10.3 SPENT FUEL STORAGE

BFN has chosen to comply with the criticality requirements specified in 10 CFR 50.68(b). This section presents a description of the spent fuel storage facilities presently installed at the plant. All of the original low density spent fuel storage racks have been removed from the spent fuel pools. Due to projected shortages of storage space, high density spent fuel storage racks were installed to replace the original low density racks. With the installation of high density racks in the existing spent fuel pools, the storage capacity of each fuel pool was increased from 1080 to 3471 fuel assemblies providing space for storage of approximately four-and-one-half full core loads.

10.3.1 Power Generation Objective

The objective of the spent fuel storage arrangement is to provide specially-designed underwater storage space for the spent fuel assemblies, which require shielding and cooling during storage and handling.

10.3.2 Power Generation Design Basis

1. Spent fuel storage racks for each reactor shall be supplied to accommodate 454 percent of the full core load, or 3,471 fuel assemblies.

2. Spent fuel storage racks shall be designed and arranged so that the fuel assemblies can be efficiently handled during refueling operations.

10.3.3 Safety Design Basis

1. The fuel array in fully loaded spent fuel racks shall be subcritical by a substantial margin.

2. Each spent fuel storage rack containing fuel shall be designed to withstand earthquake loading so that distortion of the spent fuel storage arrangement will be within acceptable bounds.

10.3.4 Description

There are three spent fuel storage pools (SFSPs), one per reactor. The spent fuel storage racks provide a storage place at the bottom of each fuel pool for the spent fuel received from the reactor vessel, as shown in Figures 1.6-2 and 1.6-11 of Subsection 1.6. The racks are full length, top entry, and are designed to maintain the spent fuel in a spatial geometry that precludes the possibility of criticality under normal and abnormal conditions. Normal conditions exist when the spent fuel is stored at the bottom of the fuel pool in design storage position. Abnormal conditions may result from seismic forces or mishandling of equipment.

The high-density storage rack design is free-standing, transferring shear forces to the pool slab through friction resistance provided by the normal force of the weight of the module through the support columns to support pads resting on the pool floor liner.

The high-density storage racks (see Figures 10.3-1, 10.3-2, and 10.3-3) are made up of staggered, stainless-steel container tubes. Thus, there is only one container-tube wall between adjacent spent fuel assemblies. Each tube wall has a core of Boral sandwiched between .036-inch-inside and 0.090-inch-outside stainless steel containers. The tubes are about 14 feet long and have a square cross section with an outer dimension of 6.653 inches and a total wall thickness of .2015 inches. The nominal pitch between fuel assemblies is 6.563 inches.

The Boral core is made up of a central segment of approximately 0.056-inch-thick dispersion of boron carbide in aluminum. This central segment is clad on both sides with 0.010 inches of aluminum. The minimum homogeneous concentration of the boron-10 isotope is 0.013 grams per square centimeter of the Boral plate. The Boral plates are sandwiched between the two stainless steel containers, which are closure-welded. (Vent holes have been added to these storage tubes to prevent the buildup of hydrogen gas between the stainless steel containers.) The completed storage tubes are fastened together by angles welded along the corners and attached to a base plate to form storage modules.

Spent fuel assemblies are stored both within the tubes and in the spaces between the tubes. Two module sizes are used in the Browns Ferry SFSPs, a 13 x 13 module that can store a total of 169 fuel assemblies (85 in tubes and 84 in spaces outside the tubes) and a 13 x 17 module that can store 221 assemblies (111 in tubes and 110 in spaces outside the tubes). Each SFSP contains fourteen of the 13 x 13 modules and five of the 13 x 17 modules.

Storage is provided for canned defective fuel and used control rods in each SFSP. Installation of the high-density storage racks provided five extra positions in Unit 2 pool for storage of defective fuel. Control rod storage will be provided by supplying 20 permanent storage locations in the Units 1 and 2 SFSPs and 18 locations in the Unit 3 SFSP, and an aggregate of 370 temporary storage locations.

A transfer canal is provided to join the dual pools of Units 1 and 2. This transfer canal is the same depth as the transfer slot between the reactor well and the fuel pool. The transfer canal has a gate at each end so that the fuel pools can be isolated if necessary. The transfer canal can also be drained if necessary. The canal can be used for maintenance, repairs, etc., and enables fuel assemblies or channels to be transferred between the Unit 1 and Unit 2 spent fuel pools. It also permits storage of fuel and irradiated objects in one pool if it becomes necessary to empty the other pool. A diamond plate walkway is provided for personnel crossing, and is removable in small, lightweight sections. A further description of the physical characteristics of the reactor well and its relationship to the spent fuel pool is given in Subsection 4.2, "Reactor Vessel and Appurtenances Mechanical Design," and Subsection 5.2, "Primary Containment System."

The spent fuel storage facilities are shared only for Units 1 and 2, and the sharing feature is only the transfer canal that connects the two storage pools. A watertight gate is provided at each end of the transfer canal.

10.3.5 Safety Evaluation

10.3.5.1 High-Density Spent Fuel Storage Racks

A sliding analysis of the free-standing high-density storage racks was performed. A minimum value for the coefficient of friction was used in the sliding analysis, a value that was verified by tests of steel materials, and any variations in the coefficient are covered by the conservatively-low value used. The coefficient of friction used was sufficient to ensure that only small sliding will occur for earthquake motions corresponding to OBE and SSE. An additional non linear analysis for sliding was performed to determine relative displacements if the coefficient of friction were less than the minimum value used. This analysis gives added assurance that there should be no interaction between modules as a consequence of the SSE.

TVA reevaluated the fuel pool structural capacity for the High Density Fuel Storage System (HDFSS) and determined that the existing pool structure is capable of supporting the increased load with a margin of safety within the limits of the ACI 318-71 code.

Structural integrity of the HDFSS has been demonstrated for the design basis load combinations using elastic design methods. The original vendor analysis is documented per Reference 3.

10.3.5.2 Criticality Evaluation for Fuel

Criticality analyses of the spent fuel pools have been performed to accommodate all fuel bundles in the spent fuel storage pool. Calculations were based on a bounding reference assembly defined by U-235 enrichment / Gadolinia concentration zones separated at geometry transitions. Analyses were constructed such that the assumed reactivity levels bound previous fuel products present the spent fuel pool. Requirements for
U-235 enrichment and Gadolinia concentration levels are discussed per References 1 and 2.

The CASMO-4 bundle depletion code is used to calculate k_∞ values for the ATRIUM-10 fuel assembly lattices as a function of exposure and void history for both in-core and in-rack geometries. CASMO-4 is a multigroup, two-dimensional transport theory code with an in-rack geometry option, where typical storage array geometries can be defined.

The spent fuel storage rack assembly calculations were performed with the KENO.Va Monte Carlo code, which is part of the SCALE 4.4 Modular Code System. Cross section data input to KENO.Va were taken from the 44 energy group data library and adjusted using the BONAMI and NITAWL codes to perform resonance corrections, using standard SCALE 4.4 methodology to account for resonance absorption in the uranium.

These computer codes were used to calculate the neutron multiplication factor for an infinite array of fuel assemblies with the following assumptions to ensure that the actual reactivity will always be less than the calculated reactivity:

a) Moderator temperature of 4°C, which gives the highest reactivity for the fuel storage pool.

b) Fuel assemblies are assumed to contain the high reactivity reference bounding lattices for the entire length of the assembly.

c) Fuel is assumed to be commercial uranium.

d) Each lattice in each fuel assembly in the array is assumed to be at the peak reactivity in its lifetime.

e) The most limiting orientation or position of each assembly in its rack cell is accounted for.

f) The analysis takes into account storage with or without fuel channels and channel type.

g) Neutron absorption in fuel structural components is neglected.

h) The maximum reactivity values include all significant manufacturing and calculational uncertainties.

i) The analysis uses a conservative reactivity equivalent beginning of life (REBOL) assembly, defined by U-235 enrichment / Gadolinia concentration zones separated by geometry transitions.

j) A minimum Boron-10 density 0.0130 $B^{10}g/cm^2$ is assumed when modeling the Boral plates.

k) No Boral plates are missing in the normal condition; 1 Boral plate per rack is assumed to be absent in the accident condition, even though no identified scenario can generate such a condition.

Utilizing the REBOL lattice which has a higher reactivity than the maximum reactivity of the bounding bundle and including uncertainties, biases, and the worst accident the resulting k_{eff} is less than or equal to the regulatory limit of ≤ 0.95 at a 95% confidence.

10.3.5.3 Common Safety Evaluation

Each spent fuel storage rack and cell containing fuel is designed as a seismic Class I structure to resist sufficiently the response motion at the installed location within the supporting structures for the Design Basis Earthquakes (OBE and SSE).

Stress in a fully loaded rack will not exceed allowable stresses when subjected to Design Basis Earthquake loads applied in any direction.

All materials used in the construction of the rack are specified in accordance with applicable ASTM specifications, and all welds are in accordance with the AWS standards for materials used. Materials selected are corrosion resistant.

See Section 10.5.5 for discussion on the fuel pool liner and associated piping.

10.3.6 Inspection and Testing

The neutron attenuation of each tube in each rack was tested prior to installation to detect if there were any Boral plates missing from the prescribed locations in the fabricated fuel storage modules.

TVA has committed to install corrosion test specimens in the Browns Ferry Unit 3 SFSP. These specimens will be periodically removed and examined to check the long-term behavior of the rack materials.

REFERENCES

1. ANP-3160(P), Revision 0, Browns Ferry Nuclear Plant Units 1, 2, and 3 Spent Fuel Storage Pool Criticality Safety Analysis for ATRIUM™ 10XM Fuel, AREVA NP Inc., October 2012.

2. ANP-2945(P), Revision 1, Browns Ferry Nuclear Plant Units 1, 2, and 3 Spent Fuel Storage Pool Criticality Safety Analysis, AREVA NP, Inc., July 2011.

3. NEDE-24076-P, Design Report and Safety Evaluation for High Density Fuel Storage System, Licensing Topical Report, General Electric, November 1977.