UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

IN THE MATTER OF	)	
	)	Docket No. 50-155-OLA
CONSUMERS POWER COMPANY	)	(Spent Fuel Pool
	)	Modification)
Big Rock Point Nuclear Power Plant	)	

CONSUMERS POWER COMPANY'S PROPOSED INITIAL DECISION ON CRITICALITY CONTENTION

I. BACKGROUND

O'Neill Contention IIE-3 states:

> The application has not adequately analyzed the possibility of criticality occurring in the fuel pool because of the increased density of storage without a gross distortion of the racks.

Consumers Power Company ("Licensee") and the Staff of the Nuclear Regulatory Commission ("Staff") filed motions for summary disposition of this contention on October 5, 1981. Licensee's motion was supported by the affidavit of Dr. Yong S. Kim, a nuclear engineer employed by NUS Corporation. Dr. Kim previously authored the criticality analysis set forth in the application in this proceeding. Staff's motion was supported by the affidavit of Mr. Edward Lantz. Intervenors Christa-Maria, Jim Mills and Joanne Bier and Intervenor John O'Neill submitted arguments in opposition.

On February 5, 1982, we entered a Memorandum and Order denying summary disposition on this contention on the ground that Christa-Maria had demonstrated a genuine issue of material fact. We noted that Dr. Kim had used a pool

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water temperature of 212°F in his analysis and that he had calculated a k-effective of 0.95, the maximum allowable reactivity for spent fuel under wet storage conditions according to existing Commission guidance. We accepted Christa-Maria's argument that because of the hydrostatic load the boiling temperature at the bottom of the spent fuel pool is 247°F, and that Dr. Kim's calculation therefore might not have been conservative. We also questioned the thoroughness of the Staff's review of the Licensee's criticality analysis. Furthermore, we noted that Dr. Kim did not appear to have considered the effect on k-effective of possible distortion of the fuel racks from the drop of a fuel assembly or during heating (Order at 4-5).

On February 1, 1982, John O'Neill submitted an affidavit by Charles W. Huver, Ph.D., concerning another contention in this proceeding. This affidavit cited a journal article -- Cano, J.M., Caro, R. and Martinez-Val, J. M., "Supercriticality Through Optimum Moderation in Nuclear Fuel Storage," 48 Nuclear Technology at 251-260 (1980) -- which we subsequently analyzed. In our February 19, 1982, Memorandum and Order Concerning Motions for Summary Disposition we expressed our conclusion that this article raised a genuine issue of fact concerning whether the Big Rock spent fuel pool might reach supercriticality if it were to begin boiling (Order at 48-49).

On May 10, 1982, Licensee filed the testimony of four witnesses on O'Neill Contention IIE-3:

(a) Daniel A. Prelewicz. The testimony of Dr. Prelewicz, an engineer with thermal hydraulics expertise, provides the thermal conditions for use in the criticality analysis. Dr. Prelewicz describes the natural circulation cooling process in the Big Rock Point spent fuel pool and the manner in which pool thermal conditions are determined, assuming that all pool cooling systems are lost and the pool surface begins to boil.[1/]

(b) Rodney Gay. Attached to Dr. Prelewicz's testimony is a study entitled "Spent Fuel Pool Thermal-Hydraulic Analysis For Big Rock Point Plant," co-authored by Dr. Prelewicz and Dr. Rodney Gay, who is also a thermal hydraulics expert. This study uses the GFLOW computer code, developed by Dr. Gay, to model the natural convection currents in the Big Rock pool in three dimensions. The study confirms Dr. Prelewicz's assumption about the inlet temperature of water currents at the bottom of the fuel rods.[2/]

(c) Raymond F. Sacramo. The testimony of Mr. Sacramo, a mechanical engineer employed by NUS Corp., analyzes the nature of the distortion of the racks that could occur as a result of a fuel assembly drop or heating of the pool.[3/]

1/ "Testimony of Daniel A. Prelewicz Concerning Thermal Hydraulic Conditions for Criticality Analysis," hereinafter "Prelewicz Testimony," following Tr. 1420.

2/ "Spent Fuel Pool Thermal-Hydraulic Analysis For Big Rock Point Plant," Attachment A to the Prelewicz Testimony.

3/ "Testimony of Raymond F. Sacramo Concerning Possible Distortion of the Spent Fuel Pool Racks (O'Neill Contention IIE-3)", hereinafter "Sacramo Testimony," following Tr. 1421.

(d) Yong S. Kim. The testimony of Dr. Kim addresses the questions raised by the Board in its orders of February 5 and February 19: the effect of possible pool water temperatures higher than 212°F on k-effective, the effect of possible rack distortions on k-effective, and the potential of supercriticality through optimum moderation in nuclear fuel storage.4/

Also on May 10, 1982, the Staff submitted the testimony of Mr. Edward Lantz, a Senior Reactor Engineer in its Reactor Systems Branch. Mr. Lantz also addressed the Board's concerns regarding the effects of pool temperature or rack distortion on k-effective and the possibility of supercriticality through optimum moderation.5/

On May 13, 1982, the Board issued another memorandum regarding the criticality contention. After a preliminary review of Licensee's testimony, the Board requested comments on whether natural convection currents could be substantially altered by either (a) the geometry of the pool, the racks or the fuel elements, or (b) by debris that could fall into the pool under a credible scenario. If so, the Board queried the possible effects on k-effective (Memorandum (Clarification Concerning O'Neill Contention IIE-3), May 13, 1982, at 1). On June 1, 1982, Licensee filed the testimony of David P. Blanchard, a Technical Engineer stationed at Big Rock Point.

4/ "Testimony of Yong S. Kim Concerning Criticality Analysis (O'Neill Contention IIE-3)", hereinafter "Kim Testimony", following Tr. 1419.

5/ "Testimony of Edward Lantz Concerning O'Neill Contention No. II.E.3.", hereinafter "Lantz Testimony," following Tr. 1905.

Mr. Blanchard's testimony addresses the questions raised by the Board.[6/]

O'Neill Contention IIE-3 was fully litigated during the course of the evidentiary hearings held on June 9-12, 1982, in Boyne Falls, Michigan (Tr. 1392-1692, 1748-2002, 2006-2009, 2092-2094 and 2383-2384). Cross-examination of all witnesses testifying on this contention, both by the Intervenors and by the Board, was lengthy and vigorous. Intervenors did not file testimony or rebuttal testimony on the contention. Nonetheless, at the close of hearings, Intervenors requested the right to call rebuttal witnesses (Tr. 2367-69), a request amplified in a written motion of July 1, 1982. On July 21, 1982, we ruled that hearings on the criticality issues had been completed and that Intervenors' allegations that the record contained ambiguous or conflicting testimony were insufficient to depart from the pre-established schedule. Noting the importance of the issue, however, we allowed Intervenors until August 9, 1982, to identify a witness and to explain why the record should be kept open. We stated that failing a timely filing, the hearing on the criticality issue would be considered complete (Memorandum (Motion Regarding Rebuttal Witnesses on Criticality Contention), July 21, 1982 at 1). Intervenors filed no motion.

6/ "Testimony of David P. Blanchard in Response to Board Questions Relating to Natural Water Convection Currents," hereinafter "Blanchard Testimony," following Tr. 1431.

II. APPLICABLE LAW

The NRC, by regulation - 10 C.F.R. § 54.57 (a)(3)(i), requires reasonable assurance that all license activities be conducted without endangering the health and safety of the public. In furtherance of this objective and within the framework of the issue presently being considered by the Board, General Design Criterion 62 (10 C.F.R. Part 50, Appendix A) requires that "criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations." Implementing guidelines developed by the NRC Staff establish a maximum "k-effective" of 0.95 for spent nuclear fuel under wet storage conditions. See Standard Review Plan, NUREG-0800, dated July 1981, § 9.1.2; NRC Branch Technical Position entitled "OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications," and NRC Regulatory Guide 1.13, Rev. 1 dated December 1975.[7/] It is against these regulations and guidelines that the Licensee's evidence on the criticality issues should be weighed.

7/ Revision 2 to Regulatory Guide 1.13 was proposed for comment in December 1981. That document has not yet been adopted by the NRC Staff as regulatory guidance.

III. DISCUSSION

Four issues regarding criticality may conveniently be separated for analysis: (1) the question regarding the conservatism of the criticality analysis for the pool boiling condition; (2) the question regarding the possibility of supercriticality through optimum moderation; (3) the rack distortion issue; and (4) the pool debris issue.

1. Criticality analysis for the pool boiling condition

Three of Licensee's experts contributed to the criticality analysis of the spent fuel racks under pool boiling conditions. Dr. Prelewicz provided the thermal conditions for the criticality analysis. Dr. Gay performed a study to verify one of Dr. Prelewicz's assumptions. Finally, relying on these thermal conditions, Dr. Kim calculated the effective neutron multiplication factor, or chain reaction constant -- abbreviated "k-effective" --for the storage racks.

The testimony of Dr. Prelewicz presents the thermal conditions that would occur in the Big Rock spent fuel pool if all cooling systems were lost. Dr. Prelewicz explains that the saturation, or boiling, temperature of water is a function of pressure and will increase with depth due to the hydrostatic head of water in the pool. Once this temperature is reached, further energy input to the water results in generation of steam bubbles or voids (Prelewicz Testimony at 3). This maximum temperature, however, will not necessarily be reached. Dr. Prelewicz's analysis shows that although the saturation temperature at the bottom of the Big Rock spent fuel pool is 243°F, a natural circulation process prevents this temperature from actually occurring. Because water becomes less dense and hence lighter as its temperature increases, a situation in which water temperature increases with depth is unstable. When heat is continuously added, a natural circulation flow is established, whereby heated water rises continuously to the surface near the center of the pool, while cooler water flows downward near the pool walls (Prelewicz Testimony at 4).

Dr. Prelewicz modeled this natural circulation flow in the most limiting location in the pool, using the computer code SFPT2. The model is based on one-dimensional flow in the pathway, known as a downcomer, between the pool wall and the racks and the up-flow through a row of fuel bundles fed by the downcomer. The inlet temperature of the water at the bottom of the racks is taken as 212°F and its heat-up as it rises through the fuel bundles is calculated from an energy balance (Prelewicz Testimony at 5). This analysis shows that the water in the most limiting bundle will reach the saturation temperature of 237°F at .276

inches below the top of the bundle. The water temperature along the active length of the fuel will thus vary from approximately 212°F at the bottom to 237°F at the top, an average temperature of 224.5°F (Prelewicz Testimony at 6).

Once the saturation temperature is reached, further energy input to the water goes into the generation of steam voids. The length of the fuel over which this occurs, called the boiling length, is thus .276 inches (Prelewicz Testimony at 7). Dr. Prelewicz determined the extent of void formation in the boiling length from an energy balance equation. At the exit of the bundles the void fraction, or ratio of steam volume to total fluid volume, is .206. The void fraction will vary over the boiling length from zero at the start of boiling position to .206 at the exit (Prelewicz Testimony at 7).

To verify that the temperature of the water entering the bottom of the fuel racks is approximately 212°F, Dr. Gay performed detailed calculations of the natural circulation flow patterns in the Big Rock spent fuel pool using the GFLOW computer program that he developed. GFLOW models the pool in three dimensions and determines velocities and temperatures throughout the pool. The GFLOW analysis demonstrates that natural circulation patterns in the pool cause the water entering the bottom of the fuel racks to be approximately 212°F, thus verifying Dr. Prelewicz's assumption (Prelewicz Testimony at 8).

The Board conducted a very lengthy examination of Dr. Gay, largely for its own information, since his GFLOW code has not previously been used for licensing purposes. Dr. Gay testified that the GFLOW predictions have been checked for mathematical consistency, that they have been compared to those of a conservative calculation for spent fuel pools and shown to be reasonable, and that earlier versions of the code were compared to experimental data in chemical reactors and proved correct (Tr. 1610). Most of the examination of Dr. Gay centered on the way in which his code modeled various aspects of pool geometry and hydraulic flows and need not be summarized here. Although Dr. Gay's study predicts temperatures and circulation patterns throughout the pool, it was offered in evidence only to verify the assumption made by Dr. Prelewicz that the inlet temperature at the bottom of the racks would be approximately 212°F, which Dr. Gay testified is a normal assumption routinely made in spent fuel storage pool analyses (Tr. 1613). Consequently, although Dr. Gay reasoned persuasively about the assumptions built into his computer code, we do not believe it is necessary for us to determine the accuracy of his overall predictions. Dr. Gay testified that even if the overall predictions of the code as to maximum pool temperatures were not accurate, its predictions of the 212°F inlet temperature are very insensitive to the process of heat transfer involving the fuel elements themselves. They depend only on the circulation patterns in the downcomer from the top of the pool, a much easier thing to predict (Tr. 1630).

The Board initially had some difficulty visualizing the process by which water would descend along the pool walls with virtually no rise in temperature. Dr. Prelewicz, however, explained this effect as follows: The cooler water would begin to descend over a much larger area than that of the eventual downcomer. At the inside edge of this descending stream, there would be a sacrificial interface mixing with the warmer water coming up, pushing it into the center and thus protecting the water nearest the pool wall from mixing (Tr. 1656-1663). Moreover, as Dr. Gay explained, GFLOW predicts that as the water descends, its temperature decreases from 212°F at the surface to as little as 206°F before reaching approximately 212°F at the inlet of the fuel racks (Tr. 1668). We note also that the Board asked Mr. Lantz the Staff's criticality expert, for guidance on whether it would be appropriate to rely on the GFLOW code for licensing purposes (Tr. 1692). Mr. Lantz testified that although he did not think the accuracy of the program had been completely proven, he believed it was perfectly adequate for the purpose of verifying the inlet temperature (Tr. 1930-1932).

Dr. Prelewicz testified that when Dr. Kim performed his initial criticality analysis for the Big Rock spent fuel pool, the thermal conditions that he was supplied with were a coolant temperature of 212°F and an exit void fraction of 20.6% (Prelewicz Testimony at 7). In view of the Board's concern about thermal conditions used for the criticality analysis and Dr. Kim's results, which show k-effective increasing with temperature, Dr. Prelewicz provided Dr. Kim with the following, more realistic, thermal conditions: The water temperature varies along the length of the fuel bundles from approximately 212°F at the inlet to 237°F at the exit; the average temperature over the active fuel length is 224.5°F. Bulk voids exist only for the upper .376 inches of the channel; the ratio of steam volume to total fluid volume is .206 at the exit (Prelewicz Testimony at 7-8).

The testimony of Dr. Kim presents a new calculation of k-effective based on these more realistic thermal conditions. Dr. Kim initially points out what the other parties and the Board apparently had not understood previously, that his original analysis did not determine that existing fuel stored at the Big Rock Point reactor reached the maximum k-effective of 0.95. The purpose of his analysis had been to determine the limiting fuel design by searching the highest enrichment consistent with this maximum permitted value. All the existing fuel at Big Rock Point is much less reactive than this limiting fuel design (Kim Testimony at 4-5).

Dr. Kim explains that 212°F had been used in his earlier calculation because it had been an industry practice to use 212°F as the boiling temperature when considering the formation of small steam voids in a spent fuel pool. For most pools, this is conservative because k-effective decreases with increasing temperature. Dr. Kim's original analysis, however, showed that for the Big Rock pool, k-effective increases with temperature (Kim Testimony at 6). This positive correlation is attributable to over-moderated fuel racks (Kim at Tr. 1464-1465; Blanchard at Tr. 1850). When Dr. Kim performed this analysis, he was not aware that the water temperature varied from 212°F at the bottom of the racks to 237°F near the top (Kim Testimony at 6). Moreover, his result made use of the 212°F figure non-conservative. Dr. Kim therefore performed new calculations based on the thermal-hydraulic conditions provided in Dr. Prelewicz's testimony (Id.). Instead of a temperature of 212°F, the new calculations utilize a temperature of 224.5°F, the average temperature along the length of the fuel bundles (Kim Testimony at 7). This resulted in an increase of 0.0014 in k-effective over the previous analysis (Id.). Testimony elicited at the hearing further clarified the appropriateness of using this average temperature figure. Dr. Prelewicz testified that the temperature will rise in a linear fashion, making use of the arithmetic mean appropriate (Tr. 1553). Dr. Kim concluded, based on his experience doing other criticality analyses, that reactivity varies in a linear enough fashion to make use of the arithmetic average appropriate. (Tr. 1522).

In his original calculation of k-effective, Dr. Kim assumed that the steam void volume fraction of 0.206 provided by Dr. Prelewicz was uniformly distributed along the entire height of the fuel assembly. He testified that this assumption was excessively conservative, however, in relation to the actual void distribution, showing that steam voids exist only for the upper 0.276 inches of the fuel length (Kim Testimony at 7-8). When the more realistic average void fraction is calculated, it yields an increase in k-effective of only 0.00001, which is effectively zero. Because the original analysis had attributed an increase in k-effective of 0.0044 to steam voids, a net decrease of 0.0044 in k-effective results from the new calculation (Id.).

The effects of the revised steam void volume fraction and the revised average water temperature yield a net decreas in k-effective 0.0030, so that the revised k-effective calculated by Dr. Kim is 0.9470, less than the permitted maximum of 0.95 (Kim Testimony at 8-9).

We find that Dr. Kim's analysis of k-effective assuming a total pool cooling system failure, supported as it is by the rationale for the thermal hydraulics conditions provided by Drs. Prelewicz and Gay, is both thorough and persuasive. At the hearing the Board examined Dr. Kim at length and found him to be not only intelligent, but a particularly frank and forthcoming witness. Moreover, the tesimony of Mr. Blanchard, who is expert in both thermal hydraulics and criticality (Tr. 1798-1801), provides independent support for the accuracy of Dr. Kim's analysis. Mr. Blanchard testified that he had reviewed both the original criticality analysis and the revised analysis prepared by Dr. Kim and considered both analyses correct, given their assumptions (Tr. 1821-1822). Moreover, Mr. Blanchard verified those assumptions; he reviewed the initial conditions of the calculations, especially the fuel design, to determine that the analysis bounded any conditions that might exist in the Big Rock pool (Tr. 1823). Mr. Blanchard considers that the initial conditions assumed both in Dr. Kim's original analysis and his revised analysis are conservative (Tr. 1824).

At the hearing, Intervenors' counsel subjected Drs. Kim and Prelewicz to extensive cross-examination intended to elicit testimony reflecting what Intervenors perceive as a record of inconsistencies in the calculation of k-effective indicative of deliberate manipulation of the results. Upon counsel's allegation of these inconsistencies (Tr. 1392-1398), we acceded to counsel's request for sequestered cross-examination of these two witnesses for the limited purpose of testing whether there were factual inconsistencies on the conveying of the premises for the criticality calculations (Tr. 1400-1415).

In part, Intervenors' allegations were clearly based on a misunderstanding of Dr. Kim's original analysis. Their counsel examined Dr. Kim with regard to a workpaper from his analysis file showing a calculation of .9502 for k-effective (Tr. 1453-1454). As Dr. Kim explained, however, the purpose of his analysis was to search by an iterative process the maximum fuel enrichment which would yield a value of 0.95 for k-effective (Tr. 1454-1459). In part also, we believe the record indicates a certain lack of communication between Dr. Prelewicz and Dr. Kim in the early stages of their analyses. The two men were performing their calculations in parallel. Dr. Prelewicz did not know that reactivity in the Big Rock pool increased with increasing temperature (Tr. 1593-1594); likewise Dr. Kim did not know that a temperature of 237°F was reached at the exit of the fuel bundles or that the boiling length was .276 inches (Kim Testimony at 6-8; Kim at Tr. 1509, 1513; Prelewicz at Tr. 1579-1580). We conclude, however, that the record in no way impugns the integrity of either Dr. Prelewicz or Dr. Kim nor diminishes the credibility of their testimony.

Mr. Lantz of the Staff followed a somewhat different methodology in determining k-effective. Mr. Lantz accepted Dr. Kim's calculation of k-effective at various temperatures and water densities which he testified there was no reason to doubt the accuracy of (Lantz Testimony at 5-6). He plotted these results as a smooth curve and determined that k-effective peaks at 212°F with a 1% steam void, which corresponds to a water density of 0.948 gm/cm^3 (Id.). Any variation from this optimum density caused by changes in temperature or void fraction would reduce k-effective (Lantz Testimony at 5, 7). K-effective as calculated for the Big Rock pool would therefore remain within the allowable limits (Lantz Testimony at 6). In addition, Mr. Lantz verified the conservatism of Dr. Kim's calculation of k-effective by an independent method regarded as reliable by the Staff, which compares the calculation for a given storage pool to a curve derived from results in many other pools (Lantz Testimony at 6-7).

Any apparent discrepancies between the assumptions of Dr. Kim and Mr. Lantz about the calculation of k-effective at the relatively low void fractions that would occur if the pool began to boil were resolved at the hearing. Mr. Lantz testified that there was no disagreement between them as to the relation between temperature, void fraction, water density and k-effective (Tr. 1926-1927, 1933). Dr. Kim testified that the difference between their methods was that Mr. Lantz converted a temperature effect into a density effect and that any resulting difference in calculation occurred in decimal places generally regarded as non-significant (Tr. 1947-1948). To the extent that there was disagreement between Dr. Kim and Mr. Lantz, it concerned predictions of reactivity at extremely low water densities, which is the subject of the next section of this opinion.

We conclude that Dr. Kim's testimony adequately analyzes the possibility of criticality occurring, assuming that all pool cooling systems were lost and the pool began to boil. We believe that the assumptions on which his analysis is based are appropriately conservative, and that, given those assumptions, his calculations are correct.

2. Potential for Supercriticality at Very Low Water Densities

Dr. Kim's testimony addressed the article mentioned in our order on summary disposition. Dr. Kim testified that not only this article, but also others, have recognized the possibility of supercriticality (k-effective greater than 1.0) occurring under conditions where the water in a spent fuel pool is replaced by mist, foam, or some other form of very low density water (Kim Testimony at 10-11). For such densities to occur at Big Rock Point, the water in the fuel storage pool would have to boil away at least below the level of the fuel racks. Moreover, the article cited by the Board found that for stainless steel racks of the Big Rock Point type, the supercritical condition never exists even for very low water densities, the maximum k-effective being less than 0.97 (Kim Testimony at 11).

Dr. Kim stated that no quantitative analysis with respect to supercriticality has been performed for the Big Rock spent fuel pool; normally such an analysis is required and performed only for new fuel storage racks under dry storage conditions, not for spent fuel pools (Kim Testimony at 12). The possibility of the water in the pool boiling away to the extent necessary to achieve the densities in question is extremely unlikely in view of the ability to remotely supply make-up water and the very long time required to boil away the water in the pool (Id.). Dr. Kim therefore concluded that the supercritical condition will not occur in the Big Rock pool under the assumed accident condition (Kim Testimony at 13). Moreover, the differences in calculated k-effective among different computer codes and methodologies alluded to by the authors of the cited article are comparatively small, according to Dr. Kim, at the densities that would prevail at Big Rock Point after the cooling system failure, and his analysis adequately accounts for them (Kim Testimony at 13).

At the hearing Dr. Kim explained that the results of his calculations show k-effective going down between 0% and 10% void, then turning around at 15% to 20% and thereafter slowly rising (Tr. 1945). The maximum k-effective would occur in the region of more than 80% void, or less than 20% olid water (Kim Testimony at 12). Dr. Kim agreed with the authors of the cited article that differences between different computer codes and methodologies can be significant at very low water densities (Kim Testimony at 13). Moreover, Dr. Kim conceded that at very low water densities the calculations he had performed could not be relied on for accuracy. He stated that for accurate calculations of k-effective at void fractions of 40% to 50% he would have to employ a different computer code, more energy groups and different neutron transport calculations (Tr. 1944). Until he performed those more sophisticated calculations, Dr. Kim stated that he could not predict whether the value of k-effective would be higher or lower than that indicated by his previous calculations (Tr. 1952-1953).

Mr. Lantz also discussed the conclusions of the cited article in his testimony. Mr. Lantz testified that the article was in fact supportive of the evaluation and conclusions of the Staff (Lantz Testimony at 8-9).

Mr. Lantz also testified that one would need more energy groups than Dr. Kim used to perform an accurate calculation of k-effective at low water densities. Moreover, he believed that these more sophisticated calculations would show k-effective continually decreasing with decreasing water density. He stated that a double peak in the curve of k-effective is not physically credible at Big Rock, given the thickness of steel in the fuel cans and the spacing between assemblies (Tr. 1942-1943, 1963-1966). He explained that this conclusion was based on studies of temperature and void coefficients that he had performed in reactor cores, as well as parametric studies he had done for fuel assemblies, some of them over-moderated, like those at Big Rock (Tr. 1953-1955).

Despite Mr. Lantz's assurance, we believe there is substantial uncertainty about whether k-effective for the limiting fuel design calculated by Dr. Kim for the Big Rock spent fuel pool would be higher or lower than 0.95 at very low water densities. These very low densities, however, could not occur without the pool water boiling off down to about the level of the fuel racks. Even a 40% void fraction could not be attained without a drop of this magnitude in the water level, according to Dr. Prelewicz (Tr. 1854-1855). We conclude that it is not necessary to perform the sophisticated calculations necessary to determine k-effective under these conditions, which Dr. Kim estimated would take three to four months (Tr. 2092). The requisite boiling-off would take a very long time; Mr. Blanchard testified that it would take 700 hours to boil off all the water in the pool (Testimony of David P. Blanchard Concerning Christ-Maria Contention 8 and O'Neill Contention IIE-2 at 8). Moreover, Licensee has the capability to make up water lost from the pool during boiling through a remotely activated make-up line, and we make our finding in this decision contingent on our determining elsewhere in this proceeding that this make-up line is reliable.[8/]

Furthermore, we note that a criticality analysis for spent fuel racks under what are essentially conditions of mist or foam is normally neither required nor performed. Such analyses are performed for new fuel racks under dry storage conditions, as Dr. Kim pointed out; but the allowable limit for k-effective under these conditions, as he also pointed out, is 0.98, not 0.95 (Tr. 1847).[9/] Dr. Kim testified that the results given in the article cited in our earlier order, based on a similar can thickness but a more enriched fuel than that at Big Rock, indicate that k-effective never exceeds 0.97 for any water density (Tr. 1834-1835). The spent fuel in the Big Rock Point storage pool will therefore not attain supercriticality under any conditions.

3. Possible Distortion of the Fuel Racks

In response to the concern we expressed whether the drop of a fuel assembly or heating of the pool might distort the fuel racks to the point of adversely affecting

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8/ See Genuine Issue of Fact (1) under Christa-Maria Contention 8 and O'Neill Contention IIE-2.

9/ See Standard Review Plan, NUREG-0800, dated July 1981, §9.1.1

criticality, Licensee submitted the testimony of Raymond F. Sacramo and Dr. Kim. Mr. Sacramo testified that the drop of a fuel assembly onto a storage rack could distort the fuel assembly support plate at the bottom of the racks or the lead-in guides at the top of the rack, depending on the way it fell. In neither case, however, would there be any distortion of the rack along the length of the stored fuel assembly. Thus, the center-to-center distance between the storage cans would be maintained (Sacramo Testimony at 3-4). Because of this, Dr. Kim testified that such an accident would not change k-effective (Kim Testimony at 9).

Mr. Sacramo testified that as the water temperature of the pool increases the stainless steel racks will expand. The maximum temperature increase calculated by Dr. Prelewicz would produce an increase in the center-to-center spacing of the storage cans of 0.015 inches over the nominal value of 9 inches (Sacramo Testimony at 5). Dr. Kim testified that this would result in a decrease of 0.0018 in k-effective (Kim Testimony at 9-10).[10/]

Mr. Lantz also addressed this issue in his testimony and his conclusions were the same as those of Licensee's witnesses (Lantz Testimony at 7). There was no cross-examination on this issue at the hearing. We find the testimony of

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10/ For purposes of conservatism Dr. Kim did not take credit for this decrease in his calculation of the value of k-effective (Kim Testimony at 10). We note, however, that if he had done so his calculation of k-effective would have decreased from .9470 to .9452.

the witnesses credible and conclude that the concerns we expressed earlier have been satisfied.

4. Possible Blockage of Natural Circulation by Debris

As noted earler, on May 3, 1982, we asked for comments on whether anything in the geometry of the pool or racks or any debris that might fall into the pool could alter natural circulation patterns, thus possibly affecting k-effective. In response to these questions, Licensee submitted the testimony of David P. Blanchard, a Technical Engineer stationed at Big Rock Point. Mr. Blanchard is expert in both thermal hydraulics and criticality and has, in addition, a first-hand knowledge of plant operation on a daily basis. Mr. Blanchard testified that there are no features in the design of the fuel pool, the storage racks or the fuel elements that would substantially alter natural water convection currents which were not considered and adequately accounted for in the testimony and analysis of Drs. Prelewicz and Gay (Blanchard Testimony at 4). Water circulation is slightly altered by the storage of various small hardware items in the pool, but this effect is minimal because of the small volume of this hardware; moreover, such effects are adequately accounted for in the analysis of Drs. Prelewicz and Gay (Blanchard Testimony at 3-4).

With regard to possible reduction of natural circulation flows from the introduction of debris into the pool, Mr. Blanchard initially states that because Dr. Kim's analysis assumes an infinite array of fuel assemblies, localized increases in the temperature and void fraction of individual assemblies will not significantly alter k-effective (Blanchard Testimony at 5). A large amount of debris would have to enter the pool, producing flow restrictions in large portions of the racks, before a significant increase in reactivity would occur (Id.). After examining the Big Rock spent fuel pool, Mr. Blanchard determined four potential sources of debris during normal operation and accident conditions. He concluded that none of them would result in significant alteration of convective circulation currents in the fuel pool (Blanchard Testimony at 6).

Particulate matter commonly referred to as "crud", consisting mainly of iron oxide, is introduced into the pool from the reactor coolant during normal refueling operations. This crud does not build up, however, because the pool water is cycled through a set of filter socks during refueling operations as well as normal power operation. There is therefore no detrimental effect on natural circulation (Blanchard Testimony at 7-8). Crud could also be introduced into the pool in the make-up water that might have to be supplied to the pool following a loss-of-coolant accident. The introduction of significant amounts, however, is limited by the fine mesh strainers through which water for the post-incident recirculation system must pass (Blanchard Testimony at 8-9).

The third potential source of debris consists of paint and coatings on surfaces within containment above and around the pool. The possibility exists that such coatings could flake or peel and fall into the pool as a result of the high temperature, moisture and radiation that would be caused by a loss-of-coolant accident. Mr. Blanchard testified, however, that the Licensee has evaluated these surfaces for such accident conditions and concluded that no significant loss of these coatings would occur (Blanchard Testimony at 9-10). Any flaking within containment would be limited to very localized effects (Blanchard at Tr. 1804-1805). Mr. Blanchard concluded that paint flaking would not introduce debris into the pool under the assumed accident condition (Blanchard Testimony at 10).

The fourth potential source of debris is the steam drum blowout panel. This panel, mounted over the reactor deck, is filled with aggregate -- rocks one to two inches in diameter -- to provide biological shielding for the reactor deck. The panel is intended to equalize pressure within containment after a loss-of-coolant accident by "blowing out" and falling on the reactor deck. If this happened, a small portion of the aggregate within the easternmost section of the panel could slide into the pool (Blanchard Testimony at 10-11). Mr. Blanchard testified at the hearing that the majority of any aggregate that might fall into the pool would fall into the southwest corner, where there is no fuel (Tr. 1812). This is the area of the pool where casks are lowered to be loaded. The closest fuel rack is located some seven feet from the edge of the pool where the panel would be lying and does not contain fuel (Tr. 1812). Any effects of the aggregate would be limited to a few fuel assemblies (Blanchard Testimony at 11).

We conclude that nothing in the record casts doubt on Mr. Blanchard's conclusion that there is no credible scenario in which debris could fall in the spent fuel storage pool and substantially alter natural water convection currents. The question raised in our memorandum of May 13 has therefore been satisfactorily answered.

IV. CONCLUSION

Based on the weight of the evidence, the Licensing Board finds that the modified Big Rock Point spent fuel storage pool will not attain criticality and thereby endanger the health and safety of the public. O'Neill Contention IIE-3 concerning criticality thus does not raise matters posing a significant public health and safety concern and is without merit.

Respectfully submitted,

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DATED: October 1, 1982

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

IN THE MATTER OF	)	
	)	Docket No. 50-155-OLA
CONSUMERS POWER COMPANY	)	(Spent Fuel Pool
	)	Modification)
Big Rock Point Nuclear Power Plant	)	
	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of CONSUMERS POWER COMPANY'S PROPOSED INITIAL DECISION ON CRITICALITY CONTENTION and CONSUMERS POWER COMPANY'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW ON CRITICALITY CONTENTION were served on all persons listed below by deposit in the United States mail, first-class postage prepaid, or by Federal Express overnight delivery this 1st day of October, 1982.

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