UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
COMMONWEALTH EDISON COMPANY	)	Docket Nos. 50-454
	)	50-455
(Byron Station, Units 1 and 2)	)	

TESTIMONY OF ROBERT ROTHMAN ON LEAGUE CONTENTION 106

ROTHMAN TESTIMONY

This testimony addresses the seismological aspects of League contention 106. It incorporates the relevant section of the SER. It makes the following points:

1. At the construction permit stage of review, the Staff found a Safe Shutdown Earthquake (SES) of 0.2g to be adequately conservative for the Byron site based on the postulated occurrence of a magnitude 5.8 Modified Mercali intensity VIII earthquake near the site.

2. At the operating license stage of review, a comparison of the Byron SSE response spectrum with site-specific response spectra obtained from the analysis of strong ground motion records with magnitude, geology and distance parameters similar to those at Byron confirmed the conservatism of the Byron SSE.

3. To justify an Operating Basis Earthquake (OBE) of 0.09g, which is less than half the SSE, the Applicant computed a 2150 year recurrence interval for a maximum MM intensity VI earthquake. The Staff consultant, Lawrence Livermore National Laboratory, calculated a return period in the range of 200-1000 years. The difference in return periods between the Applicant and Lawrence Livermore estimates is most probably caused by different methods and assumptions used. Another expert researcher has obtained a return period on the order of 1000 years. All three studies predict return periods for the OBE much longer than the expected operating life of the Byron plant.

4. The OBE of 0.09g is an adequate estimate of the maximum earthquake motion likely to be experienced at the site during the operating life of the plant.

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TESTIMONY OF ROBERT L. ROTHMAN REGARDING
LEAGUE CONTENTION 106

Q1. Please state your name and affiliation.

A1. My name is Robert L. Rothman. I am a Seismologist in the Geosciences Branch, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission. A copy of my professional qualifications is attached.

Q2. What is the purpose of your testimony?

A2. The purpose of this testimony is to address the seismological aspects of League Contention 106.

Q3. Do you adopt the seismology section (2.5.2) of the February 1982 Byron Safety Evaluation Report (SER) as part of your testimony?

A3. Yes. I prepared that section of the SER (copy attached) and adopt it as part of my testimony.

Q4. Contention 106 alleges, in part, that the Plum River fault is capable. From a seismological point of view, is the Plum River fault capable as that term is used in 10 C.F.R., Part 100, Appendix A.

A4. No. In addition to the geological definition of capable faults in Appendix A III(g)(1), section III(g)(2) defines a capable fault as one which exhibits "macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault". A review of seismicity studies of the Byron Station region[1] indicates no evidence for any seismicity directly associated with the Plum River fault.

Q5. Did the Staff perform a particularized seismology study of the earthquake hazard for the Byron Station during its safety review?

A5. Yes. As discussed in Section 2.5.2 of the SER, the Staff reviewed the SSE design input used for the Byron Station with respect to the particular seismological conditions of the site. This included the assumption of the occurrence of a maximum Modified Mercalli (MM) intensity VIII, magnitude (m_b) 5.8 earthquake near the site. The comparison of site-specific response spectra obtained from the analysis of strong ground motion records with magnitude, geology and distance parameters similar to those at Byron to the Byron SSE response spectrum was made.

[1] Byron Station Final Safety Analysis Report, Figure 2.5-32 and Table 2.5-9, and Earthquake Source Zones In The Central United States Determined From Historical Seismicity by Otto W. Nuttli and Kenneth G. Brill, Jr., NUREG/CR-1577.

The site-specific spectra used in these comparisons were generated from real accelerograms of earthquakes with body wave magnitudes of 5.8 ± 0.5 (5.3 to 6.3) recorded at rock sites, at distances of approximately 25 kilometers (15.5 miles) or less.

Based on its review the Staff concluded that the SSE with a high-frequency acceleration of 0.20g anchoring a Regulatory Guide 1.60 spectrum at the foundation level of the structures founded on rock is adequately conservative.

Q6. Does the maximum MM intensity VI earthquake which occurred in 1972 30 miles from Byron have any association with the Plum River fault or the Sandwich fault?

A6. No. A comparison of the epicenter of the September 15, 1972, maximum MM intensity VI, magnitude (m_b) 4.4 earthquake, Latitude 41.6°, Longitude 89.4°[2] with the locations of the Plum River and Sandwich faults as indicated on Plate 1 (Structural Features in Illinois) of Illinois State Geological Survey Circular 519, indicates no association of this earthquake with either fault.

[2] Nuttli and Brill, Jr. NUREG/CR-1577.

In any event, the occurrence of this earthquake is of no significance to the safety of the Byron Station since it is smaller and at a greater distance from the plant site than the earthquake assumed for the establishment of the SSE.

Q7. Is the 0.09g maximum ground acceleration for the Byron Operating Basis Earthquake (OBE) consistent with 10 CFR Part 100, Appendix A?

A7. Yes. At one point, Appendix A defines the OBE as being that earthquake which, considering the regional and local geology and seismology and specific characteristics of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant (III(d)). This implies a probabilistic assessment over the 40 year operating life of a plant. Elsewhere in Appendix A, the maximum acceleration corresponding to the OBE is required to be at least half that of the SSE V(a)(2).

Based on earthquake data for most of the U.S. an acceleration level of one-half that of the SSE does not correspond to an event reasonably expected during a 40 year period but rather to an earthquake having a much larger return period. This is evident for the Byron site from both the Applicant's estimate of a recurrence interval of 2150 years for a maximum MM intensity VI earthquake and Lawrence Livermore National Laboratory's (LLNL) calculation of a return period in the range of 200 to 1000 years for a Regulatory Guide 1.60 spectrum with a high frequency anchor of 0.09g. See SER, Appendix E.

To meet the better definition of the OBE as specified in Appendix A paragraph III(d), the Staff has accepted OBE acceleration values of less than half those of the SSE for some sites. This is done when supporting data such as probabilistic analyses of earthquake hazard justifies it. In the Byron context, from a seismological point of view, the difference between a Regulatory Guide 1.60 spectrum anchored at 0.09g and one anchored at 0.10 is less than the scatter of the data.

Q8. Is the apparent difference between the Applicant and LLNL estimates of return periods significant?

A8. No. The apparent difference in return periods between the studies performed by the Applicant and LLNL are most probably caused by the different methods and assumptions used. Recently, Dr. Robert B. Herrmann of Saint Louis University has performed some, as yet unpublished, probabilistic estimates of earthquake hazard in the central United States. He obtained a return period on the order of 1000 years for peak accelerations of about the OBE level in the site area. More importantly, all three of these studies predict return periods for the OBE much longer than the expected operating life of the plant. Thus, there is no reason to doubt the adequacy of the Byron Station OBE value.

Q9. Dr. Henry H. Woodward in his deposition of January 13, 1983 referred to a recent earthquake in Arkansas with a reported horizontal acceleration of 0.59g. Do you know of such an earthquake and if so can you describe it?

A9. Yes. On July 5, 1982 at 04:13:49.81 GMT (4 July 1982, at about 11:14 p.m. CDT) there was a magnitude 3.8 earthquake with an epicentral location of 35° 11.1' North latitude, 92° 13.72' West longitude, near the town of Enola, Arkansas. This earthquake was one of over 20,000 small earthquakes which have occurred in the area since about January 12, 1982.

An SMA-1 strong motion seismograph was located about 200 meters from the epicenter and recorded a peak acceleration of 0.59g on its east-west component. Another strong motion seismograph, a DR-100 which was co-sited with the SMA-1 recorded a peak horizontal acceleration of 0.19g. The discrepancy in accelerations between the co-sited SMA-1 and the DR-100 instruments is currently unexplained. The Tennessee Earthquake Information Center (TEIC), the agency which is monitoring the earthquake has stated that: "A distinct possibility is that the high SMA-1 acceleration is an installation effect and does not represent a true free-field acceleration."[3] The entire earthquake recording had a duration of about 3 seconds and the high acceleration had a frequency of about 17 hertz.

[3] TEIC Special Report #8, The Central Arkansas Earthquake Swarm Part 1: 12 January - 12 July 1982 By Arch Johnston and Ann Metzger, October, 1982.

Q10. Can significance be attached to this earthquake as far as damage to nuclear power plants is concerned?

A10. No. If indeed this acceleration is not due to installation effects, then it would represent a very close (near field) high frequency, short duration record of an earthquake with little energy. There was no damage reported to the shed in which the SMA-1 instrument is located or to any other building from this earthquake. Since there was no damage to these buildings which were not designed to withstand earthquake motion there is no reason to believe that earthquake motion of this type could cause damage to a nuclear power plant which is designed using a broad band response spectrum which encompasses the wider frequency range and higher energies of larger earthquakes.

2.5.2 Seismology

2.5.2.1 Introduction

In its review the staff has followed the tectonic province approach to determine the vibratory ground motion corresponding to the SSE (Appendix A of 10 CFR 100). Two important considerations in this approach are the earthquakes that can be considered to be related to known tectonic structures and the random individual events which occur in the same tectonic province as the site but which cannot be related to tectonic structures. Where the occurrence of historic earthquakes can be correlated with tectonic structure, the ground motion at the site is determined assuming that the largest earthquake related to the tectonic structure is situated at the point on the structure closest to the site. Where the occurrence of the earthquake cannot be reasonably related to a tectonic structure, ground motion at the site is usually determined assuming that the largest historic earthquake in the tectonic province can occur near the site.

At the conclusion of the CP review, the staff considered an SSE of 0.20 g at the bedrock-till interface to be an adequately conservative value for the Byron site. This was based on the assumed occurrence of a maximum modified mercalli (MM) intensity VIII earthquake at the Byron site. Byron station is located in the central stable region (CSR) tectonic province. Although, the largest historical earthquake, in terms of intensity, which is not associated with tectonic structure is the 1937 Anna, Ohio, event (MM VIIVIII), the staff's position was that the historical frequency of earthquakes in the site region, including three MM VII events within 200 mi, is too high to consider an SSE of less than MM VIII conservative. The staff also concluded that the maximum ground acceleration of 0.09 g for the OBE was conservative and acceptable on the basis of the applicant's computed recurrence interval of 2150 years for an earthquake of maximum MM intensity VI (CP-SER).

It is the staff's current position that the accelerations of 0.20 g and 0.09 g anchoring Regulatory Guide 1.60 spectra at the foundation level are adequately conservative for the SSE and OBE, respectively, for plant structures supported on bedrock. Lawrence Livermore National Laboratory (LLNL) has acted as consultant to the staff in this review and has concluded that an SSE of 0.20 g is adequate and an OBE of 0.09 g is a conservative representation of the maximum earthquake motion likely to be experienced at the foundation level of the Byron site during the operating life of the plant. The LLNL letter report is attached as Appendix E to this SER.

2.5.2.2 Tectonic Province

The Byron site lies within the CSR tectonic province described by Eardley (1962). The CSR is a region of relative consistency of surface geologic structural features characterized by a series of arches, basins, and domes formed during the Paleozoic era. King (1969) describes the area as "platform deposits on Precambrian foldbelts." The province is a rather extensive region which is, in general, characterized by a relatively low level of seismicity. However, a few areas within the province have experienced significant earthquakes and/or activity above this moderate level. Barstow et al. (NUREG/CR-1577) developed an earthquake frequency map of the Central and Eastern United States. Their work shows that the Byron site region has experienced between 4 and 8 earthquakes per 11,680 km^2 in the period 1800 to 1977.

The staff has recognized that the surface geology of the CSR may not explain the fact that different areas of this large region exhibit different levels of seismicity. Earthquakes typically occur at depths (below ground surface) of 5 to 20 km in the Central United States; therefore, the relevant explanation of the geologic mechanism causing earthquakes is to be found in the geologic structural features at these depths rather than those at the surface. In the absence of any definite knowledge as to the causative geologic structure, levels of seismicity are an important means of assessing earthquake potential.

2.5.2.3 Maximum Earthquake

As discussed in Section 2.5.2.1, to determine the vibratory ground motion under the tectonic province approach, the largest historical earthquakes in the site's tectonic province are considered. The largest historical earthquake, in terms of intensity, in the CSR tectonic province was the 1929 Attica, New York, event (maximum MM intensity VIII). This earthquake is associated with the Clarendon-Lindon structure (CP-SER Nine Mile Point Nuclear Station Unit 2, June 1973; CP-SER Erie Nuclear Plant Units 2 and 3, July 1978). The largest historical earthquake, in terms of intensity, in the CSR tectonic province that has not been associated with tectonic structure is the 1937 Anna, Ohio, event (maximum MM intensity VII-VIII). As stated in the CP-SER (NUREG-7023), historically 3 earthquakes of maximum MM intensity VII, 6 of maximum MM intensity VI, 11 of maximum MM intensity V, and many smaller events have occurred within approximately 200 mi of the Byron site. The earthquake of May 26, 1909 which had an epicenter at 42.5 N, 89.0 W (Coffman and von Hake, 1973) probably produced the highest historical intensity (MM VI) at the site. Generally, in the CSR tectonic province the controlling earthquake for nuclear power plant seismic design is an Anna, Ohio, type event (MM VII-VIII). However, based on the seismicity level that was perceived to be relatively higher than other parts of the CSR tectonic province, the staff concluded, at the CP stage, that the likelihood that the site could experience intensity VII is too high for a controlling earthquake of MM intensity less than VIII to be considered conservative. Accordingly, the staff based the SSE for the Byron site on the postulated occurrence of a maximum MM intensity VIII near the site. The applicant, while accepting this position maintains in Section 2.5.2.4 of the FSAR that the maximum earthquake which could be expected near the site should be intensity VII. The staff has not been made aware of any compelling information during the operating license review which would cause us to change its position as to the possible occurrence of an MM intensity VIII event near the site.

2.5.2.4 Safe Shutdown Earthquake

In the CP-SER the staff accepted an SSE of 0.20 g to be an adequately conservative value for the Byron site based on the postulated occurrence of a maximum MM intensity VIII earthquake near the site. While the seismological and geological evaluation of this controlling earthquake has not been altered since the CP review, the staff has in the interim adopted an SRP and Regulatory Guides which have the effect of changing the acceleration for a MM intensity VIII earthquake. Specifically, following the present SRP an MM VIII earthquake is characterized by a peak acceleration of 0.25 g which is used as the high-frequency anchor of a Regulatory Guide 1.60 spectrum. This higher reference acceleration is determined using the trend of the means relating peak acceleration to intensity shown by Trifunac and Brady (1975). The SRP and Regulatory Guides represent one approach which the staff considers acceptable to establish conformance with NRC regulations. Another acceptable approach to establish the adequacy of the seismic design of nuclear power plants is the use of site-specific spectra (see Sequoyah SER, Watts Bar SER, and Fermi 2 SER). In order to compute site-specific response spectra, it is necessary to characterize the earthquake size, the epicentral distance (distance between the surface location of the earthquake and the site), and the site conditions (soil or rock) being modelled. There are relatively few recordings of strong ground motion at intensity VIII and none (at least in the western United States) recorded at rock sites. This and the more dependable classification of strong motion records by magnitude has led the staff to use magnitude estimates in site-specific studies.

Nuttli and Hermann (1978) developed a relation between maximum MM intensity and magnitude for the Central United States. Using this relation results in an estimated magnitude of 5.75 for an MM intensity VIII. Nuttli and Brill (NUREG/CR-1577) estimates the magnitude of the May 26, 1909 northern Illinois earthquake (MM VII) as 5.1. Estimates of the magnitude of the 1937 Anna, Ohio, earthquake (MM VII-VIII) range from 5.0 to 5.3 (Nuttli and Hermann, 1978; Nuttli and Brill, (NUREG/CR-1577). Therefore, using the site-specific spectrum developed from magnitude 5.8 earthquakes provides a conservative estimate of the vibratory ground motion expected at the site.

The staff has available for its use two site-specific spectra that are suitable for use in establishing the adequacy of the Byron seismic design for structures founded on rock. One of these was generated by the Tennessee Valley Authority for the justification of the seismic design of the Sequoyah, Watts Bar, and Bellefonte nuclear power plants (Tennessee Valley Authority, 1979) and the other was generated by LLNL for use in the NRC-sponsored seismic hazard analysis program (NUREG/CR-1581, Vol.4).

Each of these spectra was generated from real accelerograms of earthquakes in the body wave magnitude range 5.8 ± 0.5 (5.3 to 6.3), recorded at rock sites, at epicentral distances of less than about 25 km. Using a magnitude range helps account for uncertainty in the characterization of the earthquake and also helps ensure an adequate amount of data. The distance range chosen, less than about 25 km, is the distance range to which maximum intensities are felt in the Central United Stages (Gupta and Nuttli, 1976). In addition, at these close distances, the differences in seismic wave attenuation between earthquakes east and west of the Rocky Mountains have not yet affected the ground motion (Nuttli, 1981). It is the staff's position that the 84th percentile spectrum represents an appropriately conservative representation of the site-specific earthquake (see Sequoyah SER, 1979 (NUREG-0011); Watts Bar SER, 1982 (NUREG-0847); Fermi Unit 2 SER, 1981 (NUREG-0793); and San Onofre Units 2 and 3 SER, 1981 (NUREG-0712)). While neither of the two site-specific spectra was established directly for the Byron site, they generally conform to the Byron site-specific spectrum criteria of earthquake magnitude and site geology. The staff has compared the Byron site SSE (Regulatory Guide 1.60 spectrum anchored at zero period by a peak acceleration of 0.20 g) to both of these site-specific spectra and found it to be more conservative than both these site-specific spectra because it exceeds them at all frequencies.

The New Madrid earthquakes of 1811-1812 are the largest historical earthquakes in the United States east of the Rocky Mountains. Nuttli (1981) indicated that the New Madrid 1811-1812 type earthquake would have a body wave magnitude of 7.2. The staff's position has been that the closest approach to the Byron site of a possible recurrence of a New Madrid type earthquake is Vincennes, Indiana. This is over 400 km from the site. The staff has calculated the effect of a magnitude 7.2 earthquake at a distance of approximately 400 km and used the results in conjunction with the mean plus one standard deviation amplification factors from NUREG/CR-0098 to estimate a response spectrum. The Byron SSE response spectrum is greater than the estimated spectrum at all frequencies.

Staff consultants at LLNL used another approach to investigate the adequacy of the seismic design of Byron. They performed a seismic hazard analysis of the Byron site using the data and models given in NUREG/CR-1582, Vols. 2 and 3 and Bernreuter (NUREG/CR-1581). They concluded that the SSE (0.20 g high frequency anchor for Regulatory Guide 1.60 spectrum) for the Byron site is sufficiently conservative. While the staff considers the probabilistic information relevant, it has not used probabilistic procedures to directly determine design ground motion levels for the SSE in operating license reviews. They have been used in a comparative manner such as the comparison of different levels of ground motion at the same site (Sequoyah SER) or equivalent hazard at different sites (Midland Hearing Testimony and Clinton SER). The staff considers the probabilistic approach in the nature of a confirmation of its deterministic approach. Therefore, based on its review and the report of its consultant (Appendix E), it is the staff's position that the SSE with a high-frequency acceleration of 0.20 g anchoring a Regulatory Guide 1.60 spectrum at the foundation level of the structures founded on rock is adequately conservative.

2.5.2.5 Operating Basis Earthquake (OBE)

To justify an OBE of 0.09 g, which is less than half the SSE, the applicant computed the recurrence interval for an earthquake of maximum MM intensity VI in the site region. The result obtained is 2150 years. Using the trend of the means relating peak acceleration to an intensity as shown by Trifunac and Brady (1975) results in a peak acceleration of less than 0.07 g for MM VI. Therefore, the return period for a peak acceleration of 0.09 g should be greater than 2150 years. Consultants at LLNL calculated a return period in the range of 200 to 1000 years for a Regulatory Guide 1.60 spectrum with a high frequency anchor of 0.09 g. This apparent conflict in return periods between the recurrence studies performed by the applicant and LLNL are most probably caused by the different methods and assumptions used. However, in light of the Appendix A to 10 CFR 100 definition of the OBE, these differences in estimated return period do not effect the staff's conclusion that the OBE of 0.09 g is acceptable. This definition states that the OBE is "that earthquake which... could reasonably be expected to affect the plant site during the operating life of the plant." The staff concludes that the OBE of 0.09 g is an adequate estimate of the maximum earthquake motion likely to be experienced at the site during the operating life of the plant.

ROBERT L. ROTHMAN
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DIVISION OF ENGINEERING
U. S. NUCLEAR REGULATORY COMMISSION

My name is Robert L. Rothman. I am presently employed as a Seismologist in the Geosciences Branch, Division of Engineering, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

PROFESSIONAL QUALIFICATIONS

I received a B.S. degree in Geology from Brooklyn College and M.S. and Ph.D. degrees in Geophysics from the Pennsylvania State University.

I have been employed by the NRC since October 1979 as a Seismologist in the evaluation of the suitability of nuclear power plant sites. My areas of expertise include seismicity, rupture mechanics, seismic wave propagation and seismic instrumentation. I am now or have been responsible for the seismological safety review of approximately ten nuclear power plant sites.

From 1975 through 1979, I was employed by the U. S. Air Force Technical Applications Center as a Seismologist in the nuclear explosion detection program. I was involved in several projects of this program both as a Technical Project Officer and as a researcher. These projects included the detection of and the discrimination between underground explosions and earthquakes, magnitude and yield relationship studies, seismic network detection and location capability studies, regional and teleseismic wave propagation studies and projects to operate seismic instrument arrays and automatic data processing and communications systems.

From 1965 through 1970 I was employed as a Seismologist by the U. S. Coast and Geodetic Survey. In this position I was involved in studies in the areas of engineering seismology, seismicity and earthquake aftershock sequences. This work was performed as part of a program to investigate seismic hazard in the United States.

From 1959 to 1962 and during 1964-1965 I was an Engineering Geologist with the New York State Department of Public Works. In this position, I conducted geophysical field surveys in support of construction projects such as bridges, buildings and highways.