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DENTON,H.R. Office of Nuclear Reactor Regulation, Director

SUBJECT: Forwards addl info re concrete curing requirements (FSAR,Section 3.8,App A),in response to Structural Engineering Branch 841001 request.

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Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
United States Nuclear Regulatory Commission
Washington, DC 20555

SHEARON HARRIS NUCLEAR POWER PLANT
UNIT NO. 1 - DOCKET NO. 50-400
CONCRETE CURING REQUIREMENTS

Dear Mr. Denton:

Carolina Power & Light Company hereby submits additional information concerning concrete curing requirements at the Shearon Harris Nuclear Power Plant. This attached information is submitted in response to NRC Structural Engineering Branch questions transmitted by letter dated October 1, 1984.

If you have further questions or require additional information, please contact me.

Yours very truly,

S. R. Zimmerman
S. R. Zimmerman
Manager
Nuclear Licensing Section

GAS/ccc (776GAS)

Attachment

cc: Mr. B. C. Buckley (NRC)
Mr. S. B. Kim (NRC-SEB)
Mr. G. F. Maxwell (NRC-SHNPP)
Mr. J. P. O'Reilly (NRC-RII)
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Dr. Richard D. Wilson
Mr. G. O. Bright (ASLB)
Dr. J. H. Carpenter (ASLB)
Mr. J. L. Kelley (ASLB)

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ENCLOSURE

Response to NRC Questions Concerning Concrete Curing (FSAR Section 3.8, Appendix A)

Question 1

The amendment states that there has been engineering data available to justify the alternative requirements for concrete curing. Please provide such data.

Response 1

Attached is the written justification to address the revision in curing requirements. The "engineering data" requested ("research" referenced in Amendment 11) is part of the attached justification.

Question 2

The amendment provides minimum temperature and moisture requirements for the first three days out of seven day curing. Provide the requirements for the fourth through seventh day. If there is no requirement during these days, provide justification.

Response 2

Implementation criteria Item 3 in the attached justification provides the requirements for minimum temperature and moisture for days 1 through 7.

(776GAS/ccc)

Exception to CC-4240 - Curing

Recommended Action:

Approve the field practice of allowing the cure period to be extended at least one full day for each day of deficient cure for all weather conditions, subject to the following provisions:

*Note: "Cure" refers to both moist cure and/or temperature protection.

1. The concrete temperature may not drop below 32°F during the initial 24 hours following placement. In-place strength tests will be conducted should this occur.

2. If the concrete temperature drops below 40°F during the first 3 days after placing, the field shall verify that the in-situ strength of the concrete exceeds 0.7 f'c before discontinuing curing operations.

Revision of the FSAR to include incorporation of the exception to ASME/ACI-359 with justification in order that a cure extension be allowed for each day of deficient cure.

*Curing requirements of specification CAR-SH-CH-6 will continue to be enforced in that moist cure and temperature protection above 50°F will still be applied. Inspection requirements on site, however, require that moisture and temperature be checked at the most unfavorable position. While virtually all placements have average temperatures of 50° and above, by checking in a particular unfavorable spot, it is often possible to find nonconforming conditions. The intent of the exception is to provide the field a corrective action for these spot deficient cure violations.

Justification:

1. Curing of containment concrete is governed by ASME/ACI-359, 1975 Winter Addenda, Subsection CC-4240. This document requires that containment concrete be maintained above 40°F in a moist condition for the first 7 days following placement. Present Ebasco specification CAR-SH-CH-6, Section II, requires that the concrete be maintained above 50°F for 7 days; this requirement is much in excess of the 40°F protection requirement which is considered adequate by the ACI Committee. Therefore, condition 2 in Recommended Action is justifiable as only temperatures below 40° are considered low enough to inhibit strength gain to an unacceptable degree. Condition 2 will ensure that ASME/ACI-359 curing and strength gain criteria are being complied with.

2. Condition 1 of Recommended Action will guarantee that the concrete shall not suffer irreparable damage caused by frost heave caused by frozen concrete. Concrete which has been placed for 24 hours will gain in excess of 500 psi during this period. Concrete experts have published literature which states that concrete which has reached a compressive strength of 500 psi will not be permanently damaged by subfreezing temperatures. Therefore, unless concrete is frozen within the first 24 hours after placement, no irreparable damage will occur. The curing process will be

slowed down due to low temperatures, but this can easily be regained with an extension of cure to ensure that the concrete has gained .7 f'c. Any concrete which has sustained freeze damage will be evaluated on site for conformance to design requirements.

3. ACI-306 lists minimum protection periods for durability. The intent of this chart in ACI-306 is not to infer that concrete which does not receive the minimum protection will lack adequate durability later on during the service life of the structure. Rather, this chart is intended to give minimum protection periods to supply immediate durability to the concrete by ensuring that the concrete reaches sufficient strength to resist freezing and thawing deterioration soon after placement.

   Durability is primarily aided by two factors: Air entrainment and low permeabilities.

   The higher the strength of concrete, the lower the W/C ratio is generally, and therefore the concrete has a lower permeability.

   Our site mixes have sufficiently low W/C ratios such that the durability is ensured because of the low permeabilities. These low W/C ratios also ensure a rapid strength development such that minimum immediate durability requirements are met to resist freeze-thaw provided the concrete reaches .7 f'c before cure is discontinued.

4. The dashed line portion of the attached curve indicates that probable anticipated worst temperature cure conditions for site concrete during cold weather conditions. These conditions would result when concrete is allowed to drop to 33°F within 6 hours of placement and is subsequently cured the first 7 days at 33°F. Between day 7 and day 14, the concrete temperature is maintained at 50°F (in order to rectify the initial 7 days of 33°F cure - one day of cure extension for each day of deficient cure). Beyond day 14 all protection would be removed and it is assumed the concrete temperature would return to ambient temperatures of 33°F for the duration of the initial 28 days. The dashed portion of the curve is superimposed using the 50°F and 33°F curves.

   Most recent statistical analysis of concrete mix design M-72 (used on the majority of site concrete operations - Class AA 5,000 psi design strength) indicates a mean value of 5,968 psi for a total of 219 28-day moist cure laboratory compressive cylinder tests. It is thus evident that at 28 days, only an 8% reduction in strength is realized due to worst probable site cure conditions as opposed to the ideal cure period of 50°F for the entirety of 28 days.

   In summary, while the difference in compressive strengths is large, early in the cure period for concrete cured at 33°F and 50°F, this difference becomes quite small as the concrete approaches an age of 28 days. Thus, the design strength of the concrete will ultimately be easily reached even assuming worst probable site cure conditions.

   In addition, a liberal overdesign of site mix M-72 (and other site concrete mixes) assures that design strength will be reached even under adverse cure conditions.

(776GAS/ccc)

Also attached is data taken from Concrete Technology by D. F. Orchard, Applied Science Publishers Ltd., London, Copyright 1979, pp. 234 and 235. This data indicates that concrete subjected to freezing temperatures as early as 6 hours after placement suffers negligible freeze damage.

Implementation Criteria:

1. The concrete temperature shall not be allowed to drop below 40°F during the initial 48 hours following placement.

2. If the concrete temperature drops below 50°F anytime during the first three (3) days after placing, the field shall verify that the in-situ strength of the concrete is not less than 0.7 f'c before discontinuing curing operations.

3. If the concrete temperature drops below 50°F or interruption in moist curing occurs anytime during the first seven (7) days after placing, the curing period shall be extended at least one full day for each day of deficient (temperature or moist) cure.

(776GAS/ccc)

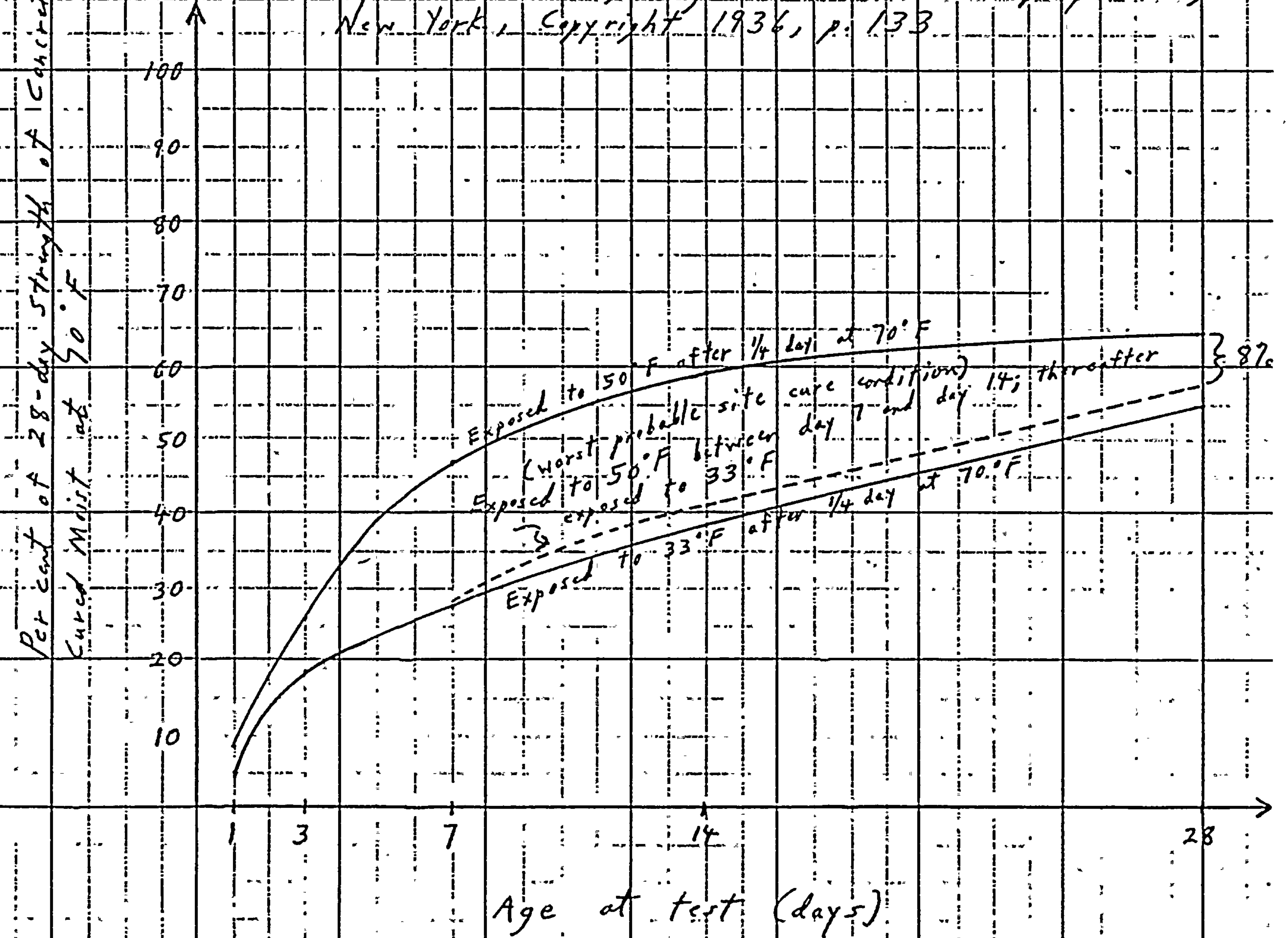
POWER PLANT CONSTRUCTION
COMPUTATION SHEET

SHEET___ OF___
DEPT.___

BY___ DATE___
CHKD. BY___ DATE___
SUBJECT___

FORM NO. 1630

Note: All portions of graph except dashed portion of curve were reproduced from: Plain Concrete, by Edward Bauer, Magraw Hill Book Company Inc., New York, Copyright 1936, p. 133



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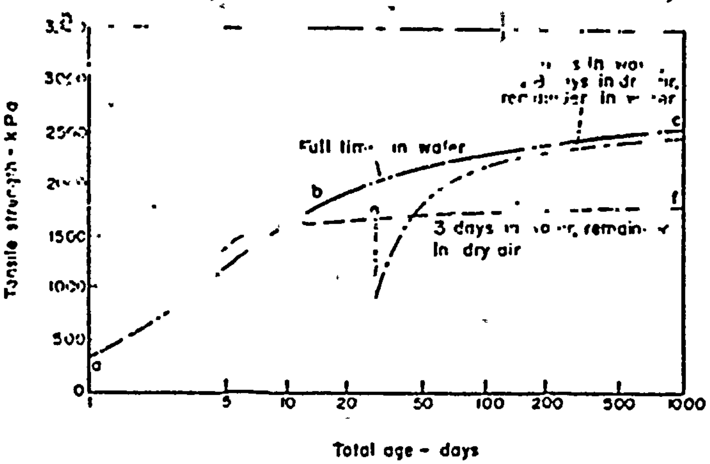

FIG. 6.3. Effect of allowing concrete to dry before it has fully cured.

but this point was not noted by Waters). The rise and fall in strength on drying and subsequent wetting can be repeated any number of times.

It is thus evident that, even if proper curing is not effected, exterior concrete should eventually reach the same strength as concrete which has been carefully cured, as periods of wet weather will give it the necessary moisture, but that if interior concrete is not carefully cured, there will be a loss in strength. Lack of proper curing at an early age may of course lead to serious shrinkage cracking, especially in thin slabs.

FREEZING OF FRESH CONCRETE

It was found by McNeese[12] that in the absence of entrained air, the loss of strength due to freezing depends on the mixing temperature and how soon the concrete is frozen after casting. If it is allowed to set for only 1 h before freezing, the loss of strength can be as much as 50 per cent but this appears to be about the maximum loss possible under any conditions. If it is placed at a temperature of 24 °C (75 °F) and is not subjected to severe freezing conditions within about 6 h, very little loss of strength results. If the temperature of the concrete when placed is only 4 °C (40 °F) even a freezing temperature as mild as −4 °C (25 °F), if applied immediately, produces a considerable loss of strength. If the concrete is completely frozen before it has set and is subsequently thawed at 24 °C (75 °F) it still loses about 45 per cent of its strength. The intensity of the freezing temperature and the time for which it is applied appears to have little effect once freezing has occurred. After freezing and thawing, the concrete appears to gain strength normally with age, about the same percentage loss of strength being

TABLE 6.III. EFFECT OF FREEZING CONCRETE AT VARIOUS AGES

Freezing temperature		Curing time, days	Relative per cent strength when frozen at various intervals after moulding			
°C	(°F)		0 h	1 h	3 h	6 h
−15	(5)	3	44	50	63	81
		7	52	56	80	91
		28	54	58	72	83
−9	(15)	3	51	60	71	92
		7	66	75	78	98
		28	60	71	89	98
−4	(25)	7	73		96	

maintained throughout the curing period. Some of the results obtained by McNeese are given in Table 6.III.

It seems probable that, provided the area above freezing point of the curve of temperature of the freshly placed concrete against time exceeds a certain value depending probably on the kind of cement, then no loss of strength will result due to freezing but McNeese does not appear to have investigated this point in detail.

Storing of Concrete by Freezing

The storing of concrete by freezing has been suggested[13] as a way of smoothing out the testing load. If freezing is adopted, samples taken can be transported to and tested at a central laboratory instead of on a construction site and they can be stored at the laboratory until it is convenient to test them. The sample of concrete is placed in an insulated container and solid carbon dioxide placed between the sample and the insulation. It was found necessary to top up with solid carbon dioxide every 3–4 days. The sample could be thawed out when wanted by placing it in hot water, or better within 4 min by microwaves. The concrete was then used for making the test specimens which were cured and tested in the ordinary way. The samples do not appear to have suffered in any way although storage periods extended to up to 5 days.

THE EFFECT OF DELAYED PLACING OF CONCRETE

A review of available information on the effects of delayed placing of concrete and some additional experimental evidence has been given by Zietsman.[14] It is well agreed that there is an increase of strength and a decrease in slump if a period elapses between mixing and placing of the concrete. Varying figures are given, however, for the amount of change in happen to the frozen concrete if it were subjected ...ng temperatures after freezing? It often happens on construction that concrete is frozen a day or two after placing and the question is raised, whether the concrete will ever develop strength. H. M. Fitch[1] reports that if the concrete is given a day

TABLE 7-1.—COMPARISON OF THE RATES OF GAINING STRENGTH OF CONCRETE CURED AT VARIOUS TEMPERATURES

Values, lb. per square inch

Age, days	5°F.	40°F.	70°F.	100°F.	200°F.
1	.....	.....	1,005		
3	1,555	1,740	2,530	3,280	3,730
5	1,545	2,335	3,410	4,260	4,470
7	1,395	2,730	3,940	4,650	4,670
14	1,415	3,600	4,520	5,440	3,650
28	1,460	4,140	5,440	6,200	3,370
49	.....	.....	.....	.....	3,430

at 70°F. it will begin to develop strength at the normal rate upon being thawed out. Results shown in Fig. 7-6 are similar to those secured by Fitch. A study of all his tests' results leads Fitch to conclude that if the freezing period is omitted in the plotting of the age-strength curves, the curve will be essentially the same as though the concrete had never been frozen. Curing before and after freezing was done in the usual moist storage room at 70°F. Results secured by Fitch for all series of the same mix are shown in Fig. 7-7.

A. G. Timms and N. H. Withey[2] conducted tests with initial curing periods of 1/4, 1/2, 1 and 3 days, using a standard and two high-early-strength cements, and with three different water contents. Results for the standard portland cement are shown in Fig. 7-8. Results for the high-early-strength cements are similar, but the strengths developed in the initial curing periods at 70°F. are higher. These investigators found that "subse-

[1] "Effect of Low Curing Temperatures on the Strength of Concrete," Master's thesis (1933) at the University of Illinois.

[2] "Temperature Effects on Compressive Strength of Concrete," *Proc. Am. Concrete Inst.*, Vol. 30, pp. 159-180 (1934).

Taken from: Plain Concrete by Edward Bauer, Mcgraw Hill Book Company Inc. New York 1936

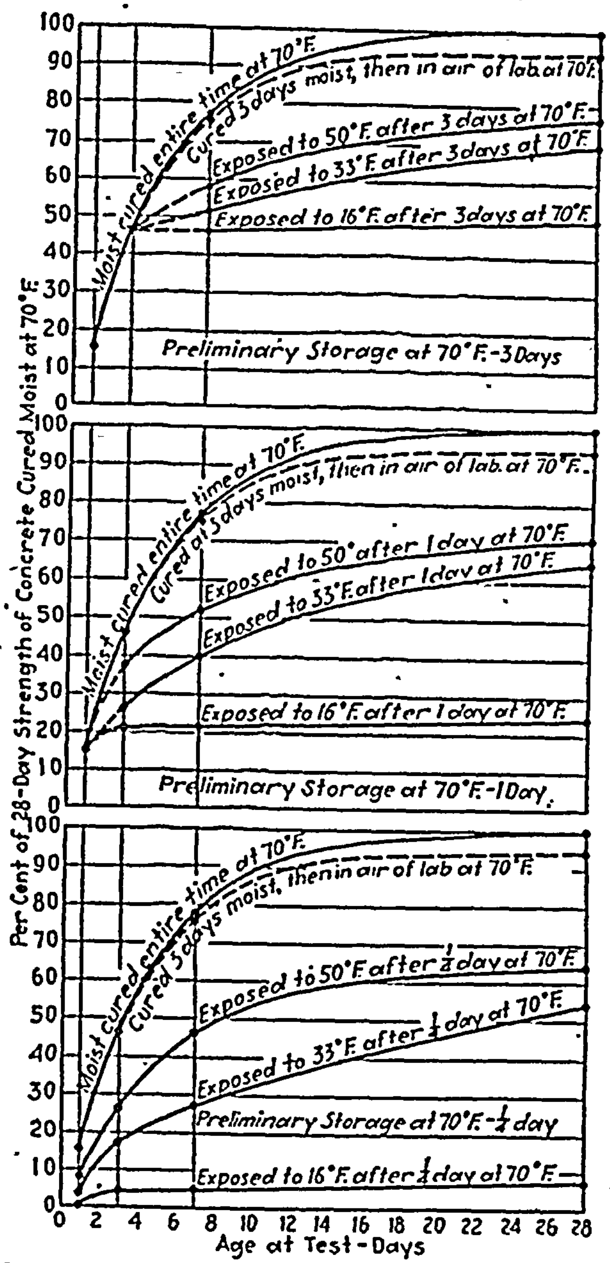

FIG. 7-8.—Showing effect of storage temperatures on the compressive strength of a concrete made with a standard portland cement, with a water-cement ratio of 6 gal. per bag of cement and with a cement content of 5.03 bags per cu. yd. (From Timms and Withey, "Temperature Effects on Compressive Strength of Concrete," *Proc. Am. Concrete Inst.*, Vol. 30, pp. 159-180.)