Duquesne Light

Nuclear Construction Division
Robinson Plaza, Building 2, Suite 210
Pittsburgh, PA 15205

2NRC-5-049
(412) 787-5141
(412) 923-1960
Telecopy (412) 787-2629

March 25, 1985

United States Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Mr. Hugh L. Thompson, Jr., Director
Division of Licensing
Office of Nuclear Reactor Regulation

Mr. James P. Knight, Director
Division of Engineering
Office of Nuclear Reactor Regulation

SUBJECT: Beaver Valley Power Station - Unit No. 2
Docket No. 50-412
Soil-Structure Interaction - Additional Information

REFERENCE: DLC letter 2NRC-5-016, dated February 1, 1985

Gentlemen:

In letter 2NRC-5-016, dated February 1, 1985, we provided our response to the NRC Structural and Geotechnical Engineering Branch's (SGEB) Draft SER open item on Soil-Structure Interaction. DLC's position on this issue, which is stated in detail in that submittal, was discussed with members of the SGEB and Licensing Branch in a telephone conversation on February 12, 1985. In this conversation, the SGEB indicated that their position remains as stated in our November 30, 1984, meeting with them. The SGEB position requires that DLC provide a soil-structure interaction analysis with the free-field ground surface motion applied at the containment structure foundation level. However, the SGEB gave no indication as to whether they would address this request for information as a backfit as requested by DLC in our February 1, 1985, submittal.

DLC's position as provided in our February 1, 1985, submittal, can be summarized as follows:

> The information on soil-structure interaction that exists on the BVPS-2 docket provides a complete record for the satisfactory closure of this issue. Included on the BVPS-2 docket are two technically appropriate soil-structure interaction analyses (a finite element method analysis and a Kausel-Whitman, three-step method analysis) which demonstrate that BVPS-2 meets the underlying requirements of SRP 3.7.2.II.4. DLC believes that performing additional soil-structure interaction analyses using alternative methods will provide no meaningful additions to the existing record. In particular, DLC believes that the analysis requested by the SGEB

8504010188 850325
PDR ADOCK 05000412
A PDR

B001
1/1

would yield results which are neither physically representative of the actual site conditions nor technically appropriate.

To obtain an additional review of our position, DLC has assembled a panel of consultants to evaluate the soil-structure interaction analyses that have been docketed for BVPS-2. The panel consists of the following individuals:

E. M. Kausel, Ph.D. (Massachusetts Institute of Technology)
J. M. Roesset, Ph.D (University of Texas at Austin)
J. Lysmer, Ph.D (University of California at Berkeley)
I. M. Idriss, Ph.D (Woodward-Clyde Consultants)
D. E. Shaw, P.E. (Consultant)
C. W. Lin, Ph.D (Westinghouse Electric Corporation)

To accomplish the evaluation, representatives of DLC and Stone & Webster Engineering Corporation (SWEC) met with the panel members at SWEC offices in Boston, MA, on February 4, 1985. SWEC presented the docketed soil-structure interaction analyses to the panel at that meeting and the panel members were requested to provide written evaluations based on their review of these analyses. These evaluations have been provided and are attached.

DLC believes that the attached evaluations further substantiate our position. We would again like to state our willingness to meet with the SGEB staff and appropriate NRC management personnel to clarify any points in this or previous submittals if you feel such a meeting would facilitate the resolution of this issue. We would appreciate being informed as soon as possible of the NRC's status on this issue in order to avoid any unnecessary delays in reaching a resolution.

DUQUESNE LIGHT COMPANY

By J. J. Carey
J. J. Carey
Vice President

SUBSCRIBED AND SWORN TO BEFORE ME THIS
25 DAY OF March, 1985.

Sheila M. Fattore
Notary Public

SHEILA M. FATTORE, NOTARY PUBLIC
SHIPPINGPORT BORO, BEAVER COUNTY
MY COMMISSION EXPIRES SEPT. 16, 1985
Member, Pennsylvania Association of Notaries

JDO/wjs
Attachment

cc: Dr. W. Kerr, ACRS (w/a)
Dr. D. Okrent, ACRS (w/a)
Dr. C. P. Siess, ACRS (w/a)
Mr. G. E. Lear, NRC SGEB Chief (w/a)
Mr. B. K. Singh, Project Manager (w/a)
Mr. G. Walton, NRC Resident Inspector (w/a)

COMMONWEALTH OF PENNSYLVANIA)
) SS:
COUNTY OF BEAVER)

On this 25th day of March, 1985, before me, a Notary Public in and for said Commonwealth and County, personally appeared J. J. Carey, who being duly sworn, deposed and said that (1) he is Vice President of Duquesne Light, (2) he is duly authorized to execute and file the foregoing Submittal on behalf of said Company, and (3) the statements set forth in the Submittal are true and correct to the best of his knowledge.

Sheila M. Fattore
Notary Public

SHEILA M. FATTORE, NOTARY PUBLIC
SHIPPINGPORT BORO, BEAVER COUNTY
MY COMMISSION EXPIRES SEPT. 16, 1985
Member, Pennsylvania Association of Notaries

CAMBRIDGE MASSACHUSETTS 02139

Feb. 7, 1986

PHONE (617) 253- 5336

Dr. John T. Christian
Stone & Webster Engineering Corp.
245 Summer St.
Boston, MA 02107

Ref.: Seismic Analyses, Beaver Valley 2 Nuclear Power Station

Dear Dr. Christian:

In the course of my work as member of a consulting board to Duquesne Light Co., I had the opportunity to review in detail the procedures used by Stone & Webster in the analyses of the Beaver Valley 2 nuclear containment structure for soil-structure interaction effects. This letter is to give my strongest endorsement to these analyses. Specifically, the following points are worth emphasizing:

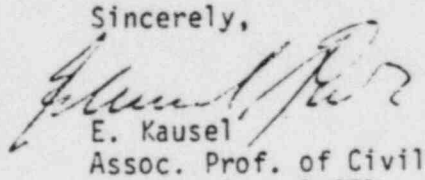
1) It is consistent with current practice and understanding to allow for reductions in the levels of earthquake ground motion in the free field resulting from wave interference. Such reductions are a necessary corollary of the computational models used, and to ignore or suppress them is tantamount to violations of demonstrable physical laws.

2) It can also be rigorously demonstrated that an embedded foundation is subjected to an excitation that differs from the motions that would have been observed at that location in the absence of the structure (i.e., in the free field). Such an effect, as you well know, is referred to as Kinematic Interaction. Thus, analyses such as Stone & Webster's, which account for this phenomenon, provide a more realistic description of the actual seismic event. On the other hand, use of the surface motion as input at the base of the structure is clearly erroneous, and should be vigorously rejected by Stone and Webster. Its use may not only lead to grossly overconservative results at some points in the structure, but to unconservative results at others, especially at higher elevations.

3) A comparison shown to me between the results of a finite element idealization of the BV2 system and an analysis with a spring and dashpot model (accounting for kinematic interactions) demonstrated excellent agreement, particularly when consideration is given to the widely different techniques employed. This is, perhaps, the strongest evidence that the analyses performed are beyond reproach.

In conclusion, it is my conviction that the soil-structure interaction analyses performed by Stone and Websger conform with current technical standards and state of the art.

Sincerely,



E. Kausel
Assoc. Prof. of Civil Engineering
M.I.T., Room 1-271

EK/jm

Jose M. Roesset, Sc.D.
Consulting Engineer

11909 Arch Hill Drive
Austin, Texas 78750
February 5, 1985

Dr. John T. Christian
Stone & Webster Engineering Corporation
245 Summer Street
Boston, Mass. 02107

Dear Dr. Christian:

At the request of Duquesne Light I have reviewed the various documents related to the seismic design and soil structure interaction analyses of the Beaver Valley Power Station #2, which were sent to me by Stone & Webster Engineering Corporation. These documents are:

1. Attachments A and B to letter, dated February 1, 1985, from E.J. Woolever, Duquesne Light Company to U.S. N.R.C. attention George W. Knighton.

2. Sections 3.7.1 and 3.7.2 of the FSAR for the Beaver Valley Power Station, unit 2.

3. Item 7 of attachment to letter, dated June 15, 1984, from E.J. Woolever, Duquesne Light Company to U.S. N.R.C. attention George W. Knighton.

In addition I attended a meeting at the offices of Stone & Webster on February 4, 1985, in which the background history of the analyses and the results obtained from the various models were presented by the Structural Staff of SWEC. Questions on the details of the analyses were asked at the meeting and answered by SWEC.

On the basis of these documents and the presentation of February 4, it is my opinion that the soil structure interaction analyses for the containment building of the Beaver Valley Power Station, unit 2, have been performed in a rational and competent manner, in a way which is in fact very similar to what I would have suggested or requested myself.

The analyses described in the Beaver Valley Power Station unit 2 FSAR were conducted using a two dimensional finite element model with the program PLAXLY, which is essentially the same as FLUSH. This was for many years the best available state of the art technique in engineering practice and it was widely used. The most significant question that had been raised in relation to the accuracy of this type of solution concerned the two dimensional idealization.

The new analyses were conducted using the three step, substructure or impedance approach using a three dimensional idealization of the soil and the foundation. This is the procedure I personally would prefer. A comparison of the results from the two series of analyses indicates good agreement, with the selected design spectra enveloping both solutions. This provides a desirable check on the reasonableness of the results, since different approximations were involved in the two formulations.

I understand a question has been raised about the fact that the control motion was specified at the free surface of the soil. This is, in my opinion, the best approach. A concern was raised some years ago about the fact that the corresponding, deconvoluted, motions at the foundation level in the free field would exhibit very sharp valleys in their response spectra around the natural frequency of the embedment layer. It is important to realize that:

a) these valleys are not so sharp when performing a kinematic interaction analysis and determining the motions at the foundation level accounting for the geometry of the excavation and the stiffness of the foundation, instead of the free field.

b) the foundation motions resulting from kinematic interaction have both a translational and a rotational component. Their combination may produce higher responses in some cases than direct use of the control motion at the foundation level. There is now mounting evidence that the decrease in the high frequency range of the translational motions predicted by theoretical considerations does in fact take place and the use of kinematic interaction is the most reasonable and realistic approach from a physical point of view as long as both translational and rotational components of motion are included.

c) the existence of sharp valleys in the response spectra is eliminated if analyses are conducted with logical variations in the soil properties and the final results are enveloped. This is the approach that was followed in the analyses for the containment building. Figure B.4 of attachment B to the letter of February 1, 1985, shows clearly that the envelope, design response spectrum at the base of the mat has only a very small decrease over the spectrum of the control motion in the range of 3 to 4 cps and is in fact larger at other frequencies. Thus not only is the procedure used correct but by enveloping results for various soil properties safeguards have been introduced to guarantee conservatism.

I do not find from my review any point I would contest or any issue that may lead to unrealistic or unconservative results.

Sincerely yours,

Jose M. Roesset

Jose M. Roesset

JOHN LYSMER, Ph.D.

Engineering Consultant
1968 Marin Avenue
Berkeley, California 94707
(415) 527-2615

File: SWE501B/EW8 February 8 , 1985

Dr. John T. Christian
Stone & Webster Engineering Corporation
P.O. Box 2325
Boston, Mass. 02107

Subject: Beaver Valley Power Station - Unit 2
Seismic Soil-Structure Interaction Analysis

Dear Dr. Christian:

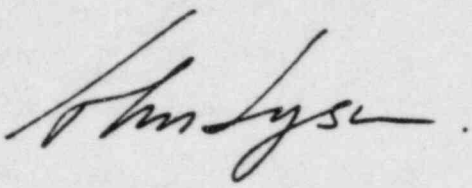
At the request of the Duquesne Light Company, I have reviewed Refs. 1, 2 and 3 which relate to the seismic soil-structure interaction analysis of the above plant. On February 4, 1985, I participated in a full-day meeting in your offices during which your technical staff presented further details and results of the different analyses which have been performed for the containment structure of the plant.

I am pleased to confirm that I consider your methods rational and in agreement with the current state of the art of seismic interaction analysis. By your methods, I refer to the complete finite element analyses performed by the computer program PLAXLY and the so-called 3-Step Method, including the kinematic interaction step. This last step must be included for the method to yield a proper solution to the equations of motion.

I agree that the seismic input motion is best defined at the ground surface in the free field. This does not conform with the most recent version, Rev. 1 - July 1981, of the U.S. NRC Standard Review Plan, Section 3.7.2, II, Paragraph 4.iii, which specifies that the controlling motion should be specified at the foundation level in the free field. This provision, however, has no rational basis and leads to unrealistic results if applied. A detailed explanation of this statement is given in Ref. 4. and there appears to be consensus within academic community on this matter.

You have in my opinion provided adequate checks on your results which also agree with my experience of how the plant should move if subjected to the specified event.

Sincerely yours,



John Lysmer

Professor of Civil Engineering
Univ. of Calif., Berkeley

References:

1. Attachments A and B to letter dated February 1, 1985.
   From: E. J. Woolever, Duquesne Light Company.
   To: U.S. NRC, attention George W. Knighton.

2. Beaver Valley Power Station - Unit 2 - F.S.A.R.,
   Sections 3.7.1 and 3.7.2

3. Item 7 of Attachment to letter dated June 15, 1984.
   From: E. J. Woolever, Duquesne Light Company.
   To: U.S. NRC, attention George W. Knighton.

4. Seed, H. B., and Lysmer, J., "The Seismic Soil-Structure Interaction Problem for Nuclear Facilities". Appendix to: Johnson, J.J., "Soil-Structure Interaction: The Status of Current Analysis Methods and Research - Seismic Safety Margins Research Program". NUREG/CR-1780 or UCRL-53011, Lawrence Livermore Laboratory, January 1981.

203 North Golden Circle Drive
Santa Ana, CA 92705
(714) 835-6886
(213) 581-7164
Telex 68-3420

Woodward-Clyde Consultants

15 February 1985

Dr. John T. Christian
Stone & Webster Engineering Corpo ation
245 Summer Street
Boston, Massachusetts 02107

Dear Dr. Christian:

As requested by Duquesne Light Company and Stone & Webster, I have reviewed documents pertaining to the seismic soil-structure interaction (SSI) considerations for the Beaver Valley Power Station, Unit No. 2. The documents reviewed are the following:

1. Attachments A and B to letter, dated 1 February 1985, from E. J. Woolever, Duquesne Light Company to the USNRC, Attention: George W. Knighton.

2. Sections 3.7.1 and 3.7.2 of the FSAR, Beaver Valley Power Station, Unit No. 2.

3. Item 7 of the attachment to letter, dated 15 June 1984, from E. J. Woolever, Duquesne Light Company to the USNRC, Attention: George W. Knighton.

In addition, the results of the SSI analyses for this unit were presented by representatives of the Structural Engineering Staff of SWEC at our meeting on 4 February 1985 in Boston. These results covered analyses dating back to 1973-74 and included the most recent analyses completed in 1984.

Based on this review, I find that the SSI analyses completed by SWEC for this power plant are appropriate and are in accordance with the current State of the Art for conducting such analyses.

In particular, I am in full agreement that the design earthquake ground motions be specified at the finished ground surface and that kinematic interaction be explicitly incorporated in the soil-structure interaction analyses.

Very truly yours,

I. M. Idriss

IMI/hab

DONALD E. SHAW, P.E.

5558-C Old William Penn Highway
Export, PA 15632
(412) 327-0851

February 8, 1985

Project No. 84-020-03

Dr. John T. Christian
Stone & Webster Engineering Corporation
245 Summer Street
Boston, MA 02107

Beaver Valley Power Station, Unit 2
Soil-Structure Interaction Analyes

Dear Dr. Christian:

As requested by you and Duquesne Light Company, I have reviewed the material describing the soil-structure interaction analyses performed for the Beaver Valley Power Station, Unit 2, (BVPS-2) which you supplied (Refs 1,2,and 3). Also, I, along with other members of the Soil-Structure Interaction Assessment Panel met at Stone & Webster Engineering Corporation (SWEC) offices on February 4, 1985, for a presentation of the soil-structure interaction analyses and results.

Based on the material provided and the presentation, I find that the analytical methods used for the soil-structure interaction analyses of the BVPS-2 containment structure are consistent with generally accepted principles of soil-structure interaction analysis.

Specifically, I note the following points:

1. The Three-Step analytical procedure includes kinematic interaction as a method for deriving the vibratory motion (translational and rotational) at the foundation level of the containment building from the free-field ground-surface motion. The use of kinematic interaction is physically appropriate and consistent with well-recognized principles of soil-structure interaction.

2. The results of the Three-Step soil-structure interaction agree very well with the results of the finite element analyses performed using both the PLAXLY and FLUSH computer programs. This agreement is expected because the finite element method of analysis implicitly includes the use of kinematic interaction which is explicitly used in the Three-Step method of analysis.

3. While I have not reviewed the detailed numerical calculations used in the Three-Step analyis, the procedures which were used relative to strain-dependent soil properties, foundation rigidity, embedment effects and compliance functions are consistent with my understanding of site conditions and the structural configuration.

4. Response spectra of the vibratory motion at the foundation level computed by both the Three-Step method and the finite element analyses show the expected "dip" at approximately 2.5 Hz which is the natural frequency of the soil layer between the ground surface and the base of the foundation. This dip in the response spectra is a result of physical phenomena and is less than would be obtained in the free field at the foundation level. By free-field motion at the foundation level I mean that motion which is derived by simply deconvoluting the free-field ground-surface motion without considering geometric effects of the foundation as included in kinematic interaction.

In view of these findings, I believe that the NRC request to perform soil-structure interaction analyses using the Three-Step method with the free-field ground-surface time history applied at the foundation level is physically inappropriate. It neglects the substantial body of evidence which has been generated over the past 15 years which exhaustively demonstrates that the vibratory motion at depth is different from the ground-surface motion. Furthermore, I find that the soil-structure interaction analyses performed for BVPS-2 are consistent with the requirements of 10CFR100, Appendix A, as I understand them, and that the NRC request would be inconsistent with the regulations.

I might add that a study which I performed for the NRC while at D'Appolonia Consulting Engineers and published as NUREG/CR-0693 investigated the question of where to apply the control motion. It concluded that the control motion should be applied at the ground surface with the motion at the foundation level computed based on actual site conditions relative to soil properties and the depth of the foundation. While the study did not consider the effects of foundation geometry and rigidity as is done in the kinematic interaction formulation used in the Three-Step analysis, the use of kinematic interaction is a refinement of the methods which were considered in the study.

I will be pleased to participate in any meeting with the NRC to clarify the above issues and will also be pleased to participate in any formal presentations or hearings on this issue, if required.

Respectfully submitted,

Donald E. Shaw

Donald E. Shaw, P.E.

DES/saa

cc. Mr. Pedro A. Cadena, Duquesne Light Company
Mr. Jack Oneil, Duquesne Light Company

LIST OF REFERENCES

1. Attachments A and B to Letter 2NRC-5-016, dated February 1, 1985, from E. J. Woolever, Duquesne Light Company, to U.S. NRC, attention George W. Knighton.

2. Beaver Valley Power Station, Unit 2 - F.S.A.R., Sections 3.7.1 and 3.7.2.

3. Item 7 of Attachment to Letter, dated June 15, 1984, from E. J. Woolever, Duquesne Light Company, to U.S. NRC, attention George W. Knighton.

Westinghouse Electric Corporation
Water Reactor Divisions

Plant Engineering Division
Box 355
Pittsburgh Pennsylvania 15230

February 11, 1985

Dr. John T. Christian
Stone and Webster Engineering Corporation
245 Summer Street
Boston, MA 02210

Dear Dr. Christian:

SUBJECT: Soil Structure Interaction Advisory Panel Review for BVPS-2

As a panelist of the subject panel, I participated in the review of the soil structure interaction analysis for Beaver Valley Power Station Unit No. 2. The review was primarily conducted to address the issue of whether the Kinematic Interaction technique is appropriate for the Unit No. 2 analysis, and whether the technique was properly applied by SWEC.

The objective of the review has been achieved based on the materials provided by the Duquesne Light Company (Refs. 1, 2, and 3) publications in the literature (Refs. 4 and 5), and the presentations made by SWEC engineers on February 4, 1985.

Although only limited detail was made available to the panel concerning the soil structure interaction analyses conducted by SWEC, the following points can be made as a result of this review:

1. When applying the soil spring approach in the soil-structure interaction analysis, free field motion should not be applied at the subgrade (embedment) level.

2. Kinematic interaction provides acceptable estimation to the motions at the subgrade (embedment level). Therefore, it is an acceptable approach in the soil structure interaction analysis.

3. Comparison of the numerical data indicates that the original finite element analysis results as described in the BVPS-2 FSAR Section 3.7.2 for containment building are, in general, more conservative than the results obtained by the kinematic interaction approach.

In conclusion, based on the information presented to me, I feel that Kinematic interaction technique is appropriate for developing the subgrade (embedment) motions in the soil structure interaction analysis using soil springs. Further, it appears that the results obtained for BVPS-2 using the kinematic interaction technique have shown that the original finite element soil structure interaction analysis results are conservative and, therefore, should continue to be used in the design and qualification process.

Very truly yours,

C.-W. Lin, Advisory Engineer
Engineering Mechanics

rln

cc: D. A. Bartol
J. O'Neil (Duquesne Light Co.)
P. Cadena (Duquesne Light Co.)

REFERENCES

1. Attachments A and B to

   Letter, dated February 1, 1985 from E. J. Woolever, Duquesne Light Co., to U.S. NRC, attention George W. Knighton

2. Beaver Valley Power Station - Unit 2 - F.S.A.R. Sections 3.7.1 and 3.7.2

3. Item 7 of Attachment to

   Letter, dated June 15, 1984, from E. J. Woolever, Duquesne Light Co., to U.S. NRC, attention George W. Knighton

4. Johnson, J. J. - Soil-Structure Interaction - The Status of Current Analysis Methods and Research, Seismic Safety Margins Research Program, NUREG/CR-1780, January 1981.

5. Kausel, E., et.al. "The Spring Method for Embedded Foundations", Nuclear Engineering and Design, 48 (1979) 377-392.