LOUISIANA POWER & LIGHT / 142 DELARONDE STREET • P.O. BOX 6008 NEW ORLEANS, LOUISIANA 70174-6008 • (504) 366-2345
MIDDLE SOUTH UTILITIES SYSTEM

October 31, 1983

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Director of Nuclear Reactor Regulation
Attention: Mr. G. W. Knighton, Chief
Licensing Branch No. 3
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

SUBJECT: Waterford 3 SES
Docket No. 50-382
Response to NRC Basemat Questions

REFERENCE: 1.) Letter dated October 17, 1983 from G. W. Knighton to R. S. Leddick

Dear Sir:

Reference 1 transmitted to LP&L a set of questions relating to the structural integrity of the Waterford 3 basemat. Please find attached our response to those questions. On October 26, 1983, a draft of this response was given to those members of the staff conducting an independent evaluation of the Waterford 3 basemat; however, the attached response provides some additional information resulting from discussions held at that time. Responses to additional clarifying questions posed by your staff at that time are being investigated and will be provided to you shortly.

I would also like to take this opportunity to emphasize not only LP&L's commitment to support a timely resolution of your concerns, but also LP&L's complete confidence that the application of engineering practices and regulatory guidelines to the design of the Waterford 3 basemat have fully accounted for any and all conditions and functional requirements which the Waterford 3 basemat will realistically see. More detailed discussions of the bases of our confidence can be found in the attached response and in the reports and evaluations previously forwarded to you. As you are probably aware, LP&L retained a renowned engineering specialist, Harstead Engineering Associates, to investigate this matter independently of the evaluations performed by the NRC staff and Ebasco Services, Inc. I would like to conclude by noting to you the closing sentences of the Harstead Engineering Associates final report, which summarizes the results of their engineering and technical evaluation:

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> "While the seepage of water from the cracks precipitated the investigation, all aspects of the [basemat] design were considered, not just those associated with the cracks and seepage. It is our conclusion that the design of the mat is extremely conservative...Therefore, we see no need for any remedial measures or the necessity of additional analyses", (HıA Report No. 8304-2 dated October 12,1983).

Since timely resolution of this issue is of considerable import to LP&L, we are willing to support the staff review in any way possible. Please let me know if you have any additional questions or identify the need for additional information.

KW Cook

K. W. Cook
Nuclear Support and Licensing Manager

KWC/RMF/pjl

cc: E. L. Blake, B. W. Churchill, W. M. Stevenson, J. Wilson,
G. L. Constable

Introductory Question I

In a condensed form, this is a request to provide discussions of the following:

a. Postulated path of ground water though the mat addressing:

   1. vertical construction joints
   2. vertical through cracks
   3. localized porous zones

b. The adequacy of the analysis and design of the mat.

c. The effect of possible porous zones on the structural integrity of the mat.

Response

We have concluded that the most probable path of the seeping water which is showing as moisture at some hairline cracks in the surface of the mat originated at flexural cracks at the bottom of the mat and follows embedded items which intersect these cracks, such as structural steel rebar support structures and conduit, horizontally through the mat to an intersection with hairline cracks at the top of the mat. These hairline cracks were mapped during the period of August 30-September 2, 1983 (Reference 1, Appendix A and Subsections 4.5 and 4.6). The path of the water seeping through the hairline cracks need not be determined with a high degree of certainty in order to ascertain that the cracks are not indicative of a safety concern. When the NRC's independent reviewer postulates mechanisms such as vertical through cracks or localized porous zones, they should be evaluated based on project records and I&E inspections currently in NRC hands to determine whether such mechanisms are credible. This later approach is the one independently adopted by both Harstead Engineering Associates and Ebasco in evaluating this concern and these independent evaluations arrived at the same conclusion that no safety concerns exist. Recognizing that a portion of the information available to Ebasco and Harstead Engineering Associates is not currently available to your independent reviewers, it is of course necessary to identify and supply this information so that informed decisions can be made. We will be glad to support your review by supplying any such information as you identify a need. There is no direct evidence, nor is it reasonable to assume, that vertical through-cracks have occurred and/or localized porous zone exist. We base this statement on the following points:

a. The cracks were found to reflect a pattern of flexure resulting in the development of tension stresses in the concrete, which type of cracking only extends through to the neutral axis. This type of cracking is expected in concrete construction. The formation of vertical or near vertical through-cracks would imply an occurrence of shear failure in the mat concrete. Under such an assumption one would expect to find hairline cracks in the high shear stress zones and along the edges of walls and columns. However, no such crack patterns have been identified.

b. The formation of vertical through cracks would imply overstress in shear, however, the design of the mat is conservative so that such an overstress would not occur. (Reference 2)

c. The interconnection of the tension hairline cracks with those near the top and the bottom of mat was possible because of the presence of the embedded structural steel beam and column system utilized to support the top layer reinforcing bars, and other embedded items - steel plates, electric conduits and equipment anchor bolts, etc. The surfaces of these embedded structural items have provided additional vertical and horizontal seepage paths within the mat concrete interconnecting the fine concrete tensile cracks.

d. The placement of mat concrete was accomplished under an approved quality assurance program to implement a satisfactory production, placement and curing of the concrete to meet the design requirements and to prevent the occurrence of voids or other deficiencies in the concrete. The compression tests continuously performed during all construction periods had provided the assurance that the concrete had properly obtained the required 28-day compression strength, 4000 psi.

e. Any localized porous zones which were formed because of construction difficulties have been identified during and immediately following placement and properly treated and repaired. These areas involved only the placement of Blocks 10B and 19, and the results of the treatment have been documented.

With regard to the adequacy of the analysis and design of the mat, evaluations performed as part of our normal Quality Assurance program, and the additional independent evaluation performed by Harstead Engineering Associates, have provided adequate assurance of the Waterford 3 basement capability to perform as required. HEA notes that "The basement is very structurally redundant and is very capable of carrying loads well in excess of the applied loading combinations", (Reference 2, Section 6.0; emphasis added). The presence of the flexural cracks discovered does not alter in any way our confidence in the basemat performance capability. "Cracking of the type evidenced at the top of the Waterford 3 basement is expected in concrete construction, and is assumed in establishing the structural capacity requirements in the ACI 318 Code", (Reference 2, Section 6.0; emphasis added).

We believe that the adequacy of the analysis and design of the mat has been well demonstrated. While a reanalysis of the mat to take into account the effect of possible localized porous zones has not been done, we believe that because we have been unable to discover any factual basis for such zones, and furthermore believe that our Quality Assurance program effectively ensured that no such zones exist (See response parts d & e above), such reanalysis is neither necessary nor warranted. We further believe the staff will concur with this position when they have had an opportunity to evaluate our documentation and the results of inspections by the I&E staff.

<u>Question 1</u> Was the mat treated as a one dimensional beam or two dimensional plate in structural analysis?

<u>Response</u>: In the structural analysis, the mat was treated as a two dimensional plate. For the design and analysis procedures used for the mat, please refer to FSAR Section 3.8.5.4.

<u>Question 2</u> How were the shear and bending moment (flexure) diagrams of the mat obtained for proportioning the depth of the mat and the area of reinforcing bars?

<u>Response</u>: The shear and bending moment of the mat were obtained from the finite element analysis to include all cases of related load combinations as discussed in FSAR Section 3.8.4.3.2. The reinforcement steel areas were calculated based on the maximum shear and moment in E-W and N-S directions obtained for each of the mat elements from the results of finite element stress analyses.

Furthermore, Harstead Engineering Associates (HEA) has concluded on the basis of an independent review and analysis that the bending reinforcement is well over that required (Reference 2, Section 6.3).

<u>Question 3</u> State the causes of the convex shape of the mat prior to placement of the containment vessel fill concrete.

<u>Response</u>: The convex shape of the mat resulted from a complex series of events involving the placement of the concrete mat and the scheduling of concrete placement for the superstructure. The construction of the mat was divided into 28 blocks. The blocks located beneath the containment were placed first and then the blocks away from the containment were placed. Three E-W strips (Strips 1, 2 and 3) of the mat beneath the containment were placed and completed prior to the placement of the mat strips north and south of the containment (Strips 4, 5 and 6). The block placement dates for each of the mat blocks are given in FSAR Figure 2.5-118. The top elevation of the concrete for each block was essentially level with that of the previous block at the time of placement, which previous block had already undergone some settlement. Therefore each block would settle so its surface would reflect the differential settlement only from the time of placement.

In addition, the subsoils beneath the mat in the area which was placed first had started their consolidation process earlier as compared to the areas which were placed later. The lag in the starting of the consolidation introduced part of the differential settlement creating the convex shape. Furthermore, the area of the containment was left unloaded by superstructure concrete for a considerable period of time while the area outside the shield building was loaded by superstructure concrete during the period of steel containment erection. This resulted in further differential settlements causing the convex mat shape. As noted in FSAR Figure 2.5-118, the convex shape is only a matter of approximately two inches in height differential over the 380 foot length of the basemat.

Question 4 — Figure 2.5-117, Composite Foundation Mat Settlement, indicating the mat settlement in the N-S direction from 1975 to 1980, does not indicate a convex shape for the mat. Was the convex shape observed only in the E-W direction?

Response: The convex shape was observed in E-W and N-S directions. FSAR Figure 2.5-117 plotted the average of the absolute block settlements within each E-W mat strip, and not relative settlements. Relative settlements are shown in Figure 2.5-118.

Question 5 — Figure 2.5-117 indicates a concave shape for the mat, but Figure 2.5-118 indicates a convex shape for the mat. Clarify the apparent inconsistency between these two figures.

Response: FSAR Figure 2.5-118 shows the mat differential settlement contours which had used Block No. 6, the first block placed, located at the center of the containment area, as a reference point. The figure indicates that the amount of differential settlement increases in the area of the mat away from the containment area.

Question 6 — Furnish the settlement data for the mat from 1981 to present.

Response: The settlement of the mat has practically stabilized since the second quarter of 1979 as reflected in FSAR Figure 2.5-117, Sheet 1 of 2 (Amendment 33). Beginning in 1981, the bench mark points for settlement measurement were transferred from the mat to the exterior walls; the readings are shown in FSAR Figure 2.5-117, Sheet 2 of 2 (Amendment 33).

Question 7 Describe the procedures used to determine the subgrade modulus for mat design; how were the effects of the heave (which was larger than estimated) accounted for in determining the subgrade modulus?

Response: As noted by HEA in Reference 1 (Section 6.0), the selection of the subgrade modulus applicable to the foundation soils and mat geometry is judgemental. The actual value used in the design analysis was a mean value of:

1. A typical textbook value
2. A value derived using Waterford 3 soils data and soil recompression characteristics.

The heave phenomenon was taken into consideration in the recompression program of the subsoil system. The recompression process had been completed earlier in the stages of construction, as discussed in FSAR Subsection 2.5.4.1.3.2b) (Page 2.5-96), "the average heave readings at the site were recompressed to their initial readings by July, 1977."

Furthermore, for the finite element analysis, additional conservation was established by assuming a variable spring, ie, the soil springs under the Reactor Building were reduced to 70pci while the area adjacent to the Reactor Building was set at 110pci. The other parts of the mat remained at 150pci. HEA agreement with this approach is indicated in Reference 2 (Section 6.0).

Question 8 Was a waterproofing membrane placed around all the exterior faces of the mat?

Response: A waterproofing membrane was placed around the exterior face of the mat from the top of the mat down to 2'-0 below the top of the mat (FSAR Figure 3.4-1).

Question 9 Are the seepage zones in close proximity to vertical construction joints?

Response: Only a small part of the hairline cracks exhibiting moisture are located in close proximity to vertical construction joints. In a few cases, a construction joint appears to have seepage. The fact that construction joints have little seepage is to be expected in that construction joints have continuous waterstops. Obviously random forming cracks will not have mechanical water stops. Considering the substantial hydrostatic ground water head, the amount of seepage is insignificant, indicating considerable resistance to water pressure.

<u>Question 10</u> Were waterstops placed in the vertical construction joints, and if so, where?

<u>Response:</u> T o nine inch PVC waterstops were provided at all vertical construction joints of the mat. The bottom waterstop is located 2'-6 above the bottom of the mat, and the top is 2'-0 below the top of the mat.

<u>References</u>

1. HEA Report No. 8304-1 dated September 19, 1983

2. HEA Report No. 8304-2 dated October 12, 1983