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SERVED AUG 29 1986

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

DOCKETED
USNRC

'86 AUG 29 P2:53

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

August 28, 1986

MEMORANDUM FOR: Chairman Zech

FROM: Victor Stello, Jr.
Executive Director for Operations

SUBJECT: STAFF RESPONSE TO JOHNSON CONCERN RE: THE PERRY EARTHQUAKE

DOCKET NUMBER
PROD. & UTIL. FAC. 50-440/441-OL

This is in response to your request of August 7, 1986 for a point-by-point response to a letter from Dr. W. Reed Johnson of the Atomic Safety and Licensing Appeal Board. As the staff understands it, Dr. Johnson was concerned about the Perry SSE having been exceeded, in the high frequency region, during the January 31, 1986 earthquake which occurred about 10 miles south of the Perry plant site.

The applicant and the staff and their respective consultants have evaluated this earthquake, and the effects, in general, of short duration, high frequency ground motion on equipment and structures. The January 31, 1986 Ohio earthquake was judged to have an insignificant effect on the Perry plant structures and equipment. The staff concluded the seismic design of the Perry plant remains acceptable and unaffected by the earthquake.

A point-by-point response to Dr. Johnson's letter is enclosed.

Victor Stello, Jr.
Executive Director
for Operations

Enclosure: Point-by-point
response to W.R. Johnson's
letter of 7/29/86

cc: Commissioner Roberts
Commissioner Asselstine
Commissioner Bernthal
Commissioner Carr
OGC
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ENCLOSURE

POINT BY POINT RESPONSE TO W. R. JOHNSON'S LETTER OF 7/29/86

Item No. 1 - Earthquake Energy

"The 1986 Ohio earthquake had a magnitude of 5.0. The Perry design basis Safe Shutdown Earthquake (SSE) is described as a magnitude 5.3 event. If one accepts the logarithmic nature of the earthquake magnitude scale, the 1986 Ohio earthquake was about a factor of two less energetic than the SSE."

Response

The staff does not believe that a comparison of the 1986 Ohio earthquake with the Perry SSE by simple scaling of earthquake magnitudes is appropriate for assessing its effect on the plant. Ground motion can be affected by source, wave travelling path, and site effects. The total energy (Fourier energy) contained in the 1986 Ohio earthquake records was compared to the foundation design motions for the N-S, E-W, and vertical directions by the staff's consultant. The 1986 Perry records have 3.25%, 1.75%, and 1.94% of the energy for the respective design components of the SSE.

Item No. 2 -Instrument Recordings

"Five seismic instruments recorded the motion of the event at the basemat or foundation level at Perry -- three in the auxiliary building and two in the reactor building. In the staff's response to the motion to reopen, affiant Arnold Lee suggested that the motion recorded at these foundation stations would be similar to free field ground motion. Despite the lower magnitude of the earthquake, 10 of the 14 values of peak ground acceleration obtained from these instruments exceeded the acceleration value used as the anchor point for the Perry SSE spectrum, 0.15g. Recordings of these five instruments yielded the following average peak accelerations in the horizontal directions: North/South, 0.46g; East/West, 0.20g. The average peak acceleration in the vertical direction was 0.18g.

It is accepted that a response spectrum derived from the entire time-history-of-motion of an earthquake represents a more definitive measure of the event's ability to affect structures and mechanical systems than do values of peak acceleration. In the case of the 1986 Ohio event there were twelve response spectra derived from four instruments located at foundation levels (3 PSR-1200s memtioned in footnote 1 and a Kinemetrics accelerograph D51-N101). As noted in the March 20 order, nine of these spectra exceeded the SSE spectrum throughout the frequency range above about 15 Hz.

The recorders registering the highest values of peak ground acceleration were Engdahl Peak Shock Recorders (Model PSR-1200). The applicants, in Table 2 of Attachment 5 of their answer to OCRE's motion to reopen, did not include the data from PSR-1200 units at the auxiliary building foundation (D51-R180 and D51-R190) or one at the reactor building foundation (D51-R160). They did, however, give the data for a PSR-1200 at the 630' elevation in the reactor building (D51-R170). To obtain a peak acceleration from this instrument (the PSR-1200 records response spectrum values directly and not a time-history-of-motion), the applicants selected the acceleration value recorded at the highest frequency, 25.4 Hz, and I have done the same for the comparison above. Although there were no reservations stated by the applicants for using the PSR-1200 data this way -- and they did it themselves -- there may be some reason why data from this type of recorder do not accurately reflect peak accelerations, thus explaining why this information was not included in Table 2 and changing the average values given above."

Response

We agree several response spectra were exceeded. However, we believe that 8 of 11 spectra were exceeded at the frequency range above 15 Hz. A spectrum was not available for D51-R180 (vertical) since it was out of service for calibration.

The data shown in Table 2 of Attachment 5 of CEI's response to OCRE's motion to reopen are the zero-period-accelerations (ZPA) from acceleration time history recorders (Kinemetrics time history recorders D51-N101 and D51-N111) and the peak recording accelerometers (Engdahl D51-R140 and D51-R120). Additionally the table shows values for the response spectra recorder (Engdahl D51-R170). This instrument is not capable of providing the ZPA directly; instead the value shown is an estimate of the ZPA based on the maximum acceleration value at 25.4 Hz. This value is not the ZPA, but is a value in the amplified region of the floor response spectra and is therefore somewhat larger than the ZPA. The omission of the data from the other response spectra recorders is appropriate for the following reasons:

1) The ZPA at Auxiliary Building elevation 568' is determined from peak recording accelerometer D51-R140. Since this instrument measures peak acceleration at high frequency directly, the ZPA is determined from a measured value rather than by estimation of a ZPA from the 25.4 Hz value of the D51-R180 or the D51-R190 response spectra recorders located at this elevation.

2) The ZPA at the Reactor Building foundation mat at elevation 574'-10" was determined from the time history recorded by Kinemetrics D51-N101. Again the ZPA can be determined from the recorded data rather than by estimation of a ZPA from the 25.4 Hz value of the response spectra recorder D51-R160.

It should be emphasized that, while an estimate of the ZPA based on the maximum acceleration value at a certain frequency lower than the high frequency cut-off, such as 25.4 Hz, may not induce significant error for a "common" earthquake motion, such as Regulatory Guide 1.60 spectrum, the same procedure will cause significant error for a high frequency earthquake such as the 1986 Ohio earthquake.

On the basis of the above discussion, the staff finds that average values of the ZPA's measured from D51-R140 and D51-N101, and the peak acceleration values measured at 25.4 Hz from D51-R160, D51-R180 and D51-R190, should not be compared to the SSE's because these are different types of measurements. Instead, the ZPA's obtained from D51-R140 and D51-N101 alone should be compared to the SSE's. Such comparison indicates the following: In the N-S direction, D51-R140 and D51-N101 recorded the ZPA's of 0.17 g and 0.18 g, respectively, which match the corresponding SSE values calculated at the same foundation locations. In the E-W direction, the recorded ZPA's are 0.06 g and 0.10 g, which are well below the corresponding SSE values of 0.20 g and 0.18 g, respectively. Finally, in the vertical direction, the recorded ZPA's are 0.03 g and 0.11 g, which again are well below the corresponding SSE values of 0.20 g and 0.18 g, respectively. Based on the above comparison, it can be stated, therefore, that the ZPA's of the SSE at the foundations of Reactor Building and Auxiliary Building were not exceeded by those of the 1986 Ohio earthquakes.

Item No. 3 - Induced Stresses/Effects

"The most direct way to measure an earthquake's effect would be to determine stresses developed in structures and equipment due to its motion. Such stresses can be calculated for a particular event if a response spectrum or time-history-of-motion for the event exists. The staff's safety evaluation report, SSER-9, states at page 3-10 that stresses have been calculated using the 1986 Ohio event as input for certain pumps located at the auxiliary building foundation level. The resulting stresses were within allowable limits, but they might exceed "original" calculated values. The Appeal Board was not told the basis for the "original" calculations, but assumed that it would be earthquake motion equivalent to the SSE. If this assumption is valid, then the excitations (i.e., stresses) due to the 1986 Ohio earthquake exceed those for the SSE for these items. The equipment in the auxiliary building to which these results apply was not identified in SSER-9, but we believe the pumps involved were in the Low Pressure Core Spray (LPCS), the Residual Heat Removal (RHR), and High Pressure Core Spray (HPCS) systems.

Appendix A of SSER-9 refers to a letter of February 28, 1986, from the applicants to the staff. Attachment 3, Section III 3 of this letter apparently provides some of the bases for the staff testimony on stresses in pumps. Table 2 of Attachement 3 illustrates that, for the LPCS, RHR, and HPCS systems, the "new" stress ratios are generally higher than the previously calculated values (presumably using the SSE as the exciting event)."

Response

In the analyses for seismic effects on structures and equipment, the plant-induced dynamic loadings as well as end loadings, such as nozzle loads for mechanical equipment, are combined with the loading induced by the earthquake input motion. The stresses due to loads induced by the earthquake in some cases did exceed those in the original analyses. However, the increases in the earthquake-induced stresses did not exceed the overall design allowable limits for the equipment or structures that were reevaluated. The reanalysis

performed for the RHR, HPCS, and the LPCS pump/motor at Perry demonstrates that the equipment was designed with sufficient margins to accommodate the exceedances at high frequency region of the earthquake. For instance, the stress ratio for the LPCS pump discharge column flange and bolting originally was calculated at 0.890 and was recalculated considering the 1986 earthquake at 0.921. It should be emphasized that these stress ratios are for combined loads under faulted conditions. Further, the ratios are for design allowable stresses. Actual capacity of the equipment prior to failure would be considerably greater.

A comprehensive list of equipment, consisting of about 160 equipment items, was selected by the applicant for a confirmatory study. Among them, 58 equipment items were qualified by analysis or a combined test/analysis method, using similar criteria as for the above-mentioned pump/motor. In all cases, the quantitative study on margin relative to the design limits indicates the safety margins to be greater than one.

Item No. 4 - Extrapolation of Induced Stresses

"Thus, the information that was supplied or referred to regarding the 1986 Ohio earthquake indicates that this earthquake, a factor of two less energetic than the SSE for Perry, has exceeded the SSE in peak acceleration and in the high frequency portion of the response spectra. Calculations using the motion of this event as input have apparently led to stress levels in certain safety-related items that exceed those that would be calculated for the SSE. Presumably an earthquake of similar spectral characteristics but having the 5.3 magnitude of the SSE would cause even greater stresses."

Response

As indicated in the response to Item No. 1, the simple scaling of energy content of an earthquake magnitude is not appropriate. The damage potential of an earthquake can be estimated based on two different concepts: One is to relate the damage potential to the frequency content of the input motion -- specifically, the acceleration level as a function of frequency. The other is to relate it to the energy content accumulated over the strong motion period of the earthquake. While the former concept is suited for assessment of elastic stresses and deflections and the functionality of some active components (such as relays), the latter concept should be realistically considered for assessing the total (elastic and inelastic) response capability of the equipment (such as ductility demand calculation). In all these cases, the duration of the strong motion is an important factor, as is also discussed in the response to Item No. 5 which follows below.

As stated in the response to Item No. 1, in the study conducted by the staff's consultant, the energy associated with the 1986 Ohio earthquake is only about 3.25%, 1.75%, and 1.94% of that associated with the Perry design motions for N-S, E-W, and vertical components, respectively. This indicates that when considering the inherent ductility of the components, the Ohio earthquake has relatively insignificant capability in causing stress failure. On the other hand, the deflection which generally dictates the operability of active mechanical components would still be within allowables, even if the damaging capability of the earthquake is doubled. This can be readily seen from the result of the reanalysis performed by the applicant, for the RHR, HPCS and the LPCS pump/motor mentioned in the response to Item No. 3.

As for the functionality of relays, no relay chattering or contact bounces associated with safety-related components have been observed which impacted the safety systems operating during the earthquake.

In addition, the staff's Unresolved Safety Issue (USI) A-46 program has been developed to handle the seismic qualification for all safety-related equipment in operating plants, based on actual earthquake experience as well as test experience methods. The information collected so far in the USI A-46 program indicates that the equipment, active or passive, is generally rugged enough to withstand the earthquake vibratory motions occurring in the Eastern United States.

Item No. 5 - Generic Concern on High Frequency, Short Duration Earthquakes

"It is well documented that the 1986 Ohio earthquake was of short duration, and that its principal motions were in the high frequency range. Response spectra derived from these motions have an odd shape, with a broad peak in the range of about 20 Hz. Very little was presented to us regarding the unusual character of this earthquake, its origins, or whether future earthquakes that might be experienced at the Perry site could be expected to have similar characteristics. Given that the peculiar motion frequency characteristics of this event have apparently caused calculated stress values in excess of what might be expected for an earthquake of its magnitude, it would appear that more information should be developed regarding the nature of this event and the possibility of the recurrence of this type of high frequency motion at Perry and possibly other sites.

The Appeal Board's concern about this earthquake seems to be shared by ACRS geology consultant, Dr. Paul W. Pomeroy. In response to OCRE correspondence to the ACRS, Dr. Pomeroy concluded (in a letter that was included in the NRC's April 8, 1986 presentation to the House Committee on Interior and Insular Affairs):

> The large high frequency content of earthquake signals is a generic problem of significance to the successful operation of these plants. At frequencies greater than 14 Hz, the SSE for Perry was significantly exceeded. No significant failures in systems operating at the time of the earthquake have been reported. Nonetheless, at somewhat higher magnitude levels, these high frequency signals will be of importance and a generic study should be undertaken with the goal of modifying required response spectra and to insure the continuing safe operation of relays, valves and other devices that can potentially be affected by these frequencies."

Response

The staff, in Supplement 9 to the SER, stated the applicant's commitment to provide confirmatory information that included additional quantitative assessments of a more comprehensive sample of equipment. Also the applicant would conduct a generic evaluation of high frequency, short duration ground motion with regard to energy content and potential safety significance for equipment and structures at Perry. In addition the applicant would assess the seismic capability of the Perry plant, assuming that other earthquakes of similar characteristics, but with higher magnitude and/or longer duration occur near the site.

The applicant and its contractors have completed additional seismologic, geologic and engineering studies of the 1986 Ohio earthquake. The studies in the seismologic and geologic area have included fault plane solutions for the event, the search for a possible source structure, assessment of faults at the plant site and studies of the high-frequency content of the earthquake and its aftershocks. The staff and its consultants, the U.S. Geological Survey, have reviewed the applicant's efforts and performed independent investigations and analyses to characterize the 1986 Ohio earthquake. Both the applicant and the staff and their consultants agree, that the 1986 Ohio earthquake was similar in character to other Eastern earthquakes, no discernible capable fault was associated with the earthquake and it is unlikely that chemical injection wells 7 miles from the epicenter were related to the earthquake. The 20 Hz motion recorded at the plant is due to some combination of source mechanism, path and site effects. Earthquakes of short duration and rich in high frequency content have been observed for other Eastern U.S. earthquakes. However, these high frequency ground motions have not been used to scale design spectra, such as Regulatory Guide 1.60, because they are usually of short duration and little energy and are not representative of spectral response at lower, more significant frequencies. The applicant and its consultant, as well as the staff and its consultant have evaluated the effects of short duration, high frequency earthquakes on plant equipment and structures. All parties agree that the 1986 Ohio earthquake was considerably less energetic and had much less ductility demand than the SSE.

There is a substantial literature documenting the low damage potential of earthquakes of short duration and high frequency. The staff consultant performed a similar study to investigate differences in identifying characteristics and damage potential for different classes of earthquakes. The 1986 Ohio records were found to contain less energy than for any other records considered and much less energy than earthquakes with longer duration motion.

The applicant's consultant performed a reevaluation of equipment qualified by analysis and testing and found that the Perry plant seismic design has adequate safety margin to accommodate the recorded 1986 Ohio earthquake even though the design response spectra were exceeded at around 20 Hz. The applicant studied the effect of a hypothetical higher amplitude and longer duration ground motion similar to the 1986 record and found that the ductility demand would only be slightly increased and that the elastic spectra would not increase significantly around 20 Hz but may increase in the lower frequency region. The applicant concluded and the staff concurred that if an earthquake similar to the 1986 Ohio earthquake of somewhat higher amplitude and longer duration should occur near the Perry site, the current seismic design and equipment qualification program would still be adequate to ensure that plant equipment and structures would not be damaged.