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

# SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

## SUPPORTING AMENDMENT NOS. 49 AND 48 TO FACILITY LICENSE NOS. DPR-44 AND DPR-56

PHILADELPHIA ELECTRIC COMPANY
PUBLIC SERVICE ELECTRIC AND GAS COMPANY
DELMARVA POWER AND LIGHT COMPANY
ATLANTIC CITY ELECTRIC COMPANY

PEACH BOTTOM ATOMIC POWER STATION UNITS NOS. 2 AND 3

DOCKETS NOS. 50-277 AND 50-278

## 1.0 Introduction

By letters dated January 18, April 12, May 19, June 12, and September 19, 1978, the Philadelphia Electric Company (PECO) proposed to change the spent fuel pool (SFP) storage design for Peach Bottom Atomic Power Station, Units 2 and 3, from the design which was reviewed and approved in the operating license review and described in the FSAR. The proposed change consists of increasing the existing spent fuel storage capacity for both units from 2220 fuel assemblies to 5632 fuel assemblies. This licensing action was noticed in the FEDERAL RECISTER on February 23, 1978 (43FR7490).

## 2.0 Discussion

The licensee proposed to replace the existing spent fuel pool storage racks in Peach Bottom Unit Nos. 2 and 3 with high density racks. The licensee plans to initially procure sufficient racks to expand the capacity from 1110 fuel assemblies to 2608 assemblies per pool. However, to provide for further expansion, if necessary, the licensee has provided information and analysis based on an assumed assembly capacity of 2816 per pool. The licensee does not propose any modification to the SFP structure or its cooling system.

The proposed spent fuel storage racks will consist of alternating, double-walled aluminum containers. Each will be approximately 14 feet long and will have a square cross section with an inner dimension of 6.44 inches. The nominal pitch between fuel assemblies is 7.0 inches. This results in an overall fuel region volume fraction of 0.53 in the nominal storage lattice cell. A Boral plate is to be seal welded in the cavity between the double walls. Thus, in this arrangement there will be only one Boral plate between adjacent fuel assemblies. In its January 18, 1978 submittal, PECO states that the minimum amount of boron-10 per unit area of Boral plate will be 0.0232 grams per square centimeter. This is equivalent to $1.4 \times 10^{21}$ boron-10 atoms per square centimeter.

## 3. Evaluation

### 3.1 Criticality Analyses

As stated in PECO's January 18, 1978 submittal, the fuel pool criticality calculations are based on an unirradiated BWR fuel assembly with no burnable poison and a fuel loading of 17.3 grams of uranium-235 per axial centimeter of fuel assembly.

The Nuclear Associates International Corporation (NAI) performed the criticality analyses for PECO. NAI made parametric calculations by using the CHEETAH-B computer program to obtain four-group cross sections for PDQ-7 diffusion theory calculations. The effective boron cross sections for the Boral plates were calculated with the CORC-Blade program. NAI stated that these programs have been extensively tested by using them to make benchmark experiment calculations and core physics calculations for several existing operating power reactors.

These computer programs were used to calculate the neutron multiplication factor for an infinite array of fuel assemblies in the nominal storage lattice at 20°C with the minimum boron concentration in the Boral, i.e., 0.0232 grams of boron-10 per square centimeter. NAI then performed calculations to determine: (1) the highest neutron multiplication factor as a function of pool water temperature; (2) the effect of a possible reduction in the lattice pitch; and (3) the effect of eccentrically positioning fuel assemblies in the storage lattice. In its January 18, 1978 submittal, PECO states that the calculations showed that when all of these effects are accounted for, the maximum effective neutron multiplication factor ($K_{eff}$) in the fuel pool will be less than 0.91. The accuracy of the diffusion theory method for this storage rack application was then checked by calculating the nominal reference case with the KENO-IV Monte Carlo program using 123 group cross sections from the GAM-THERMOS library, and it was found that the results of the diffusion theory method agree within one percent $\Delta k$.

These storage racks are designed to prohibit the insertion of a fuel assembly anywhere except in prescribed locations. However, it will be possible to place a fuel assembly between the outer periphery of the storage racks and the fuel pool walls. In its January 18, 1978 submittal PECO states that this situation was analyzed by assuming that a fuel assembly is lodged parallel to an assembly in an outer cavity with no Boral sheet separating the two parallel assemblies. PECO found, based on a conservative analysis, that the increase in the $K_{eff}$ will be less than 0.5% $\Delta k$.

In response to our request for additional information, PECO stated in its April 12, and September 19, 1978 submittals that a neutron source and detector will be used on site to verify the presence of all the Boral plates in the racks. The staff concludes that the combination of quality control measures at the Boral fabricator, the rack fabricator's testing and the on-site verification are adequate to verify that the Boral plates are installed to maintain $k_{eff} \leq 0.95$.

The above described results compare favorably with the results of parametric calculations made with other methods for similar fuel pool storage lattices. By assuming new, unirradiated fuel with no burnable poison or control rods, these calculations yield the maximum neutron multiplication factor that could be obtained throughout the life of the fuel assemblies. This includes the effect of the plutonium which is generated during the fuel cycle.

We find that all factors that could affect the neutron multiplication factor in this pool have been conservatively accounted for and that the maximum neutron multiplication factor in this pool with the proposed racks will not exceed 0.95. This is NRC's acceptance criterion for the maximum (worst case) calculated neutron multiplication factor in a spent fuel pool. This 0.95 acceptance criterion is based on the uncertainties associated with the calculational methods and provides sufficient margins to preclude criticality in the fuel. Accordingly, as proposed by PECO, we have included in the amendment a Technical Specification which limits the effective neutron multiplication factor in the spent fuel pools to 0.95.

We find that when any number of the fuel assemblies which PECO described in these submittals, which have no more than 17.3 grams of uranium-235 per axial centimeter of fuel assembly, are loaded into the proposed racks, the neutron multiplication factor will be less than 0.95. On this basis, we conclude that by prohibiting the storage of fuel assemblies that contain more than 17.3 grams of uranium-235 per axial centimeter of fuel assembly, there is reasonable assurance that the health and safety of the public will not be endangered by the use of the proposed racks.

## 3.2 Spent Fuel Cooling

The licensed thermal power for each of the two Peach Bottom reactors is 3293MWT. PECO plans to refuel these plants on an 18 month cycle. This will require the replacement of about 270 of the 764 fuel assemblies in each core every 18 months. In its January 18, 1978 submittal, PECO states that there will be a cooling time of 120 hours prior to unloading the first spent fuel assembly into the fuel pool; and after these 120 hours, the spent fuel assemblies will be unloaded into the pool at a rate of one hundred assemblies per day. PECO assumed a burnup of 40,000 $MWD/_{MTU}$ for a normal refueling batch of spent fuel and an average burnup of 30,000 $MWD/_{MTU}$ for a full core discharge. For these cooling times and fuel burnups PECO calculated the maximum heat load in the spent fuel pool to be $15.7 \times 10^6$ $BTU/_{hr}$ for the final 18 month refueling which fills the pool, and $32.3 \times 10^6$ $BTU/_{hr}$ for a full core offload which fills the pool after eleven annual refuelings.

The spent fuel pool cooling system consists of three pumps and three heat exchangers in parallel for each unit. Each pump is designed to pump 533 gpm [$2.67 \times 10^5$ pounds per hour]. Each heat exchanger is designed to transfer $3.75 \times 10^6$ $BTU/_{hr}$ from 115°F fuel pool water to 90°F service water which is flowing through the heat exchanger at a rate of $4.0 \times 10^5$ pounds per hour.

PECO stated that when a full core is offloaded into the spent fuel pool, the Residual Heat Removal (RHR) system will be used to maintain the fuel pool water temperature below 150°F.

In its April 12, 1978 submittal, PECO stated that in addition to the normal makeup water capability for the spent fuel pool from the condensate storage tank, there are four other sources of demineralized water and two sources of river water available for restoring water to the spent fuel pool.

We find that PECO's calculated peak heat loads for the modified pool with a storage capacity for 2816 fuel assemblies are conservative and acceptable. We also find that the maximum incremental heat load that will be added by increasing the number of spent fuel assemblies that are to be stored in each of these pools from 1110 to 2816 will be $1.7 \times 10^6$ BTU/hr. This is the difference in peak heat loads for full core offloads that essentially fill the present and the modified pools.

PECO's calculated fuel pool outlet water temperatures are consistent with the stated cooling water flow rates and the design of the heat exchangers. We calculate that with all three spent fuel cooling pumps and heat exchangers operating at design capacity with PECO's peak heat load for any refueling [i.e., $15.7 \times 10^6$ BTU/hr] the maximum spent fuel pool outlet water temperature will be approximately 125°F. The $70 \times 10^6$ BTU/hr capacity of the four Residual Heat Removal Heat exchangers is more than adequate to remove the maximum full core heat load of $32.2 \times 10^6$ BTU/hr and still maintain the spent fuel pool outlet water temperature below the 150°F design limit.

Assuming a maximum fuel pool temperature of 150°F, the minimum possible time to achieve bulk pool boiling after any credible accident will be about six hours. After bulk boiling commences, the maximum evaporation rate will be 66 gpm. We find that six hours would be sufficient time for PECO to establish a 66 gpm makeup rate. We also find that under bulk boiling conditions the temperature of the fuel will not exceed 350°F. This is an acceptable temperature from the standpoint of fuel element integrity and surface corrosion.

We find that the present cooling capacities in the spent fuel pools of the Peach Bottom Atomic Power Station, Units 2 and 3 will be sufficient to handle the incremental load that will be added by the proposed modifications. We also find that this incremental heat load will not alter the safety considerations of spent fuel pool cooling from that which we previously reviewed and found to be acceptable. The spent fuel cooling system satisfies the Staff's requirements set forth in Regulatory Position C6 of Regulatory Guide 1.13 in that failure or maloperation will not cause the fuel to be uncovered. To assure that our conservative evaluation remains valid, the Technical Specifications have been amended to require a minimum of 120 hours cooling time prior to placing a spent fuel assembly in the storage pool.

3.3 Installation of Racks

In response to our request for additional information, PECO stated in its April 12, 1978 and May 19, 1978 submittals that the following measures in conjunction with the use of the 125 ton reactor building crane should preclude the dropping of a storage rack during their removal and installation:

1) The lifting fixture is designed with a minimum 3:1 factor of safety on yield.

2) The lifting fixture will be proof-loaded to 125% of the rated load prior to the lifting of any racks.

3) The lifting fixture is designed so that failure of the hydraulic system used to operate the fixture will not cause rack release.

4) Visual confirmation of lifting fixture dog engagement into the rack will be made prior to each use.

5) The heaviest rack that is to be moved will weigh 16,300 pounds.

In its January 18, 1978 submittal, PECO states that the handling of all materials entering or leaving the spent fuel pools will be scheduled and controlled to preclude movement over racks which contain spent fuel assemblies. This will be done by moving the spent fuel assemblies, which are in the pool, to that half of the pool which is not going to be modified at that time.

We find that the safety measures described by PECO in its submittals dealing with the removal and installation of the spent fuel storage racks in the Peach Bottom Atomic Power Station, Units 2 and 3 are adequate and acceptable. We conclude that there is reasonable assurance that the health and safety of the public will not be endangered by the installation and use of the proposed racks.

3.4 Fuel Handling

The NRC staff has under way a generic review of load handling operations in the vicinity of spent fuel pools to determine the likelihood of a heavy load impacting fuel in the pool and, if necessary, the radiological consequences of such an event. In view of this ongoing review, Peach Bottom will be required by Technical Specification to prohibit the movement of loads greater than the approximate weight of a fuel assembly over spent fuel in the SFP. This is consistent with the acceptance criteria set forth in reference 1. We have concluded that the likelihood of a heavy load handling accident is sufficiently small that the proposed modification is acceptable and no additional restrictions on load handling operations in the vicinity of the SFP are necessary while our review is under way.

The consequences of fuel handling accidents in the spent fuel pool area are not changed from those presented in the Safety Evaluation (SE) dated August 1972.

### 3.5 Structural and Mechanical Design

The proposed spent fuel pool storage racks are a bolted anodized aluminum construction. They consist of the following basic components: top grid castings, bottom grid casting, poison can assembly, side plates, corner angle clips, adjustable foot assembly, and bolts, dowel pins and rivets. Each component is anodized separately. The top and bottom grids maintain nominal fuel element spacing of 7 inches center to center within the rack. The grid structures are bolted and riveted together by four corner angles and four side shear panels. Large leveling screws are located at the rack corner to adjust for variations in pool floor level. Stainless steel bearing pads are installed at the bottom of the screw's pivot to allow for maintaining a flat uniform contact area. The closely spaced arrangement of the storage racks is such that no structural loads will be imposed on the poison cans.

Pockets are cast in alternate cavity openings of the grids into which poison cans rest. A poison can consists of two concentric square aluminum tubes. Sealed within these tubes are Boral ($B_4C$) poison plates. Each poison can is capable of containing one fuel assembly. The outer can is formed into the inner can at the ends and totally seal welded to isolate the Boral from the pool water. Each can is pressure and vacuum leak tested. The design of the racks is such that no structural loads will be imposed on the poison cans.

The racks are a free standing design with no connections between racks and no lateral restraints to the pool walls. The only interface with the floor are the four stainless bearing pads attached to the corner leveling screws. These pads do not provide vertical support against upward movement. Lateral loads are transferred in shear developed by friction between the pads and the pool floor. A 1/4 inch ABS plastic sheet separates the stainless steel pad and aluminum leveling screw to prevent galvanic corrosion. The ABS plastic sheet is held in place by the geometric configuration of the adjustable foot.

The design, fabrication, and installation procedures; the structural design and analyses procedures for all loadings, including seismic and impact loading; the load combinations and structural acceptance criteria; the quality control for the design, fabrication, and installation; and the applicable industry codes were all reviewed in accordance with the Branch Technical Position (BTP) entitled "Review and Acceptance of Spent Fuel Storage and Handling Applications" (Ref. 1).

Our review of the licensee's submittal indicates that the loads, loading combinations, and acceptance criteria are in accordance with Section 3.8.4 of the Standard Review Plan (SRP). The allowable stresses for stainless steel are in accordance with Appendix XVII and Appendix I Section III of the ASME B&PV Code 2. Since the SRP does not specifically reference allowable stresses for aluminum members, our acceptance criteria is based on the "Aluminum Construction Manual, Section I, Specifications for Aluminum Association." Use of this latter code provides the same degree of specificity as the ASME Code.

The seismic analysis performed was a combination time history/static analysis utilizing the computer programs ANSYS and SAPIV. For the simplified dynamic model used in the ANSYS analysis, the rack structure is idealized as a planar frame. Fundamental frequencies of this linear system were calculated and agreed closely with the more detailed SAPIV model. Non-linear effects due to rocking and sliding of the racks, and movement of the fuel within the racks are considered by expanding the ANSYS model. In this model all fuel assemblies are assumed to move in phase in order to arrive at maximum impact forces. In addition a two rack model is also analyzed in order to compute the maximum potential for interaction or contacting with other racks in the pool.

Simultaneous horizontal and vertical time histories are used as input. These generated time histories correspond to plus or minus 15% broadened equipment spectra at the spent fuel pool floor elevation. The mass of the water within the racks is added to the mass of the racks for calculations in the horizontal direction, but not for calculation in the vertical direction. The structural damping used is consistent with values documented in the Peach Bottom FSAR, Appendix C for in-air bolted structures. No increase in damping was attributed due to the pool water.

The coefficients of friction values between the stainless steel feet and liner are based on the following test reports: "Simulated Rack Minimum Coefficient of Friction" by PaR and "Friction Coefficients of Water-Lubricated Stainless Steels for a Spent Fuel Rack Facility" by Professor Ernest Rabinowicz of MIT.

Results from the time history analysis were applied to the more detailed SARIV static model. This model consisted of over 400 flexural beam column elements and over 800 plate elements.

Our review of the licensee's submittal indicates that the results of the seismic analyses show that the racks are capable of withstanding the loads associated with all the design loading conditions without exceeding allowable stresses. Interface loads transmitted to the fuel pool floor due to rocking are within the load carrying capability of the floor and rack legs. The maximum calculated sliding of 1.32 inches shows that the racks will not impact the pool walls, existing swing bolts on the pool floor, or other structures present at any time during replacement. Rack to rack impact loadings result in acceptable stress levels. Also, fuel rattling results in no damage to the racks or fuel assemblies themselves. Calculations show that the plastic will remain within its elastic limits and will withstand the design loadings.

The racks have been designed to withstand the local as well as gross effects of a dropped fuel assembly. The following drop conditions were examined: 18" fuel drop on the corner of the top grid castings and fuel rollover, 18" drop in the middle of the top castings, and a fuel drop full length through the cavity impacting on the bottom grid. The impact loads applied in the first two cases have been verified by full-size tests on an actual top grid casting. For the last case the bottom fuel support shears out and the fuel bundle impacts the pool floor liner plate. Results of these analyses show that applicable stress allowables are satisfied and no adverse effects on the racks or pool floor result.

The effects from a postulated stuck fuel assembly have been examined. A maximum uplift load of 4000 lbs. (capacity of the crane) results in stresses below those allowed for the applicable loading combination.

Because of the increased loading imparted to pool structure resulting from this increase in storage capacity, a structural analysis was made to establish the maximum load carrying capacity of the existing spent fuel pool. Forces transmitted by the model interface elements, which represent the rack legs, were computed for each time step of the analysis. These loads were used to determine the bearing and punching shear stress in the reinforced concrete floor.

The allowable stresses were taken from Section 8.10, Alternative Design Method, of American Concrete Institute (ACI 318-71). Results of the analysis show that for the critical loading conditions, the calculated loads are below code allowables, demonstrating that the racks were designed to preclude shear failures in the SFP floor.

Since the possibility of long term storage of spent fuel exists, the effects of the pool environment on the racks and fuel cladding must be examined. The pool water is unborated and constantly being purified. The new racks are anodized and, therefore, have greater resistance to corrosion. It is highly unlikely that the racks or fuel cladding will incur any corrosion problems during the life of the plant. No corrosion of the plastic, used to eliminate possible galvanic effects, is expected. Also, corrosion of the Boral will not be a problem since the material is sealed within the poison cans and vacuum and pressure tests performed to verify leak-tightness. Even in the event a leak developed a 40 year life would be expected for the Boral with no reduction in neutron absorbing capability. This is based on the licensee's letter dated May 19, 1978 which states that recent tests by the Boral Manufacturers have shown Boral to undergo no reduction in neutron capability due to corrosion for at least 53 and probably more than 60 years following the rupture of the poison can.

Based on the above, we find that the new proposed spent fuel storage racks and the design and analyses performed for the racks and pool are in conformance with established criteria, codes and standards specified in the staff position for acceptance of spent fuel storage and handling applications (Ref. 1).

We find that the subject modification proposed by the licensee is acceptable and satisfies the applicable requirements of General Design Criteria 2, 4, 61 and 62 of Appendix A to 10 CFR 50.

### 3.6 Occupational Radiation Exposure

We have reviewed the licensee's plan for the removal, crating and disposal of the low density racks and the two step installation of the high density racks for each unit (i.e., installing 26 racks in 1978 and 3 in the 1980's) with respect to occupational radiation exposure. The occupational radiation exposure for both operations is estimated by the licensee to be about 20 man-rem for each unit. We consider this to be a conservative estimate based on relevant experience for this type operation. This operation represents a small fraction of the total man-rem burden from occupational exposure at the plant. We conclude the exposures will be as low as is reasonably achievable since the facility design and procedures take into account state of technology and further reduction of occupational exposure is not practical.

Installing the new high density racks in both pools in two steps instead of completing the modification in a single step is acceptable because the occupational exposure for either method of installation should be approximately the same. The present pools are each contaminated from two refuelings. The proposed modification is not expected to significantly increase the pool water activity and resulting radiation levels in the vicinity of the pool. Divers will not be needed during the installation of the last three racks. Therefore, the occupational exposure for installing the new racks in two steps will be approximately the same as for installing these racks in a single step.

We have estimated the increment in onsite occupational dose resulting from the proposed increase in stored fuel assemblies on the basis of information supplied by the licensee and by utilizing relevant assumptions for occupancy times and for dose rates in the spent fuel area from radionuclide concentrations in the SFP water. The spent fuel assemblies themselves contribute a negligible amount to dose rates in the pool area because of the depth of water shielding the fuel. The occupational radiation exposure resulting from the proposed action represents a negligible burden. Based on present and projected operations in the spent fuel pool area, we estimate that the proposed modification should add less than one percent to the total annual occupational radiation exposure burden at this facility. As discussed above, we conclude based on impracticality of reducing occupational exposures, that the small increase in radiation exposure will not affect the licensee's ability to maintain individual occupational doses to as low as is reasonably achievable and within the limits of 10 CFR 20. Thus, we conclude that storing additional fuel in the SFP will not result in any significant increase in doses received by occupational workers.

## 3.7 Radioactive Waste Treatment

The plant contains waste treatment systems designed to collect and process the gaseous, liquid and solid wastes that might contain radioactive material. The waste treatment systems were evaluated in the Safety Evaluation (SE) dated August 1972. There will be no change in the waste treatment systems or in the conclusions of the evaluation of these systems as described in Section 8.0 of the SE because of the proposed modification. Our evaluation of the amount of additional waste to be generated by the modification is discussed in Section 5.3 of the Environmental Impact Appraisal accompanying this amendment.

## 4.0 Technical Specification Changes

Each of the Technical Specification changes associated with this licensing action is discussed below:

a) As proposed by the licensee, the $K_{eff}$ of the spent fuel pool has been changed from less than or equal to 0.90 to less than or equal to 0.95. The acceptability of this change is discussed in Section 3.1.

b) In order to insure that the $K_{eff}$ of the stored fuel is less than or equal to 0.95 the staff has added a specification to limit the axial U-235 loading of a stored fuel assembly. This specification is discussed in Section 3.1.

c) To assure that the spent fuel cooling evaluation remains valid, the staff has added a specification to require at least 120 hours of cooling prior to transferring an element from the core to the spent fuel pool. This specification is discussed in Section 3.2.

d) In view of the ongoing review on heavy loads over spent fuel, the staff has added a specification to limit the weight of any load being transported over spent fuel. This specification is discussed in Section 3.4.

Items (b), (c) and (d) above were discussed with the licensee. He agrees with these additions.

5.0 Summary

Our evaluation supports the conclusion that the proposed modification to the Peach Bottom SFP is acceptable because:

(1) The physical design of the new storage racks will preclude criticality for any credible moderating condition with the limits to be stated in the Technical Specifications.

(2) The SFP cooling system has adequate cooling capacity.

(3) The installation and use of the proposed fuel handling racks can be accomplished safely with the limit that no rack modules will be moved over any spent fuel assemblies.

(4) The installation and use of the new fuel racks can be done safely and do not alter the consequences of the design basis accident for the SFP, i.e., the rupture of a fuel assembly and subsequent release of the assembly's radioactive inventory within the gap.

(5) The likelihood of an accident involving heavy loads in the vicinity of the spent fuel pool is sufficiently small that no additional restrictions on load movement are necessary while our generic review of the issues is under way.

(6) The structural design and the materials of construction are adequate to function normally for the duration of the plant lifetime and to withstand the seismic loading of the design basis earthquake.

(7) The increase in occupational radiation exposure to individuals due to the storage of additional fuel in the SFP would be negligible.

6.0 Conclusion

We have 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, and (2) such activities will be conducted in compliance with the Commission's regulations and the issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public.

Dated: November 30, 1978

Reference: NRC letter (Grimes) to All Power Reactor Licensees transmitting OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications, April 14, 1978.