UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
DUKE POWER COMPANY, et al.	)	Docket Nos. 50-413
	)	50-414
(Catawba Nuclear Station, Units 1 and 2)	)	

APPLICANTS' INTERROGATORIES AND REQUESTS TO PRODUCE DOCUMENTS ON DIESEL GENERATOR CONTENTION TO CAROLINA ENVIRONMENTAL STUDY GROUP AND PALMETTO ALLIANCE

Pursuant to 10 C.F.R. §§ 2.740b and 2.741 and in accordance with the Licensing Board's Order dated February 23, 1984, and the expedited hearing schedule established by the Board (Tr. 12,545-46), Duke Power Company, et al. ("Applicants") hereby serve Applicants' Interrogatories and Requests to Produce on the Diesel Generator Contention upon Intervenors, Carolina Environmental Study Group (CESG) and Palmetto Alliance (PA). These interrogatories involve the joint Intervenor contention on the adequacy of design of diesel generator crankshafts.

Each interrogatory shall be answered in writing, under oath or affirmation, and include all pertinent information known to CESG or PA, their officers, directors or members as well as any pertinent information known to their employees, advisors or counsel. Each request to produce applies to pertinent documents which are in the possession, custody or control of CESG or PA,

their officers, directors or members as well as their employees, advisors or counsel. In answering each interrogatory and responding to each request, please recite the interrogatory or request preceding each answer or response. Also, please identify the person providing each answer or response.

These interrogatories and requests shall be continuing in nature. Thus, any time CESG or PA obtains information which renders any previous response incorrect or indicates that a response was incorrect when made, CESG or PA should supplement its previous response to the appropriate interrogatory or request to produce. CESG or PA should also supplement its responses as necessary with respect to identification of each person expected to be called at the hearing as an expert witness, the subject matter of his or her testimony, and the substance of that testimony. Applicants are particularly interested in the names and areas of expertise of CESG's or PA's witnesses, if any. Each identification of such witnesses is necessary if Applicants are to be afforded adequate time to depose them.

The term "document" shall include any writings, drawings, graphs, charts, photographs, and other data compilations from which information can be obtained. We request that at a date or dates to be agreed upon, CESG or PA make available for inspection and copying, all documents subject to the requests set forth below.

REQUESTS FOR DOCUMENTS

Pursuant to 10 C.F.R. § 2.741, Applicants request CESG and PA by and through their attorneys to make available for inspection and copying at a time and location to be designated, any and all documents, of whatsoever description, identified in the responses to the Applicants' interrogatories below, including but not limited to:

(1) any written record of any oral communication between or among Intervenors, their advisors, consultants, agents, attorneys and/or any other persons, including but not limited to the NRC Staff, the Applicants and their advisors, consultants, agents, attorneys and/or any other persons; and

(2) any documents, correspondence, letter, memorandum, notes, diagrams, reports, charts, photographs, or any other writing of whatsoever description, including but not limited to work papers, prior drafts, and notes of meetings.

If CESG or PA maintains some documents should not be made available for inspection, it should specify the documents and explain why such are not being made available. This request extends to any such document, described above, in the possession of CESG or PA, its advisors, consultants, agents or attorneys.

INTERROGATORIES

Pursuant to 10 C.F.R. § 2.740b, the Applicants request CESG or PA by and through its attorneys, to answer separately and fully in writing under oath or affirmation, by persons having knowledge of the information requested, the following general and specific interrogatories.

A. General Interrogatories

The following interrogatories apply to the diesel generator contention admitted as an issue in controversy in this proceeding.

1. Please state the full name, address, occupation and employer of each person answering the interrogatories and designate the interrogatory or the part thereof he or she answered.

2. Please identify each and every person whom you are considering to call as a witness at the hearing in this matter on this contention, and with respect to each such person, please:

   a. State the substance of the facts and opinions to which the witness is expected to testify;

   b. Give a summary of the grounds for each opinion; and

c. Describe the witness' educational and professional background.

3. Is the contention based on one or more calculations? If so:

a. Describe each calculation and identify any document setting forth such calculation.

b. Who performed each calculation?

c. When was each calculation performed?

d. Describe each parameter used in such calculation and each value assigned to the parameter, and describe the source of your data.

e. What are the results of each calculation?

f. Explain in detail how each calculation provides a basis for the contention.

4. Is the contention based on one or more experiments or tests? If so:

a. Describe each experiment or test and identify any document setting forth such experiment or test.

b. Who performed each experiment or test?

c. When was such experiment or test performed?

d. Describe each parameter or variable measured in such experiment or test.

e. What are the results of each experiment or test?

f. Explain in detail how each experiment or test provides a basis for the contention.

5. Is the contention based upon conversations, consultations, correspondence or any other type of communication with one or more individuals? If so,

a. Identify by name and address each such individual.

b. State the educational and professional background of each such individual, including occupation and institutional affiliations.

c. Describe the nature of each communication with such individual, when it occurred, and identify all other individuals involved.

d. Describe the information received from such individuals and explain how it provides a basis for the issue.

e. Identify each letter, memorandum, tape, note or other record related to each conversation, consultation, correspondence, or other communication with such individual.

6. Is the contention based upon one or more NRC Staff documents? If so, please identify such documents and make them available for inspection and copying.

B. Specific Interrogatories

1. Identify what you believe to be the relevant design standards which apply to diesel generator crankshaft design. Identify any and all documents upon which you base your response.

2. State any standards which you contend have been violated and the bases for your response.

3. Do you contend that the design of the diesel generator crankshafts at the Catawba nuclear station is inadequate? If your response is in the affirmative, identify each aspect in which you contend such design is inadequate and state specifically the bases for your conclusion.

4. What data, experiments, calculations or operational history is relied upon to support the assertion that the Catawba crankshaft design is inadequate? State with particularity those data, experiments,

calculations or operational history which you believe to be directly applicable to the Catawba nuclear station diesel generator crankshafts.

5. State the differences between the data, experiments or operational history relied upon in response to question 3 and that which characterizes the Catawba diesel generator crankshafts. State further the assumptions used to apply this data to the Catawba diesel generator crankshafts.

6. State and describe fully all failures in diesel generator crankshafts while in nuclear power plant application upon which you rely to support your contention.

7. What are the Diesel Engine Manufacturers Association (DEMA) standards?

8. Are the DEMA standards applicable to diesel generator design for use in nuclear power plant application?

   a. If your answer is in the affirmative, do you contend that such standards are inadequate for such use? If so, please identify and specify with particularity the bases for your response, and explain in detail the bases for your response. Identify the standards which you believe should be applicable and explain why you believe each such standard should apply.

b. If your answer is in the negative, explain in detail the bases for your conclusion. In addition, identify the standards you believe should be applicable and explain why you believe each such standard should apply.

9. Based upon your answer in question 8, state the particular standards and their corresponding values that you believe to be applicable to diesel generator crankshaft design. Identify and specify with particularity the bases for your response, and explain in detail the bases for your response.

10. Identify the number, type, model and engine configuration of the Shoreham diesel generators. State whether and to what extent any or all of the Shoreham diesel generator crankshafts have failed. State further where such failures have occurred, how such failures have occurred and why such failures have occurred.

Questions 11 through 39 refer to the Failure Analysis Associates (FaAA) reports dated October 31, 1983. These reports are entitled "Emergency Diesel Generator Crankshaft Failure Investigation Shoreham Nuclear Power Station" and "Analysis of the Replacement Crankshafts for Emergency Diesel Generators Shoreham Nuclear Power Station." These documents were included in Board Notification 83-160A, dated November 17, 1983, as

enclosures 1 and 2, respectively. The Transamerica Delaval, Inc. harmonic load coefficients referred to in the following questions are included as part of enclosure 2 to Board Notification 84-013, dated January 24, 1984. Palmetto Alliance, Robert Guild (PA Counsel) and Jesse L. Riley (CESG spokesperson) are on the distribution list for these Board Notifications.

11. The FaAA report concerning the crankshaft failure investigation concluded that the Shoreham diesel generator crankshaft failures were caused by high-cycle torsional fatigue. Do you agree with this conclusion? If your answer is in the negative, state the basis for your conclusion and explain fully.

12. For the purposes of this and succeeding questions, the Transamerica Delaval, Inc. (TDI) harmonic load coefficient (T_n) values represent the amplitude of the harmonic loads (maximum amplitude) due to the cylinder gas pressure as well as the inertia effects of the piston and connecting rod, converted to a force tangential to the crank throw and normalized by dividing by the piston area and crank throw radius. Given that, for the original Shoreham 13 x 11 crankshafts, TDI originally calculated the crank pin peak-to-peak average torsional stress for a single order of vibration to be 2600 psi using its 1975 group 1 harmonic coefficients and given further that TDI

calculated this stress to be 5370 psi using TDI 1983 group 4 harmonic coefficients and that this latter TDI-calculated stress exceeds the DEMA recommendation of less than 5000 psi, do you agree that this indicates that the crank pin was overstressed by industry standards and that it indicates the error in the original design? If your answer is in the negative, state the bases for your conclusion, including reference to applicable industry standards, identifying and explaining what you believe to be the error in the original design.

13. Given that, for the original Shoreham 13 x 11 crankshaft, FaAA calculated the crank pin peak-to-peak average torsional stress for a single order of vibration to be 5790 psi employing a modal superposition technique and that the DEMA recommendation is that such stress should be less than 5000 psi, do you agree that the crank pin is overstressed by industry standards and that this indicates the error in the original design? If your answer is in the negative, state the bases for your conclusion, including reference to applicable industry standards, identifying and explaining what you believe to be the error in the original design.

14. Given that, for the original Shoreham 13 x 11 crankshaft, FaAA calculated the crank pin peak-to-peak average torsional stress from all major harmonic orders and modes to be 8910 psi and that the DEMA recommendation is for the average torsional stress from all major harmonic orders to be less than 7000 psi, do you agree that the crank pin is overstressed by industry standards and that this indicates the error in the original design? If your answer is in the negative, state the bases for your conclusion, including reference to applicable industry standards, identifying and explaining what you believe to be the error in the original design.

15. Do you agree with the FaAA conclusion that the values of the harmonic coefficients (T_n) in the TDI 1975 analysis of the 13 x 11 crankshaft are inappropriate? State the basis for your conclusion.

16. Do you agree that the 1983 values of the TDI harmonic coefficients (T_n) are appropriate? If the answer is in the negative, state the basis for your conclusion and provide values of T_n you believe to be appropriate and explain why you believe such values to be appropriate in lieu of TDI's 1983 values.

17. Do you agree that, for the Shoreham in-line 8 cylinder diesel generator crankshafts, the 4th order harmonic is the most important because it produces the highest contribution to total stress at the machine's operating speed of 450 rpm? If the answer is in the negative, state the basis for your conclusion, identifying the harmonic you believe produces the highest contribution to total stress.

18. Do you agree with the FaAA finite element model employed to calculate stresses in the fillet region of the Shoreham crank pin? If the answer is in the negative, state the basis for your conclusion. If you do not so agree, identify the method which you believe should be employed to calculate such stresses and explain in detail why you believe each such method is preferrable to the FaAA finite element model.

19. Do you agree with the FaAA conclusion that the fatigue crack in Shoreham diesel generator 102 (DG102) crankshaft started in a score mark on the machined surface of the fillet where a crank pin journal blends into a web section? If the answer is in the negative, state the basis for your conclusion explaining what you believe the point of origin to be and the reason for such point of origin.

20. Do you agree with the FaAA conclusion that the finite element model calculation of the location, magnitude and direction of the maximum principal stress of the Shoreham 13 x 11 crankshaft is in close agreement with results of experimental strain gage measurements on the intact Shoreham diesel generator 101 (DG 101) crankshaft? If the answer is in the negative, state the basis for your conclusion.

21. Do you agree with the FaAA conclusion that the finite element model calculation of the principal stress range of the Shoreham 13 x 11 crankshaft falls within the range of measured fatigue endurance limits from tests on large crankshafts of similar material? If the answer is in the negative, state the basis for your conclusion.

22. Do you agree with the FaAA conclusion that the large number of stress cycles at or very close to the fatigue endurance limit, accumulated over a few hundred hours of running time, has resulted in the observed field fatigue cracks in the Shoreham 13 x 11 crankshafts? If the answer is in the negative, state the basis for your conclusion, explaining what you believe the cause to be and the reason for such cause.

23. Do you agree with the FaAA conclusion that a metallurgical failure analysis of the fractured crankshaft from Shoreham diesel generator 102 (DG 102) showed that failure occurred by fatigue? If the answer is in the negative, state the basis for your conclusion, explaining what you believe the cause to be and the reason for such cause.

24. Do you agree with the FaAA conclusion that the location and orientation of the fatigue crack in Shoreham DG 102 crank pin indicates that torsional stresses were responsible for the fatigue crack formation? If the answer is in the negative, state the basis for your conclusion, explaining what you believe the cause to be and the reason for such cause.

25. Do you agree with the FaAA conclusion that the Shoreham DG 102 crankshaft is metallurgically sound and that its composition, microstructure, and properties are appropriate and in compliance with pertinent specifications? If your answer is in the negative, state the basis for your conclusion, explaining with respect to the composition, microstructure and properties why you do not agree and why any of these factors is not in compliance with pertinent specifications.

26. Do you agree with the FaAA conclusion that the fatigue failure of the Shoreham DG 102 crankshaft occurred because the crankshaft experienced excessively high cyclic mechanical loads during testing? If the answer is in the negative, state the basis for your conclusion, identifying mechanisms which you believe contributed to or caused the failure and explaining why you believe each such mechanism so contributed to a greater extent than mechanical loads.

27. Given that during the startup tests of the Shoreham crankshaft, FaAA observed no large strain excursions and given further that the torques experienced during startup are much smaller than those resulting from dynamic oscillation at full power, do you agree with the FaAA conclusion that the possibility of low-cycle fatigue failure is remote? If the answer is in the negative, state the basis for your conclusion.

28. Do you agree with the FaAA conclusion that of the possible causes of bending fatigue -- bearing misalignment, piston loads applied to the crankshaft between main journals, and the transfer of torque through the crankshaft throws, only the latter source is most significant and contributed directly to the fatigue loading? If the answer is in the negative,

state the basis for your conclusion, explaining specifically why the former sources or other factors are more significant contributors.

29. Do you agree with the FaAA conclusion that measurements of crankshaft torque and displacement and calculations of the dynamic response of the system show that the electrical restoring torque on the generator rotor if the rotor speed varies from synchronous is negligible compared with that associated with the 4th harmonic and, therefore, operation with the generator synchronized with the grid was not the cause of fatigue? If the answer is in the negative, state the basis for your conclusion, explaining what contribution you believe electrical restoring torque would have on total stress and why this is a non-negligible stress compared with the 4th harmonic stress.

30. Do you agree with the FaAA conclusion, that in the absence of operating log references to increased exhaust temperature, and the consistency of cracking among the three original Shoreham 13 x 11 crankshafts, no malfunctions of fuel injectors occurred causing severe torsional loading which resulted in the crankshaft failure? If the answer is in the negative, state the basis for your conclusion.

31. Do you agree with the FaAA conclusion that the metallurgical examination of the DG 102 crankshaft failed to identify any material or surface property that would have contributed to fatigue cracking? If the answer is in the negative, state the basis for your conclusion, explaining why you believe this conclusion is erroneous and how it will affect the analysis of the failed crankshaft.

32. Given that the fillets in the Shoreham crankshafts underwent on the order of 10^7 cycles of the largest torsional oscillation, do you agree with the FaAA conclusion that the stress amplitudes were close to the fatigue limit? If the answer is in the negative, state the basis for your conclusion.

33. Assuming that the stress amplitudes were close to the fatigue limit, do you agree with the FaAA conclusion that for a relatively small reduction in stress or slight improvement in surface fatigue strength, the original Shoreham 13 x 11 crankshafts could have been run indefinitely? If the answer is in the negative, state the basis for your conclusion.

34. What is the effect on stress reduction of increasing the Shoreham crank pin diameter from 11 to 12 inches? Provide bases for your answer.

35. Does increasing the diameter of the Shoreham crank pin from 11 to 12 inches stiffen the crankshaft? Provide the bases for your answer.

36. Does stiffening the crankshaft reduce the amplitude of oscillating torque, thereby reducing the crank pin peak-to-peak average stress resulting from the application of the torque? Provide the bases for your answer.

37. Given that the TDI analysis of the 13 x 12 Shoreham crankshaft yields a crank pin peak-to-peak average torsional stress due to the 4th order harmonic of 2990 psi and given further that the FaAA modal superposition analysis yields a value of 3300 psi for the same harmonic order stress, values both of which are less than the DEMA recommendation of less than 5000 psi, does this indicate that the 13 x 12 crankshaft is designed within industry standards?

    a. If your answer is in the affirmative, is it your position that these standards are adequate? If not, explain why the standards are inadequate and what standards should apply.

    b. If your answer is in the negative, explain why you believe the crankshafts are not designed within applicable industry standards.

38. Given that the FaAA modal superposition analysis of the 13 x 12 crankshaft yields an average torsional stress due to summation of harmonic orders and modes of 5640 psi and given further that the DEMA recommendation is that such stress should be less than 7000 psi, does this indicate that the 13 x 12 crankshaft meets accepted industry standards?

    a. If your answer is in the affirmative, is it your position that these standards are adequate? If not, explain why the standards are inadequate and what standards should apply.

    b. If your answer is in the negative, explain why you believe the crankshafts are not designed within applicable industry standards.

39. Do you agree with the FaAA conclusion that for the 13 x 12 Shoreham crankshafts, since the maximum stress range is predicted to be 37 ksi compared with 66 ksi at the location of the fatigue crack in the old 13 x 11 design, this factor of 1.78 difference in stress will be adequate to provide indefinite fatigue life for the new crankshafts? If the answer is in the negative, state the basis for your conclusion, explaining what factor of difference you believe would be adequate.

40. For a given input vibratory torque, how does torsional stress vary with crank pin diameter?

41. For a given input vibratory torque, how do stresses vary in the crank pin fillet region as a function of fillet radius?

42. What is the effect of increasing the size of the web which connects the crank pin to the main journal?

43. What is the effect of changing the shape of the web from a flat-sided shape to a circular shape?

44. What is the effect of increasing the crank pin diameter from 11 inches to 13 inches?

45. What is the effect of increasing the crank pin fillet radius from 1/2 inch to 3/4 inch?

46. What is the effect of the use of counterweights?

47. What is a torsiograph test?

48. What is the effect of torsiograph confirmation of the first mode natural frequency of the crankshaft on the confidence one has in the accuracy of the mathematical model used?

49. Do you agree with the FaAA conclusion that the major portion of the response for the Shoreham engine comes from the first flexible mode? If the answer is in the negative, state the basis for your conclusion, detailing your explanation of the source of the major response.

50. Do you agree that the vibratory torque exciting the shaft can be represented by the combined effect of appropriate harmonic load coefficients (T_n) (including the inertia effects of the piston and the connecting rod), the cylinder firing sequence and the engine configuration? If the answer is in the negative, state the basis for your conclusion, explaining what mechanisms you believe represent the vibratory torque.

51. Do you agree that, for diesel engines of the type used at Catawba, the general trend of the harmonic load coefficient amplitudes (T_n value) is to decrease with increasing harmonic order? If the answer is in the negative, state the basis for your conclusion, explaining how harmonic load coefficients vary with increasing harmonic order.

52. Would you expect the harmonic load coefficients for the Shoreham in-line 8 cylinder and Catawba V-16 cylinder engines to be similar? If your answer is in the negative, what differences would you expect between the harmonic load coefficients for the two machines? Explain the bases for your conclusions.

53. Using your conclusions from Questions 50 and 51, what major trend in the torsional vibratory response can be expected between the Shoreham in-line 8 cylinder engine and the Catawba V configuration 16 cylinder engine if

the first mode natural frequencies are 35.5 Hz and 28.85 Hz, respectively for the Shoreham and Catawba machines? State the basis for your conclusion.

54. Using your conclusions from questions 40 and 52, what comparisons can be made between the vibratory shaft stresses of the Shoreham and Catawba machines for which the Catawba crank pin diameter is 13 inches whereas the original Shoreham crank pin diameter is 11 inches?

55. Given that the Shoreham crankshaft with 11 inch crank pin has a single order stress calculated to be 5790 psi, given that the Catawba crankshaft with 13 inch crank pin has a single order stress of 2389 psi, and given that the DEMA recommendation is that single order stress be less than 5000 psi, does this indicate that the design of the Catawba crankshafts meets industry standards?

    a. If your answer is in the affirmative, is it your position that these standards are adequate? If not, explain why the standards are inadequate and what standards should apply.

    b. If your answer is in the negative, explain why you believe the crankshafts are not designed within applicable industry standards.

56. Given the calculated stress values detailed in question 55, do these stress values indicate that the Catawba crankshafts will not be susceptible to the cracking problems encountered in the original Shoreham crankshafts? If your answer is in the negative, state the bases for your conclusion, explaining why the Catawba crankshafts will be susceptible to cracking.

57. Given that the total average stress for the Shoreham crankshaft with 11 inch crank pin is calculated to be 8910 psi, given that the total average peak-to-peak stress for the Catawba crankshaft with 13 inch crank pin is calculated to be 5084 psi, with a peak value of 6053 psi, and given further that the DEMA recommended value for such stress is less than 7000 psi, does this indicate that the design of the Catawba crankshafts meets industry standards?

a. If your answer is in the affirmative, is it your position that these standards are adequate? If not, explain why the standards are inadequate and what standards should apply.

b. If your answer is in the negative, explain why you believe the crankshafts are not designed within applicable industry standards.

58. Given the calculated stress values detailed in question 57, do these stress values indicate that the Catawba crankshafts will not be susceptible to the cracking problems encountered in the original Shoreham crankshafts? If your answer is in the negative, state the bases for your conclusion, explaining why the Catawba crankshafts will be susceptible to cracking.

59. What is the effect on stress concentration of a shot-peened surface finish on the fillet radius between the web and crank pin?

60. What is the combined effect of increased web area fillet radius, application of counterweights and shot-peened fillet radius surface finish on stress concentrations in the web fillet area?

Respectfully submitted,

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March 11, 1984

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NUCLEAR REGULATORY COMMISSION

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CERTIFICATE OF SERVICE

I hereby certify that copies of "Applicants' Interrogatories and Request to Produce Documents on Diesel Generator Contention to Carolina Environmental Study Group and Palmetto Alliance" in the above captioned matter has been served upon the following by deposit in the United States mail this 11th day of March, 1984.

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