Consumers Power Company

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September 28, 1983

Harold R Denton, Director
Office of Nuclear Reactor Regulation
US Nuclear Regulatory Commission
Washington, DC 20555

MIDLAND ENERGY CENTER
MIDLAND DOCKET NOS 50-329, 50-330
NRC REQUEST FOR ADDITIONAL INFORMATION ON THE
SEISMIC MARGIN REVIEW REPORT
FILE: B3.7.1 SERIAL: 25654

REFERENCE: (1) LETTER FROM J W COOK TO H R DENTON
DATED FEBRUARY 4, 1983, SERIAL 21010

(2) LETTER FROM E G ADENSAM (NRC) TO J W COOK
DATED MAY 26, 1983

In reference (1), Consumers Power Company submitted Volume I of the Seismic Margin Review Report titled, "Methodology and Criteria," for the Staff's review. Subsequently, in reference (2) the NRC requested additional information on Volume I in question number 130.28. As an attachment to this letter, CPCo is submitting the response to question 130.28 for Staff review.

It is expected that this information will enable the NRC Staff to complete its review of Volume I of the Seismic Margin Review Report.

James W. Cook

JWC/MFC/bjw

CC RJCook, Midland Resident Inspector
JGKeppler, Administrator, NRC Region III
DSHood, US NRC
FRinaldi, US NRC
GHarstead, Harstead Engineering Company
GBagchi, US NRC
RBosnak, US NRC
MAMiller, US NRC Licensing Branch No 4 (2)

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oc0983-0625a100

CONSUMERS POWER COMPANY
Midland Units 1 and 2
Docket No 50-329, 50-330

Letter Serial 25654 Dated September 28, 1983

At the request of the Commission and pursuant to the Atomic Energy Act of 1954, and the Energy Reorganization Act of 1974, as amended and the Commission's Rules and Regulations thereunder, Consumers Power Company submits additional information on the Seismic Margin Review Report Volume I titled, "Methodology and Criteria."

CONSUMERS POWER COMPANY

By J W Cook
J W Cook, Vice President
Projects, Engineering and Construction

Sworn and subscribed before me this 4 day of October, 1983

Barbara Blunsend
Notary Public
Jackson County, Michigan

My Commission Expires Sept 8, 1984

oc0983-0625a100

Question 130.28.1 State how the STUF computer code discussed in Section 2.4 meets the verification requirements identified in the Standard Review Plan (SRP) Section 3.8.4.III.4.

Response: STUF creates artificial earthquake time histories from given response spectra. The method is an iterative process that operates on the Fourier Series representation of the artificial earthquake. Once the time history has been generated by STUF, the response spectra developed from the time history record are compared with the given response spectra. The comparison of the response spectra with the given response spectra assures the computer program results produce spectra which essentially envelop the given response spectra and thus provides the verification of results. The computer manual for STUF together with associated check problems is maintained by Structural Mechanics Associates, Inc.

Question 130.28.2 A statement is made in Section 2.4 that the synthetic time histories were baseline corrected. However, the displacement and velocity time histories (Figure I-2-5) shows positive values for displacement and velocity at the end of the specified 10 seconds period, respectively. Explain the apparent inconsistency between the statement and the data provided in Figure I-2-5. Also, address the limited changes between positive and negative sign for the displacement curve in Figure I-2-5.

Response: A parabolic baseline correction was used for the synthetic earthquake time history records. This procedure typically results in the type of drift exhibited in the velocity and displacement records shown in Figure I-2-5. The acceleration time history record shown produces response spectra which essentially envelop the Seismic Margin Earthquake (SME) spectra. The evaluation of the Midland structures was based on seismic responses developed from response spectrum analyses. The in-structure response spectra developed using the synthetic earthquake time history are pseudo-absolute acceleration spectra which are essentially unaffected by velocity or displacement drift. Thus, the method of baseline correction used is immaterial to any results developed in the Seismic Margin Review, and the number of zero-crossings of the displacement trace or the existence of a small residual velocity or displacement does not influence any results for either structures or equipment.

Question 130.28.3 Explain why the value for Vs utilized in Section 3.2 for the intermediate soil profile (Figure I-3-3) between Elevations 553' - 603' is larger than the equivalent value used for stiff soil profile (Figure I-3-2).

Response: Figures I-3-1 through I-3-3 present a soft site, a stiff site, and an intermediate representation of the soil profiles, respectively, beneath the auxiliary building, reactor building, and service water pump structures at the Midland site. These three profiles were selected to reasonably span the uncertainty range which exists for soil-structure interaction (SSI) impedance functions for the buildings. The soft site profile (Figure I-3-1) results in the lowest values for all SSI impedance function terms, the intermediate profile (Figure I-3-3) results in intermediate values, and the stiff profile (Figure I-3-2) results in the highest values. The labels "soft", "stiff", and "intermediate" were simply selected to indicate the relative values for the SSI impedance functions which result from the use of these profiles. These terms were not meant to imply that the soil properties for every layer in the intermediate profile lay midway between those for the corresponding layer of soft and stiff profiles. All three profiles were selected to represent possible and slightly bounding profiles which might exist under the Midland buildings.

The intermediate profile was established based upon the following considerations. First, both the soft site profile (Figure I-3-1) and the stiff site profile (Figure I-3-2) contain two major impedance mismatches above bedrock. It was decided to retain this feature of two major impedance mismatches for the intermediate profile.

Secondly, the impedance mismatch at Elevation 550 has the greatest influence on stiffness (K) and damping (C) SSI impedance function terms for the soft site profile while that at Elevation 463 has the greatest influence for the stiff site profile. Therefore, for the intermediate profile, it was decided to place the two impedance mismatches at Elevations 553 (approximately 550) and 463 so as to be consistent with the location of impedance mismatches of both the soft site and stiff site profiles which most influence radiation damping. Next, the ratio of G_{SME} above and below Elevation 553 for the intermediate profile was selected to be approximately equal to that for the soft site profile near this elevation. Similarly, the ratio of G_{SME} above and below Elevaton 463 for the intermediate profile was selected to be approximately equal to that for the stiff site profile at this elevation. In this way, the primary impedance mismatch influences of both the soft and stiff profiles on the reduction in radiation damping was incorporated into the intermediate profile.

For both the soft and stiff site profiles, SSI stiffness (K) impedance terms are primarily influenced by the soil properties between Elevations 410 and the foundation level. Therefore, in addition to the impedance mismatch ratios described above, it was decided that the intermediate profile should have G_{SME} values approximately midway between those for the soft and stiff site profiles between Elevations 410 and the building foundation levels (Elevations 562 to 587).

An intermediate profile should have SSI stiffness (K) impedance terms approximately midway between those for the soft and stiff site profiles while maintaining about the same radiation damping reduction factors due to layering as exhibited by both the soft and stiff profiles. In this way, the intermediate profile retains the most important characteristics of both the soft site and stiff site profiles while providing SSI impedance terms approximately midway between these two profiles.

It is recognized that the intermediate profile has a V_S value of 1500 fps as compared to 1400 fps for the stiff site profile at elevations above Elevation 568 to 585 (depending upon building being considered). This condition results from ignoring the rather unimportant impedance mismatch at Elevations 568 to 585 for the stiff site profile while retaining in the intermediate profile the more important impedance mismatch characteristics of the soft site profile at about Elevation 550. Similarly, the intermediate profile has a V_S value of 2468 fps at elevations between Bedrock and Elevation 410. This V_S is less than that for the soft site profile at these elevations. This also occurs because the intermediate profile ignores the less important impedance mismatch at Elevation 410 of the soft site profile while retaining the more important impedance mismatch characteristics of the stiff site profile at Elevation 463. The intermediate profile retains all the most important characteristics of both the soft and stiff profiles and these apparent deficiencies are considered to be of very minor importance for the buildings founded on glacial till.

It should be noted that the largest structural responses for all buildings founded on the glacial till occurred for the upper bound SSI impedances which were taken as 1.3 times those given for the stiff site profile (Figure I-3-2) and thus are not governed by the chosen intermediate profile.

Question 130.28.4 State how the CLASSI computer code discussed in Section 4.1 meets the verification requirements identified in SRP 3.8.4.III.4.

Response: Comparison of CLASSI calculated soil impedances to classical solutions have been presented in published technical literature (References 1 and 2). These comparisons demonstrate excellent agreement between soil impedances developed by classical methods for rigid foundations on an elastic half-space and the frequency dependent impedances determined by CLASSI. CLASSI is also available in the public domain.

In addition, soil impedances determined by CLASSI have been further verified for layered sites by studies conducted for the Zion nuclear power plant (Reference 3). In this study, the structural response of a Zion reactor building was developed based on a CLASSI representation of the layered soil site at Zion. Additional analyses of the reactor building were then conducted using a linear finite element representation of the site as modeled by computer program FLUSH (Reference 4). Comparisons of reactor building acceleration response demonstrated substantial agreement between the two methods with differences in peak values generally averaging about 5 percent.

Therefore, the results presented in References 1, 2, and 3 are considered to comply with the intent of Sections 3.8.1.II.4.e. (i), (ii) and (iii) of the Standard Review Plan. The computer manual and associated check problems for CLASSI are maintained by Structural Mechanics Associates, Inc.

References:

1. Wong, H. L., and J. E. Luco, "Dynamic Response of Rigid Foundations of Arbitrary Shape", Earthquake Engineering and Structural Dynamics, Vol. 4, pp 579-587, 1976.

2. Luco, J. E., "Vibrations of a Rigid Disc on a Layered Viscoelastic Medium", Nuclear Engineering and Design, Vol. 36, pp 325-340, 1976.

3. Maslenikov, O. R., Chen, J. C., and J. J. Johnson, "Uncertainty in Soil-Structure Interation Analysis of a Nuclear Power Plant - A Comparison of Two Analysis Procedures", Lawrence Livermore Laboratory, UCRL-85702 Preprint.

4. Lysmer, J., et al, "FLUSH - A Computer Program for Approximate 3-D Analysis of Soil-Structure Interaction Problems", Report No. EERC 75-30, Earthquake Engineering Research Center, University of California, Berkeley, California, November, 1975.

Question 130.28.5 State how the idealized layered horizontal soil boundaries utilized in your analyses in Section 4.2 reflect the actual field conditions.

Response: The layered site analyses were conducted to evaluate the effects of layering on the stiffness and geometric damping characteristics of the site. A wide range of properties was used in order to conservatively bound the expected actual field conditions. The layered site analyses conducted for Midland were based on geotechnical investigations conducted by Dames & Moore, Inc. and Weston Geophysical Corporation. The Dames & Moore results are considered representative of soft site conditions at Midland while the Weston Geophysical results are representative of stiff site conditions. These investigations established the layer descriptions shown in Figure I-3-1 and I-3-2 together with the low strain properties of these layers. An intermediate site condition was developed from a weighted average of the soft and stiff site properties in order to also compute approximately mid-range response for the Midland structures and equipment.

For the layered site characteristics used in the analysis described in Section 4.2, strain degradation effects appropriate for the SME soil strain levels were introduced for the various soil layers. CLASSI analyses were then conducted using these layered site profiles together with the appropriate foundation plan dimensions at the appropriate foundation depths for the various structures. Equivalent shear moduli were developed which resulted in the same elastic half-space foundation stiffnesses as the layered site analyses. These shear moduli were reduced for the soft site and increased for the stiff site to conservatively increase the range of soil properties considered. Where uncertainties exist, assumptions were introduced to further stiffen the stiff site compliance functions and soften the soft site compliance functions.

Question 130.28.6 Explain in more detail in Section 4.4 the different approaches utilized in developing the impedance values for the auxiliary building and the service water pump structure for horizontal and torsional considerations vs. vertical and rocking.

Response: The development of the soil impedance values for the auxiliary building and the service water pump structure are discussed in more detail in Volumes III and IV, respectively. In summary, for the horizontal translation and torsion degrees of freedom, the entrapped soil is considered to act integrally with the foundation base mat. For rocking and vertical translation, the assumed foundation shape was based on the foundation contact area only. For horizontal translation, an equivalent rectangle was developed for the foundation based on equivalence of area and moment of inertia considering the entire foundation plan dimensions including entrapped soil. For torsion, an equivalent circle with radius based on the polar moment of inertia was developed, again including the entrapped soil. For the vertical translation, an equivalent rectangle based on the contact area of the foundation was calculated. An equivalent rectangle based on both the contact area and moment of inertia was used for the rocking degrees-of-freedom.

The above approach is considered to most accurately simulate the foundation stiffness characteristics of structures with entrapped soil subject to seismic excitation. Since the entrapped soil is forced to move in-phase with the structure for horizontal motions, soil shear forces will be transmitted through the entrapped soil to the vertical structural walls enclosing the soil and a stiffness based on the foundation plan area including the

Question 130.28.6 (Continued)

soil is considered appropriate. However, for vertical motion (including rocking) separation of the soil and structure may occur due to the lack of ability to transmit tension across the soil-structure interface, and the entrapped soil does not necessarily all have to move in-phase with the structure. For these degrees-of-freedom, an equivalent foundation stiffness based on the foundation contact area only is considered appropriate.

Where any significant uncertainty exists on including the entrapped soil in the stiffness and mass properties of the structure, as for instance in the diesel generator building, a parametric study was conducted and the structural loads and in-structure response spectra were based on an envelope of the parametric results. Details of these calculations are discussed in the appropriate volumes for the individual structures.

Question 130.28.7 Explain in Section 4.4 how you consider in your analyses the fact that when a complicated foundation shape is simplified into a rectangular shape the center of stiffness for the complicated shape may not coincide with the geometric center of the simplified rectangular shape. Also, address how you account for changes in the distribution of reactions, at the foundation level, between the actual and simplified models.

Response: As discussed in Volumes III and IV, different equivalent rectangular foundations were developed for structures with entrapped soil. When this is done, the centers of rigidity for the different degrees-of-freedom do not necessarily correspond. When these centers of rigidity are not coincident, the soil compliance functions were located at the rocking center of rigidity. As an example, for the auxiliary building, the center of rigidity of the equivalent rectangular foundation was calculated at approximately 123.6' north of Column Line K_c of the structure for the vertical and rocking degrees-of-freedom compared to approximately 117.0' for the horizontal translation and torsion degrees-of-freedom, or about a 5 percent shift. When the foundation center of rigidity does not correspond with either the center of mass or the center or rigidity of the shear walls above the base slab, these locations were connected in the model by rigid links.

Distribution of reactions at the foundation level is of concern only for the calculation of bearing pressures in the soil. For this calculation, a rigid base mat was assumed together with a linear soil stress distribution based on the actual foundation geometry.

Question 130.28.8 Explain in Section 4.4 why the impedance for rocking is not based upon the entire foundation area (R = 28.5') when the BWST is analyzed as full of water. It appears that in this condition most of the water load will be transmitted to the soil, therefore, requiring complete participation of the entire area (R = 28.5). Also, identify all terms used in Figure I-4-5 and state if the relationships identified in this figure apply for rectangular foot-prints as well as for circular ones.

Response: For horizontal and vertical translation of tanks, seismic induced forces are transmitted to the underlying soil over the entire tank area. However for rocking, it was judged that seismic-induced forces are transmitted to the underlying soil primarily through the ring wall foundation. For translation, the water is forced to respond by seismic response of the tank as the walls and the base of the tank force the water into compatible deformations with the tank. In the rocking mode, the tank can respond somewhat independently of the contained water because the flexible tank bottom does not induce significant rocking response of the fluid.

In Figure I-4-5, α_i is the normalized embedment coefficient used in Equation 4-6, $a_0 = \omega R/V_s$ is the dimensionless frequency, h is the embedment depth, and R is the radius of the embedment structure. The relationship can be used for rectangular footprints if an equivalent radius, R, is used based on equal stiffnesses for corresponding degrees-of-freedom.

Question 130.28.9 The electrical penetration wings act as horizontal cantilevers, thereby producing increased horizontal acceleration at locations away from the control tower. Discuss in Section 5.2 the magnitude of this effect and how it is incorporated into the response spectra results. If these details are to be provided in the proposed Volume III, please state so.

Response: The overall model as shown in Figure I-5-3 includes three-dimensional representations of the Electrical Penetration Areas (EPAs) as well as the main auxiliary and control tower portions of the structure. Thus, the amplification through the EPAs is predicted from the overall model, and the structural loads developed in the EPAs reflect this amplification. In-structure response spectra were developed at locations near the extremities of the EPAs for use in evaluating the EPA mounted equipment. In addition, a parametric evaluation was conducted to determine the effects of relative soil stiffness modeling assumptions for the EPAs, and the structural loads were based on the worst-case results of this parametric study. The results of the auxiliary building analysis are presented in Volume III of this report.

Question 130.28.10 In Section 5.2, state if you have analyzed the diesel generators and the respective foundations separate from the building, since they are physically seprated. Also, proide details of these analyses in Volume V of the proposed reports.

Response: The in-structure response spectra presented in Volume V for the diesel generator building were considered to be applicable for equipment mounted in the building. Additional in-structure response spectra were developed for the diesel generators which account for the small foundation size and independence of the diesel generator pedestals from the rest of the structure. Details of this anlaysis and the resulting spectra used to evaluate the diesel generators will be presented in Volume VII on electrical, control, instrumentation, and mechanical equipment.

Question 130.28.11 Explain how Equation 6-1 in Section 6.4 will ensure that sufficient modes will be obtained in the evaluation of the structures. This formulation differs from the requirements identified in the SRP Section 3.7.2.7.

Response: The criteria presented in Section 6.4 provide a conservative basis to establish the seismic response of the structures since Equation 6-1 is applied to any nodal location rather than to a total percentage of structure mass participating. All structures analyzed as part of the SMR had essentially 100 percent of the mass participating in the response spectrum analyses for all directions of response. Therefore, the use of additional modes would not alter the building responses as they are presented in their respective volumes. The actual total percentages of mass participating as well as a breakdown of the mass participating on a mode by mode basis is presented in the appropriate volumes for the individual structures.

Question 130.28.12 In Section 6.7, the walls are assumed to be rotationally fixed at floor levels (top and bottom) for the calculation of horizontal shear stiffness of each wall at each floor level. Explain how the overall building cantilever bending stiffness was evaluated.

Response: The overall building cantilever dynamic response models used for the SMR were the same models developed for design and reported in the FSAR. These models include both the shear and cantilever bending flexibility. The models are based on a linearly elastic system assuming plane sections remain plane, and consist of lumped masses connected by massless flexible elements. Plate finite elements were incorporated where additional detail was required. The overall dynamic building models are discussed in Section 5 of Volume I and in more detail in the appropriate volumes for the individual structures. In general, the contribution of bending stiffness to the overall response of the Midland structures is small.

In Section 6.7, the distribution of load from the overall dynamic models to the individual shear walls is discussed. For shear wall-type structures, these loads were proportioned to the shear walls based on their relative stiffnesses as determined based on the assumption the walls are rotationally fixed top and bottom. The capacity of the walls was also checked for overturning moment capacity where the incremental changes in overall building overturning moment are distributed to the individual walls in the same proportion as the distribution of the shears in the resisting system.

Question 130.28.13 Explain in detail how you determined in Section 8.1 that the translational response in the vertical direction, due to rotations about the two horizontal building axes, should not be considered in the development of the vertical in-structure response spectra.

Response: The small vertical component due to horizontal rocking of the structures is maximized for the lower bound soil condition. However, the vertical response of the structure, and hence the in-structure response spectra in the governing frequency range of the equipment, is controlled by the stiff site soil condition where the rocking is much less pronounced. Because of its height-to-diameter ratio, rocking is more pronounced for the reactor building than for the other structures. Therefore, increases in vertical response due to horizontal rocking are maximized for the reactor building. Rotational response about a horizontal axis was computed for this structure and the increase in the vertical input to equipment was found to be less than 20 percent at the maximum distance from the center of the structure. For equipment located away from the containment building wall or in other structures, the effect of rocking is less.

One reason for the relatively small increase in the vertical response compared to the effect of torsion on the horizontal response is that the contribution to the vertical from rocking is combined with the vertical translation by SRSS since the vertical and horizontal ground motions are expected to be out-of-phase. Since the torsional response occurs in-phase with the horizontal translational response, these effects must be combined on an absolute sum basis. Where significant vertical

amplification is expected, as for instance, towards the centers of the more flexible floor slabs, it has been included in the analysis by accounting for dynamic amplification due to floor slab flexibility.

Question 130.28.14 State how the SOILST computer code discussed in Section 8.1 meets the verification requirements identified in SRP Section 3.8.4, Paragraph III.4.

Response: Computer program SOILST was verified by comparison of test problem results with computer program EASE (Reference 1) in accordance with SRP 3.8.1.II.4.e.(ii). EASE is available in the public domain. Direct integration time history analysis of the Service Water Pump Structure dynamic model were conducted using both EASE and SOILST computer codes. Peak accelerations were compared at typical locations in the structure. Results from the two analyses were shown to be virtually identical with the maximum difference in acceleration response being less than 3.5 percent. Similar comparisons of displacement response showed a maximum difference in peak displacements of about 4 percent. The minor differences in results are attributable to slightly different methods of modeling damping in the two codes. The computer manual and associated check problems for SOILST are maintained by Structural Mechanics Associates, Inc.

Reference:

1. EASE2 - "Finite Element Application for Performing Static/Dynamic Linear Elastic Analyses of 3-D Structural Systems", Engineering Analysis Corporation, Lomita, California.

Question 130.28.15 Expand your justification in Section 8.2 and 3.7.2.9 for using a broadening factor of ±10% instead of the value of ±15% recommended in R.G. 1.122.

Question: SRP Section 3.7.2.III.9 states that peak broadening should not be less than ± 10%. Regulatory Guide 1.122 also permits broadening of the response spectra peaks by ± 10% if a parameteric study is performed to justify this value. The response of the Midland structures is controlled to a large extent by the soil parameters at the site. As discussed in Section 8.2, a very wide range of soil properties was used in the SMR. The soil properties were further varied by multiplying the lower bound soil properties by 0.6 and the upper bound soil properties by 1.3. This wide range is reflected in very broad in-structure response spectra peaks since the in-structure spectra consist of an envelope of the spectra from the entire soil range. These spectra were further broadened to conservatively cover any additional uncertainty in the structural models as discussed in Section 3.7.2.III.9 of the SRP. Where additional uncertainty could be possible, as for instance in the soil-structure interaction of the diesel generator building, additional parametric studies were conducted, and the in-structure response spectra were generated from an envelope of the parametric results. Thus, the combination of a parametric study based on a very broad range of soil parameters in combination with an additional peak broadening is considered to conservatively meet the intent of R. G. 1.122.

Question 130.28.16 Discuss and/or correct the following apparent typographical errors:

(a) In Section 1.0, SSE peak ground acceleration should be 0.06g. (3rd line 1st paragraph).

(b) In Section 4.1, (+) should be replaced with (=) (Equation 4-1).

(c) In Section 4.5, Vs should be Vw (3rd line p. I-4-12).

(d) In Section 7.1, K in the second equation should be replaced with k (p. I-7-1).

Response:

(a) The 1st line of the 1st paragraph should read 0.06g peak horizontal ground acceleration for the Operating Basis Earthquake (OBE).

(b) In Section 4.1, (+) should be replaced with (=) in Equation 4-1 as indicated.

(c) In Section 4.5, the v_w in the denominator of Equation 4-7 should be replaced with v_s where v_s is the high strain shear wave velocity.

(d) In Section 7.1, the K in the second equation should be replaced with a k as noted.