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Washington, D.C. 20555

In the Matter of
Louisiana Power & Light Company
(Waterford Steam Electric Station, Unit 3)
Docket No. 50-382 OL

Dear Administrative Judges:

Enclosed for your information are two documents related to the Waterford 3 basemat which were submitted to the staff under cover letters dated November 7, 1984. The first is entitled, "Summary Evaluation - Structural Significance of

DS03

Basemat Nondestructive Testing Results." The report is a revision of the report of the same name which we provided you on October 29.

The second is Appendix 5 to the Muenow Report which was also provided you on October 29.

Sincerely yours,

Bruce W. Churchill

Enclosure

cc: Sherwin E. Turk, Esq.
Carole H. Burstein, Esq.
NRC Docketing & Service Section (3)

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November 7, 1984

W3P84-3142
3-A1.16.07
A4.05

Director of Nuclear Reactor Regulation
ATTN: Mr. Dennis M. Crutchfield, Asst. Director
for Safety Assessment
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUBJECT: WATERFORD 3 SES
ADDITIONAL INFORMATION ON BASEMAT
HAIRLINE CRACKS

Referrences:
1. Letter W3P84-3044, K. W. Cook to D. M. Crutchfield, dated October 26, 1984.
2. Letter, D. M. Crutchfield to J. M. Cain dated October 19, 1984.

Dear Mr. Crutchfield:

The purpose of this letter is to supplement the additional information, provided in Reference 1, in response to the requests in your letter of October 19, 1984.

A report detailing the ultrasonic testing results on the hairline cracks in the basemat, performed by Muenow and Associates, was submitted by Reference 1 for staff review. On November 2, 1984, the NRC staff requested LP&L to provide larger scale diagrams indicating the location and depth of the hairline cracks for Staff and Brookhaven National Laboratory (BNL) review. These are being prepared by Muenow and Associates and will be provided under separate cover. These diagrams include the conservative data interpretation included in the report as well as a best estimate of depth and extent of cracks based on engineering judgement of Muenow and Associates.

In Reference 1, LP&L provided a review of Ebasco of the ultrasonic test results to evaluate the structural significance of the hairline cracks. This review was, of necessity, limited in scope and depth due to the proximity of the submittal due date and availability of the ultrasonic test report for LP&L and Ebasco review. Since the initial submittal, LP&L and Ebasco have met with the NRC Staff to review the Ebasco report and discuss additional issues which should be addressed in the report. Additionally, LP&L has retained Professor M. J. Holley, Jr., of MIT, to assist in development and presentation of an evaluation of the structural significance of the hairline cracks and conclusion on the capability of the basemat to perform its design function. The initial Ebasco report has been expanded and restructured and a revised version is attached.

LP&L is firmly convinced that the ultrasonic testing results and evaluations performed by Ebasco and LP&L's consultants all support the fact that the hairline cracks have no adverse affects on the structural integrity of the basemat and that it has and will continue to function per the design requirements.

If you have any questions regarding the transmittal please call.

Very truly yours,

K.W. Cook

K.W. Cook
Nuclear Support & Licensing Manager

KWC:sms

ATTACHMENT

cc: E.L. Blake (NRC), G.L. Constable (NRC), W.M. Stevenson, J.T. Collins (NRC), J.H. Wilson (NRC)

LOUISIANA POWER AND LIGHT COMPANY
WATERFORD STEAM ELECTRIC STATION
UNIT NO. 3

SUMMARY EVALUATION
STRUCTURAL SIGNIFICANCE OF BASEMAT
NONDESTRUCTIVE TESTING RESULTS

REVISION 1*

November 7, 1984
Ebasco Services Incorporated
Two World Trade Center
New York, NY 10048

*Includes revisions, clarifications and additions to the Report of October 25, 1984 based on the November 2, 1984 meeting with NRC staff and Brookhaven National Laboratory.

LOUISIANA POWER AND LIGHT COMPANY

WATERFORD STEAM ELECTRIC STATION

UNIT NO. 3

SUMMARY EVALUATION
STRUCTURAL SIGNIFICANCE OF BASEMAT
NONDESTRUCTIVE TESTING RESULTS

TABLE OF CONTENTS

LOUISIANA POWER AND LIGHT COMPANY
WATERFORD STEAM ELECTRIC STATION
UNIT NO. 3

SUMMARY EVALUATION
STRUCTURAL SIGNIFICANCE OF BASEMAT
NONDESTRUCTIVE TESTING RESULTS

1.0 PURPOSE

The purpose of this report is to review the results of nondestructive testing (NDT) of Nuclear Plant Island Structure (NPIS) basemat hairline cracks to evaluate their significance with respect to the structural integrity of the NPIS.

2.0 SCOPE

The scope of this report covers the following:

1. Review and interpret data and results of NDT related to basemat as presented in the Muenow and Associates, Inc. Report of October 1984.

2. Evaluate the significance of the cracks on the structural integrity of the NPIS basemat.

3. Study the crack patterns as defined by NDT, such as inclination, depth, spacing, and width in order to determine the probable causes of basemat and wall cracks.

3.0 BACKGROUND

An NDT program of the basemat hairline cracks was performed by Muenow and Associates, Inc. to determine the following:

1. Inclination of the cracks - whether the basemat cracks are vertically and/or diagonally inclined.

3.0 BACKGROUND (Cont'd)

2. Estimate depth, length, and width of the basemat cracks.

As an auxiliary study, the depth of some cracks of the Reactor Containment Building (RCB) wall surfaces above the basemat was evaluated.

This NDT examination was performed at the Waterford 3 Site mainly during the months of July and August 1984.

4.0 NDT RESULTS SUMMARY

4.1 HAIRLINE CRACKS OF BASEMAT (Tables 1, 2 and 3)

The majority of the hairline cracks are oriented in an east-west direction and located within a distance of thirty (30) feet from the east-west centerline of the RCB. Based on their appearance and nearness to each other they are grouped into 10 families:* 4 on the east side of the RCB and 6 on the west side of the RCB. Seven cracks beneath the RCB were also identified by NDT, four of these cracks (Numbers 1, 4, 5 and 7) appear to coincide with east-west cracks on either side of the RCB and probably are interconnected (Figure 1).

Other cracks are oriented in a northeast/southwest or northwest/southeast direction and they are grouped into a total of 7 families. Of these families, 4 of them were evaluated by NDT: 3 in the northeast and 1 in the northwest corners of the RCB. These cracks are also referred to as East or West Diagonal cracks in the Muenow and Associates, Inc. Report. Two of the cracks beneath the RCB (Numbers 2 and 6) appear to coincide with the East or West Diagonal cracks and probably are interconnected (Figure 1).

---

*The grouping by families is somewhat arbitrary and intended only to present an overview of the mat cracking. No analyses or conclusions are dependent upon the grouping other than the order of magnitude calculations of rebar tensil stress in Appendix 1.

4.1 HAIRLINE CRACKS OF BASEMAT (Cont'd)

Ebasco review indicates that within the above families of cracks, the data show cracks originating from the top surface of the basemat (top cracks), some from the bottom surface of the basemat (bottom cracks), and some within the middle portic.. of the basemat (middle cracks).

Tables 1 and 2 present a summary of the NDT examination of the basemat hairline cracks on each side of the RCB. This includes length, depth, group spacing and inclination of hairline cracks which originate from the top surface of the basemat. In addition, a summary of cracks in the middle or near the bottom of the basemat is also included.

Table 3 presents a summary of hairline cracks beneath the RCB.

4.1.1 Depth

East-West Cracks Outside RCB

The depth of cracks varies depending on the locations of the cracks.

The depth of top cracks near the east-west centerline of the RCB is found to be the maximum. Generally, individual cracks do not extend into the bottom layer of reinforcing steel located approximately ten (10) feet depth from the top surface. The neutral axis for positive bending (tension at top surface of the basemat) is calculated to be approximately 10'-6 from the top surface.

The bottom cracks are found mostly in the vicinity of the east-west centerline of the RCB and their depths range from 2 to 3 feet, measured from the bottom of the basemat. Within this area a possible local interconnection between top and bottom cracks is indicated for Cracks J and Ke.

The middle cracks are few and randomly distributed. In general, they are not interconnected with top or bottom cracks.

4.1.1 Depth (Cont'd)

East-West Cracks Beneath the RCB

The cracks beneath the RCB are described by the Muenow and Associates, Inc. Report to be noncontinuous both in depth and length. At some locations, their depth extends to the region of the lower layer of reinforcement steel.

Diagonal Cracks (Northeast/Southwest and Northwest/Southeast)

The depth of these cracks, which in plan view run diagonally to the plant grid, is generally less than six (6) feet. A few bottom and middle cracks are present, however, there are no indications of interconnection between the top and bottom cracks.

4.1.2 Inclination

All hairline cracks in the basemat evaluated by NDT are essentially vertical. In Page 2, of the Muenow and Associates, Inc. Report stated that "there is no evidence of diagonal (shear) cracks; either occurring singularly or as a connection between two individual cracks within the areas investigated."

4.1.3 Length

The cracks are variable in their length. The east-west cracks outside the RCB extend between the exterior walls of the RCB and the NPIS. The diagonal cracks extend from the exterior wall of the RCB but end well before they reach the exterior wall of the NPIS. When the cracks

4.1.3 Length (Cont'd)

intersect with a construction joint they go through the construction joint. It appears that there are 5 to 6 families of cracks that extend from the east to the west side of the NPIS basemat since many of the individual families located in three areas (east, west and beneath the RCB) coincide and are probably joined.

4.1.4 Spacing

The east-west crack families have an average spacing of approximately 11'-0. The diagonal (north-east/southwest or northwest/southeast) crack families have an average spacing of approximately 15'-0 at the exterior wall of the RCB.

4.1.5 Width

The NDT evaluation has estimated the crack width to be less than .007 in. and all the cracks are tight. Our recent field surface measurement of crack L found the maximum crack width to be .003 in. The crack was observed to be filled with laitance and there was no actual open crack. Our field surface measurements in 1977 found the crack widths beneath the RCB to be between .002 and .005 in. Field measurements were made using a Bausch & Lomb optical comparator.

4.2 HAIRLINE CRACKS OF RCB WALL

Four hairline cracks on the exterior surface of the RCB wall near the basemat (Elev -35.0 ft) were evaluated using NDT. All of them were found to penetrate less than one (1) ft of the 10 ft wall thickness (Table 4).

5.0 PROBABLE CAUSES OF CRACKS

The causes of the top hairline cracks were evaluated in 1977 and 1983 (References 1 and 2) and the conclusion was that they were mainly due to flexure of the basemat from initial loading (prior to the completion of superstructure). The NDT evaluation has determined that all of the top cracks are vertical, extremely narrow and do not generally extend below the neutral axis.

From the summary of NDT results, it is clear that the top cracks are greater in number than the bottom cracks. This reflects that the crack pattern generally followed the basemat flexure, which was found to be predominantly convex shape throughout the construction stages. The top cracks are located primarily in an east-west band centered on the RCB centerline. This matches closely the area of maximum convex flexure of the basemat in the early stages of construction as shown on Figure 2.

The crack width produced is well within the allowable crack width of the ACI Codes. Section 1508.6, ACI 318-63 Code for control of cracking states that "....the average crack width at service load at the concrete surface of extreme tension edge, does not exceed 0.010 in. for exterior members..." Section 10.6.4, ACI 318-83 Code Commentary for control of flexure cracking states that "...for interior and exterior exposure respectively, ... limiting crack widths of 0.016 and 0.013 in."

The NDT examination performed at service load conditions has established the estimated crack width to be less than .007 in. and the actual field measurements of crack "L" less than .003 in. When the basemat hairline cracks were first observed under the RCB in mid-1977, the crack widths were observed to be between .002 and .005 in. The present tensile stress in the top reinforcing steel associated with these observed crack widths (approximately .005 in.) is small, on the order of 4 to 11 ksi, and well within the allowable design limits (Appendix 1). The design yield strength of the reinforcing steel is 60 ksi.

5.0 PROBABLE CAUSES OF CRACKS (Cont'd)

In Reference 1, it was stated that "...The mat, as are all other reinforced concrete structures, is designed to carry loads and in so doing depends only on the compressive and shear strengths of concrete and the tensile strength of reinforcing steel. No credit is taken in the design for the tensile strength of concrete, ... Thus, as loading on the foundation mat causes flexure and resultant tension of the concrete, cracks are expected to form. This cracking enables transfer of the tensile load from the concrete to the embedded reinforcing steel as contemplated in the design of all steel reinforced concrete structures."

Although the predominant cause of hairline cracks has been concluded to be flexure, it is recognized that other factors such as thermal and/or shrinkage may have contributed to the development of some of these cracks. Also the early placement of the lower portion of the RCB ring wall apparently also influenced the cracking orientation as evidenced by the radial nature of the most northerly and southerly cracks.

The hairline cracks in RCB walls are found to be superficial by NDT and, therefore, appear to be caused by shrinkage. These cracks are apparently not related to adjacent basemat cracks, which were caused by mat flexure.

The basic cause of the basemat flexing and cracking bears no importance to the present structural integrity of the basemat. The cracks are present and such presence can be evaluated as to their significance on the structural integrity.

6.0 SIGNIFICANCE OF CRACKS AND EFFECTS ON STRUCTURAL INTEGRITY

The following conclusions are of importance in the determination of the significance of the cracks in the Waterford 3 basemat and their effect upon the structural integrity of the basemat:

1. The cracks are flexural cracks possibly combined in some cases with thermal shrinkage cracks. The consistent vertical orientation of the cracks is the evidence of this.

2. There are no inclined cracks within the basemat. This provides evidence that no excessive diagonal tension, hence no excessive shear, exists or has existed within the basemat and confirms the design calculations which predicted this.

3. There are no through cracks from top to bottom of the basemat with the possible exception of a very few localized areas where top and bottom flexural cracks have apparently coincided and joined. The cracks are primarily extending down from the top surface of the basemat. This is evidence that the cracks are the result of flexure and that the flexure was of a convex nature which agrees with the measured deformations of the basemat.

4. Presently there is virtually no water seepage or wetness present at any of the observed cracks and the amount of water seepage in the past has been minimal causing only a wetness of the basemat in the immediate vicinity of the cracks. The cracks are believed to have filled with a laitance derived from the parent concrete material. The general stress condition at the top of the basemat has become compression since the occurrence of the original cracking. These conditions will not change during normal operation, hence, the continued minimal water seepage condition during the operation of the plant is assured. Therefore, the amount of water seepage presently meets, and will continue to meet, the original design intent for minimal water leakage.

5. The width of the cracks and the spacing between them, 11 feet (roughly equal to the thickness of the basemat), indicates a low steel stress as a result of the flexure which caused the concrete to crack (Appendix 1).

6. The crack pattern is predominantly in an east-west direction (Figure 1), localized in a band running east-west and centered near the RCB centerline. This band is within the region subjected to the most extreme convex curvature during the early stages of construction (Figure 2). This evidence indicates that the cracks resulted from early settlements of the basemat occurring during placement or shortly thereafter. The cracks lying in a northeasterly or northwesterly direction were influenced by the rigidity of the early placements of the RCB wall.

7. The cracks in the RCB wall are shallow, shrinkage induced and are not related to the cracks in the basemat. The existence of cracks in the basemat and the wall at the same, or nearly the same, location appears to be coincidence.

8. The concrete quality is uniform and there are no significant voids and/or honeycombs within the mat. This indicates that the concrete consolidation was more than adequate during construction. The concrete strength is indicated to be 5,000 to 7,000 psi by NDT, which is higher than the required design strength of 4,000 psi.

FLEXURAL CONSIDERATIONS

"It is well known that load-induced tensile stresses result in cracks in concrete members. This point is readily acknowledged and accepted in concrete design. Current design procedures.... use reinforcing steel, not only to carry the tensile forces, but to obtain an adequate crack distribution and a reasonable limit on crack width."(1)

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(1) Causes, Evaluation, and Repair of Cracks in Concrete Structures - ACI 224 ACI Journal - May-June 1984, Paragraph 1.3.9.

6.0 SIGNIFICANCE OF CRACKS AND EFFECTS ON STRUCTURAL INTEGRITY (Cont'd)

The cracks in the Waterford 3 foundation basemat are to be expected considering the flexural situation. They have no negative effect on the structural integrity or strength of the basemat or on the ability of the basemat to resist adequately any design load combinations, nor do they alter the design response of the structure to seismic vibrations. The cracks, being quite narrow and tight, will not increase the flexure of the basemat and hence will not cause any additional transfer of load to building members than that already accounted for in the design.

Reinforced concrete members subjected to flexural loads are designed to accept cracking of the concrete in the tension zone. The ACI code for design of reinforced concrete structures states that "tensile strength of concrete is to be neglected in flexural calculations,"[(2)] and that all tensile stresses are to be directed to the steel reinforcing. This is normal concrete cracked section analysis and the concrete must crack since it has lower rigidity than the steel. Therefore, the steel is the structural component in the cracked tension zone.

When reversal of stresses occur and a previously cracked tension zone becomes subjected to compressive forces, the cracks close and the adjacent sides of the cracks bear against each other. The concrete crack surfaces in the Waterford 3 basemat are well able to bear against each other since they are tight and have been filled with laitance and under flexural loading the basemat will react the same as a normal concrete cracked section. Therefore, the flexural strength has experienced no degradation for bending in either direction and no increase in the flexure of the basemat will occur.

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(2) Building Code Requirements for Reinforced Concrete, ACI 318-63, Paragraph 1503(e).

6.0 SIGNIFICANCE OF CRACKS AND EFFECTS ON STRUCTURAL INTEGRITY (Cont'd)

SHEAR CONSIDERATIONS

"If a (vertical) plane under consideration is an existing crack or interface, failure usually involves slippage or relative movement along the crack or plane."[3] "If an initially cracked specimen is tested, shear can be transmitted only if lateral confinement or transverse steel exists. The irregularities of the surfaces of the two sides of the crack ride up on each other and this tends to open the crack and create forces in the transverse steel ...... In a heavily reinforced shear plane or one subjected to a normal compressive stress, the shear resistance due to friction and dowel action may reach the shear corresponding to failure of an initially uncracked specimen having the same characteristics. In such a case the crack locks and the behavior and strength are similar to those for an initially uncracked section."[4]

The Waterford basemat vertical cracks are both heavily reinforced and under "compressive stress."[5] In addition they are very narrow, do not extend through the basemat, and are filled with laitance. Essentially they are "locked." In actuality, they resemble construction joints and respond similarly.

In accordance with the ACI 318-63 code, the maximum shear capacity of a given section is less than the potential shear capacity across a vertically cracked section when utilizing the shear frinction concept. Therefore, the presence of the cracks will not reduce the shear capcity of the basemat.

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(3) The Shear Strength of Reinforced Members - ACI-ASCE 426R-74, ACI Manual of Concrete Practice, 1983, Part 4, Paragraph 2.2.2.

(4) Ibid - Paragraph 2.2.2b.

(5) Review of Waterford 3 Basemat Analysis Structural Analysis Division, Dept. of Nuclear Energy, Brookhaven National Laboratory, July 18, 1984, p. 21.

The Potential for "Shear Slip" on Mat Crack Planes

If vertical shear on the basemat crack planes could produce "shear slip" (ie, a step change in vertical deflection across the crack plane), and if such shear slip were large, it would be appropriate to investigate its possible significance to the dynamic response of the structure. For the reasons discussed below there is no basis for believing that slip will occur.

Background Reguarding Shear Strength and Shear Slip on Crack Planes

The matter of shear strength along a crack plane, or a potential crack plane, has been relevant to reinforced concrete design. This is of interest primarily at the junctions of precast concrete members (where large shear forces must be transferred across such planes), in short reinforced concrete (R/C) brackets (where large shear forces sometimes accompanied by tensile forces must be transmitted across such planes), and in R/C membranes subjected to concurrent large shear and tensile forces acting on vertical crack planes. In contrast, for beams and slabs designed to resist internal transverse shear force and bending moments rather than membrane forces, the question of shear strength across potential transverse crack planes normally does not arise. Also, the evaluation of shear resistance across these planes is not normally a part of the design process. This is true even though transverse (flexural) cracks can develop in beams and slabs, particularly when there are bending moment reversals. It may be noted that provisions for shear reinforcement focus on inclined crack planes. The requirements for such reinforcement may be satisfied by transverse bars (which do not cross any potential transverse crack) and that such a reinforcing pattern is acceptable for very substantial magnitudes of transverse shear stress. The validity of this practice for conventional beams and slabs reflects (a) the absence of large tension forces on actual or potential crack planes, which could imply large crack widths; and (b) the great shear strength and slip resistance along a crack plane if the crack is closed (or of small initial width), and if "clamping" (compression) force of adequate magnitude is available. This compression force may be provided either by the compression component of a bending moment acting on the section, by tension (flexural) steel crossing the section, by both, or by an externally applied compression force.

Much of the present understanding of shear strength and slip on crack planes was developed by research studies stimulated by the design of R/C containment shells for nuclear power plants. Such shells are subjected to very large membrane forces (ie, large tension and shear forces) acting on transverse crack planes. The tensile forces can cause cracks of substantial width, and both shear strength and shear slip are matters of design interest. This is a very different condition than exists in the Waterford 3 basemat, but some of the results of the research on the membrane problem are relevant to this discussion of the basemat. In particular, we refer to a report of tests conducted at Cornell University (Reference 3), which for crack planes with initial crack widths of 0.01 inch, and subjected to cycles of shear stress reversals of ± 180 psi, demonstrated the following results:

1) clamping forces developed in the bars that were used to restrain crack width growth did not exceed 20 percent of the applied shear force; and

2) total slip, after 25 cycles of shear reversal, did not exceed 0.01 inch.

It should be noted that the clamping forces developed here were from reinforcing steel responding to the shear slip displacement, an active clamping force only present when slip occurs.

Basic Mat Strength and Slip Resistance on Crack Planes

The cracks in the basemat are predominantly east-west oriented, and are everywhere less than 0.01 inch in width. Of major importance is the fact that the crack planes are not subjected to any tensile force. Indeed there is a very substantial compression force (exerted by soil and water pressure on the north and south boundaries of the mat and the walls above), which is conservatively neglected for purposes of computing shear strength on the crack plane. With regard to its influence on slip, the effect of this compression force, conservatively discounted for strength, is of great interest and will be accounted for. Any north-south bending moment, whether positive or negative, which may be acting on the crack plane does not diminish the shear strength of the crack plane. Bending moment which causes tension force in the bottom rebars must cause an equal and opposite compression force in the top few feet of the section. Similarly, bending moment which causes tension force in the top rebars must cause an equal and opposite compression force in the bottom few feet of the section. This diminished resistance in the bottom (or top) is offset by an enhanced resistance in the top (or bottom).

In the regions of interest the top rebars are #11 @ 6", i.e., 3.12 in^2 ft, and the minimum bottom rebars are #11 @ 6" + #11 @ 12", i.e., 4.68 in^2/ft. Over a representative crack plane length (50 ft) the maximum total shear forces on any crack plane are found at either end of the East-West running cracks. The maximum total shear forces on these 50 ft representative lengths correspond to the following values:

Loading Condition	Total Shear Force	Unit Shear Force
1.5 x Gravity Load	42 K/ft	27 psi
1.1 x Vert EQ	5 K/ft	3 psi
1.1 x E-W EQ*	96 K/ft	61 psi
1.1 (Vert EQ + E-W EQ)	101 K/ft	64 psi
1.5 Gravity + 1.1 (Vert EQ + E-W EQ)	143 K/ft	91 psi

*N-S EQ (earthquake) gives smaller shear forces.

It should be noted that averaging of forces over a 50 ft crack length is very conservative since this is only about 4 times the mat thickness. The shear forces would decrease rapidly with increase in the crack length considered. It also should be noted that the corresponding shear forces on any other 50 ft length of any other cracks are less than the values tabulated above.

Shear Capacities

Using shear provisions of Section 11.7.4, ACI-1983, shear strength of the entire section is given by:

$$V_u = \phi V_n = \phi A_{vf} f_y \mu$$

where V_u = factored shear force at section
ϕ = strength reduction factor = 0.85
V_n = nominal shear strength
A_{vf} = area of shear-friction reinforcement
fy = specified yield strength of reinforcement = 60 ksi
μ = coefficient of friction = 1.4 λ
λ = correction factor related to unit weight of concrete = 1.0

therefore,

$$V_u = 0.85 (3.12 + 4.68) 60 \times 1.4 \times 1.0 = 556.9 \text{ k/ft}$$

which corresponds to an average unit shear strenght of: stress

$$v = \frac{556,900}{12x11x12} = 352 \text{ psi}$$

Because the rebars are concentrated near the top and bottom of the section, rather than distributed throughout the depth of the section we conservatively reduce the above shear capacity by 50 percent, i.e., to 278 K/ft. This is 1.9 times the 143 K/ft shear demand.

It is clear that the shear strength along the crack plane, even ignoring the inescapable active compressions force, is much in excess of the demand.

Slip Resistance

As reported in Reference 3, for an initial crack width of 0.01 inches, and cycles of shear stress reversal to 180 psi a slip of about 0.004 in. was developed at the end of the first cycle increasing to 0.01 in. after 25 cycles. Moreover the maximum clamping force developed during this cycling was only 20 percent of the applied shear force. In the mat we are interested in an applied shear stress of 91 psi, for which a 20 percent clamping force would be 18 psi.

The compression acting on the cracked section, due to horizontal soil and water pressure on the mat and walls, is 50 psi.[6] Based on the finite element model, this compression exists in all areas of the basemat during earthquake loading conditions with the small exception of a very narrow band immediately adjacent to the north and south walls. It is not credible that this compression stress, reduced as may be reasonable for the effect of an earthquake, would not still be

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(6) The Brookhaven report (Footnote 5) states that "under normal operating conditions the loads acting on the sidewalls produce an average compressive stress inthe basemat of about 50 psi."

substantially in excess of 18 psi. This means that more than the required clamping pressure of 18 psi is available from the outset; i.e., no rebar tension is required to provide the required clamping force. Since, the clamping force is a passive force, the friction resulting from it is available without shear slip and is a static friction.

The conclusion then is drawn that the shear resistance across the crack is a state of static friction wherein the available static friction must be overcome prior to the occurance of any shear slip. Since the available friction (clamping force) is at least equal to and undoubtedly far in excess of the applied shear stress we conclude that the shear stress we conclude that the shear resistance would develop without any slip. Therefore, there is no change in the rigidity of the mat and no effect upon the dynamic response of the basemat to the earthquake.

CONCLUSION

Considering each of the above items individually and in concert, we conclude that the cracks in the Waterford 3 basemat, as defined by the nondestructive testing, have no adverse influence on the structural integrity of the basemat. It is fully capable of functioning as required by the design.

REFERENCES

1. Affidavit of Joseph L Ehasz, Ebasco Services Incorporated, submitted before the Atomic Safety and Licensing Appeal Board, USNRC, September 1983.

2. "NPIS Wall Hairline Crack Evaluation," by Ebasco Services Incorporated, April 1984.

3. J P Laible, R N White, and P Gergely, "Experimental Investigation of Seismic Shear Transfer Across Cracks in Concrete Nuclear Containment Vessels," ACI SP 53-9, Reinforced Concrete Structures in Seismic Zones, 1977.

TABLE 1 - SUMMARY OF CRACKS WEST SIDE OF RCB

amily	Crack I.D.	Top Crack: Test Lines	Top Crack: Length (exposed)	Top Crack: Depth (ft.) Min	Top Crack: Depth (ft.) Max	Top Crack: Depth (ft.) Average	Family Spacing	Presence of Subsurface Cracks (See Notes): Bottom Crack: Below Bottom Re-bar	Presence of Subsurface Cracks (See Notes): Bottom Crack: Through Bottom Re-bar	Presence of Subsurface Cracks (See Notes): Middle Crack	Inclination
I	A	7	7'- 6	1	2	2		*	*	*	vertical
	B	7	9'- 0	2	3	3		*	*	*	vertical
	C	12	16'- 6	1	3	2		*	*	*	vertical
							±10'	*	*	*	vertical
II	D	5	6'- 0	2	5	4		*	***	*	vertical
	E	1	2'- 0	3	3	3		*	*	**	vertical
	F	6	9'- 0	4	10	5		**	**	*	vertical
	G	4	6'- 0	1	5	4		*	*	*	vertical
							±16'				
III	1	4	5'- 0	7	10	8		**	**	*	vertical
	H	6	9'- 0	5	10	8		**	**	*	vertical
	J	20	28'- 0	3	12	9		***	****	**	vertical
	K	10	13'- 0	3	11	8		**	***	*	vertical
							±10'				
IV	L	10	28'- 0	6	10	8		**	**	*	vertical
							±8'				

otes: *None

**Presence of crack is not probable since only at one or two test line location(s).

***Presence of crack is probable since indication at several test locations but not interconnected with top crack.

****Similar to *** except probably interconnected with top crack.

TABLE 1 - SUMMARY OF CRACKS WEST SIDE OF RCB (Cont'd)

amily	Crack I.D.	Top Crack: Test Lines	Length (exposed)	Depth (ft.) Min	Depth (ft.) Max	Depth (ft.) Average	Family Spacing	Presence of Subsurface Cracks (See Notes): Bottom Crack – Below Bottom Re-bar	Bottom Crack – Through Bottom Re-bar	Middle Crack	Inclination
V	M	4	6'- 0	4	5	4		*	*	*	vertical
	N	3	5'- 0	2	6	3		*	*	*	vertical
	2	3	5'- 0	1	3	2		*	*	*	vertical
	3	9	12'- 0	1	5	2		*	*	*	vertical
	P	9	14'- 0	8	10	9		*	**	*	vertical
	R	1	2'- 0	2	2	2		*	*	*	vertical
	Q	3	8'- 0	3	5	4		*	*	*	vertical
	S	3	4'- 0	4	4	4		*	*	*	vertical
	T	14	20'- 0	3	10	6		*	***	*	vertical
	Y	3	6'- 0	1	1	1		*	*	*	vertical
							± 6'				
VI	U	9	14'- 0	2	10	5		*	**	*	vertical
	V	5	13'- 0	2	5	3		*	*	*	vertical
	X	22	25'- 0(+)	1	5	3		*	*	*	vertical
VII	West Diagonal	19	27'- 0	1	4	3		**	***	*	vertical

otes: *None

**Presence of crack is not probable since only at one or two test line location(s).

***Presence of crack is probable since indication at several test locations but not interconnected with top crack.

****Similar to *** except probably interconnected with top crack.

TABLE 2 - SUMMARY OF CRACKS EAST SIDE OF RCB

mily	Crack I.D.	Top Crack: Test Lines	Top Crack: Length (exposed)	Depth (ft.) Min	Depth (ft.) Max	Depth (ft.) Average	Family Spacing	Presence of Subsurface Cracks (See Notes): Bottom Crack: Below Bottom Re-bar	Bottom Crack: Through Bottom Re-bar	Middle Crack	Inclinatio
Ie	Ae	4	6'- 0	1	1	1		*	*	*	vertical
	Be-Ce	5	6'- 0	1	4	3		*	*	*	vertical
	De	2	4'- 9	1	1	1		*	*	*	vertical
	le	2	3'- 0	3	3	3		*	*	*	vertical
							±10'				
IIe	Ee	4	4'- 6	1	1	1		*	*	*	vertical
	Fe	8	12'- 0	2	10	6		*	***	*	vertical
							+13'				
IIIe	He	5	6'- 0	2	3	2		**	*	**	vertical
	Je	5	7'- 0	2	4	3		***	*	**	vertical
	Le	8	13'- 0	3	12	7		***	**	*	vertical
							±11'				
IVe	Ke	15	26'- 0	4	12	8		**	****	*	vertical
							±16'				
Ve	De1	3	4'- 0	1	1	1		*	*	*	vertical
	De3	15	23'- 0	1	6	3		*	*	*	vertical
	De4	5	10- 0	1	1	1		*	*	**	vertical
							±15'				

tes: *None

**Presence of crack is not probable since only at one or two test line location(s).

***Presence of crack is probable since indication at several test locations but not interconnected with top crack.

****Similar to *** except probably interconnected with top crack.

TABLE 2 - SUMMARY OF CRACKS EAST SIDE OF RCB (Cont'd)

amily	Crack I.D.	Top Crack: Test Lines	Top Crack: Length (exposed)	Top Crack: Depth (ft.) Min	Top Crack: Depth (ft.) Max	Top Crack: Depth (ft.) Average	Family Spacing	Presence of Subsurface Cracks (See Notes): Bottom Crack: Below Bottom Re-bar	Presence of Subsurface Cracks (See Notes): Bottom Crack: Through Bottom Re-bar	Presence of Subsurface Cracks (See Notes): Middle Crack	Inclinatio
VIe	De5	17	24'-0	1	10	3		***	*	***	vertical
	De6	5	7'-3	2	6	4		**	*	*	vertical
							± 15'				
	De7	9	12'- 0	1	6	3		*	**	***	vertical
VIIe	De8	8	10'- 0	1	3	2		*	***	***	vertical
	De9	11	15'- 0	1	5	2		**	*	***	vertical

otes: *None

**Presence of crack is not probable since only at one or two test line location(s).

***Presence of crack is probable since indication at several test locations but not interconnected with top crack.

****Similar to *** except probably interconnected with top crack.

TABLE 3 - SUMMARY OF CRACKS BENEATH RCB

rack I.D.	Correlation with 1977 Mapping	Depth	Inclination	Spacing @ C.L. RCB	Remarks
6	None (Note 1)	Variable	vertical		All cracks are intermittent, based on NDT evaluation and 1977 Mapping Data.
				18'	
2	None (Note 1)	"	"		
				12'	
1	Yes	"	"		
				9'	
7	Partial	"	"		
				6'	
3	Yes	"	"		
				9'	
5	Partial	"	"		
				13'	
4	Yes	"	"		
			Average Spacing =	11'	

ote 1 - This crack was not identified during 1977 mapping of cracks beneath RCB.

TABLE 4 - SUMMARY OF CRACKS IN RCB WALLS

rack I.D.	Test Lines	Maximum Dept of Penetration (ft.)	Inclination	Remarks
RCB 1	3	1	Perpendicular to wall surface	Wall thickness = 10'- (
RCB 2	3	1	"	"
RCB 3	3	1	"	"
RCB 4	3	1	"	"

APPENDIX 1

REINFORCING STEEL STRESS AS DEFINED BY CRACK WIDTH

Assumptions

Crack Width = .005 in.

Crack Spacing = 11 ft.

Method 1

By Gergely & Lutz equation ("Causes, Evaluation and Repair of Cracks in Concrete", ACI 224, ACI Journal May-June 1984, p. 218).

$$\omega = 0.076\ \beta\ f_s\ \sqrt[3]{d_c A_1} \times 10^{-3}$$

$$A_1 = 6 \times 8.5 = 51 \text{ in}^2$$

$$\beta = \frac{10.5}{10.125} = 1.04$$

$$d_c = 4.25 \text{ in}$$

$$\omega = 5 \text{ mils}$$

$$f_s = 10{,}500 \text{ psi} = 10.5 \text{ ksi}$$

Method 2

By average strain

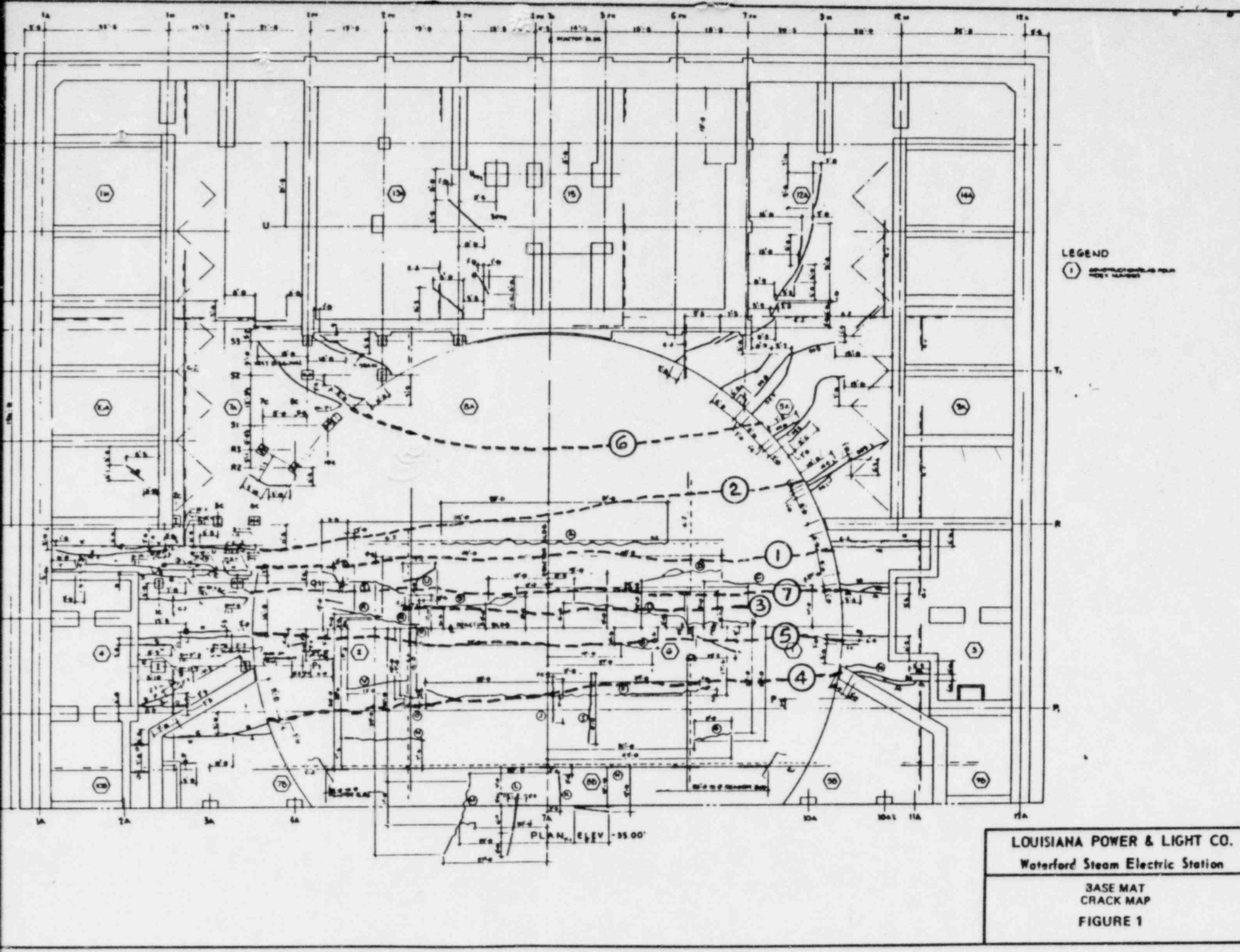
Say 3 cracks in each family with each crack having width of .005 in. and a crack family spacing of 11 ft.

$$\Delta = 3 \times .005 \text{ in} = .015 \text{ in}$$

$$\delta = \frac{.015 \text{ in}}{11 \text{ ft} \times 12} = 1.136 \times 10^{-4} \text{ in/in}$$

$$E = \frac{f_s}{\delta}$$

$$f_s = \delta \times 30 \times 10^6 = 3409 \text{ psi} = 3.4 \text{ ksi}$$

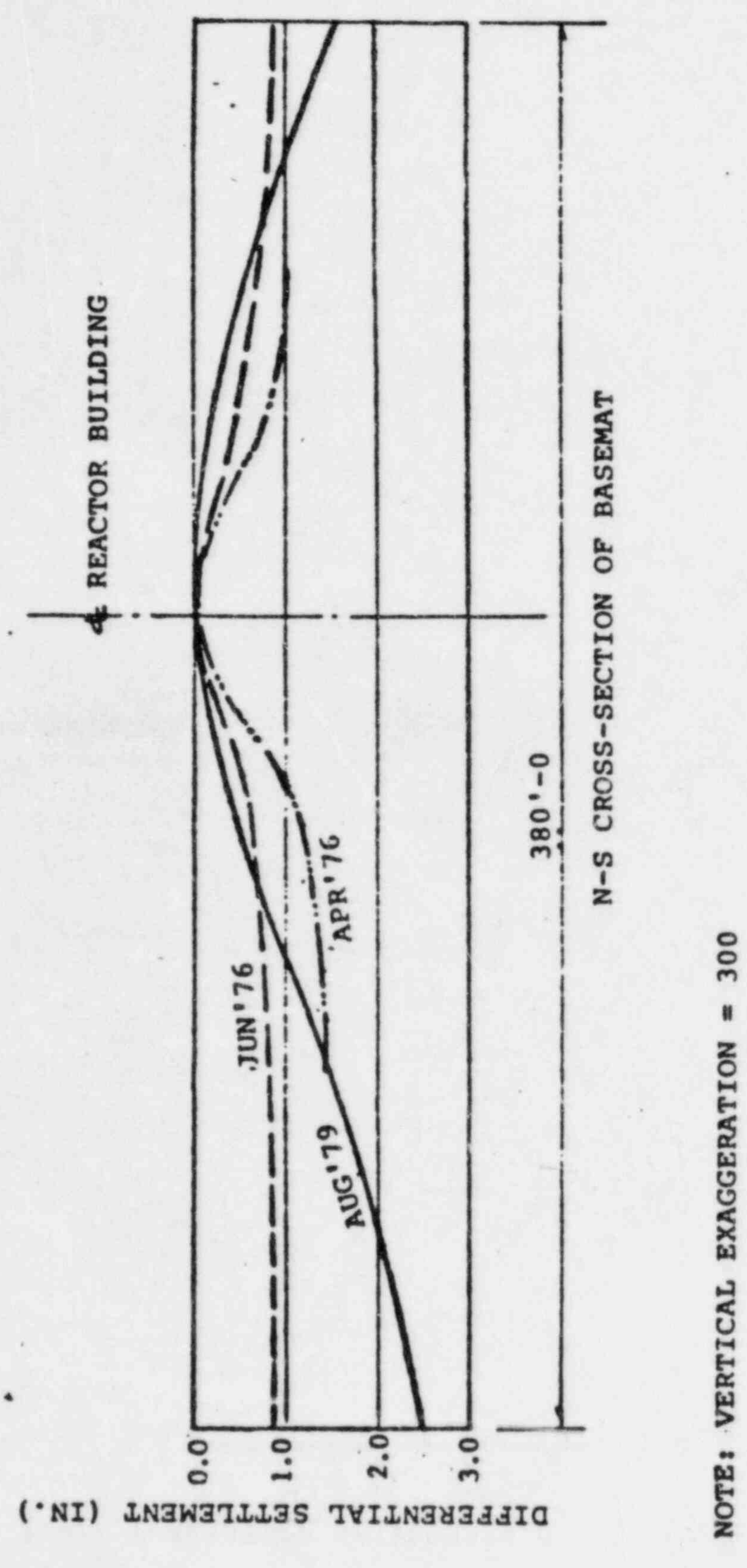


LOUISIANA POWER & LIGHT CO.

Waterford Steam Electric Station

BASE MAT
CRACK MAP

FIGURE 1



DATE	WATERFORD SES UNIT NO. 3 BASEMAT CURVATURE	Figure 2

Bruce Churchill

RELATED CORRESPONDENCE

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

MIDDLE SOUTH UTILITIES SYSTEM

DOCKETED USNRC

November 7, 1984

'84 NOV 13 A11:28

OFFICE OF SECRETARY DOCKETING & SERVICE BRANCH

W3P84-3152
3-A1.16.07
3-A1.01.04
A4.05

Director Of Nuclear Reactor Regulation
ATTN: Mr. Dennis M. Crutchfield, Asst. Director
for Safety Assessment
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUBJECT: WATERFORD 3 SES
ADDITIONAL INFORMATION ON BASEMAT
HAIRLINE CRACKS

References:
1. Letter W3P84-3044, K.W. Cook to D.M. Crutchfield, dated October 26, 1984.
2. Letter W3P84-3142, K.W. Cook to D.M. Crutchfield, dated November 7, 1984.
3. Letter, D.M. Crutchfield to J.M. Cain dated October 19, 1984.

Dear Mr. Crutchfield:

The purpose of this letter is to supplement the additional information, provided in References 1 and 2, in response to the requests in your letter of October 19, 1984.

A report detailing the ultrasonic testing results on the hairline cracks in the basemat, performed by Meunow and Associates, was submitted by Reference 1 for staff review. On November 2, 1984, the NRC staff requested LP&L to provide confirmation that the locations internal discontinuities under the Reactor Containment Building can be related to the mat concrete and are not affected by the fill concrete above the mat. Muenow and Associates, Inc. has performed ultrasonic testing of the interface between the top of the basemat and the bottom of the fill concrete. These results are summarized in the attached supplement to the report issued via Reference 2. The tests did indeed confirm the original assumption that sonic energy was not penetrating the fill concrete to a significant degree and that the internal reflectors identified are located in the basemat concrete.

If you have any questions regarding the transmittal please call.

Very truly yours,

K.W. Cook
Nuclear Support & Licensing Manager

KWC:sms

ATTACHMENT

cc: E.L. Blake (NRC), G.L. Constable (NRC), W.M. Stevenson, J.T. Collins (NRC), J.H. Wilson (NRC)

Muenow and Associates, Inc.
MATERIALS AND NONDESTRUCTIVE TESTING
3940 HUNTCLIFF DR.
CHARLOTTE, NORTH CAROLINA 28211
(704) 377-4041 · (704) 542-2223

APPENDIX NO.5

NONDESTRUCTIVE TEST EVALUATION
OF BASEMAT CONCRETE
WATERFORD NO. 3
LOUISIANA POWER AND LIGHT CO.

On November 7, 1984, a series of NDT pulse echo tests were conducted at the Waterford No. 3 plant of the Louisiana Power and Light Co. The purpose of our additional investigation was based upon inquiries by the NRC and their consultant, Brookhaven National Laboratories, as to adhesion or bonding between fill concrete within the RCB and foundation mat concrete.

In specific; the question was, "how can the location of internal discontinuities be pinpointed to the mat concrete and not actually located in the fill concrete".

Our answer, at the time of inquiry was, "that by transducer test locations and manipulation, we felt that the transmitted sonic energy never entered the fill concrete because of a nonbond condition at that interface". However, this assumption was based upon indirect test data and it was suggested, that a more direct test program be conducted. As a result, a series of tests using 0° and 45° transducers, see drawing number 1, were conducted from the top of fill concrete, around the annulus, down to the mat-fill concrete interface. See drawings numbered 2 for test locations.

Test criteria was set at 50 feet of vertical time propagation for our 0° transducer; and a false back reflector was set at 100 feet of time propagation for our 45° transducer. Both time propagation limits allowed for sufficient travel time to penetrate the mat-fill interface by at least 15 to 20 percent of total travel distance. As a point of interest, illustrating that the pulse echo system was operating within its established guidelines; noncontinuous internal discontinuities were identified at approximately 15 feet above the mat-fill concrete interface. These reflectors were identified to be a "shelf of concrete" used during construction to support an "A" frame structure for containment vessel erection.

Test data indicates that a nonbond condition exists at 20 of our 24 test locations. This substantiates our original assumption; that sonic energy could not be penetrating the fill concrete, and that internal reflectors are located in the mat concrete.

At test locations 9, 17, 19 and 22 minor amounts of bond were apparent as evidenced by a reflection from the basemat bottom. However, strong amplitude reflectors were received from the mat-fill concrete interface, also. These strong amplitude reflectors would indicate that only minor amounts of energy were transmitted through the interface, with a majority of the energy reflecting from the mat-fill concrete interface.

It would be our opinion, based upon this test program and prior test data, that sufficient nonbonding exists at the mat-fill concrete interface to preclude sonic energy from entering and reflecting from the fill concrete interior. Furthermore, the intermittent character of the slight bond, that does exist, would not be capable of producing the positive and high amplitude reflectors upon which our original crack location data is based.

BY ______ DATE ______ SHEET ______ OF ______

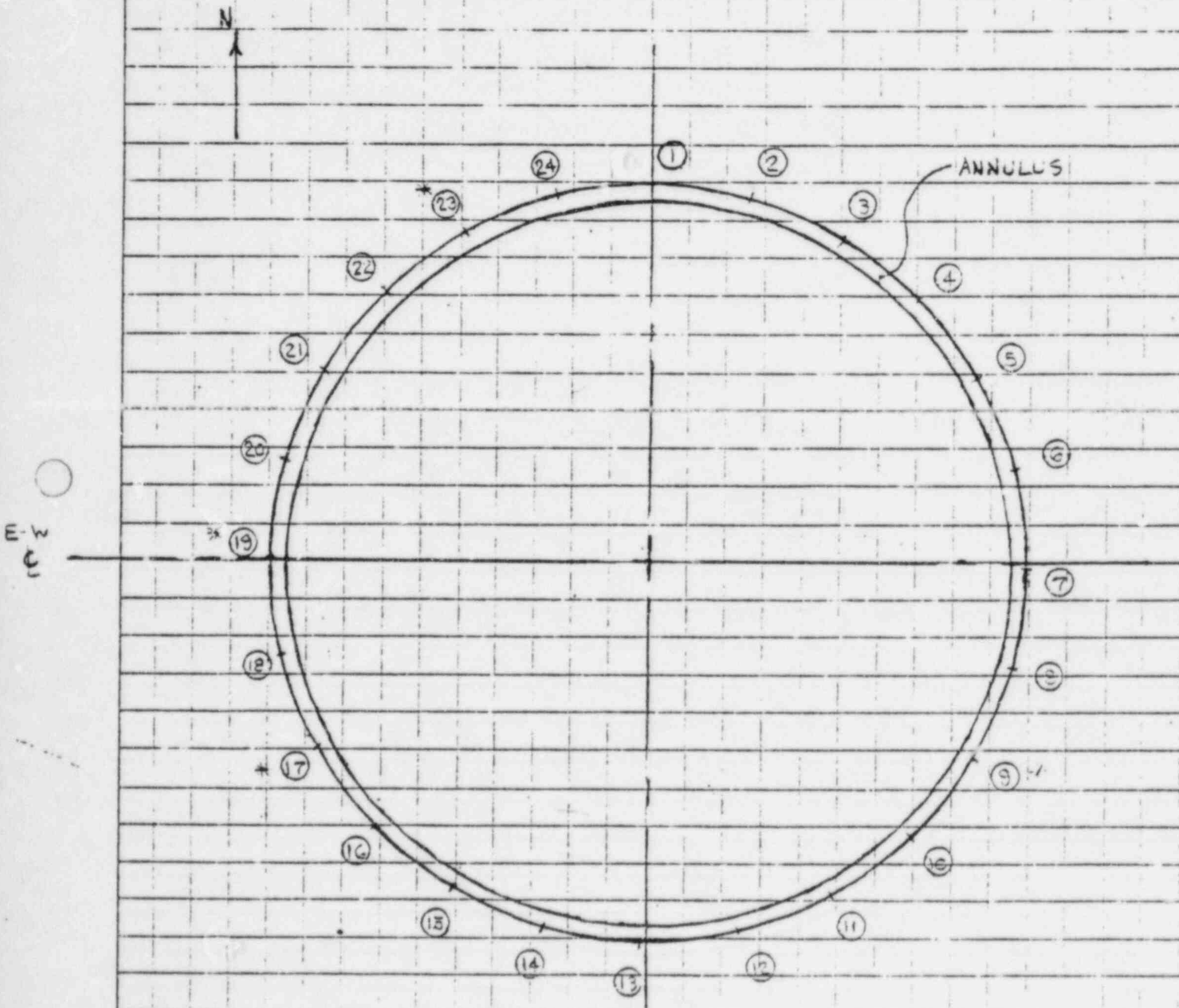
CHKD. BY ______ DATE ______ DEPT. ______

DRAWING NO 2

PROJECT ______

SUBJECT ______

LOCATION OF TEST POINTS



* INDICATES TEST POINTS AT WHICH SOME BONDING EXISTS

NOTES - ALL TEST POINTS WERE TAKEN APPROXIMATELY AT THE ℄ OF THE ANNULUS

- ALL TEST POINTS WERE TAKEN AT APPROXIMATELY 20 FT INTERVALS

N-S ℄

BY ________ DATE ________ SHEET ____ OF ____

CHKD. BY ________ DATE ________ DEPT. ____

DRAWING NO. 1

PROJECT ________

SUBJECT ________

TRANSDUCER COVERAGE WITH
0° & 45° TRANSDUCER