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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

SUPPORTING AMENDMENT NO. 53 TO FACILITY OPERATING LICENSE NO. DPR-3

YANKEE ATOMIC ELECTRIC COMPANY

YANKEE NUCLEAR POWER STATION (YANKEE-ROWE)

DOCKET NO. 50-29

Introduction

By application dated December 14, 1977, (Proposed Change No. 155) and supplements dated April 6, 1978, May 11, 1978, June 15, 1978, and October 4, 1978, Yankee Atomic Electric Company (the licensee) requested an amendment to Facility Operating License No. DPR-3 for the Yankee Nuclear Power Station (Yankee-Rowe). The amendment would change the facility Technical Specifications to reduce the number of incore neutron detector thimbles (also called detector paths in this Safety Evaluation) required to be operable from 17 (75%) to 12.

Discussion

In 1974 the licensee installed a traversing fission chamber incore detector system in the Yankee-Rowe reactor. This incore detector system has been in continuous use for incore monitoring during cycles 11, 12, and 13.

The incore detector system contained 22 Detector Paths (DP's). Presently, the Technical Specifications require that if the incore detector system is to be used for incore monitoring there must be at least two Operable DP's (ODP's) in each core quadrant, and at least 75%, or 17, of the 22 DP's must remain operable. Due to leakage of reactor coolant into the DP's, it had been necessary to periodically seal them off. There are presently 17 ODP's. In December 1977, in anticipation that more DP's may fail, the licensee submitted an application for license amendment to reduce the required number of ODP's from 17 to 12 (Reference 1).

In Reference 2 the staff requested additional information and in particular indicated the scope of the study that would be required to justify operation with as few as 12 ODP's. In References 3, 4, and 5 the licensee addressed the staff's concerns and provided the results of the additional studies that were performed.

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Evaluation

A. Nuclear Peaking Factor Uncertainty

For normal operation the licensee uses the INCORE code (Reference 6) to reduce the data obtained from the movable incore detectors. In our evaluation the word "Map" will be consistently used to mean the data set resulting from analyzing movable detector data with INCORE. The licensee performed the following study to justify operation with as few as 12 ODP's.

1. Six base case 17-ODP Maps were selected. These were based on real plant data taken from the beginning, middle, and end of life for cycles 12 and 13. All even numbered cycles have a similar loading pattern and all odd numbered cycles have a similar loading pattern.

2. For each base case Map, 10 randomly selected sets of 12 ODP's were chosen with the requirement that there be at least two ODP's in each core quadrant. INCORE was run using each set to produce a 12-ODP Map.

3. The Peak Linear Heat Generation Rate (PLHGR) for each 12-ODP Map was compared with the corresponding base case PLHGR. A summary of these results along with the results of computations performed by us is given in Table 1.

In Table 1 (page 8), Δ is the percentage increase of PLHGR in a 12-ODP Map over that for a corresponding base case 17-ODP Map. It can be seen that Δ exhibits a fairly consistent positive bias, i.e., for 5 of the 6 cases $\bar{\Delta}$ is positive. That is, in most cases the PLHGR is higher (more conservative) for the 12-ODP Maps than for the 17-ODP Maps.

From our evaluation of the licensee's study and our independent computations, we have determined the following.

a. In cycle 12 the measured PLHGR is normally in assembly B5 and in cycle 13 the measured PLHGR is normally in assembly C8. This is true at all times in the cycle and is true in both the 17-ODP Maps and the 12-ODP Maps.

b. In the 17-ODP Maps the PLHGR measured in assembly B5 is determined from the activations measured in assemblies (A5, C4, D5), and the PLHGR measured in assembly C8 is determined from the activations measured in assemblies (C9, D8, B7).

This and item a are incidental to the conclusions reached. However, the discussion of items c and d is facilitated if assemblies are specifically named.

c. In the 12-ODP Maps, the measured PLHGR in B5 and C8 is determined by the activations in however many of the DP's in assemblies (A5, C4, D5) or assemblies (C9, D8, B7) are still assumed to be operable.

d. One important factor which determines the difference between the PLHGR in the 17-ODP Maps and the 12-ODP Maps is the relative value of the Measured Minus Predicted Activations (MMPA's) in assemblies (A5, D8, D5) for cycle 12 and assemblies (C9, D8, B7) for cycle 13. The details of how the relative values of the determining MMPA's bias the comparison of the 17-ODP Maps with the 12-ODP Maps are described in the following two paragraphs.

   If the lowest MMPA which is determining the PLHGR in the 17-ODP Maps is absent from a 12-ODP Map, then the PLHGR will be expected to be higher in the 12-ODP Map. Upon examining the data in the 5 cases where the PLHGR is seen to generally increase from the 17-ODP Maps to the 12-ODP Maps, this effect is seen to be a contributing factor in 4 of the 5 cases.

   In the single case where a decreasing PLHGR is observed (Cycle 12, 1020 MWD/MTU), the MMPA of assembly A5, which dominates the PLHGR in the 17-ODP Maps, is large and positive (3.4%). The DP of assembly A5 is inoperable in about half the 12-ODP Maps and in these 12-ODP Maps a substantial decrease in PLHGR is observed. We inquired about other flux maps taken around the same time, and the licensee stated that the MMPA for assembly A5 was roughly 3.4% in the other maps as well. This is strong evidence that there may exist a fairly permanent "hot spot" at this point which would go undetected in many of the 12-ODP Maps. In numerical terms, for about half the assumed sets of 12 ODP's, the 12-ODP Maps taken near the beginning of cycle 12 would underpredict the PLHGR by about 2.5%.

e. Due to the difference in normalization, the relative MMPA's change in a somewhat arbitrary fashion when going from a 17-ODP Map to a 12-ODP Map. Frequently, when the PLHGR rod of the 17-ODP Maps decreases in power in the 12-ODP Maps, some other rod power in the 12-ODP Map increases above the 17-ODP Map PLHGR, and the 12-ODP Map exhibits a higher PLHGR than the 17-ODP Map. The location of the PLHGR in the 17-ODP Maps is different from the location of the PLHGR in only about a quarter of the 12-ODP Maps, and thus this effect only slightly increases the PLHGR of the 12-ODP Maps over that of the 17-ODP Maps.

f. As just stated, due to the difference in normalization, the MMPA in the 12-ODP Maps is different from that in the corresponding 17-ODP Maps. While no reason is readily apparant for the phenomenon, in the cases observed this normalization generally produced higher PLHGR in the 12-ODP Maps than the corresponding 17-ODP Maps, even when the effect of the shifting location of the PLHGR described in item e did not occur.

In most reactors the PLHGR location shifts during the cycle and shifts if the selection of ODP's is changed. In such cases the value of the PLHGR is to a large measure a core-wide phenomenon. As such a conclusion concerning the PLHGR supported by 5 of 6 test cases would normally be considered to be well founded. However, as shown above the conservatism of the 12-ODP Maps shown in 5 of 6 test cases was to a large measure due to the particular values assumed by the three determining MMPA's. The values of the determining MMPA's change slowly with time, so that if a particular relationship is seen between the determining MMPA's at one point in a cycle, this relationship is likely to persist for a good fraction of the cycle. Thus, there is a correlation between the test cases such that a trend seen for a test case taken at one point in a cycle is likely to exist in test cases taken over a good fraction of that cycle. It seems likely that if data for other cycles were used instead a completely opposite trend may have been observed. Based on the above considerations, we consider the fact that in 5 of the 6 cases the 12-ODP Maps generally predicted higher PLHGR's than the 17-ODP Maps is a fortuitous result; further, that the conservatism of the 12-ODP Maps should not be considered as a proven test unless it is substantiated by considerably more data.

As indicated in item d, the nonconservatism which existed in the 12-ODP Maps for cycle 12, 1020 MWD/MTU seems to have persisted for some period of time. This fact alone would be a basis for increasing the assumed nuclear uncertainty with the reduced compliment of ODP's.

Based on the above considerations, we have concluded that for operation with the proposed 12 ODP's it would be necessary to increase the nuclear uncertainty factor of 5% presently required in the Technical Specifications to 6.8% (See Table 1). The reason for this is that the use of an increased uncertainty factor (6.8%) for the proposed reduced number (12) of ODP's would not decrease the existing safety margin associated with the use of a 5% uncertainty factor for 17 ODP's presently required in the Technical Specifications. We have changed the affected sections in the Technical Specifications to require that if the number of operable incore detector thimbles is less than 17 the nuclear measurement uncertainty factor shall be increased from 5% to 6.8%. The licensee accepted these changes.

B. Verification of Core Loading

We questioned the ability to detect fuel misloadings during start-up tests with the reduced number (12) of operable incore neutron detector thimbles. The licensee has stated that with at least 75% of the DP's operable it would be possible to detect a misloading error with the incore detector system. It is not readily apparent that it would be possible to detect a misloading with substantially less than 75% of the DP's operable and we believe that 12-ODP's may be inadequate to detect many misloadings.

To demonstrate the ability to detect core misloadings with the incore detection system would require complex and extensive analysis. Therefore, the licensee has proposed a core inspection procedure in lieu of using the incore detection system to verify that the core has been properly loaded. This approved written procedure would consist of the following:

1. The core will be inspected visually for proper loading.
2. While the visual inspection is performed, a video tape of the core will be made.
3. A map of the core loading will be reconstructed from the video tape. This will be done by a person who was not involved in the visual inspection or video taping procedure.
4. The reconstructed map will be verified to be identical to the core design map.

In most reactor cores all fuel assemblies are physically identical, and hence physically interchangeable. In order to accommodate the cruciform control rods, two physically different assembly designs are used in the Yankee-Rowe reactor which cannot be physically interchanged. This fact coupled with the small size of the Yankee-Rowe core makes a fuel misloading much less likely than for most other reactors.

Cycle	Cycle Burnup (MWD/MTU)	Base Case PLHGR (=P17) (KW/FT)	12-ODP Map PLHGR = P12							Assumed 95/95 uncertainty in base case (%)	95/95 uncertainty in ** 12-ODP Maps = ks12 (%)	ks12 - $\bar{\Delta}$
			$\Delta = \frac{P12-P17}{P17}$ (%)				Number 12-ODP Maps	* 95/95 k for 12-ODP Maps	95/95 ks for ($\Delta - \bar{\Delta}$) (%)			
			Highest Δ	Lowest Δ	Bias = $\bar{\Delta}$	S = RMS ($\bar{\Delta} - \Delta$)						
12	1020	8.659	1.89	-2.73	-0.62	1.67	10	2.815	4.70	5.00	6.18	6.80
12	5991	9.756	1.57	-0.74	0.44	0.66	10	2.815	1.86	5.00	5.13	4.69
12	9581	8.540	1.63	-0.23	0.35	0.50	10	2.815	1.41	5.00	5.07	4.72
13	408	8.990	2.46	-1.35	0.73	1.60	10	2.815	4.50	5.00	6.07	5.34
13	2795	10.303	2.28	-1.29	1.09	1.35	10	2.815	3.80	5.00	5.73	4.64
13	6530	9.418	2.89	-0.29	1.32	1.01	10	2.815	2.84	5.00	5.36	4.04

* k is a value such that, assuming the Δ's are drawn from a normal percent population, one can say with 95% confidence that 95% of the population lies above $\bar{\Delta}$ - ks.

**In many applications an uncertainty such as ks12, which consists of several statistically independent components, is computed as the root-sum-square of the components. ks12 is predicted by a more accurate algorithm than root-sum-square which the staff has programmed on an HP-67 programmable calculator.

REFERENCES

1. Letter from D. E. Vandenburgh, Senior Vice President, YAEC to USNRC, December 14, 1977.
2. Letter from Dennis L. Ziemann, Chief, Systematic Evaluation Projects Branch, Division of Operating Reactors, to Robert H. Groce, Licensing, March 16, 1978.
3. Letter from W. P. Johnson, Vice President, YAEC to USNRC, April 6, 1978.
4. Letter from W. P. Johnson, Vice President, YAEC to USNRC, May 11, 1978.
5. Letter from W. P. Johnson, Vice President, YAEC to USNRC, June 15, 1978.
6. WCAP-8498, INCORE POWER DISTRIBUTION DETERMINATION IN WESTINGHOUSE PRESSURIZED WATER REACTORS, Meyer & Stover, Westinghouse Electric Corporation, July 1975.
7. Letter from W. P. Johnson, Vice President, YAEC to U.S.N.R.C., October 4, 1978.