 *Manifestly Faulty Specimens*—Visually examine each test specimen before testing and discard any specimen found to be manifestly faulty. Visually examine each test specimen after testing and discard any test result associated with a specimen found to be manifestly faulty. If there are not enough replacement specimens to provide at least two valid results for each test, the entire test shall be disregarded and repeated. The test report shall be the average of the individual test results of the specimens tested or, in the event that one specimen or one result has been discarded, it shall be the average of the remaining test specimens.

16. Test Specimens for Hardened Concrete

16.1 *Number of Specimens*—The minimum number of specimens and the number of test ages are shown in Table 2.

16.2 *Types of Specimens*—Specimens made from control concrete and test concrete shall be prepared in accordance with the following:

16.2.1 *Compressive Strength*—Make specimens in accordance with Practice C 192/C 192M. Specimen size shall be 4- by 8-in. (100- by 200-mm) cylinders to facilitate adequate cooling rates using readily available cooling equipment. All specimens shall be cured in a sealed condition.

NOTE 8—Typically, plastic cylindrical molds are sealed with plastic caps. Alternately, a plastic bag may be placed over the top of a mold and held snugly to the side of the mold with a rubber band.

16.2.1.1 *Control Concrete:* Specimens shall be stored in a 73.5 ± 3.5 °F [23 ± 2 °C] environment within 40 min of initial contact of cement and water until time of testing.

16.2.1.2 *Test Concrete:* Specimens shall be stored in the low-temperature curing environment within 40 min of initial contact of cement and water so that within 8 h after being placed in the low-temperature curing environment the center of mass shall be at 23.0 ± 2.0 °F [-5.0 ± 1 °C]. Use the dummy specimen to record the maximum initial starting temperature of one batch of test specimens, their temperature history while in the low-temperature environment, and the time required to cool the test specimens to the required temperature range. Test concrete specimens shall be stored in a sealed condition so that their internal temperatures are maintained at 23 ± 2 °F (-5 ± 1 °C) until an age of 7 days from initial contact of cement and water. After 7 days, cure the test concrete in accordance with Practice C 192/C 192M until the 28-day test. After 28 days, cure the remaining test specimens at not less than 95 % relative humidity until time of test. The thermal history of the dummy specimen shall be included in the test report.

16.2.2 *Resistance to Freezing and Thawing*—Concrete specimens shall be prisms made in accordance with Practice C 192/C 192M, and having dimensions in accordance with Test Method C 666/C 666M. Make one set of three specimens from each batch of the control concrete and one set of three specimens from each batch of the test concrete. The air content of each mixture shall be as specified in 12.4 and 12.5. The control and test concrete specimens shall be cured in accordance with Practice C 192/C 192M. Test the specimens in accordance with Test Method C 666/C 666M, Procedure A, unless specified otherwise.

16.2.3 *Length Change*—Concrete specimens shall be made in accordance with Test Method C 157/C 157M, except for the following curing conditions. Make one set of three specimens from each batch of the control concrete and one set of three specimens from each batch of the test concrete. Remove the molds at 24 h and store all specimens in lime-saturated water at 73.5 ± 2.0 °F (23.0 ± 1.0 °C) until age of 28 days. At 28 days, remove all specimens from water bath and store in accordance with the air storage procedure in Test Method C 157/C 157M for an additional 28 days.

17. Tests on Hardened Concrete

17.1 *Compressive Strength*—Test in accordance with Test Method C 39/C 39M at 7, 28 and 90 days. For the 7-day tests, the test concrete specimens shall be moved from the low-temperature environment to a 73.5 ± 3.5 °F [23 ± 2 °C] environment for no less than 2 h and no more than 4 h before testing (See Note 9). The test concrete specimens shall be spaced at least 2 in. [50 mm] apart during this warming period. Record the temperature history of the dummy specimen from the time of removal from the low-temperature environment until testing. Compute the average compressive strength from the separate batches of test concrete and control concrete. Divide the average strength of the test concrete by the average strength of the control concrete at each test age and multiply by 100 to obtain relative strength. Report the results to the nearest 1 %.

NOTE 9—The intent is to have the center of the test concrete specimens at 40 to 45 °F [4 and 7 °C] at the time of testing to avoid possible influence of ice crystals inside the specimens.

17.1.1 *Resistance to Freezing and Thawing*—Comparison of the test concrete with the control concrete shall be made in accordance with Test Method C 666/C 666M, Procedure A, unless specified otherwise. Calculate the relative durability factor in accordance with Specification C 260, where DF is the durability factor of the control concrete.

17.1.2 *Length Change*—Measure the initial length at 28 days within 5 min of removing the specimen from curing water. After 28 days of air drying, determine the length in

accordance with Test Method C 157/C 157M. The drying shrinkage is the length change during the 28-day drying period, based on the initial length at the time of removal of the specimen from the curing water, expressed as a percentage of the initial length to the nearest 0.001 %. Calculate the relative shrinkage by dividing the average shrinkage of the test concrete by the average shrinkage of the control concrete and multiplying by 100. If the shrinkage of the control concrete after 28 days is 0.030 % or greater, the relative shrinkage of the test concrete shall not exceed 135 %. If the shrinkage of the control concrete at 28 days is less than 0.030 %, the test concrete shrinkage shall be not more than 0.010 percentage points greater than the control concrete.

NOTE 10—Since the specific effects produced by a cold-weather admixture system may vary with the properties of other ingredients of the concrete, results of length change tests using aggregates of such a nature that the shrinkage on drying is low may not accurately indicate relative performance to be expected with other aggregates having properties such as to produce concrete of high shrinkage on drying.

18. Uniformity and Equivalence Tests

18.1 Perform the infrared analysis and relative density (specific gravity) procedures in accordance with Specification C 494/C 494M Section on Uniformity and Equivalence Tests.

19. Report

19.1 Report the following:

19.1.1 Results of tests specified in Section 14 and Sections 16-18 and the relevant specification requirements, with which they are compared,

19.1.2 Brand name, manufacturer's name, lot number, and the quantity represented by the sample of cold-weather admixture system under test,

19.1.3 Brand name, manufacturer's name and specification conformance for air entraining admixture and any other admixtures used,

19.1.4 Brand name, manufacturer's name, type, and specification conformance for cementitious materials used,

19.1.5 Producer's name, description, and specification conformance for fine and coarse aggregates,

19.1.6 Data on concrete mixtures used, including amounts and dosages of admixtures, cementitious materials content, water-cementitious materials ratios, water content, ratio of fine to coarse aggregates, slumps, total air contents, initial setting times, and temperature history of the dummy specimens stored at low-temperature conditions.

19.1.7 In the event that some of the tests have been waived, the circumstances under which such action was taken shall be stated.

20. Keywords

20.1 Chemical admixture; cold-weather admixture; concrete; performance requirements