UNIVERSITY OF LOUISVILLE
LOUISVILLE, KENTUCKY 40208

SPEED SCIENTIFIC SCHOOL
JAMES BRECKENRIDGE SPEED FOUNDATION
DEPARTMENT OF CIVIL ENGINEERING

March 4, 1981

Mr. G. Fiorelli, Chief
Projects Branch 2
U.S. Nuclear Regulatory Commission
Region III
799 Roosevelt Road
Glen Ellyn, IL 60137

Dear Mr. Fiorelli:

During the Marble Hill meeting on February 9 and 10, 1981, I informed Cordelle Williams that an analysis was being prepared as a follow-up to my letter and report to D. W. Hayes dated September 26, 1980. The analysis has been prepared by S. M. Alexander, Ph.D., PE, Assistant Professor of Engineering Management and Industrial Engineering at the University of Louisville. A copy of Prof. Alexander's report is attached.

The objective of Prof. Alexander's analysis was to investigate the actual confidence of the S&L/PSI evaluation study of in-place concrete at Marble Hill performed by Construction Technology Laboratories. His analysis establishes a specification which considers the risk associated with the sampling plan used at Marble Hill involving 60 test sites. Inherent in the S&L plan, which is intended to assure with a confidence level of 95% that no more than 5% of the concrete volume is defective, is the assumption that no test error exists. The analysis is intended to determine the risk associated with this assumption. Thus, the probability that defective concrete will be erroneously accepted is not conjoined with the probability of finding defective concrete in the S&L plan. This omission results in a plan that inevitably provides less than the required 95% confidence.

The probability of test error which will result in accepting defective concrete has not been evaluated or considered by Construction Technology Laboratories in their report for this test program. However, there is ample evidence that error of this type exists. The following is a summary of some factors which provide clear indication of the need to consider the probability of testing error of the type cited above.

The qualification test was performed on June 28, 1979 on concrete test blocks which contained several different types of flaws including representative conditions for honeycomb, cracks, air voids, and embedments. Although no photo record is available to verify the results, the test was witnessed by several persons including representatives of NRC. The

Exhibit "A"

conclusions of the qualification test was that the microseismic procedure was able to distinguish the several types of defects and accurately describe their condition. Presumably this qualification also included the ability of the analyst to identify honeycomb and to distinguish between honeycomb and dispersed air of 1/8- to 1/2-inch diameter size. On June 27, 28, and 29 of 1979 several tests conducted on the in-place concrete produced the following results indicating the presence of honeycomb. The results are cited in the test data supplied with Mr. Robert T. Bartczak's letter to Mr. Donald Stegemoller dated January 29, 1981. The data represent raw field data and test photos in several areas at Marble Hill not included in Volume II of Report SL-3753, Revision 1.

Date	Area	Page No.	Grid Point	Photo No.
6/27/79	1	4	B-3	8
6/27/79	2	7	A-1	9
6/28/79	8	16	A-7	No Photo
6/29/79	9	14	B-3	49
6/29/79	Rad Waste	1	C-9	1 & 3

These interpretation results were changed during the February 9 & 10, 1981 meeting from honeycomb to dispersed air or entrapped air. Such revision which may be appropriate for the tests leads to serious doubt concerning the accuracy of the qualification test. No matter how the responses were interpreted at the time of the qualification tests, it would appear reasonable to expect that a consistent basis for interpretation was being applied over the three-day period of June 27-29, 1979. A change of definition with respect to the test results for in-place concrete may also be interpreted as a corresponding change in the interpretations applied during the qualification tests. Then how are we to interpret the difference between a honeycomb reflection and dispersed air in the qualification tests vis-a-vis the field tests. No photographic data exist in the qualification tests record, and what record does exist is uncertain with respect to size of defect and corresponding reflection signal.

Other situations involving interpretation of wave reflections also raise concern about the need to consider test error. For example, on July 6, 1979 a test reported in Area 16 on pages C-43, photo 61 of Volume II of Report SL-3753, Revision 1, indicates a discontinuity. The field notes for the test report honeycomb, separation and entrapped air. The uncertainties of the definitions being applied require that some provision be made to evaluate the probability of test error.

Other situations involving different thicknesses of wave reflections that are termed discontinuities raise the question concerning extent of the opening. An example of this is in connection with tests of area 50 reported on page C-160 of Volume II of Report SL-3753, Revision 1. Photo 289 reports discontinuities for two wave reflections in which the space for one is twice as wide as for the other. Further, the member thickness is 54 inches, making the larger reflection about 2 inches wide.

When these considerations are applied to the S&L sampling plan the result is that the probability of test error must be considered. Applying equation (c) in Prof. Alexander's report (typical results are given in the accompanying table) for a test error of 15% with 60 samples the confidence level will be 92% rather than 95% as required by NRC. Actually, there is reason to believe that test errors may be greater than 15% resulting in a confidence level less than 90%.

Since no qualification test data are available to evaluate the test error to be applied, it is recommended that such an evaluation be made. A series of concrete test specimens with various types of flaws should be tested with appropriate photography to both evaluate the analyst's ability to discern differences in response signals and to identify large voids. When an appropriate test error has been determined, it may then be applied to the appropriate sampling plan to determine the number of test sites needed to satisfy a condition of 95% confidence with more than 5% defective concrete.

Sincerely,

Michael A. Cassaro, Ph.D., PE
Professor of Civil Engineering

lw

cc: D. W. Hayes-NRC
C. Williams-NRC
A. Parme
R. Hamm
T. Datillo

This is a critique of the section "Statistical Basis for Testing Program" (Section III - Pgs. 4-8) included in the report SL-3753 - Revision 1. This critique was prepared by Suraj M. Alexander, Ph.D., P.E., Asst. Professor, Engineering Management/Industrial Engineering, Speed Scientific School, University of Louisville, Louisville, KY.

This critique addresses three main areas of the above section. They are as follows:

(i) The lack of specification of risk associated with Statistical Quality Assurance Program.

(ii) Incorrectness of the theoretical background provided as related to the statistical program actually used.

(iii) Possible misinterpretation of terminology.

A. DEFINITIONS

Some standard Quality Assurance definitions are provided below in order to clarify the use of these terms in the critique which follows.

(i) Sampling Plan - A specific plan which states

a) the sample sizes and

b) the criteria for accepting, rejecting or taking another sample, to be used in inspecting the lot.

(ii) Single Sampling: Sampling inspection in which a decision to accept or to reject is reached after the inspection of a single sample.

(iii) Multiple Sampling: Sampling inspection in which after each sample, the decision may be to accept, to reject, or to take another sample but in which there is usually a prescribed maximum number of samples, after which a decision to accept or reject is reached. Note: Multiple sampling as defined here is sometimes called sequential sampling or group sequential sampling. The term multiple sampling is preferred.

(iv) Sequential Sampling: Sampling inspection in which, after each unit is inspected, the decision is made to accept, to reject, or to inspect another unit. Note: Sequential sampling as defined here is sometimes called unit sequential sampling.

(v) Acceptance Number: The largest number of defectives (or defects) in the sample or samples under consideration that will permit the acceptance of the inspection lot.

B. <u>CRITIQUE</u>

(i) <u>The lack of specification of risk associated with the Statistical Quality Assurance Program.</u>

In deriving the sampling plan, Sargent & Lundy Engineers (S & L) define

$$C = 1 - \sum_{x=0}^{r} \frac{\binom{Np}{x}\binom{Nq}{n-x}}{\binom{N}{n}} \qquad (1)$$

where they define C = Confidence level

n = Sample size

N = Size of population

p = Acceptable maximum fraction defectives in the population.

They go on to state that, "by testing a number of random samples (n out of a population N), we can establish with confidence C that the max. fraction defective is p if the observed number of defectives is r."

The above equation for C is infact the probability of rejecting a lot of quality p (fraction defective p), when a single sampling plan is used with a sample size n and acceptance number r. Since NRC expects the sampling plan to reject 'defective' concrete volumes 95% of the time (95% confidence level), the presumption here is that concrete volumes with p% defective are 'defective.' The above equation (i), which represents the probability of having more than r defectives in a lot is derived from the Hypergeometric distribution. S & L uses the Binomial approximation to the Hypergeometric distribution in deriving a value for n using a value of r equal to 0. The Binomial approximation to the Hypergeometric is shown below in equation (2).

$$C = 1 - \sum_{x=0}^{r} \binom{n}{x} p^x q^{n-x} \qquad (2)$$

The above Binomial approximation is valid if n is small compared to N.

S & L uses equation (2) with a value of C = 95. p = .05 and r = 0 to solve for n and obtains a value of n = 59. They then suggest a sampling plan with sample size n = 59 and acceptance number r = 0. In their words, "as a first step, a sample of 59 areas is to be tested. In order to establish with a confidence level of 95% that no more than 5% of the population is defective (i.e. reliability of 95%) none of the samples should fail the test". If the sampling plan selected was used as a single sampling plan, (i.e. Sample size n = 59, Acceptance number r = 0); it would reject a population with 5% defective 95% of the time. In order to understand what happens to populations with larger and fewer defective percentages an Operations Characteristic (O.C.) curve must be constructed for the sampling plan. As an example the O.C. Curve shown in Figure (1), which was plotted after some rough calculations were made by me, detail the probabilities of acceptance of different quality populations using a single sampling plan with n = 59 and r = 0.

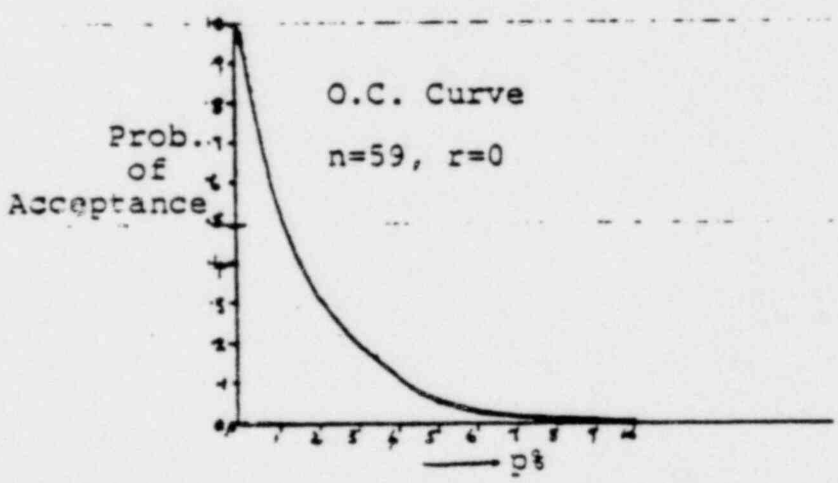

Figure 1

Thus if the sampling plan was a single sampling plan (the equations used to derive n are only valid for a single sampling plan) the risks associated with using the plan is best illustrated by the O.C. Curve Figure (1). These risks have not been specified by S & L in their statistical program.

(ii) Incorrectness of the theoretical background provided as related to the statistical program actually used. S & L's theoretical backing for its sampling procedure (equations (1) & (2)) are for a single sampling plan, but at the end of the section on Methodology (See Pgs. 5 & 6 of the report) they state that "the sampling program is sequential in that if a defective area is encountered in the first 59 samples, the sample size is increased to a total of 93 units and the acceptance number is increased to 1, if another defective is found the sample size is increased to 124 with acceptance number 2 and so on (See Table III-1 on pg. 8 of the report SL-3753). No explanation is provided as to how these numbers are obtained, though a quick check reveals that they are obtained from the same two equations (1) and (2). These equations as mentioned before, determine the probability of rejection of a population of fraction defective p by a single sampling plan of size n and acceptance number r. However the procedure followed in the testing program is that of pseudo sequential sampling (see pages 5 and 6) no theoretical background or references is provided for this sampling procedure in the report. The sampling procedure is neither a unit sequential sampling plan, (which is generally used to minimize the number of samples taken to make a decision for acceptance or rejection), nor is it a multiple sampling plan (group sequential; see definitions provided at the beginning of the critique).

The main point to be noted here is that the program suggested by S & L is not a single sampling plan hence it is incorrect to derive parameters for the plan from equations (1) and (2). Moreover, since the plan is not a standard plan and since no references are provided the determination of risks associated with the plan become difficult. In my opinion no sampling procedure for testing should be used without a proper indication of the risks associated with the procedure. Therefore S & L should either change their testing program or provide correct theoretical backing for their sampling program and indicate the associated risks.

(iii) Possible misinterpretation of terminology. S & L defines a population with 5% defective as 95% reliable. In other words they state that if 5% of the concrete volumes existing are defective then they are 95% reliable. This interpretation of reliability is not clear from the letter from NRC (Exhibit 1) which states, "Public Service of Indiana will: 1. With its contracted organizations, continue surface and volumetric examination of existing concrete volumes to establish its adequacy and test a statistical sample, representative of both congested and other concrete volumes to assure with 95% reliability and 95% confidence level, that concrete volume meets requirements." The term reliability used above is quite ambiguous, it could for example relate to the accuracy of the test, whereas S & L has interpreted reliability to be synonomous with requirements and hence attempted to design a sampling plan which rejects populations of 5% defective (95% reliability according to S & L interpretation, See bottom of pg. 6) with a probability of .95 (Confidence level 95%).

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POOR ORIGINAL

March 26, 1981

DOCKETED
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Office of the Secretary
Docketing & Service
Branch

United States
Nuclear Regulatory Commission
Region III
799 Roosevelt Road
Glen Ellyn, Illinois 60137

ATTN: Mr. James G. Keppler,
Director

Re: STN 50-546
STN 50-547

Dear Mr. Keppler:

Thank you for your response to Dr. Cassaro dated March 20, 1981. Find enclosed as Exhibit "A" herein Dr. Cassaro's specific response to yours.

This writer in conjunction with the enclosed Exhibit "A" categorically states that the NRC has not responded to the March 4, 1981 letter of Dr. Cassaro and the specific statistical and quality control engineering comments therein. It is our position that your alleged explanations are simply insufficient to manifest to the NRC that its own criteria of 95% reliability with 95% confidence has been met and/or exceeded by the test program devised by Sgt. & Lundy and conducted by Portland Cement Association.

In addition, it was our specific understanding that no NRC responses would be made until there was time to review what the independent engineers stated in a final written report subject to the additional input of Dr. Cassaro.

From all indications, it is not necessarily correct that the NRC has approved the testing standards and criteria specifically set out by the NRC in its prior orders herein. For that reason, we await the final written reports of the independent engineers and the specific reports of the NRC.

Very truly yours,

Thomas M. Dattilo

Thomas M. Dattilo

TMD/mjb
Enclosure

dupe of
8105040046

Exhibit "B"

POOR ORIGINAL

Michael A. Cassaro, Ph.D.,PE
Professor of Civil Engineering
Speed Scientific School
Dept. of Civil Engineering
University of Louisville
Louisville, Kentucky 40208

March 26, 1981

APR 2 2 1981

United States
Nuclear Regulatory Commission
Region III
799 Roosevelt Road
Glen Ellyn, Illinois 60137

ATTN: Mr. James G. Keppler,
Director

Re: STN 50-546
STN 50-547

Dear Mr. Keppler:

The NRC letter of March 20, 1981 is quite detailed and reasonably comprehensive.

Most of the points in my letter of September 26, 1980 have been discussed and handled. It is the March 4, 1981 letter of mine that has not been completely answered and is the subject of this correspondence.

The NRC must rely on microseismic investigation to determine if voids, separations or honeycombs exist in the concrete since all observable voids are considered "surface concrete defectives". Since the NRC has established the criteria, 95% reliability with 95% confidence, using Equation 2, it must be recognized that this is a probabilistic equation implying no instrument or human error associated with the statistical approach.

The March 4 letter gives an acceptible procedure for determining and including the human error and the instrument error in the test program. Several examples of this type of error are cited in the March 4 letter. For example, if the interpretor declared a "honeycomb" the same day he passed the qualification test and the honeycomb turned out to have significant bubbles in the concrete, then there appears to be reasonable room for error.

EXHIBIT "A"

dupe of
8105040053

We do not question Mr. Muenow's qualifications. However, everyone is capable of making an error. It appears that no written qualification exists in the record at Marble Hill. A qualification record must be performed to evaluate if we have 95% reliability with 95% confidence.

As it now stands, there is certainly less than 95% reliability as outlined in the March 4 letter, and we believe that no verbiage will erase that reality, only clear statistics.

This writer awaits the further response of the NRC.

Sincerely,

Michael A. Cascaro by mjb

Michael A. Cascaro, Ph.D., PE

MAC/mjb

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1. Scope of Work:

Provide NRC-IE assitance as a technical consultant in the review of 1) concrete deficiencies, known as "honeycombing," found at the Marble Hill facility through visual observation, 2) the program to determine if internal voids exist, 3) the repair procedures, 4) the completed repairs, and 5) evaluation of the affected structures to meet the original design intent.

The effort will involve a review of the techniques used to locate voids, discontinuities, etc., to determine if all significant deficiencies have in all probability been detected. These techniques included coring and pulse echo. The repair procedures and repairs made as a result of the findings of the investigations are also to be reviewed for adequacy. The main basis of the consultant's review effort will be the report submitted by the licensee and its references as prepared by Sargent & Lundy, Report SL-3753, 11/20/79, "Evaluation of In-Place Concrete, Marble Hill Generating Station, Units 1 and 2," dated November 20, 1979.

2. Objectives of Tasks:

a. To provide an independent assessment of the type and extent of deficiencies in concrete construction defined as honeycombing and/or voids that could have safety significance;

b. to provide an independent assessment of any needed repairs or remedial actions;

c. to provide independent conclusions regarding the capability of the affected structures to perform the intended design functions.

3. Statement of Work:

a. Determine that any structurally significant honeycombing and/or voids visually detectable have been located and identified.

b. Evaluate the need for and adequacy of the nondestructive techniques used by the licensee in the investigation of possible internal voids. If other techniques or additional investigation are necessary to assure structural adequacy, recommendations should be provided. This evaluation and any necessary recommendations should consider sample location and size.

Exhibit "C"