UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 175

TO FACILITY OPERATING LICENSE NO. DPR-61

CONNECTICUT YANKEE ATOMIC POWER COMPANY

HADDAM NECK PLANT

DOCKET NO. 50-213

1.0 INTRODUCTION

By letter dated January 6, 1994, and supplemented on March 16, 1994, Connecticut Yankee Atomic Power Company (CYAPCO) requested changes to the Haddam Neck Technical Specifications (TS) to allow an increased limit for fuel enrichment. The current new (fresh) and spent fuel storage rack maximum nominal enrichment is 3.9 weight percent (w/o) U-235 for Zircaloy clad fuel and 4.0 w/o U-235 for stainless steel clad fuel. The proposed changes would allow for the storage of fuel with an enrichment not to exceed a nominal 5.0 w/o U-235 in the Haddam Neck new and spent fuel storage racks.

The staff's evaluation of the criticality aspects of the proposed use of enriched fuel.

2.0 EVALUATION

The analysis of the reactivity effects of fuel storage in the new and spent fuel storage racks was performed with the three-dimensional multi-group Monte Carlo computer code, KENO Va, using neutron cross sections generated by the AMPX code package from the 227 energy group ENDF/B-V data library. Since the KENO Va code package does not have depletion capability, burnup analyses were performed with the two-dimensional transport theory code, PHOENIX, using a 25 energy group nuclear data library based on a modified version of the British WIMS cross section library. These codes are widely used for the analysis of fuel rack reactivity and have been benchmarked against results from numerous critical experiments. These experiments simulate the Haddam Neck fuel storage racks as realistically as possible with respect to parameters important to reactivity such as enrichment, assembly spacing, and absorber thickness. The intercomparison between two independent methods of analysis (KENO-Va and PHOENIX) also provides an acceptable technique for validating calculational methods for nuclear criticality safety. To minimize the statistical uncertainty of the KENO-Va reactivity calculations, a minimum of 60,000 neutron histories were accumulated in each calculation. Experience has shown that this number of histories is sufficient to assure convergence of KENO Va reactivity calculations. The staff concludes that the analysis methods used are acceptable and capable of predicting the reactivity of the Haddam Neck storage racks with a high degree of confidence.

The fresh fuel storage racks are normally maintained in a dry condition; i.e., the new fuel is stored in air. However, the NRC criteria for new fuel storage require that the effective multiplication factor, k_{eff}, of the storage rack be no greater than 0.95 if accidentally flooded by pure water and no greater than 0.98 if accidentally moderated by low density hydrogenous material (optimum moderation). The new fuel storage racks were analyzed for 4.60 w/o U-235 enriched fuel for the full density flooding scenario and for 5.05 w/o fuel (5.0 nominal plus manufacturing tolerance of 0.05) for the optimum moderation scenario.

For the full density moderation case, the new fuel storage racks were assumed to be moderated by pure water at a density of 1.0 gm/cc at a temperature of 68° F. The resulting k_{eff} was 0.9477. Appropriate biases and uncertainties due to the calculational method and material tolerances were included at the 95/95 probability/confidence level. This meets the staff acceptance criterion of 0.95 for full density water flooding and is, therefore, acceptable.

For the low density optimum moderation analysis, the maximum rack k_{eff} occurred at a water density of 0.094 gm/cc. The resulting k_{eff}, including all appropriate uncertainties at a 95/95 probability/confidence level, was 0.9237, meeting the acceptance criterion of 0.98.

Storage of fuel assemblies with nominal enrichments greater than 4.60 w/o U-235 were evaluated by means of reactivity equivalencing. This concept is predicated on the reactivity decrease associated with the addition of integral fuel burnable absorbers (IFBAs), which consists of a thin coating of ZrB_2 neutron absorber on the fuel pellet surface. The staff has found this to be acceptable in previous fuel storage applications. Based on this evaluation, a set of IFBA rod number versus initial enrichment ordered pairs was generated which all yield the equivalent k_{eff} no greater than 0.95 when the fuel is stored in the new fuel racks under fully flooded accident conditions. As seen from Figure 6, the reactivity of the fuel rack array when filled with fuel assemblies enriched to 5.0 w/o U-235 with each assembly containing 32 IFBA rods is equivalent to the reactivity of the rack when filled with assemblies enriched to 4.60 w/o and containing no IFBAs.

Since the worth of individual IFBA rods can change depending on position within the assemblies due to local variations in thermal neutron flux, the licensee has included a conservative reactivity margin to assure that the IFBA requirement remains valid at intermediate enrichments where standard IFBA patterns may not be available. In addition, to account for calculational uncertainties, the IFBA requirements also include a conservatism of approximately 10% on the total number of IFBA rods at the 5.0 w/o enrichment limit (i.e., about 3 extra IFBA rods for a 5.0 w/o fuel assembly). The staff concludes that sufficient conservatism has been incorporated to bound the calculational assumption that the IFBA requirements were based on the standard IFBA patterns used by Westinghouse.

As an alternative method for determining the acceptability of fuel storage in the new fuel racks, the infinite multiplication factor, k_∞, is used as a reference reactivity point. The PHOENIX code was used for the fuel assembly k_∞ calculations based on a unit assembly configuration in the Haddam Neck core geometry moderated by pure water at a temperature of 68° F with a density of 1.0 gm/cc. A 1% reactivity bias was included to account for calculational uncertainties. Calculations for a fresh 4.6 w/o Westinghouse 15x15 OFA fuel assembly, which yields equivalent or bounding reactivity results relative to the other Westinghouse 15x15 fuel types, in the Haddam Neck core geometry resulted in a reference k_∞ of 1.483. Since the fuel rack reactivity of a fresh 4.6 w/o assembly is less than 0.95 and has been shown to be equivalent to a 5.0 w/o assembly with the standard number of IFBA rods, an assembly of maximum nominal enrichment of 5.0 w/o U-235 with a maximum reference k_∞ less than or equal to 1.483 at 68° F can be safely stored in the fresh fuel racks.

Fuel in the spent fuel pool racks is normally stored in water with a boron concentration of approximately 2000 ppm. However, the NRC acceptance criterion requires that the rack k_{eff} be no greater than 0.95, including all appropriate uncertainties at the 95/95 probability/confidence level, if fully flooded by unborated water.

The spent fuel storage racks were reanalyzed using alternating rows of fresh and burned (irradiated) fuel assemblies. The calculations were made for pure water moderator at 68° F with a density of 1.0 gm/cc. All fuel assemblies stored in the fresh fuel rows contained fuel enriched to a nominal enrichment of 5.0 w/o U-235. All fuel assemblies stored in the burned fuel rows contained fuel enriched to a nominal enrichment of 3.2 w/o U-235. For the nominal storage cell design, uncertainties due to tolerances in fuel enrichment and density, fuel pellet dishing, storage cell I.D. and pitch, stainless steel thickness, and B_4C panel width were accounted for as well as eccentric fuel positioning. These uncertainties were appropriately determined at the 95/95 probability/confidence level. In addition, calculational and methodology biases and uncertainties due to benchmarking and pool water temperature ranges were included. The maximum k_{eff} for the alternating rows storage configuration was 0.9485 when combined with all known uncertainties. This meets the staff's criterion of k_{eff} no greater than 0.95 including all uncertainties at the 95/95 probability/confidence level and is, therefore, acceptable.

To enable the storage of burned fuel assemblies initially enriched to greater than 3.2 w/o U-235, the concept of burnup credit reactivity equivalencing was used. This is predicated upon the reactivity decrease associated with fuel depletion and has been previously accepted by the staff for spent fuel storage analysis. For burnup credit, a series of reactivity calculations are performed to generate a set of initial enrichment-fuel assembly discharge burnup ordered pairs which all yield an equivalent k_{eff} less than 0.95 when stored in the spent fuel storage racks. This is shown in Figure 8 in which a fresh 3.2 w/o enriched fuel assembly yields the same rack reactivity as an initially enriched 5.0 w/o assembly depleted to 12,400 MWD/MTU. This curve includes a reactivity uncertainty of 0.0041 due to depletion calculations. In response to a staff question, CYAPCO verified that the effect of axial burnup distribution on assembly reactivity had been considered in the development of the burnup credit limit. Previous Westinghouse evaluations have shown that although axial burnup effects can cause assembly reactivity to increase, the burnup-enrichment combinations required to cause this are well beyond those required by the reported Haddam Neck burnup credit limits.

The k_{eff} of a single Westinghouse 15x15 OFA enriched to 5.0 w/o U-235 and surrounded by cold, unborated water was calculated to be 0.9615. The only time a single assembly would be surrounded by water is during fuel handling maneuvers. However, proposed TS 3.9.13 requires a minimum boron concentration of 800 ppm whenever fuel is being moved in the spent fuel pool. This level of soluble boron has been shown to be more than sufficient to maintain the k_{eff} of a single 5.0 w/o enriched assembly to no greater than 0.95.

Most abnormal storage conditions will not result in an increase in the k_{eff} of the racks. However, it is possible to postulate events, such as an assembly drop between the rack and the pool walls or the misloading of an assembly with a burnup and enrichment combination outside of the acceptable area in Figure 8, which could lead to an increase in reactivity. However, for such events credit may be taken for the presence of approximately 800 ppm of boron in the pool water required during fuel handling operations since the staff does not require the assumption of two unlikely, independent, concurrent events to ensure protection against a criticality accident (Double Contingency Principle). The reduction in k_{eff} caused by the boron more than offsets the reactivity addition caused by credible accidents. In fact, the licensee has determined that only 500 ppm of boron is necessary to mitigate the worst postulated accident in any pool region. Therefore, the staff criterion of k_{eff} no greater than 0.95 for any postulated accident is met.

The following Technical Specification (TS) changes have been proposed as a result of the requested enrichment increase. The staff finds these changes acceptable.

(1) TS 1.38 is added to describe a "type I fuel assembly" as one which has an initial enrichment no greater than 3.2 w/o U-235 (nominal) or has achieved sufficient burnup to be stored anywhere in the spent fuel pool.

(2) TS 1.39 is added to describe a "type II fuel assembly" as one which requires a controlled storage in the spent fuel pool because of its higher initial enrichment and lower achieved burnup level.

(3) TS 3.9.13 and its associated Bases is added to require a minimum 800 ppm boron concentration in the spent fuel pool during fuel movement.

(4) TS 3.9.14 and its associated Bases, as well as Figure 3.9-1, and Figure 3.9-2, are added to provide the minimum burnup requirements for type I and type II assemblies and to show the spent fuel pool rack alternating row storage configuration. In response to a staff comment, the licensee has changed the required Action to immediately initiate actions to correct the

loading error if the placement of fuel assemblies does not meet the requirements of both Figure 3.9-1 and Figure 3.9-2, rather than rely on boration to maintain k_{eff} no greater than 0.95.

(5) TS 5.6.1.1.b is revised to reflect the new higher enrichments allowed in the spent fuel pool along with the required storage pattern and enrichment versus burnup requirements.

(6) TS 5.6.1.2.a is revised to require polyvinyl-chloride (PVC) liners in any new fuel storage rack location that is allowed to store new fuel.

(7) TS 5.6.1.2.b is revised to reflect the new higher enrichments allowed for new fuel. New Figures 5.6-1 and 5.6-2 are added to be consistent with the criticality analysis assumptions.

3.0 SUMMARY

Based on the review described above, the staff finds the criticality aspects of the proposed enrichment increase to the Haddam Neck new and spent fuel pool storage racks are acceptable and meet the requirements of General Design Criterion 62 for the prevention of criticality in fuel storage and handling.

Although the Haddam Neck TS have been modified to specify the above-mentioned fuel as acceptable for storage in the fresh or spent fuel racks, evaluations of reload core designs (using any enrichment) will, of course, be performed on a cycle by cycle basis as part of the reload safety evaluation process. Each reload design is evaluated to confirm that the cycle core design adheres to the limits that exist in the accident analyses and TS to ensure that reactor operation is acceptable.

5.0 STATE CONSULTATION

In accordance with the Commission's regulations, the Connecticut State official was notified of the proposed issuance of the amendment. The State official had no comments.

6.0 ENVIRONMENTAL CONSIDERATION

Pursuant to 10 CFR 51.21, 51.32 and 51.35, an environmental assessment and finding of no significant impact have been prepared and published in the Federal Register on August 10, 1994 (59 FR 40926). Accordingly, based upon the environmental assessment, the staff has determined that the issuance of the amendment will not have a significant effect on the quality of the human environment.

7.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

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Date: August 16, 1994