ACI 305.1-06

Specification for Hot Weather Concreting

An ACI Standard

Reported by ACI Committee 305

American Concrete Institute®

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Specification for Hot Weather Concreting

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Specification for Hot Weather Concreting

An ACI Standard

Reported by ACI Committee 305

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This specification provides requirements for hot weather concreting that the Architect/ Engineer can make applicable to any construction project by citing it in project specifications.

It is intended that the Architect/Engineer use the checklists included in this specification to customize the project specification.

The document includes hot weather requirements for production preparations, delivery, placement, finishing, bleed-water evaporation, curing, and protection of concrete. Provisions governing a preplacement conference, concrete mixture proportions, maximum allowable concrete temperature, measurement of the rate of surface evaporation, evaporation control measures, and acceptance of a concrete mixture from past field experience or preconstruction testing are included.

Keywords: bleeding; concrete, curing; finishing; hot weather concreting; mixture proportioning; plastic shrinkage cracking; protection period; trial batch.

NOTE TO SPECIFIER

This specification is incorporated by reference in the Project Specification using the wording in P3 of the Preface and including information from the Optional Requirements and Submittals checklists following the Specification.

PREFACE

P1. ACI Specification 305.1 is intended to be used by reference or incorporation in its entirety in the Project Specification. Do not copy individual Parts, Sections, Articles, or Paragraphs into the Project Specification, because taking them out of context may change their meaning.

P2. If Sections or Parts of ACI Specification 305.1 are copied into the Project Specification or any other document, do not refer to them as an ACI Specification, because the specification has been altered.

P3. A statement such as the following will serve to make ACI Specification 305.1 a part of the Project Specification:

> Work on (Project Title) shall conform to all requirements of ACI 305.1-06, Specification for Hot Weather Concreting, published by the American Concrete Institute, Farmington Hills, Michigan, except as modified by these Contract Documents.

P4. Each technical Section of ACI Specification 305.1 is written in the three-part Section format of the Construction Specifications Institute, as adapted for ACI requirements. The language is imperative and terse.

P5. The Specification is written to the Contractor. When a provision of this Specification requires action by the Contractor, the verb "shall" is used. If the Contractor is allowed to exercise an option when limited alternatives are available, the phrasing "either...or..." is used. Statements provided in the Specification as information to the Contractor use the verbs "may" or "will." Informational statements typically identify activities or options that "will be taken" or "may be taken" by the Owner or Architect/Engineer.

ACI 305.1-06 was adopted November 7, 2006 and published March 2007.

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SECTION 1—GENERAL

1.1—Scope

This Specification covers requirements for hot weather concrete construction. Provisions of this Specification shall govern, except where other provisions are specified in Contract Documents. This Specification shall not be used in conjunction with ACI 301 or ACI 530.1.

1.2—Referenced standards

1.2.1 Standards of ACI and ASTM referred to in this Specification are listed with serial designation, including year of adoption or revision, and are part of this Specification.

1.2.2 *ACI Standards*

308.1-98	Standard Specification for Curing Concrete

1.2.3 *ASTM Standards*

C 31/C31 M-03a	Practice for Making and Curing Concrete Test Specimens in the Field
C 39/C 39M-05	Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 78-02	Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C 94/C 94M-05	Specification for Ready-Mixed Concrete
C 138/C 138M-01a	Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C 143/C 143M-05a	Test Method for Slump of Hydraulic-Cement Concrete
C 171-03	Specification for Sheet Materials for Curing Concrete
C 173/C 173M- 01$^{\varepsilon 1}$	Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 192/C 192M-05	Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 231-04	Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 293-02	Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)
C 1064/C 1064M-05	Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

1.2.4 Abbreviations for and complete names and addresses of organizations issuing documents referred to in this Specification are listed:

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West Conshohocken, PA 19428-2959
Phone: (610) 832-9500
Fax: (610) 832-9555
website: www.astm.org

1.3—Definitions

day—a period of 24 consecutive hours.

evaporation retardant—a material that generates a continuous thin film when spread over water on the surface of fresh concrete and thus retards the evaporation of bleed water.

hot weather—job-site conditions that accelerate the rate of moisture loss or rate of cement hydration of freshly mixed concrete, including an ambient temperature of 27 °C (80 °F) or higher, and an evaporation rate that exceeds 1 kg/m^2/h, or as revised by the Architect/Engineer.

hot weather concreting—operations concerning the preparation, production, delivery, placement, finishing, protection, and curing of concrete during hot weather.

moist—slightly damp but not quite dry to the touch; "wet" implies visible free water, "damp" implies less wetness than "wet," and "moist" implies not quite dry.

protection period—the required time during which the concrete is protected against thermal cracking due to rapid temperature drops.

temperature of fresh concrete—the temperature measured during the discharge and placement in accordance with ASTM C 1064/C 1064M.

temperature of hardened concrete—the temperature measured at the concrete surface.

units—values stated in either U.S. Customary or SI units shall be regarded separately as standard. Values stated in each system might not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

1.4—Submittal of procedures

1.4.1 Before hot weather concreting and the preplacement conference, submit to Architect/Engineer for review and comment detailed procedures, including production, placement, finishing, curing and protection of concrete during hot weather concreting.

1.5—Preplacement conference

1.5.1 At least 15 days before the start of the concrete construction schedule, hold a preplacement conference for the purpose of reviewing hot weather concreting requirements and mix designs.

1.5.2 Send a preplacement conference agenda on hot weather operations and procedures to representatives of concerned parties not less than 10 days before the scheduled date of the conference.

1.5.3 Preplacement conference shall include, but is not limited to, representation of Contractor, Concrete Subcontractor, Testing Agency, Pumping Contractor, and Ready-Mixed Concrete Producer.

1.5.4 Distribute the minutes of the preplacement conference to representatives of concerned parties within 5 days after the preplacement conference.

1.6—Documents required on site

1.6.1 Copies of ACI 305R, ACI 305.1, and ACI 308.1 must be available at the project site during concrete construction.

SECTION 2—PRODUCTS

2.1—General

2.1.1 Store all materials and equipment required for curing and protection at or near the project site before hot weather concreting commences.

2.1.2 *Initial site curing of strength test specimens for acceptance*—Provide facilities that ensure compliance with the initial curing requirements of ASTM C 31/C 31M.

2.2—Concrete mixture proportions

2.2.1 Submit concrete mixture proportions to Architect/Engineer for review. Include specific materials, manufacturer, and type for hot weather concreting.

SECTION 3—EXECUTION

3.1—General

3.1.1 Do not place concrete against surfaces of absorbent materials that are dry. Do not place concrete against surfaces that have free water.

3.1.2 Prepare all materials required for accepted evaporation control measures and have them available on site so that specified measures can be executed as necessary.

3.1.3 Initiate accepted evaporation control measures when concrete and air temperatures, relative humidity of the air, and the wind velocity have the capacity to evaporate water from a free water surface at a rate that is equal to or greater than 1.0 kg/m^2/h (0.2 lb/ft^2/h), unless otherwise specified. Determine the evaporation rate of surface moisture by use of the Menzel Formula:

$$W = 0.315(e_o - e_a)(0.253 + 0.060V) \text{ [SI units]}$$

$$W = 0.44(e_o - e_a)(0.253 + 0.096V) \text{ [U.S. Customary units]}$$

where

W = mass of water evaporated in kg (lb) per m^2 (ft^2) of water-covered surface per hour;

e_o = saturation water vapor pressure in kPa (psi) in the air immediately over the evaporating surface, at the temperature of the evaporating surface. Obtain this value from Table 3.1(a) or (b). The temperature of the evaporating surface shall be taken as the concrete temperature;

e_a = water vapor pressure in kPa (psi) in the air surrounding the concrete. Multiply the saturation vapor pressure at the temperature of the air surrounding the concrete by the relative humidity of the air. Air temperature and relative humidity are to be measured at a level approximately 1.2 to 1.8 m (4 to 6 ft) above the evaporating surface on the windward side and shielded from the sun's rays; and

V = average wind speed in km/h (mph), measured at 0.5 m (20 in.) above the evaporating surface.

3.1.3.1 Monitor site conditions (air temperature, humidity, wind speed) to assess the need for evaporation control measures beginning no later than 1 hour before the start of concrete placing operations. Continue to monitor site conditions at intervals of 30 minutes or less until specified curing procedures have been applied.

3.1.3.2 For measuring the rate of evaporation of surface moisture, use equipment or instruments that are certified by the manufacturer as accurate to within 1 °C (2 °F), 5% relative humidity, and 1.6 km/h (1 mph) wind speed. Use equipment in accordance with the product manufacturer recommendations.

3.2—Maximum allowable concrete temperature

3.2.1 Limit the maximum allowable fresh concrete temperature to 35 °C (95 °F), unless otherwise specified, or unless a higher allowable temperature is accepted by Architect/Engineer, based upon past field experience or preconstruction testing using a concrete mixture similar to one known to have been successfully used at a higher concrete temperature.

Table 3.1(a)—Saturation water vapor pressure (kPa) over water (SI units)

Air and concrete temperature, °C	Saturation pressure, kPa	Air and concrete temperature, °C	Saturation pressure, kPa
4	0.813	28	3.78
5	0.872	29	4.01
6	0.934	30	4.24
7	1.00	31	4.49
8	1.07	32	4.75
9	1.15	33	5.03
10	1.23	34	5.32
11	1.31	35	5.62
12	1.40	36	5.94
13	1.50	37	6.28
14	1.60	38	6.63
15	1.70	39	6.99
16	1.82	40	7.38
17	1.94	41	7.78
18	2.06	42	8.20
19	2.20	43	8.64
20	2.34	44	9.10
21	2.49	45	9.58
22	2.64	46	10.1
23	2.81	47	10.6
24	2.98	48	11.2
25	3.17	49	11.7
26	3.36	50	12.3
27	3.56		

Data source: *CRC Handbook of Chemistry and Physics*, 68th Edition, 1987, mathematically converted into kPa.

Table 3.1(b)—Saturation water vapor pressure (psi) over water (U.S. Customary units)

Air and concrete temperature, °F	Saturation pressure, psi	Air and concrete temperature, °F	Saturation pressure, psi
40	0.121	81	0.523
41	0.127	82	0.542
42	0.132	83	0.559
43	0.137	84	0.577
44	0.143	85	0.595
45	0.147	86	0.615
46	0.153	87	0.637
47	0.159	88	0.658
48	0.166	89	0.679
49	0.171	90	0.698
50	0.178	91	0.722
51	0.185	92	0.746
52	0.192	93	0.769
53	0.199	94	0.789
54	0.206	95	0.816
55	0.214	96	0.843
56	0.222	97	0.870
57	0.231	98	0.896
58	0.238	99	0.920
59	0.247	100	0.951
60	0.257	101	0.981
61	0.267	102	1.01
62	0.277	103	1.04
63	0.285	104	1.07
64	0.296	105	1.10
65	0.308	106	1.13
66	0.319	107	1.17
67	0.327	108	1.20
68	0.339	109	1.24
69	0.352	110	1.27
70	0.366	111	1.31
71	0.378	112	1.35
72	0.388	113	1.39
73	0.403	114	1.43
74	0.418	115	1.47
75	0.433	116	1.52
76	0.443	117	1.56
77	0.459	118	1.60
78	0.476	119	1.65
79	0.494	120	1.70
80	0.510		

Data source: *CRC Handbook of Chemistry and Physics*, 68th Edition, 1987, mathematically converted into °F and psi.

3.2.2 Measure the fresh concrete temperature at the point and time of discharge in accordance with ASTM C 1064/C 1064M. Frequency of temperature determination shall be in accordance with ASTM C 94/C 94M and at the option of the inspector.

3.3—Qualification of concrete mixture proportions

3.3.1 Approval of concrete mixture and proposed maximum allowable fresh concrete temperature, supported by past field experience of Section 3.2.1, shall be based, on similar climate and production conditions, materials, mixture proportions and temperatures, placing and finishing methods, and concrete delivery time.

3.3.2 Approval of concrete mixture and proposed maximum allowable fresh concrete temperature, supported by preconstruction testing of Section 3.2.1, shall require materials similar to those proposed for use in the project.

3.3.3 *Laboratory trial batch*—Batch the laboratory concrete trial mixture within 2 °C (3 °F) of the proposed maximum allowable concrete temperature and mix in accordance with ASTM C 192/C 192M, except as modified herein. If necessary, move the laboratory mixer into an enclosed, heated and ventilated space, or use heated mixing water, or both, to achieve and maintain the proposed maximum allowable concrete temperature. For drum-type mixers, the concrete mixture shall remain in the mixer for 47 minutes after completion of the 3-minute initial mixing period unless specified otherwise. During the 50-minute period, cover the mixer opening with a non-absorbent material, such as plastic, to prevent moisture loss, and rotate the mixer continuously at an agitation speed of 6 to 8 rpm. For laboratory mixers without speed adjustments, simulate agitation by rotating the mixer continuously at a drum angle between 45 and 75 degrees from horizontal. At the end of 50 minutes, mix the concrete mixture at full mixing speed designated by the manufacturer (8 to 20 rpm) for 2 minutes.

For pan-type mixers, the concrete mixture shall remain in the mixer for 41 minutes after completion of the initial 3-minute mixing period. During the 44-minute period, the mixer shall cycle through periods of rest for 5 minutes, and then mixing for 1 minute. During the rest period, cover the mixer opening with a non-absorbent material, such as plastic, to prevent moisture loss. At the end of 44 minutes, mix the concrete mixture at full mixing speed designated by the manufacturer (8 to 20 rpm) for 2 minutes.

During mixing and agitation periods for both drum-type and pan-type mixers, the addition of water, chemical admixture, or both, to adjust slump is permitted provided that the specified concrete mixture *w/cm* is not exceeded. As needed, check and adjust the slump of the concrete mixture during the middle 1/3 of the 50- or 44-minute laboratory trial mixing period.

3.3.3.1 The proposed concrete mixture shall meet the specified slump range at the end of the laboratory mixing period and meet the required strength at the specified test age.

3.3.4 *Field trial batch*—Batch the field concrete trial mixture within 2 °C (3 °F) of the proposed maximum allowable concrete temperature in a truck-mixer with a minimum batch size of 3 m^3 (4 yd^3). If necessary, move the truck mixer into an enclosed, heated, and ventilated space to achieve a concrete temperature within the specified tolerance of the proposed maximum allowable concrete temperature.

The concrete mixture shall be held in the mixer for 90 minutes, unless otherwise specified by the Architect/Engineer. During the entire 90-minute period, agitate the mixer at 1 to 6 rpm. At the end of 90 minutes, mix the concrete mixture at full mixing speed designated by the manufacturer (6 to 18 rpm) for 2 minutes. During mixing and agitation periods, the addition of water, chemical admixture, or both, to adjust slump is permitted provided that the specified concrete mixture *w/cm* is not exceeded. As needed, check and adjust the slump of the concrete mixture during the middle 1/3 of the 90-minute mixing period.

3.3.4.1 The proposed concrete mixture shall be within the specified slump range at the end of the 90-minute field mixing period and meet the required strength at the specified test age.

3.3.5 Test values obtained in accordance with the appropriate ASTM Standard shall include compressive strength (C 192/C 192M or C 31/C 31M, and C 39/C 39M), flexural strength (C 192/C 192M and either C 78 or C 293; C 31/C 31M and either C 78 or C 293), or both; slump (C 143/C 143M); air content (C 231, C 173/C 173M, or C 138/C 138M); concrete density (unit weight) (C 138/ C 138M); and concrete temperature (C 1064/C 1064M). Slump, air content, and concrete and air temperature measurements shall be performed after initial mixing, intermediately as needed or as desired, and at the conclusion of the mixing period along with the other specified tests.

3.3.6 *Acceptance of concrete mixture proportions*—Submit to the Architect/Engineer for acceptance a request for a specific higher maximum allowable concrete temperature. Include the constituent materials and proportions of the proposed concrete mixture and all values obtained from past field experience or preconstruction testing. Test results shall be within the Project Specification ranges and tolerances.

3.4—Concrete production and delivery

3.4.1 Concrete shall be produced at a temperature such that its maximum temperature at discharge will not exceed the specified maximum allowable concrete temperature. Acceptable production methods to reduce the temperature of the concrete include: shading aggregate stockpiles, sprinkling water on coarse aggregate stockpiles; using chilled water for concrete production; substituting chipped or shaved iced for portions of the mixing water; and cooling concrete materials using liquid nitrogen. The submittals for hot weather concreting shall indicate which methods will be used and in what order they will be initiated when multiple methods are to be used. The substitution of other cooling methods will be considered by the Architect/Engineer when requested in the submittal and accompanied by satisfactory supporting data.

3.4.2 Unless otherwise specified, deliver concrete in accordance with ASTM C 94/C 94M, which requires the concrete to be discharged within 1-1/2 hours or before the truck-mixer drum has revolved 300 revolutions, whichever comes first.

3.5—Concrete placement and finishing

3.5.1 Concrete placement and finishing operations shall proceed as quickly as conditions will permit.

3.6—Concrete bleed-water evaporation

3.6.1 Control concrete surface bleed-water evaporation with application of evaporation reducers, plastic sheeting, fog spray, or wind breaks. Use these materials and methods in accordance with ACI 308.1.

3.7—Concrete curing

3.7.1 *Concrete curing*—Cure concrete in accordance with ACI 308.1.

3.8—Concrete protection

3.8.1 *Protection period*—Protect the concrete against thermal shrinkage cracking due to rapid drops in concrete temperature greater than 22 °C (40 °F) during the first 24 hours unless otherwise specified.

3.8.2 *Protection materials*—Acceptable protection materials to prevent excessive temperature drops are insulating blankets, batt insulation with moisture-proof covering, layers of dry porous material such as straw, hay, or multiple layers of impervious paper meeting ASTM C 171. These protection materials shall not be applied until the concrete surface temperature has become steady or is beginning to decline.

FOREWORD TO CHECKLISTS

F1. This Foreword is included for explanatory purposes only; it does not form a part of Specification ACI 305.1.

F2. ACI Specification 305.1 may be referenced by the Specifier in the Project Specification for any building project, together with supplementary requirements for the specific project. Responsibilities for project participants must be defined in the Project Specification. The ACI Specification cannot and does not address responsibilities for any project participant other than the Contractor.

F3. Checklists do not form a part of ACI Specification 305.1. Checklists assist the Specifier in selecting and specifying project requirements in the Project Specification.

F4. The Specifier shall make adjustments to the needs of a particular project by reviewing each of the items in the checklists and including the items the Specifier selects as mandatory requirements in the Project Specification.

F5. The Optional Requirements Checklist identifies Specifier choices and alternatives. The checklists identify the Sections, Parts, and Articles of the reference specification and the action required or available to the Specifier.

F6. The Submittals Checklist identifies Specifier choices for information or data to be provided by the Contractor before, during, or after construction.

F7. *Recommended references*—Documents and publications that are referenced in the Checklists of ACI Specification 305.1 are listed. These references provide guidance to the Specifier and are not considered to be part of ACI Specification 305.1.

American Concrete Institute

305R	Hot Weather Concreting
308R	Guide to Curing Concrete

OPTIONAL REQUIREMENTS CHECKLIST

Section/Part/Article	Notes to Architect/Engineer
1.2	Review applicability of cited references and make exceptions if required.
3.1.3	The 1.0 kg/m^2/h (0.2 lb/ft^2/h) default value may be revised by the Architect/Engineer. Concrete mixtures containing conventional or ultra-fine pozzolan or other cementitious materials may require lower allowable evaporation rates. Further guidance is available in Sections 2.1.4 through 2.1.6 of ACI 305R.
3.2.1	A change in the maximum allowable concrete temperature may be appropriate. A maximum concrete temperature at the time of discharge is often used in an effort to control strength, durability, plastic shrinkage cracking, thermal cracking, and drying shrinkage. Generally, if concrete strengths are satisfactory and curing practices are sufficient to avoid undesirable drying of surfaces, durability of hot weather concrete will not differ significantly from similar concrete placed at normal temperatures. A higher allowable maximum concrete temperature may be specified by the Architect/Engineer based on previous field experience, similar conditions, and concrete materials.
3.3.3	ACI 305R presents two additional trial batch procedures available for laboratory use. These procedures (A and B of 305R, Section 2.9.4) produce slump loss similar to that expected for 30- to 40-minute delivery times. The laboratory trial batch procedure in Section 3.3.3 is based on delivery time plus holding times approaching 1-1/2 hours. Specify a shorter duration laboratory batch trial if applicable.
3.3.4	The default time of 90 minutes corresponds with the normal default time provided in ASTM C 94/C 94M. If a different maximum field mixing time is to be permitted or required, the field trial batch time should be altered to match the specification.
3.4.2	In hot weather, a time of less than 1-1/2 hours, such as 1 hour, may be specified. The limitations of ASTM C 94/C 94M, Paragraph 11.7, are permitted to be waived by the purchaser if the concrete is of such slump that it can be placed without the addition of water. With extended set control admixtures, concrete slump can be maintained without the addition of water for up to 10 hours with no detrimental effect to the concrete in place.
3.8.1	Rapid temperature drops of the concrete can lead to thermal cracking. Concrete exposed to rapid cooling has a lower tensile strain capacity and is more susceptible to cracking than concrete cooled slowly.

SUBMITTALS CHECKLIST

NOTE: The items listed will be submitted by the Contractor and reviewed by the Architect/Engineer.

Notify the Contractor of acceptance or rejection after review of submittals. All submittals and responses should be retained in files for future reference during the Work. Some submittal requirements shown will apply only when optional requirements are selected and written into the Project Specifications. Once optional requirements have been selected, review the Section/Part/Article indicated for the submittal item to see if it applies.

Section/Part/Article	Submittal items and notes to Architect/Engineer
2.2.1 3.4.1	The submittal shall include concrete mixture adjustment parameters and methods to be implemented during changes in weather conditions. These may include partial cement substitution with fly ash, pozzolans, or ground-granulated blast-furnace slag; use of chemical admixtures, ice or chilled water, or liquid nitrogen; or cooling of aggregates.
3.3.6	These submittals are a result of the preconstruction testing to verify a proposed concrete mixture will function satisfactorily at a concrete temperature greater than 35 °C (95 °F). Full-size field batches are preferred over laboratory batches. Submittals should include all test results.
3.6.1	Submit for approval the desired method to be used when concreting during periods with evaporation rates higher than permitted.

APPENDIX A—THE MENZEL FORMULA AND ESTIMATED SURFACE EVAPORATION RATES

The modified NRMCA Nomograph for Estimated Surface Evaporation Rates is intended as a graphical guide to determine an approximate solution of the Menzel Formula described in Section 3.1.3. The nomograph and this appendix are not a part of ACI Specification 305.1. They are intended only to assist in field estimations of surface evaporation rates and do not replace the Menzel Formula for meeting the requirements of Section 3.1.3.

EXAMPLE OF MENZEL FORMULA (SI UNITS)

Air temperature	40 °C
Relative humidity	45%
Concrete temperature	35 °C
Wind speed V	16 km/h

From Table 3.1(a) for saturation pressure:
Concrete temperature of 35 °C: $e_o = 5.623$ kPa
Saturated water vapor pressure of air at 40 °C = 7.374 kPa
$e_a = 7.374 \times 0.45 = 3.3$ kPa (*limited to two significant figures by relative humidity value*)

Calculations: $W = 0.315(e_o - e_a)(0.253 + 0.060V)$

$W = 0.315(5.623 - (7.374 \times 0.45))(0.253 + (0.060 \times 16))$
(*precision on wind speed is two significant figures*)
(*precision on subtraction of vapor pressures limited to two significant figures*)

$W = 0.315(5.623 - 3.318)(0.253 + 0.96)$
(*precision on addition of 0.253 + 0.96 limited to two decimal places*)

$W = 0.315(2.3)(1.21)$
(*precision limited to two significant figures by 2.3*)

$W = 0.88$ kg/m^2/h

In this example, 0.88 kg/m^2/h is less than the specified evaporation rate of free surface water of 1.0 kg/m^2/h, as listed in Section 3.1.3. This example would indicate that, although the evaporation rate is approaching the specified limit, measures to reduce the evaporation rate would not be required by specification. For some mixtures, however, this evaporation rate could result in plastic shrinkage cracking, which is why the Architect/Engineer may select a lower specified value, for example 0.75 kg/m^2/h, in accordance with the Optional Requirements Checklist.

EXAMPLE OF MENZEL FORMULA (U.S. CUSTOMARY UNITS)

Air temperature	104 °F
Relative humidity	45%
Concrete temperature	95 °F
Wind speed V	10 mph

From Table 3.1(b) for saturation pressure:
Concrete temperature of 95 °F: $e_o = 0.816$ psi
Saturated water vapor pressure of air at 104 °F = 1.070 psi
$e_a = 1.070 \times 0.45 = 0.48$ psi (*limited to two significant figures by relative humidity value*)

Calculations: $W = 0.44(e_o - e_a)(0.253 + 0.096V)$

$W = 0.44(0.816 - (1.070 \times 0.45))(0.253 + (0.096 \times 10))$
(*precision on wind speed is two significant figures*)
(*precision on subtraction of vapor pressures limited to two decimal places*)

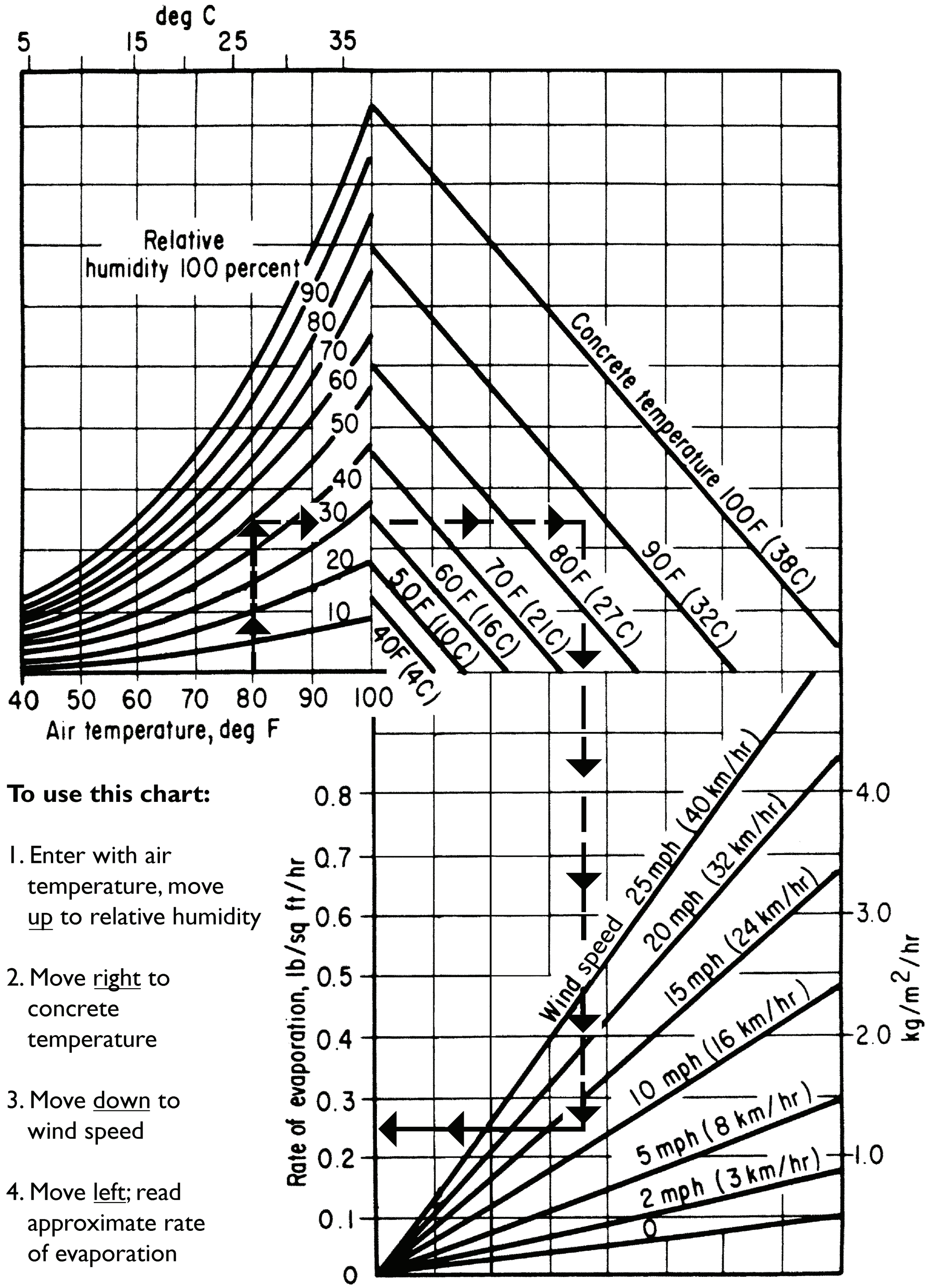
$W = 0.44(0.82 - 0.48)(0.253 + 0.96)$
(*precision on addition of 0.253 + 0.96 limited to two decimal places*)

$W = 0.44(0.34)(1.21)$
(*precision limited to two significant figures by 0.34 and by empirical constant 0.44*)

$W = 0.18$ lb/ft^2/h

In this example, 0.18 lb/ft^2/h is less than the value (0.2 lb/ft^2/h, specified in Section 3.1.3. This example would indicate that, although the evaporation rate is approaching the specified limit, measures to reduce the evaporation rate would not be required by specification. For some mixtures, however, this evaporation rate could result in plastic shrinkage cracking, which is why the Architect/Engineer may select a lower specified value, for example 0.15 lb/ft^2/h, in accordance with the Optional Requirements Checklist.

NRMCA NOMOGRAPH FOR ESTIMATING EVAPORATION RATE ON THE BASIS OF MENZEL FORMULA



*Effect of concrete and air temperatures, relative humidity, and wind speed on the rate of evaporation of surface moisture from concrete. This chart provides a graphic method of estimating the loss of surface moisture for various weather conditions. To use this chart, follow the four steps outlined above. If the rate of evaporation approaches 1 kg/m^2/h (0.2 lb/ft^2/h), precautions against plastic-shrinkage cracking are necessary (Lerch 1957). Wind speed is the average horizontal air or wind speed in km/h (mph) and should be measured at a level approximately 510 mm (20 in.) higher than the evaporating surface. Air temperature and relative humidity should be measured at a level approximately 1.2 to 1.8 m (4 to 6 ft) higher than the evaporating surface on its windward side shielded from the sun's rays (*PCA Journal *1957).*

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