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March 30, 1981

Dr. Michael A. Cassaro
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University of Louisville
Louisville, KY

Dear Dr. Cassaro:

This is in reply to your letters of September 26, 1980 and March 4, 1981, expressing your concerns and evaluation of the Public Service Company of Indiana (PSI) Report entitled "Evaluation of In-Place Concrete - Marble Hill Nuclear Generating Station, Units 1 and 2". We understand your principal concern to be that the test program devised by Sargent and Lundy (S&L) engineers and conducted by the Portland Cement Association (PCA) does not satisfy the Nuclear Regulatory Commission's (NRC) criteria for 95% reliability with 95% confidence factor.

The NRC has reviewed your concerns and concludes that the required reliability and confidence can be demonstrated by the methodology described in the S&L revised report. The NRC's basis for this conclusion is outlined in Attachment "A" to this letter which addresses your major concerns and considerations and is summarized as follows:

1. The methodology you recommend (MIL-STD-105D) is intended primarily for controlling production quality. The assessment at Marble Hill does not involve production. Testing was performed for the purpose of evaluating concrete consolidation at different locations containing various configurations of concrete and embedded reinforcing steel.

2. While MIL-STD-105D would require more samples, it would also allow more defectives, whereas the S&L methodology allowed no defectives in the first test samples. If a defect were to be found in the first 59 tests, the S&L program requires an increase in the sample size.

3. Both MIL-STD-105D and the S&L methodology are based on the same concept; however, their use for a given problem requires engineering judgment. The S&L program combined the conceptual model with engineering judgment to obtain conservative results.

4. MIL-STD-105D does not account for human error. The S&L methodology requirement of 95% reliability and 95% confidence is supported by photographic records, evaluation by drawings, review of placement records, evaluation of concrete cores, and the involvement of three separate organizations in the evaluation process. This has minimized the potential for error.

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5. It is our opinion that the total volume of concrete as it relates to locations of potential non-consolidation was accounted for by the S&L program. Moreover, a conservative bias was introduced based on engineering judgment in that the samples were representative of all structures with the exception that more examinations were conducted in "congested" areas than a purely random sample would have provided.

6. With respect to your concern that defectives were overlooked, the purpose of the S&L methodology was to identify internal concrete consolidation problems. To that extent, the external and known conditions are not considered to have an impact on the methodology used by S&L.

7. Another consideration, which has a conservative influence, is that all defects found prior to (or after) the subject test and evaluation program have been or will be repaired. This reduces the numbers of defectives in the lot (total volume of concrete).

As you know, microseismic testing is but a portion of the overall program by which NRC instructed PSI to verify the adequacy of existing concrete construction at the Marble Hill site. This verification consists of four distinct facets as follows:

A. Examination of Concrete Patches: All concrete patches placed prior to the suspension of construction will be removed for further examination (destructively evaluated) and repaired in accordance with approved procedures.

B. Volumetric testing: The interior of the concrete was tested by a nondestructive (microseismic) technique. The number of samples to be tested was derived from probabalistic considerations, and test locations were established using engineering judgment to ensure coverage of all types of structural elements. A sample of the nondestructive test results was further examined and verified by destructive testing. The destructive testing involved removal of concrete cores and line drilling for direct examination. The report of this portion of the verification program is the subject of your letter.

C. Surface Examination: All accessible concrete surfaces will be examined for defects.

D. Record examination: Previous testing results (all record types) for the existing concrete, as well as handling and placement records, have been examined. Previous NRC inspection findings have also been reviewed.

In our opinion, the evaluation of all four facets of this program will comprehensively determine the adequacy of all previously placed safety-related concrete. Unsound concrete will be repaired as necessary.

As noted above, NRC is not relying solely on the microseismic sampling examination to demonstrate the quality of the concrete at Marble Hill. There are three other separate evaluations, one of which includes substantial destructive examination. Based on all of these actions, the NRC has concluded that the quality of the in-place concrete at Marble Hill has been adequately assessed by the method described in the Sargent and Lundy report. To this extent NRC requirements have been met.

We believe this letter addresses your concerns. However, we would be pleased to arrange a meeting with you, Dr. Alexander and our technical staff to discuss any areas of further concern on your part regarding this matter.

Sincerely,

A Bert Davis

for James G. Keppler
Director

Attachment: As stated

ATTACHMENT A

Summary

You contend that the statistical model used to test Marble Hill concrete quality in S&L Report No. SL-3753, Evaluation of In-Place Concrete, does not provide the confidence and reliability levels imposed by the NRC. The S&L sampling model is described in Report No. SL-3753, Volume 1, Section III. NRC believes that the testing method used by PSI has demonstrated the imposed levels of reliability and confidence as indicated by the following specific responses to your comments:

1. Comment P. 2, line 11 — "The total volume of concrete was not accounted for in the sampling plan".

   Response — The sample size was based on the population size (i.e., the total volume of concrete) as it relates to locations where combinations of concrete and reinforcing steel could affect consolidation. Since the population size was very large (assumed to be infinitely large), Eq. 2 established a limit of 59 tests without encountering a defective to achieve 95% reliability with 95% confidence factor.

2. Comment p. 2, line 12 — "Nor could a standard multiple sampling plan be devised using Equation (2) only".

   Response — Equation 2 results in different sample sizes for different numbers of defectives. These numbers are given in Report No. SL-3753, Table III-1. If one defective was observed in the first sample of 59 test areas, the test plan required that 93 areas be tested. The fact that the first 60 areas tested did not have any defects attests to the quality of the in-place concrete. The acceptance criteria of 95% reliability with 95% confidence was met. Hence, there was no need to proceed to subsequent levels of testing. A "defective" is the existence of unacceptable internal voids or honeycombs or other consolidation condition as confirmed by additional examination, i.e., drawings review, destructive evaluation (cores from the concrete), and analysis.

3. Comment p. 2, Item 1 — "Influence of instrument error and human error on statistical approach".

   Response — Pulse-echo testing has been successfully utilized for in-place concrete examination in the past at nuclear and fossil plants. The testing procedure was also qualified at the Marble Hill site in the

presence of an NRC inspector. Qualifications entailed the identification and subsequent destructive confirmation of conditions adverse to concrete quality. In every instance, the microseismic results agreed with destructive confirmations.

The pulse-echo testing detects discontinuities in the in-place concrete. The presence of rebars, conduits, and pipe sleeves could also be recorded as discontinuities. Additional evaluation was always necessary and it was always done.

In all the qualification tests done, the testing procedure has not failed to detect a discontinuity if one was present. At Marble Hill, if a discontinuity was indicated by the pulse-echo testing but could not be explained by studying the drawings and available data, a core was taken. Because of the instrument's high sensitivity to discontinuities and because of the grid system used, it is extremely unlikely that "solid" concrete would be indicated where a void exists. The pulse-echo technique will find discontinuities. The techniques' limitation is the inability to exactly quantify or characterize the discontinuity found. Because of this, photographs of the electronic indication, construction drawings, and concrete cores were used to confirm any indication. Hence, the reliability of pulse-echo testing results, as far as detecting discontinuities in concrete is concerned, is greatly enhanced.

In the interest of further clarification, the testing of concrete at Marble Hill was done in three stages: pulse-echo testing (photographic records); review of drawings and construction records for correlation with pulse-echo test data, and finally, coring. This sequence of actions has significantly assured that the results of the testing are accurate and that human error has been minimized to the extent feasible.

Once the measuring technique and evaluation methodology were established, the testing program was based on the conservative assumption of an infinite population size. No qualification of "human and instrument error" was considered necessary because the potential for such errors was minimized by independent reviews and evaluations which confirmed that the indications were not defects.

We recognize that the sampling program recommended by you also does not include the uncertainties introduced by human and instrument errors.

With regard to Mr. Muenow's qualifications, he is an internationally known authority in this field with a degree in civil engineering and more than twenty-five years experience. Mr. Muenow is also the developer of this technology. His extreme care and professionalism in performing the tests was demonstrated to those witnessing the testing, including the NRC. Also, the photographs taken of the cathode ray tube indications represent permanent records, which can be examined by all concerned. It should be recognized that three other separate organizations participated with Mr. Muenow during these examinations. Each had a separate responsibility to minimize error during data acquisition and evaluation. In addition, transducer performance tests were conducted at the beginning and end of each test period to verify equipment signal response. These tests would minimize the potential for instrument errors.

4. Comment
p. 4, Item 2

"Random selection not used - defectives overlooked".

Since the testing program was initiated following the concern expressed by the NRC over the concrete placement procedures at Marble Hill, the question of sampling was addressed using the experience gained in nuclear concrete construction. A higher potential for voids exists in the areas of concrete congested by rebar and embedment arrangement than in noncongested areas. Hence, engineering prudence required that a high proportion of these congested areas be included. At the same time, the placement procedures required that like caution be exercised in the concreting of noncongested areas. Therefore, it was considered advisable to include noncongested areas also to assure a total cross-section of sampling.

Since the testing program was used to qualify the entire volume of in-place concrete at Marble Hill, the sample had to be representative of all structural elements. The test areas covered the containment, fuel handling building, auxiliary

building, and turbine room at different elevations. Various structural elements (i.e., basement, wall, beam, column, and floor slab) were included in the sample.

Such a representative sample could not have been obtained by a purely random sampling devoid of engineering judgment. Since half of the sample is from congested areas, a conservative bias is introduced into the testing.

The void under the Auxiliary Building slab, referred to in the Report No. SL-3753, Section VII, was one of the reasons for the testing program. Having been discovered, it could not be included as part of the statistical sampling program. The program aimed at assessing the quality of the remainder of the concrete.

5. Comment — "Risks associated with sampling plan".
p. 4, Item 3

Response

We agree with the statement that "acceptance sampling (in this context) is not used at Marble Hill to control quality, but rather to determine whether a desired quality exists".

We further believe that the concrete consolidation quality can be judged by testing an adequate sample as determined in the biased sampling program discussed above. Also, the testing program was aimed at assessing the percent of defects (concrete nonconsolidation); in this sense, past experience has no bearing on the sample size.

We do not share the concern expressed in your statement that "it must be considered alarming when a plan detects zero defects where obvious defects exist". The sampling program did not assure zero defects in the population; but it did require that the frequency of such consolidation defectives be acceptable. The testing program has demonstrated that there was no unacceptable proportion of voids deep inside the structural elements. It should be recognized that in most instances honeycomb will not occur without some surface indication of its presence.

The visible defects were not examined by the pulse-echo testing program. These defects were thoroughly inspected under the Construction

Verification Program. The pulse-echo testing strictly aimed at examining the concrete consolidation inside the structural elements.

6. Comment
p. 5, Item 4

"Proposed sampling plan".

Response

As explained earlier, a conscientious effort was made to test in areas of potential discontinuities; no defective areas were found in 60 tests.

The conditions of testing - pass or no pass - met the theoretical concept contained in Eq. 2, and appropriately considered the total volume of the concrete. We feel that with 95% confidence, the percent of defective concrete relative to internal consolidation is less than 5%.

The purpose of Military Standard MIL-STD-105D is to statistically control the quality of production. It is intended for circumstances of continuous production; for this reason we do not consider its use appropriate. In contrast, the entire population of in-place concrete at Marble Hill was available for inspection. Production was not involved. A representative sample was selected for testing, as per Eq. 2; hence the S&L plan is considered appropriate for the problem under study. At Marble Hill, an extensive in-process testing program of concrete and of concrete constituents has been and still is in effect. We do not consider production testing as being consistent with a plan to test a given quantity of in-place concrete. The program outlined in the subject S&L Report No. SL-3753 addresses a fixed quantity of concrete.

Furthermore, while the MIL-STD-105D requires a larger sample size, it also permits a higher number of defectives. It is based on the same theoretical concept contained in Eq. 2. However, Eq. 2 as used in the sampling program devised by S&L did not allow for any defectives for a sample size of 59 (60 actually used) to maintain a 95% reliability/confidence factor; and had a defective been observed, the sample size would have been increased to 93 as given in Table III-1 of S&L Report No. SL-3753.

We do not regard the basis to consider one cubic yard of concrete as one unit as meaningful because of the nature of the defects which the program is required to identify.

On the basis of the foregoing, NRC concludes that the sampling methodology used by S&L, and the additional steps taken during data acquisition and evaluation, has met or exceeded the specified level of confidence and reliability.