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U.S. Nuclear Regulatory Commission
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Subject: Duke Energy Corporation
Oconee Nuclear Station Units 1, 2 and 3
Docket Nos.: 50-269, 50-270 and 50-287
Oconee Nuclear Station Fuel Design Changes

References: Submittal to the NRC, entitled, "Transition to Mark-B11 with M5 Cladding", dated 1/31/00

License Amendment Request, regarding, "Implementation of Mark-B11 Fuel", dated 4/13/00

License Amendment Request, regarding, "Implementation of Mark-B11 Fuel",Supplement 1, dated 5/30/00

Pursuant to requirements in Section 18.3.19 of the Oconee Nuclear Station (ONS) UFSAR, attached is Framatome Technologies (FTI) document, 51-5010403-00, entitled, "Oconee Fuel Design Changes". During the Units 1 and 3 end-of-cycle (EOC)-20 and during Unit 2 EOC-19 refueling outages, Duke will insert a slightly modified fuel, manufactured by FTI, called Mark B11 (This is not a new commitment.). Although the attached analyses address only the impact of this initial (partial) core reload of Mark B11 fuel, in 2001, Duke intends to perform a more detailed analyses to address a full core loading of the Mark B11 fuel (This is a new commitment.).

In support of the ONS low leakage core design, the first batch of Mark B11 fuel assemblies will be loaded in the

A001

interior of the core. Since it has been shown that reactor pressure vessel (RPV) fluence levels are 95% affected by periphery fuel assemblies, the initial reload of Mark B11 fuel assemblies in the interior core locations will have an insignificant affect on RPV integrity matters.

If you have questions or require additional information, please contact Allison Jones-Young at(704)382-3154.

Sincerely,

M.S. Tuckman

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FRAMATOME TECHNOLOGIES

ENGINEERING INFORMATION RECORD

Document Identifier 51 - 5010403 - 00

Title OCONEE FUEL DESIGN CHANGES

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Technical Manager Statement: Initials [initials]

Reviewer is Independent.

Remarks:

The purpose of this document is to explain the program to determine the impact of the modifications to the Oconee fuel assembly design. (The program results will be completed in 2001).

The conclusion of this document is that the program to determine the impact of the changes in the neutron energy spectrum and "gamma" heating needs to be in two parts. The primary part is the bounding analyses from a hypothetical "equilibrium" cycle. In the "equilibrium" cycle, every fuel assembly will be of the modified type (Mark B11). Prior to the "equilibrium" cycle, there will be transition cycles with partial core loadings. The first transition cycle with the first batch of modified fuel is judged to have an inconsequential impact on the PTS screening criteria and P-T limits, including LTOP. This judgement is supported by a preliminary analysis in FTG document number 32-1267515-00[1].

Therefore, it is judged that there will neither be an impact on the current PTS criteria, nor on the P-T limits, including LTOP values, for Oconee Unit 1, Cycle 20, Oconee Unit 2, Cycle 19, and Oconee Unit 3, Cycle 20.

Oconee Fuel Design Changes

Introduction

Duke Power has previously evaluated, and continues to evaluate the most economically efficient means of producing power from the Oconee plant (Units 1, 2 and 3). One means of improving the economic performance of the plant is to use new fuel designs that have a higher volume fraction of coolant water and a lower fraction of uranium fuel. This new fuel rod and assembly design is termed the Mark B11. When evaluating design changes to increase the efficiency of the fuel, another goal of paramount importance is to improve or maintain the safety standards for operating the plant. The objective of this document is to describe how the safety standards for the reactor vessel and internal components will be maintained when introducing the Mark B11 design changes into operating reactors.

The cores of the Oconee nuclear reactors will be loaded with the Mark B11 fuel. The in-core safety standards that are affected by operation with this fuel are addressed in reload licensing documents. The out-of-core safety standards for the reactor vessel and internal components that are affected by operating with this fuel are addressed in this document.

There are two phenomena that occur in the out-of-core region that affect the safety and licensing of the Oconee reactors. The first phenomenon is associated with neutron - gamma collisions with the structural steel of the reactor internals and vessel. These collisions deposit heat energy in the structure. The second is associated with high energy (energies greater than 1.0 MeV) neutron collisions with the reactor vessel and material specimens. The high energy neutron collisions with the vessel cause structural degradation. Changing the fuel design from the Mark B9 and B10, to the Mark B11 increases the radiation leakage from the core for both the high energy neutrons and the neutron - gamma-rays. The increases in leakage increase the heat deposition in the structural components and increase the degradation of the vessel.

The relative increase in water and decrease in uranium in the B11 design compared to the B9 or B10 increases the radiation leakage from both the high energy neutrons and the gamma-

rays. If the methods of modeling the neutron and gamma-ray characteristics are considered, the physics phenomena causing the increases in leakage may be understood. The emission of neutrons and gamma-rays may be modeled as isotropic (uniform in all directions). As the neutrons and gamma-rays traverse the fuel assembly, the uranium fuel, the cladding, and the coolant water may be adequately modeled as uniformly distributed within each cell of the assembly. Thus, the neutron and gamma-ray collisions are proportional to the volume of the fuel, cladding, and water.

If the source of neutrons from fission and slowing-down within the fuel assembly is considered to be in a single fast group, this group of neutrons would predominantly collide with the water until they are slowed to thermal energies. Thus, the relatively larger volume of water in the B11 assembly results in a smaller number of neutrons in the fast group. The smaller number of neutrons would decrease the absolute leakage from the one fast group. However, if the source of neutrons is grouped into neutrons with energies greater than 1.0 MeV and those below, then those above 1.0 MeV will have an increased leakage while those below will have a decreased leakage. The reason for this phenomenon is that uranium - neutron collisions predominate in the groups above 1.0 MeV. These collisions result in the neutrons being back-scattered, producing less leakage. Since the Mark B11 design has an increase in the relative fraction of water and a decrease in the comparable fraction of uranium, there are fewer uranium collisions and more in water. Consequently, more of the B11 neutrons in the energy groups above 1.0 MeV will leak from the fuel assembly to the adjacent regions due to the smaller number of collisions with uranium and the larger number with water.

The gamma-rays being emitted from neutron fission and capture predominantly collide with the electrons of the fuel assembly material in what is termed Compton scattering. When the Mark B11 design increases the relative fraction of water, which has 10 electrons, and decreases the comparable fraction of uranium, which has 108 electrons, more of the gamma-rays will leak from the fuel assembly to adjacent regions. The increased leakage results from fewer Compton collisions. Thus, the leakage of high energy neutrons and gamma-rays increase as a result of the Mark B11 design changes compared to previous designs.

The neutron and gamma radiation to the reactor internals and the vessel affect the structural strength of the vessel materials and the bolts securing the internal components (baffle plates to former plates, etc.). The safety and licensing standards for the structural strength of the vessel materials are defined in 10 CFR 50.61, and the "Technical Specifications" for pressure - temperature limits. The standards for the structural strength of the bolts are defined by the American Society of Mechanical Engineers (ASME), "Boiler and Pressure Vessel Code", Section II. Various Duke Power documents that support the licensing of the Oconee Units (1, 2 and 3) note the need to evaluate changes in the design and operation that would affect the structural integrity of the reactor vessel and internals. Specifically, Section 18.3.19, "Reactor Vessel Integrity Program", of the Oconee UFSAR, addresses design and operational changes with respect to (a) the pressure - temperature limits for heat-ups, cool-downs, and testing, and (b) the end-of-life reference temperature for pressurized thermal shock.

Requirements

If modifications to the design and operation result in changes to the neutron energy spectrum, "gamma" heating, or reactor coolant temperatures relative to the reference conditions, then the NRC will be notified and a program to determine the impact will be proposed (Section 18.3.19.1 of the Oconee UFSAR).

Purpose

The purpose of this document is to explain how the Oconee Units meet the above requirements for changes in the fuel design. As noted in the introductory section, the Mark B11 fuel assembly design is replacing the Mark B10 and B9. Due to the relative reduction of the uranium density in the radial plane, the radial leakage of neutrons and gamma-rays to the out-of-core regions increases in the B11 design relative to the B10 or B9. The changes in the neutron energy spectrum and "gamma" heating can have an effect upon the structural properties of the vessel and internals. To determine the impact of the Mark B11 changes on the vessel and internals structural properties, the following program is proposed to evaluate the neutron energy spectrum and "gamma" heating.

Program to Evaluate the Mark B11 Design

Due to the changes in the Mark B11 fuel design in comparison to the previous fuel assembly designs (Mark B10 and B9) for the Oconee Units, there is an increase in the neutron and gamma-ray leakage. As discussed in the introductory section, the radiation leakage is from the surface of the B11 assembly to the adjacent regions. If the adjacent regions are Mark B10 or B9 fuel assemblies such as in Figures 1, 2 and 3, then the radiation must be transmitted through these assemblies before it can leak to the out-of-core regions. Only the increase in B11 fuel radiation from the periphery of the core is of interest in this evaluation program, not the standard radiation from B10 or B9 fuel.

Analyses of neutron and gamma-ray attenuation indicates that the mean free paths of the radiation that affects the structural properties of the vessel and internals is on the order of one-third to one-fourth of the radial width of a fuel assembly. Therefore, the effects of the Mark B11 assemblies are dependent on their core loading locations. The fuel management plan that Duke Power is utilizing for loading the Oconee cores (Units 1, 2, and 3) places the unburned fuel assemblies into the core interior. No B11 assembly is on the periphery in the first transition cycle (Figures 1, 2 and 3). With the exponential attenuation of the B11 radiation by the adjacent B9 and B10 fuel assemblies during the first transition reload cycle, the effects of the B11 assembly will be greatly diminished. Thus, the B11 radiation in the first transition reload cycle will not be significant with respect to the effects resulting from an entire core with B11 assemblies. Consequently, the evaluation program is divided into two parts. The first part is the transition cycle evaluation, and the expected impact is summarized in this document. The second part is the "equilibrium" cycle evaluation. To ensure bounding results when any B11 fuel assembly is loaded or moved to a peripheral location, the "equilibrium" cycle evaluation will model every assembly as a B11. The impact of the B11 design changes will be completely evaluated before loading the second batch of B11 fuel.

Transition Cycle Program

While there have been B11 test assemblies, the B11 transition cycles are those with the first full batch loading of B11 fuel. The evaluation of the Oconee (Units 1, 2 and 3) transition cycles is based on (a) a preliminary Framatome Technologies analysis[1], and (b) the B11 loading in the fuel cycle designs for each unit as shown in Figures 1, 2, and 3.

Framatome Technologies performed a preliminary analysis by simulating a full core loading of B11 fuel and a comparable full core loading of B9 fuel. The three-dimensional power production in the two cores was the same as were the isotopics for the burned and fresh fuel pellets. While the quality of the two preliminary results was not sufficient for safety and licensing analyses, the differences between the two did indicate the relative impact of the Mark B11 changes.

The preliminary analyses of the high energy neutrons leaking into the out-of-core region showed changes of less than 2.0 percent as a result of B11 changes. Likewise, the neutrons and gamma-rays leaking into the out-of-core region showed changes in the "gamma" heating of less than 4.0 percent as a result of B11 changes. As noted in the following paragraph, these changes are not particularly significant with respect to having an impact on the structural properties of the vessel material and internals bolts in the first B11 transition cycle. However, they do indicate that a more in-depth evaluation would be needed for the second cycle when B11 assemblies are moved to the periphery.

Reviewing Figures 1, 2 and 3 for the initial batch loading of B11 fuel assemblies, show that there are no B11 assemblies on the periphery. Thus, before the neutron and gamma-ray radiation from these assemblies can leak into the out-of-core region, the radiation must traverse an assembly of the B10 or B9 type. The transmission will reduce the 2.0 percent neutron effects and the 4.0 percent "gamma" heating effects by at least a factor of 10 (2.3 mean free paths). This means that the effects of the changes caused by the first B11 transition cycle will be insignificant in comparison to cycles with B10 or B9 fuel. Therefore, it is judged that there will neither be an impact on the current pressurized thermal shock (PTS) criteria, nor on the pressure - temperature (P-T) limits, including those for the low temperature - over pressure

(LTOP) values for Oconee Unit 1, Cycle 20, Oconee Unit 2, Cycle 19, and Oconee Unit 3, Cycle 20. However, the effects of the changes in the "equilibrium" cycle may be significant.

"Equilibrium" Cycle Program

When changes in the design and operation of the Oconee units result in changes in the neutron energy spectrum and "gamma" heating, the program to determine the impact needs to be sufficient to address the complete and bounding effects. As discussed above in the "Transition Cycle Program" section, transition cycles will not appropriately reflect the bounding impact of the Mark B11 changes. Thus, the "Equilibrium Cycle Program" is proposed to determine the complete and bounding impact of changes resulting from the B11 design.

The plans for the "Equilibrium Cycle Program" are to assess the impact on the PTS criteria, and the P-T limits, including those for the LTOP values, for heat-ups and cool-downs. The assessment will be in terms of changes in the vessel fluence resulting from a reference cycle design with B10 or B9 fuel and a comparable cycle design with B11 fuel. Additionally, the impact of "gamma" heating will be assessed in terms of changes in the energy deposition in the vessel, material specimens, and baffle bolts. Based on the preliminary evaluation that has been performed, it is expected that the changes in the neutron energy spectrum and "gamma" heating will not have any immediate impact on the PTS criteria, the P-T limits (including LTOP), and the baffle bolts or other internals.

The changes in the neutron energy spectrum and "gamma" heating caused by refueling with B11 fuel versus B10 or B9 fuel will be determined with the "Equilibrium Cycle Program". The program is based on the operation of a reference core, such as Oconee 2, Cycle 17. This reference core will have already operated, and core-follow calculations and measurements will have confirmed that the analytical modeling is valid. The reference core analysis (such as Oconee 2, Cycle 17) will be updated to include the appropriate evaluation of the neutron energy spectrum and "gamma" heating. The modified core, leading to an "equilibrium" Cycle 17, will simulate the loading of B11 fuel in earlier cycles, such as Cycle 15. The simulated loading of B11 fuel will continue such that by Cycle 17 the modified core contains

B11 fuel in each assembly location. The total core power will be constant as will the three-dimensional distribution of the power density. The neutron energy spectrum and "gamma" heating from the modified core with B11 fuel will be evaluated. The differences between the neutron and "gamma" heating results from the B11 modified core in comparison to the B10 or B9 reference core will determine the changes resulting from the B11 fuel. These changes will be extrapolated over the life of the reactor to estimate the long-term impact. It is expected that the overall impact on the PTS criteria, the P-T limits (including LTOP), and the baffle bolts or other internals will be minimal. If necessary, any detrimental impact of the changes on the PTS criteria and the P-T limits in the "Technical Specifications" could be accommodated by changing the effective full power years for the validity date. Likewise, if necessary, any detrimental impact of the changes on the aging effects associated with the baffle bolts and other internals could be accommodated by updating the frequency of monitoring.

[1] Framatome Technologies Document, "MkB11 Fluence/Gamma Heating", proprietary, released March 20, 2000.

Figure 1 Oconee 1, Cycle 20

Full Core Shuffle Map

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A						G-15	G-13	H-01	G-03	G-01					
B				N-10	K-06	N-07	01	K-08	01	N-09	K-10	N-06			
C			N-12	01	P-09	04	C-10	02	C-06	04	P-07	01	N-04		
D		L-12	01	O-08	02	M-12	03	O-11	03	M-04	02	H-03	01	L-04	
E		F-09	K-14	02	O-05	03	L-05	03	L-11	03	E-03	02	K-02	F-07	
F	R-07	G-12	04	N-11	03	L-02	D-13	P-06	D-03	B-06	03	N-05	04	G-04	R-09
G	O-07	01	L-03	03	E-10	O-04	E-08	03	H-11	O-12	E-06	03	L-13	01	O-09
H	R-08	H-09	02	E-13	03	L-14	03	G-09	03	F-02	03	M-03	02	H-07	A-08
K	C-07	01	F-03	03	M-10	C-04	H-05	03	M-08	C-12	M-06	03	F-13	01	C-09
L	A-07	K-12	04	D-11	03	P-10	N-13	B-10	N-03	F-14	03	D-05	04	K-04	A-09
M		L-09	G-14	02	M-13	03	F-05	03	F-11	03	C-11	02	G-02	L-07	
N		F-12	01	H-13	02	E-12	03	C-05	03	E-04	02	C-08	01	F-04	
O			D-12	01	B-09	04	O-10	02	O-06	04	B-07	01	D-04		
P				D-10	G-06	D-07	01	G-08	01	D-09	G-10	D-06			
R						K-15	K-13	H-15	K-03	K-01					

The B11 assembly loading locations are shaded.

Figure 2 Oconee 2, Cycle 19

Full Core Shuffle Map

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A						D-10	O-09	P-08	O-07	D-06					
B				K-05	K-06	O-06	01	O-08	01	O-10	K-10	K-11			
C			N-12	01	O-12	03	E-12	05	E-04	03	O-04	01	N-04		
D		E-09	01	G-08	06	L-02	06	E-03	06	L-14	06	H-09	01	E-07	
E		F-09	N-13	06	M-06	06	N-09	06	N-07	06	F-05	06	N-03	F-07	
F	L-04	F-13	03	B-10	06	M-03	K-02	M-08	K-14	C-05	06	B-06	03	F-03	L-12
G	K-13	01	N-05	06	K-12	B-09	F-11	05	M-10	B-07	K-04	06	N-11	01	K-03
H	H-14	H-13	05	O-05	06	H-11	05	R-07	05	H-05	06	C-11	05	H-03	H-02
K	G-13	01	D-05	06	G-12	P-09	E-06	05	L-05	P-07	G-04	06	D-11	01	G-03
L	F-04	L-13	03	P-10	06	O-11	G-02	E-08	G-14	E-13	06	P-06	03	L-03	F-12
M		L-09	D-13	06	L-11	06	D-09	06	D-07	06	E-10	06	D-03	L-07	
N		M-09	01	H-07	06	F-02	06	M-13	06	F-14	06	K-08	01	M-07	
O			D-12	01	C-12	03	M-12	05	M-04	03	C-04	01	D-04		
P				G-05	G-06	C-06	01	C-08	01	C-10	G-10	G-11			
R						N-10	C-09	B-08	C-07	N-06					

The B11 assembly loading locations are shaded.

Figure 3 Oconee 3, Cycle 20

Full Core Shuffle Map

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A						K-07	L-12	N-04	L-04	F-06					
B				M-05	F-09	P-08	5	M-08	5	O-09	F-07	H-12			
C			H-10	5	O-04	1	C-10	3	C-06	1	O-12	5	L-08		
D		D-08	5	H-09	3	N-07	4	O-08	4	N-09	3	K-08	5	E-05	
E		K-06	D-13	3	M-12	4	E-13	4	E-03	4	N-05	3	D-03	K-10	
F	L-06	G-13	1	G-12	4	N-11	P-09	L-11	P-07	M-04	4	G-04	1	H-02	G-07
G	N-10	5	L-03	4	O-05	K-14	M-10	2	L-05	K-02	O-11	4	L-13	5	N-06
H	N-12	H-11	3	H-13	4	E-10	2	*H-04*•	2	M-06	4	H-03	3	H-05	D-04
K	D-10	5	F-03	4	C-05	G-14	F-11	2	E-06	G-02	C-11	4	F-13	5	D-06
L	K-09	H-14	1	K-12	4	E-12	B-09	F-05	B-07	D-05	4	K-04	1	K-03	F-10
M		G-06	N-13	3	D-11	4	M-13	4	M-03	4	E-04	3	N-03	G-10	
N		M-11	5	G-08	3	D-07	4	C-08	4	D-09	3	H-07	5	N-08	
O			F-08	5	C-04	1	O-10	3	O-06	1	C-12	5	H-06		
P				H-04	L-09	C-07	5	E-08	5	B-08	L-07	E-11			
R						L-10	F-12	D-12	F-04	G-09					

The B11 assembly loading locations are shaded.