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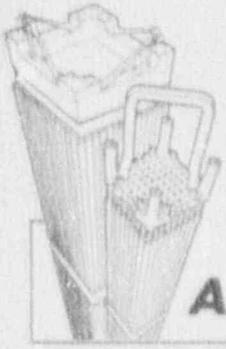

ADVANCED NUCLEAR FUELS CORPORATION

GENERIC MECHANICAL DESIGN REPORT HIGH THERMAL PERFORMANCE SPACER AND INTERMEDIATE FLOW MIXER

MARCH 1991

A Siemens Company

ADVANCED NUCLEAR FUELS CORPORATION

ANF-89-060(NP)(A)

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Supplement 1

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GENERIC MECHANICAL DESIGN REPORT

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MARCH 1991

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

February 20, 1991

Mr. R. A. Copeland, Manager
Reload Licensing
Advanced Nuclear Fuels Corporation
P. O. Box 130
Richland, WA 99352

Dear Mr. Copeland:

SUBJECT: ACCEPTANCE FOR REFERENCING OF TOPICAL REPORT ANF-89-060(P), "GENERIC MECHANICAL DESIGN REPORT HIGH THERMAL PERFORMANCE SPACER AND INTERMEDIATE FLOW MIXER" (TAC NO. 73015)

We have completed our review of the subject topical report dated April 1989, together with responses to request for additional information dated January 3, January 18, and April 13, 1990. Based on our review, we conclude that ANF-89-060(P) provides an acceptable basis for the high thermal performance spacer and intermediate flow mixer design provided that a plant-specific analysis of seismic and LOCA loading is performed during reload application. The enclosure to this letter provides our Safety Evaluation Report (SER) which details the basis and limitations of our approval. Our evaluation applies only to matters described in the topical report.

In accordance with procedures established in NUREG-0390, it is requested that the Advanced Nuclear Fuels Corporation publish accepted versions of this topical report, proprietary and non-proprietary, within three months of receipt of this letter. The accepted versions shall include an "A" (designating accepted) following the report identification symbol.

Sincerely,

AC Thadani

Ashok C. Thadani, Director
Division of Systems Technology
Office of Nuclear Reactor Regulation

Enclosure:
ANF-89-060(P) Evaluation

SAFETY EVALUATION OF ADVANCED NUCLEAR FUELS CORPORATION
TOPICAL REPORT ANF-89-060(P)
"GENERIC MECHANICAL DESIGN REPORT HIGH THERMAL PERFORMANCE SPACER AND INTERMEDIATE FLOW MIXER"

FEBRUARY 1991

OFFICE OF NUCLEAR REACTOR REGULATION
U.S. NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

1.0 INTRODUCTION

The Advanced Nuclear Fuels (ANF) Corporation has submitted a topical report (Reference 1) entitled "Generic Mechanical Design Report High Thermal Performance Spacer and Intermediate Flow Mixer," ANF-89-60(P), to the U.S. Nuclear Regulatory Commission (NRC) for review and approval. This report describes two new pressurized water reactor (PWR) fuel assembly grid spacer designs: the High Thermal Performance (HTP) spacer and the Intermediate Flow Mixer (IFM). The HTP is an all Zircaloy spacer which provides improved mixing, reduced pressure drop, and increased structural strength compared to the previous ANF bimetallic spacer design. The IFM is an all Zircaloy grid designed to be placed between HTP spacers for improved mixing of the coolant.

The purpose of this report is to review the ANF mechanical design limits and analysis methods for the new grid designs. This review is intended to assure that application of these analysis methods and design limits will prevent fuel damage or failure and maintain fuel coolability, as defined in the Standard Review Plan (SRP) (Reference 2), for those fuel assemblies using the new HTP and IFM spacer designs.

This review was based on the licensing requirements identified in Section 4.2 of the SRP (Reference 2). The objectives of this fuel system safety review, as described in Section 4.2 of the SRP, are to provide assurance that 1) the fuel system is not damaged as a result of normal operation and anticipated operational occurrences (AOOs), 2) the number of fuel rod failures is not underestimated for postulated accidents, 3) fuel system damage is never so severe as to prevent control rod insertion when it is required, and 4) coolability is always maintained. A "not damaged" fuel system is defined as one wherein fuel rods do not fail, fuel system dimensions remain within operational tolerances, and functional capabilities are not reduced below those assumed in the safety analyses. Objective 1, above, is consistent with General Design Criterion (GDC) 10 (10 CFR 50, Appendix A) (Reference 3), and the design limits that accomplish this are called specified acceptable fuel design limits (SAFDLs). "Fuel rod failure" (Objective 2) means that the fuel rod leaks and that the first fission product barrier (the cladding) has, therefore, been breached. Fuel rod failures must be accounted for in the dose analysis required by 10 CFR 100 (Reference 4) for postulated accidents. The general requirements to maintain control rod insertability (Objective 3) and core coolability (Objective 4) appear repeatedly in the GDC (e.g., GDC 27 and 35). Specific coolability requirements for the loss-of-coolant accident (LOCA) are given in 10 CFR 50, Section 50.46 (Reference 5). "Coolability," which is sometimes termed "coolable geometry," means, in general, that the fuel assembly retains it rod-bundle geometrical configuration with adequate coolant channels to permit removal of residual heat even after a severe accident.

In order to assure that the above stated objectives are met and follow the format of Section 4.2 of the SRP, this review covers the following three major categories: 1) Fuel System Damage Mechanisms, which are most applicable to normal operation and AOOs; 2) Fuel Rod Failure Mechanisms, which apply to normal operation, AOOs, and postulated accidents; and 3) Fuel Coolability, which is applied to postulated accidents. Specific fuel damage or failure mechanisms are identified under each of these categories in Section 4.2 of the SRP and these individual mechanisms are addressed in this report. The ANF design limits and analysis methods applied to the new grid designs will be briefly discussed in this report under each fuel damage or failure mechanism.

Pacific Northwest Laboratory (PNL) has acted as a consultant to the NRC in this review. As a result of the review of the subject topical report by the NRC staff and their PNL consultants, a list of questions were sent by the NRC to ANF (Reference 6) requesting clarification of the fabrication of the Zircaloy strips that make up the grids, future examinations planned for the lead test assemblies (LTAs) with the new grids, and how ANF plans to address specific mechanical analyses not provided in Reference 1. ANF has provided responses to these questions in Reference 7. ANF has provided additional responses in References 8 and 9 to verbal questions on inconsistencies in Reference 1, analytical methods used to predict fretting wear between the fuel cladding and spacer springs, and axial fuel assembly growth.

The HTP spacers and IFM designs are briefly discussed in the following section (Section 2.0). The ANF fuel damage and failure criteria/limits and analysis methods of the mechanisms defined in the SRP are addressed in Sections 3.0 and 4.0, respectively, while fuel coolability and control rod insertability are addressed in Section 5.0.

2.0 FUEL SYSTEM DESIGN

The HTP spacer and IFM grids are made of all Zircaloy strips in order to reduce their neutron cross-section as compared to the previous bimetallic grids that consisted of Inconel strips for the spacer springs. There are other important differences in these new grids that represent an improvement over the previous bimetallic grid design. Both the HTP and IFM grids have been designed to create a swirling flow pattern in the coolant, i.e., increase coolant mixing, and, therefore, improve the heat transfer from the fuel rods. These new grids are also designed to be structurally stronger than the bimetallic design. In addition, the HTP spacer grid maintains greater contact area between the Zircaloy spacer springs and the fuel rods to increase the fretting resistance with the fuel rods as compared to the contact area of the Inconel springs from the bimetallic spacer grids. The IFM grid was designed to be placed axially between the HTP spacer grids in the upper half of the assembly to increase flow mixing, and, therefore, better heat transfer in the upper axial half of the fuel rods. The outer dimensions of the IFMs are smaller than the HTP spacer to avoid interaction with adjacent fuel assemblies.

The following evaluation of damage/failure mechanisms for these new grid designs are separated into Section 3.0 (Fuel System Damage), Section 4.0 (Fuel Rod Failure), and Section 5.0 (Fuel Coolability).

3.0 FUEL SYSTEM DAMAGE

The design criteria presented in this section for the new grid designs are evaluated and, when found to be satisfactory for licensing applications, should not be exceeded during normal operation, including AOOs. For each damage mechanism, there is also an evaluation of the analysis methods used by ANF to demonstrate that the design criteria are not exceeded during normal operation, including AOOs, for the new grid designs described in Reference 1.

(a) Stress

Bases/Criteria - In keeping with the GDC 10 SAFDLs, fuel damage criteria should assure that fuel system dimensions remain within operational tolerances and that the functional capabilities are not reduced below those assumed in the safety analysis. The ANF design criteria for allowable primary membrane and bending stresses for PWR cladding and assembly components are presented in Tables 4.1 and 4.2 of Reference 10 and in ANF's response to a question (Reference 8). It is noted that this latter response corrected an inconsistency in the allowable cladding contact stresses in Sections 3.1.1 and 5.1.1 of Reference 1. These corrected criteria in Reference 8 are consistent with Section III of the ASME Boiler and Pressure Vessel Code (Reference 11) and the guidelines established in Section 4.2 of the SRP (Reference 2).

The ANF stress criteria for fuel rod cladding and assembly components have been approved by NRC for previous PWR designs up to extended burnup levels (Reference 10) and are also acceptable for PWR designs utilizing the new HTP and IFM grid spacers.

Evaluation - ANF has stated (Reference 1) that cladding stresses from the HTP and IFM spring forces will be determined by either using a finite element analysis (Reference 12) or by comparison with a finite element analysis of a similar design, such as provided in Reference 13, with spring forces that are greater or equal to those of the design in question. This stress analysis approach is consistent with standard engineering practices and, therefore, is acceptable for application to the cladding stress analyses of the HTP and IFM spacers for future PWR designs.

(b) Strain

Bases/Criteria - ANF has not proposed a design criterion or limit for cladding strains due to cladding stresses induced by the HTP and IFM spacer springs other than the 1% limit provided in the SRP. This is because ANF believes that the above stress criterion for the spacer springs and the 1% cladding strain limit for pellet cladding interaction (PCI) will control fuel cladding failure due to excessive stresses and, therefore, a separate strain criterion for the spacer springs is not necessary.

The SRP states that cladding strain shall not exceed 1% total uniform (elastic plus plastic) strain for normal operation and AOOs. The primary observed mechanism for PWR cladding strains in commercial fuel operation is related to PCI and cladding strains due to spacer springs have not been observed to date. The primary mechanism of cladding failures from spacer spring interaction is due to fretting wear.

Because the primary mechanism for fuel cladding strains is due to PCI and not due spacer spring stresses, we have concluded that the current 1% cladding strain limit for cladding strains used by ANF is acceptable and a separate strain limit for the HTP and IFM spacers is not necessary.

Evaluation - The use of HTP spacer and IFMs will not impact the analysis of cladding strains for PWR fuel assembly designs. Therefore, ANF's previously approved analysis methods described in References 10 and 14 for calculating cladding strains are also acceptable for application to those PWR assemblies that utilize the HTP spacers and IFMs.

(c) Strain Fatigue

Bases/Criteria - The principle concern for strain fatigue in the HTP and IFM spacers is due to cyclic stresses on the weld or mechanical joint between the spacer and guide tubes. A welded joint between the spacer and guide tubes is used on all ANF fuel designs except those fuel assembly designs that use large guide tubes. For those ANF fuel assemblies with large (multi-cell) guide tubes (Reference 8), ANF will use mechanical joints in HTPs and IFMs in place of the weld joints. The cyclic stresses on the welded or mechanical joints are caused by friction between the spacer springs and fuel rods as a result of axial expansion of the latter during changes in power. The stresses on the weld or mechanical joint are calculated by assuming maximum friction loads for each fuel rod in the grid cells. The minimum strength criteria of the weld and mechanical joints are based on the as-fabricated specifications for the minimum strength of these joints. The strength of the weld joints are routinely tested to demonstrate that they are within the specified minimum strength criteria. The mechanical joints used for the HTP and IFM spacers in the 14x14 C-E plants have been tested for strength and found to be stronger than the other spacer structural components, i.e., the spacer side plates buckle before the mechanical joints fail.

The O'Donnell and Langer design curve for strain fatigue (Reference 15) is used by ANF along with a conservative estimate of the cyclic stresses in the weld and mechanical joints due to power changes. The strain fatigue design criteria for the HTP spacers and IFMs are conservative and, therefore, acceptable for ANF licensing applications.

Evaluation - ANF's use of a conservative number of cyclic stresses in the weld and mechanical joints and the use of the O'Donnell and Langer design curve for strain fatigue are consistent with the recommendations in the SRP for strain fatigue. Therefore, this analysis methodology is found to be acceptable for use in evaluating the strain fatigue of the HTP and IFM spacer-to-guide tube joints for ANF licensing applications.

(d) Fretting

Bases/Criteria - The ANF design basis for fretting wear is that fuel rod failures due to fretting shall not occur. The purpose of grid springs in the HTP and IFM grid spacers is to center the fuel rod in the flow channel and also limit the rod vibration and, therefore, rod fretting. However, in-reactor irradiation of the HTP and IFM Zircaloy springs will result in relaxation of the spring forces and the fuel rods will creep down to a smaller diameter which can result in a small clearance (open gap) between the spacer springs and the fuel rods near the end-of-life (EOL). The Zircaloy springs will relax faster and to a greater degree than the Inconel springs used in the previous bimetallic grid spacers, which will result in a larger clearance than the previous design.

ANF has established a limit on the clearance between the spacer springs and the fuel rods in order to control fuel rod vibration and fretting wear that is based on their out-of-reactor wear tests and in-reactor experience. We conclude that ANF's design basis for fretting wear and limit on clearance (gap) between the spacer springs and fuel rods are acceptable for application to those PWR designs that utilize the HTP spacers and IFMs.

Evaluation - ANF has proposed an analysis methodology for predicting the fretting wear due to the clearance between the HTP and IFM spacer springs and fuel rods. This analysis methodology is based on ANF's prediction of clearance between the fuel rod and spacer spring and their conservative correlation of fretting wear as a function of this clearance and time.

The ANF calculation of the interference fit or clearance (that occurs near the EOL) between the fuel rod and spacer springs is performed using the RODEX2 cladding creepdown model,(14) a conservative model for Zircaloy spring relaxation, and the minimum cladding diameter and maximum cell size of the spacer that are determined from assembly fabrication tolerances. The ANF calculation of cladding diameter decrease with burnup utilizes the best estimate RODEX2 cladding creepdown model. However, ANF has used conservative input values to RODEX2 for cladding identification, rod pressurization, fuel densification, and linear heat generation rate in order to provide a conservative prediction of cladding creepdown and, therefore, maximum clearance with the spacer spring. The ANF calculation of Zircaloy spring relaxation for the HTP spacer and IFM utilizes a model that is a function of temperature and fast (E >1 MEV) fluence This ANF model is based on experimental Zircaloy spring data from a reactor with a fast flux greater than that typical of commercial PWRs. ANF has applied this data without a correction for the differences in fast flux between the data and their PWR application. The lack of correction of this data is judged to result in a conservative spring relaxation model because Zircaloy creep and spring relaxation increases with fast flux for a given temperature and fluence, i.e., the data used by ANF will predict greater spring relaxation than would be expected for a PWR fast flux at a given temperature and fluence. Therefore, we conclude that ANF's cladding creep down and spring relaxation models as applied in Reference 1 for determining the interference fit or clearance between the fuel rod and spacer springs for the HTP spacers and IFMs are conservative and applicable for the analysis of fretting wear.

ANF has performed out-of-reactor loop flow tests for 1000 hours on assemblies with HTP spacers and IFMs that have maximum expected EOL clearances between the fuel rods and spacer springs. ANF has measured the maximum wear rate from these tests (Reference 1) and developed a conservative fretting wear model as a function of fuel rod-to-spacer spring clearance that bounds this fretting wear data with a 95% probability at a 95% confidence level. We conclude that this fretting wear model is acceptable for predicting fretting wear for those PWR designs that utilize HTP spacers and IFMs.

ANF utilizes the above analysis methods for evaluating maximum fuel rod-to-spacer spring clearance and upper bound fretting wear in those PWR assemblies with HTP spacers and IFMs as a function of time in reactor. This methodology uses incremental time steps to calculate clearance and fretting wear for each time step and adds their incremental amounts until EOL for the assembly. The maximum calculated fretting wear is then included in their evaluation of fuel cladding stresses. This ANF analysis methodology for evaluating fretting wear is found to be conservative and, therefore, acceptable for those PWR designs that utilize the HTP spacers and IFMs.

(e) External Corrosion and Crud Buildup

Bases/Criteria - The ANF fuel design basis for cladding corrosion and crud buildup is to prevent 1) significant degradation of cladding strength, and 2) unacceptable temperature increases. Because of the thermal resistance of corrosion and crud layers, formation of these products on the cladding result in an elevation of temperature within the fuel as well as the cladding. ANF uses a cladding outer surface temperature limit for corrosion that is specified in Reference 10 for PWR fuel. The PWR temperature limit has been acceptable for previous ANF PWR designs and is also acceptable for those PWR designs that utilize HTP spacers and IFMs.

Evaluation - The use of the HTP spacers and IFMs in ANF PWR designs is not expected to significantly change the cladding corrosion of these designs and, in fact, may reduce cladding corrosion due to the increased flow mixing resulting from these new spacers. Therefore, the ANF analytical methods for application to PWR designs that are approved in Reference 10 remain acceptable for those PWR designs that utilize HTP spacers and IFMs.

(f) Rod Bowing

Bases/Criteria - Fuel and burnable poison rod bowing is a phenomenon that alters the design pitch dimensions between adjacent rods. Bowing affects local nuclear power peaking and the local heat transfer to the coolant. Rather than placing design limits on the amount of bowing that is permitted, the effects of bowing are included in the cladding overheating analysis, Section 4.0 (C) of this report, by limiting fuel rod powers when bowing exceeds a predetermined amount. ANF has established a rod-to-rod clearance limit below which a penalty is imposed by a reduction in the departure from nucleate boiling ratio (DNBR) and above which no reduction in DNBR is necessary. This approach is consistent with Section 4.2 of the SRP, and the NRC has approved this for application to current ANF PWR designs (References 10 and 16). We conclude that this approach is also acceptable for ANF PWR designs that utilize the HTP spacers and IFMs.

Evaluation - ANF has described their approved analytical model for rod bowing for PWR fuel designs in Reference 16. Rod bowing is influenced by the friction forces between the spacer springs and the fuel rods and, therefore, an increase in spacer spring friction forces will increase rod bowing. The HTP Zircaloy spacer springs have higher spring friction forces than the previous ANF bimetallic spacer springs, but these Zircaloy spacer springs will relax faster than the bimetallic spacer springs, see Section 3.0 (d) Evaluation. As a result of ANF analyses of HTP Zircaloy spring relaxation, the rod bowing for those assemblies with the HTP spacer grids are expected to be less by mid-to-end-of-life than the rod bowing in previous ANF PWR assemblies with bimetallic grid spacers. Therefore, ANF has concluded that the use of their current analytical model and rod bowing data will conservatively bound rod bowing for those assemblies with HTP spacers.

ANF has noted that those assemblies utilizing the IFMs between two HTP spacers will decrease the span length by one-half and, therefore, decrease the rod bow by a similar amount. ANF has, therefore, concluded that those assemblies with IFMs will not be limiting in terms of rod bowing.

We agree with ANF's conclusions for rod bowing in those assemblies that utilize the HTP spacers and IFMs. Therefore, the use of the current ANF analytical model and methods in References 10 and 16 for rod bowing are found to be acceptable for application to those assemblies with HTP spacers and IFMs.

(g) <u>Axial Growth</u>

Bases/Criteria - Those components requiring axial-dimensional control and evaluation are the fuel rods and fuel assembly structures. The critical clearances that must be controlled are 1) the clearance between the fuel rods and the upper and lower assembly tie plates, and 2) clearance between the assembly tie plates and core internals.

The ANF design basis for PWR fuel rod and assembly clearances is that clearance between the upper and lower tie plates and the fuel rods must be maintained for all fuel rods during their design life, and that clearance between the tie plates and the reactor core plates be maintained during the assemblies design lifetime. This design basis is consistent with the SRP and, therefore, is acceptable for application to those PWR designs that utilize the HTP spacers and IFMs.

Evaluation - The ANF analytical models and methods for predicting PWR fuel rod and assembly growth have been described in References 10 and 17. The ANF calculation of clearance between the fuel rods and the upper and lower assembly tie plates is performed by taking the worst-case as-fabricated dimensions and utilizing a conservative upper-bound rod growth curve and a lower-bound assembly growth curve. The ANF calculation of clearance between the assembly tie plates and core internals also uses worst-case dimensions but uses the conservative upper-bound assembly growth curve. These analysis methods are judged to be very conservative. ANF intends to utilize these same models and methods for calculating a) the clearance between the fuel rods and upper and lower tie plates and b) the clearance between the assembly tie plates and core internals for those assemblies that utilize the HTP spacers and IFMs.

The primary concern in the application of these earlier axial growth models, which were based on data from assemblies with the bimetallic spacers, is whether the models are applicable to PWR assemblies with the new HTP (all Zircaloy) spacers and IFMs.

As noted earlier in Section 3.0 (f) on Rod Bow, the HTP (Zircaloy) spacer spring starts off with a higher friction force early-in-life than the bimetallic spacers, but the friction force decreases more rapidly with burnup so that the HTP spacer spring has a lower time average friction force on the fuel rods than the earlier bimetallic spacer. The spacer springs introduce a compressive friction force on the fuel rods but they introduce a tensile force on the guide tubes. The tensile force on the guide tubes is because the fuel rods have greater axial thermal expansion than the guide tubes that are attached to the spacer grids. The friction forces on the fuel rods at beginning-of-life from either the HTP or bimetallic spacer springs are relatively small. Even when the total forces from the six equally spaced grid spacers along the length of the fuel rods are combined, the total compressive stresses on the rods are still relatively small. There has been no observed effect on rod growth as a result of changes to a Zircaloy spacer spring.

The tensile forces on the guide tubes due to the spacer spring friction forces with the fuel rods are relatively large because they are equal to the total compressive stresses on each rod multiplied by the number of rods in an assembly and divided by the number of guide tubes in an assembly. The influence of axial forces (stresses) on guide tubes has been shown to have a measurable effect on PWR assembly growth (Reference 10). In addition, Westinghouse has observed a decrease in assembly growth as a result of their design change to an all-Zircaloy spacer grid (Reference 18).

ANF was questioned on whether their 1) axial assembly growth analyses for the HTP spacers had taken into account the lower time average guide tube tensile stresses for these assemblies versus their earlier assembly designs with bimetallic spacers and 2) whether their axial guide tube growth data from assemblies with bimetallic spacers either bounded or matched those time averaged tensile and compressive stresses expected for the guide tubes with the HTP spacers. ANF has responded that, although the bimetallic spacer springs did not relax as fast as the new Zircaloy spacer springs, the former spacer springs did relax to a significant degree after one cycle of irradiation such that the axial tensile forces on the guide tubes were only a small fraction of beginning-of-life forces (Reference 9). Therefore, ANF claims that while the axial tensile forces on guide tubes with their bimetallic spacers are greater than those with their Zircaloy spacers, the absolute differences in the tensile forces between bimetallic and Zircaloy spacer springs are not significant enough to have a significant effect on guide tube growth. ANF has further stated that this conclusion will be verified "with additional monitoring of HTP fuel assemblies."

We conclude that ANF's use of their PWR rod and assembly growth models based on data from fuel designs with bimetallic spacers are expected to remain applicable to those PWR fuel designs that utilize the HTP spacers and IFMs because of 1) the large degree of conservatism in ANF's methodology for predicting rod and assembly growth, and 2) ANF's commitment to monitor growth in these assemblies.

(h) Rod Internal Pressure

Bases/Criteria - Rod internal pressure is a driving force for, rather than a direct mechanism of, fuel system damage that could contribute to the loss of dimensional stability and cladding integrity. Section 4.2 of the SRP presents a rod pressure limit that is sufficient to preclude fuel damage in this regard, and it has been widely used by the industry; it states that rod internal gas pressure should remain below the nominal system pressure during normal operation, unless otherwise justified. ANF has elected to justify rod internal pressure limits other than those provided in the SRP. A proprietary limit above system pressure for fuel designs has been justified in Reference 10. In addition, ANF has imposed a second limit (Reference 10) that requires the fuel-cladding gap to remain closed during constant and increasing rod power operation under normal reactor operating conditions, when internal rod pressure exceeds the system pressure. These ANF limits for PWR fuel designs are presented in Supplement 5 of XN-NF-82-06(P)(A), Revision 1 (Reference 10) and have been reviewed and accepted by the NRC. We conclude that these limits are also acceptable for ANF PWR assemblies with the HTP spacers and IFMs.

Evaluation - The use of the HTP spacers and IFMs in ANF PWR designs will not change the current ANF analyses methods used to calculate rod internal pressures nor are they expected to change the results of these analyses. Therefore, the approved ANF analytical models and methods defined in Reference 10 for calculating rod internal pressures remain acceptable for those designs that utilize HTP spacers and IFMs.

(i) Assembly Liftoff

Bases/Criteria - The guidelines in Section 4.2 of the SRP to prevent assembly liftoff are that worst-case hydraulic loads during normal operation and AOOs should not exceed the hold-down capability of the fuel assembly (which includes wet weight and hold-down spring forces). ANF has previously stated (Reference 10) that "the assembly hold-down spring must retain its ability to counteract the hydraulic force through life." We consider this to be consistent with the above SRP requirement and this criteria has been previously approved by the NRC (Reference 10) for ANF PWR designs. We also consider this to be acceptable for PWR assemblies that utilize HTP spacers and IFMs.

Evaluation - The use of the HTP spacers and IFMs in present ANF PWR designs are expected to have only a minor effect on assembly liftoff. Assembly liftoff is a function of plant coolant flow, assembly pressure drop, hold-down spring forces, assembly weight, and dimensional changes. ANF has measured the pressure drop across the HTP spacers and IFMs and these values will be used to confirm that assembly liftoff will not occur. ANF's approved methodology for evaluating PWR assembly liftoff (Reference 10) remains applicable and, therefore, is acceptable for application to those designs that utilize HTP spacers and IFMs.

(j) Control Material Leaching

Bases/Criteria - The SRP and GDC require that reactivity control be maintained. Rod reactivity may be lost by leaching of certain poison or control materials, particularly those materials containing boron, if the cladding of control-bearing material has been breached.

Evaluation - This review does not involve PWR control rods and, therefore, this issue will not be discussed further.

4.0 FUEL ROD FAILURE

Fuel rod failure thresholds and methods for analyzing the failure mechanisms listed in the SRP are reviewed in the following. When the failure thresholds are applied to normal operation including AOOs, they are used as limits (and hence SAFDLs) since fuel failure under those conditions should not occur according to GDC 10 (Reference 3). When the thresholds are used for postulated accidents, fuel failures are permitted, but they must be accounted for in the dose calculations required by 10 CFR 100 (Reference 4). The basis or reason for establishing these failure thresholds is, thus, established by GDC 10 and 10 CFR 100. The threshold values, and the methods used to assure that they are met, for PWR assemblies that utilize the HTP spacers and IFMs, are reviewed in the following.

(a) Hydriding

Bases/Criteria - The release of hydrogenous impurities inside the fuel rod can result in premature cladding failure due to the formation of hydride blisters and reduced ductility. Internal hydriding, as a cladding failure mechanism, is precluded by controlling the level of moisture and other hydrogenous impurities during fuel pellet fabrication. The ANF fabrication limit (Reference 10) for total hydrogen in fuel pellets is more stringent than the ASTM limit cited in the SRP and, thus, is acceptable for application to those ANF PWR designs that utilize the HTP spacers and IFMs.

Evaluation - The use of HTP spacers and IFMs in ANF PWR designs will not change fuel rod internal hydriding from that experienced by previous ANF PWR designs. ANF controls the moisture and hydrogenous impurity level of ANF fuel pellets by taking a statistical sample of the fabricated pellets and measuring total hydrogen content to assure that it is below the ANF limit (Reference 10). This method for controlling hydrogenous impurities in ANF fuel rods remains acceptable for application to those ANF PWR designs that utilize the HTP spacers and IFMs.

(b) Cladding Collapse

Bases/Criteria - If axial gaps in the fuel pellet column were to occur due to densification, the cladding would have the potential of collapsing into a gap, i.e., flattening. Because of the large local strains that would result from collapse, the cladding is assumed to fail. ANF's design criteria for preventing cladding collapse has been reviewed and accepted by the NRC in the review of XN-NF-82-06, Revision 1 (Reference 10). Because the cladding for

PWR assemblies utilizing the HTP spacers and IFMs is the same as for previous PWR designs, we conclude that this criteria is also applicable for PWR designs using the HTP spacers and IFMs.

Evaluation - The use of HTP spacers and IFMs in ANF PWR designs will not change ANF's analysis methods for calculating cladding collapse. ANF uses the approved RODEX2 and COLAPX codes (References 14 and 19) along with a methodology described in Reference 10 to predict cladding creep collapse for their PWR fuel rods. The RODEX2 code is used to provide initial in-reactor fuel rod conditions to COLAPX, e.g., fuel densification, radial fuel-cladding gap size, fill gas pressure, and cladding temperatures. The COLAPX code calculates cladding ovality changes (flattening) and creep deformation of the cladding as a function of time. Fuel densification and cladding creep are the two most important physical phenomena in the analysis of cladding collapse. As-fabricated fuel and cladding dimensions are also important in this analysis. Both the physical phenomena and dimensions are controlled in the fuel and cladding fabrication and their affect on cladding collapse are accounted for by ANF using the methodology described in Reference 10. These codes are also acceptable for application to those ANF PWR designs that utilize the HTP spacers and IFMs because the fuel and cladding fabrication have not changed from the previous designs.

(c) Overheating of Cladding

Bases/Criteria - As indicated in the SRP, Section 4.2.II.A.2 (d), it has been traditional practice to assume that failures will occur if the thermal margin criterion is violated. For PWR fuel, thermal margin is stated in terms of DNB. The ANF design limit for the prevention of fuel failures due to overheating of the cladding in PWRs is that there will be at least a 95% probability at a 95% confidence level that DNB will not occur on the most limiting fuel rod during normal operation and AOOs. This ANF criterion satisfies the intent of the SRP and, thus, is acceptable for application to those ANF PWR designs that utilize the HTP spacers and IFMs.

Evaluation - ANF has presented their DNB analysis methodology for those assemblies that utilize the HTP spacers and IFMs in a separate topical report (Reference 20) that was approved by the NRC. Therefore, the ANF DNB analysis methodology for designs that utilize the HTP spacers and IFMs has been addressed in the approved Reference 20. It is noted that the most limiting rod used for DNB analyses must also include the effects of rod bowing [see Section 3.0 (f)] in these analyses.

(d) Overheating of Fuel Pellets

Bases/Criteria - As a second criterion for avoiding cladding failure due to overheating, ANF precludes fuel centerline melting for normal operation and AOOs. This design limit is the same as given in the SRP, Section 4.2.II.A.2 (e), and, therefore, is acceptable for PWR designs utilizing the HTP spacers and IFMs.

Evaluation - The use of HTP spacers and IFMs in ANF PWR designs will not change ANF's analysis methods for calculating fuel centerline melting for normal operation and AOOs. Therefore, the ANF analysis methods described in the approved topical reports XN-NF-81-58(P)(A) and XN-NF-82-06(P)(A) (Reference 14 and 10) for calculating fuel centerline melting in PWR designs remain acceptable for application to those designs utilizing HTP spacers and IFMs.

(e) Excessive Fuel Enthalpy

Bases/Criteria - The SRP guidelines for a severe reactivity initiated accident (RIA) in a PWR, Section 4.2.II.A.2(f), state that "at zero or low power, fuel failure is assumed to occur if the radially averaged fuel rod enthalpy is greater than 170 cal/g at any axial location," i.e., a power excursion beginning at low or zero power. The 170 cal/g enthalpy criterion is primarily intended to address cladding overheating effects, but it also directly addresses PCI of the type associated with severe RIAs. The severest RIA for ANF PWR designs is the control rod ejection accident beginning at low or zero power. ANF utilizes this SRP guideline for evaluating fuel failure due to excessive fuel enthalpy and, therefore, this is acceptable for those ANF PWR designs using the HTP spacers and IFMs.

Evaluation - The use of HTP spacers and IFMs in present ANF PWR designs will not change the analysis methods used by ANF for the PWR control rod ejection accident. Therefore, the approved ANF analysis methods (Reference 21) for the control rod ejection accident remain applicable and acceptable for those PWR designs that utilize the HTP spacers and IFMs.

(f) Pellet/Cladding Interaction

Bases/Criteria - The design criteria for mitigating PCI fuel failures in Section 4.2.II.A.2(g) of the SRP are 1) cladding uniform strain shall not exceed 1% during any AOO, and 2) the fuel centerline temperature must remain below the melting point of the fuel. Both of these criteria are utilized by ANF for their PWR designs [see Sections 3.0 (b) and 4.0 (d) of this report] and, therefore, are acceptable for application to those PWR assemblies that utilize the HTP spacers and IFMs.

Evaluation - The use of HTP spacers and IFMs in present ANF PWR designs is not expected to change the PCI behavior of these designs. The ANF analysis methodologies for calculating cladding strains and fuel melting were addressed in Sections 3.0 (b) and 4.0 (d) of this report and found to be acceptable for application to those PWR designs that utilize the HTP spacers and IFMs. Therefore, ANF's analysis methodologies for evaluating PCI are acceptable for the subject designs.

(g) Cladding Rupture

Bases/Criteria - Zircaloy cladding will burst (rupture) under certain combinations of temperature, heating rate, and differential pressure; conditions that occur during a LOCA. While there are no specific design criteria in the SRP associated with cladding rupture, the requirements of Appendix K to 10 CFR Part 50 must be met as those requirements relate to the incidence of rupture during a LOCA; therefore, a rupture temperature correlation must be used in the LOCA emergency core cooling system (ECCS) analysis. ANF models the effects of cladding rupture as an integral part of their ECCS evaluation model, as discussed in Sections 5.0 (a) and (c) of this report. Therefore, we conclude that ANF has addressed this issue for PWR designs that utilize HTP spacers and IFMs.

Evaluation - The use of HTP spacers and IFMs in ANF PWR designs will not change ANF's analysis methods for cladding deformation and rupture. The ANF cladding deformation and rupture models are described in XN-NF-82-07(A), Revision 1 (Reference 22). The NRC has reviewed XN-NF-82-07(A), Revision 1, and concluded that the models are acceptable for use in LOCA analyses. The link between cladding deformation and rupture models to the LOCA ECCS analysis has been approved by the NRC in Reference 23. Therefore, this previously approved report and analysis methods therein (Reference 22) remain acceptable for application to those PWR designs that utilize the HTP spacers and IFMs.

(h) Fuel Rod Mechanical Fracturing

Bases/Criteria - The term "mechanical fracture" refers to a cladding defect that is caused by an externally applied force such as a load derived from core-plate motion or a hydraulic load. These stresses are bounded by the loads of a safe-shutdown earthquake (SSE) and LOCA, and the mechanical fracturing analysis is usually done as part of the SSE-LOCA loads analysis. The design limit applied by ANF is that the combined stresses due to postulated accidents shall not exceed the stress limits given in ASME Code, Section III, Appendix F for faulted conditions which are based on the cladding yield stress. This design limit is more conservative than the SRP guidelines and is, therefore, acceptable for PWR designs that utilize the HTP spacers and IFMs.

Evaluation - The discussion of the SSE-LOCA loading analysis is provided in Section 5.0 (d) of this report.

5.0 FUEL COOLABILITY

For accidents in which severe fuel damage might occur, core coolability must be maintained as required by several GDCs (e.g., GDC 27 and 35). In the following paragraphs, limits and methods to assure that coolability is maintained for those PWR designs that utilize the HTP spacers and IFMs are evaluated for the severe damage mechanisms listed in the SRP.

(a) Fragmentation of Embrittled Cladding

Bases/Criteria - The most severe occurrence of cladding oxidation and possible fragmentation during an accident results from a LOCA. In order to limit the effects of cladding oxidation for a LOCA, ANF has obtained approval (Reference 23) for an acceptance criteria of 2200°F on peak cladding temperature and 17% on maximum cladding oxidation as prescribed by 10 CFR 50.46. These criteria are not affected by the use of HTP spacers and IFMs and, therefore, these criteria remain acceptable for application to those PWR designs that utilize [illegible] spacers and IFMs.

Evaluation - The use of the HTP spacers and IFMs in present ANF PWR designs will not change the analysis methods used for LOCA ECCS. Therefore, the ANF analytical models and methods approved in Reference 23 for calculating the extended cladding oxidation and peak cladding temperatures for the LOCA ECCS analysis remain applicable and acceptable for application to those PWR designs that utilize HTP spacers and IFMs.

(b) Violent Expulsion of Fuel

Bases/Criteria - In a severe RIA, such as a PWR control rod ejection accident, large and rapid deposition of energy in the fuel could result in melting, fragmentation, and dispersal of fuel. The mechanical action associated with fuel dispersal might be sufficient to destroy fuel cladding and the rod-bundle geometry and to provide significant pressure pulses in the primary system. To limit the effects of an RIA event, Regulatory Guide 1.77 recommends that the radially-averaged energy deposition at the hottest axial location be restricted to less than 280 cal/g. ANF has endorsed this criterion for their designs (Reference 10) and it is also acceptable for application to those ANF PWR designs that utilize the HTP spacers and IFMs.

Evaluation - The use of the HTP spacers and IFMs does not change the analysis methods used to calculate the radially-averaged energy deposition from the control rod ejection accident which is the most severe RIA for ANF PWR designs. Therefore, the approved ANF analysis methods for this analysis, described in Reference 21, remains acceptable for application to those PWR designs that utilize the HTP spacers and IFMs.

(c) Cladding Ballooning

Bases/Criteria - Zircaloy cladding will balloon (swell) under certain combinations of temperature, heating rate, and stress during the LOCA. There are no specific design limits associated with cladding ballooning, other than 10 CFR 50, Appendix K requirement that the degree of swelling not be underestimated.

Evaluation - The use of HTP spacers and IFMs in ANF PWR designs will not change ANF's analysis methods for calculating cladding ballooning during the LOCA. The ANF cladding ballooning model is an integral part of the cladding rupture temperature model for the LOCA ECCS analysis. The cladding ballooning and rupture model is addressed in the approved topical report XN-NF-82-07(A), Revision 1 (Reference 22). Reference 22 has adopted the NUREG-0630 (Reference 24) data base and modeling, which specifies a method acceptable to the NRC for treating cladding swelling and rupture during a LOCA. Therefore, the approved ANF analysis methods for this analysis, described in Reference 22, remain acceptable for application to those PWR designs that utilize the HTP spacers and IFMs.

(d) Fuel Assembly Structural Damage From External Forces

Bases/Criteria - Earthquakes and postulated pipe breaks in the reactor coolant system would result in external forces on the fuel assembly. The SRP, Section 4.2 and associated Appendix A, states that fuel system coolability should be maintained and that damage should not be so severe as to prevent control rod (for PWRs) insertion when required during these low probability accidents. The ANF design basis is that the fuel assembly will maintain a geometry that is capable of being cooled under the worst case accident (Condition IV event) and that system damage is never so severe as to prevent control rod or control blade insertions. This is consistent with the design basis presented in the SRP and, therefore, is acceptable for application to PWR designs that utilize HTP spacers and IFMs.

In order to assure that these design bases are met, ANF has proposed design limits on the stresses that can be experienced by the critical fuel assembly components. These design limits are based on unirradiated yield and ultimate tensile strengths, and are described in the approved topical report XN-NF-84-97(P) (Reference 25). ANF was questioned on the minimum crushing load needed to collapse the HTP spacer grid. ANF responded (Reference 7) that the lateral strength of the HTP spacer grids is substantially greater than the lateral strength of the bi-metallic spacer grids and has provided HTP lateral strength data for some design applications that substantiate this claim for these design applications (Reference 1). This implies that the seismic-LOCA crushing load of the HTP spacer is greater than that of the bi-metallic spacer it replaces, but ANF has not presented data on all possible design applications or seismic-LOCA loading analyses to substantiate this claim. However, ANF has stated that the crushing strength of each HTP spacer design will be confirmed on a case-by-case basis that conforms to the requirements of SRP Section 4.2, Appendix A. We, therefore, conclude that ANF's plant-specific approach is acceptable and ANF has properly addressed the bases and criteria.

Evaluation - ANF has previously analyzed seismic-LOCA loading on various fuel assemblies using the approved methodology described in the approved XN-NF-76-47(P)(A) (Reference 26). ANF has stated that plant specific analyses of reload fuel assemblies with HTP spacers and IFMs will be performed to demonstrate that seismic-LOCA loading conditions, as defined in Section 4.2, Appendix A, are satisfied. We agree with ANF's approach, however, licensees using the ANF PWR assemblies with HTP spacers and IFMs along with other fuel assembly spacer designs in the same core should address this mixed core situation in their analyses. Since the ANF methodology for evaluating seismic-LOCA loading has been approved and plant specific analyses will be performed for HTP reload applications, we conclude that the issue of seismic-LOCA loading of ANF fuel assemblies using the HTP spacers and IFMs is adequately addressed.

6.0 CONCLUSIONS

We have reviewed the ANF design criteria and analysis methods proposed for PWR assemblies that utilize the HTP spacers and IFMs, described in Reference 1, in accordance with the SRP, Section 4.2. We conclude that these design criteria and analysis methods for the HTP spacer and IFM, as described in ANF-89-060, are acceptable for licensing applications with the exception, as described in Section 5.0(d), that plant specific analysis of seismic-LOCA loading is required during reload applications.

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ADVANCED NUCLEAR FUELS CORPORATION

ANF-89-060(NP)(A)
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GENERIC MECHANICAL DESIGN REPORT

HIGH THERMAL PERFORMANCE SPACER AND INTERMEDIATE FLOW MIXER

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April, 1988

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HIGH THERMAL PERFORMANCE SPACER AND INTERMEDIATE FLOW MIXER

1.0 INTRODUCTION

Advanced Nuclear Fuels (ANF) has developed two new assembly grid designs: the High Thermal Performance (HTP) spacer and the Intermediate Flow Mixer (IFM). The HTP is an all Zircaloy spacer which provides improved mixing, reduced pressure drop, and increased structural strength as compared to the ANF bi-metallic design. The IFM is an all Zircaloy grid designed to be placed between two spacers to improve mixing. Lead assemblies with HTP grids are under irradiation

There are several important design changes that make the HTP and IFM grids an improvement over the ANF bi-metallic design. The change from an Inconel spring to a Zircaloy spring reduces the neutron capture cross-section of the spacers.

The mechanical design bases for the HTP and IFM grids are similar to the ANF bi-metallic spacer design bases(3). The primary differences are in the fuel contact methods and the different stress relaxation rates.

This document contains a description of the IFM and HTP spacers, a review of the design bases, and a design evaluation based on the format of Section 4.2 of the Standard Review Plan. This report only considers the HTP and IFM spacer and assembly characteristics. The previously accepted fuel rod and fuel assembly design methods including those for the bi-metallic spacer are given in Reference 3.

2.0 SUMMARY AND CONCLUSION

The high thermal performance spacer and the intermediate flow mixer provide improvements over the ANF bi-metallic spacer design.

Relaxation and fretting data are used to demonstrate that the unique spring designs of the HTP and IFM grids do not allow significant fretting of fuel rods throughout the design life.

3.0 DESIGN BASES (STANDARD REVIEW PLAN - SECTION 4.2 A)

The function of the HTP and IFM assemblies is to maintain separation of fuel rods, guide tubes, and instrument tube components; to restrain fuel rod bowing and vibration within the fuel assembly throughout the design life of the fuel; to enhance coolant mixing around each fuel rod; and to resist hydraulic, differential expansion and accident loads. This section describes the criteria for mechanical acceptability of the designs.

3.1 Stress, Strain, and Load Limits

3.1.1 Clad Stress

The force resulting from the maximum spring deflection shall be less than the contact force at which the calculated contact stresses are equal to the ultimate strength of the clad tube.

3.1.2 Fuel Rod Axial Friction Force

The flow channel supporting each fuel rod and the normal spring forces between the cell and the fuel rod shall be designed so as to limit fuel rod creep induced bow due to axial friction forces.

3.1.3 Strength

The spacer structural components shall retain adequate strength under operating conditions to ensure functional operation throughout the design life of the fuel. The HTP spacers shall resist hydraulic, fuel rod friction, handling, and accident forces. The IFM's shall resist hydraulic, rod friction, and handling forces.

3.1.4 Grid Attachment

The design of the HTP and IFM assemblies shall provide for attachment to guide tubes, instrument tubes, or guide bars which are used to anchor each of the grids in the fuel assembly throughout the design life of the fuel. The grid attachments shall be designed to withstand the loads due to the differential thermal and irradiation induced expansion between the fuel rods and the fuel assembly skeleton.

3.2 Fatigue

The spacer and guide tube attachment shall be capable of preventing failure due to cyclic stresses throughout life.

3.3 Fretting Wear

The spacer castellations forming the flow channels shall be designed to minimize fuel rod contact stresses while assuring rod cooling.

3.4 Corrosion and Hydriding

The spacer material shall retain adequate corrosion resistance to the primary system coolant to ensure functional operation throughout the design life of the fuel.

3.5 Dimensional Requirements

3.5.1 Fuel Rod Alignment

The flow channel springs shall provide for proper alignment of the fuel rods in conformance with fuel rod pitch requirements throughout the design life of the fuel.

3.5.2 Flow Mixing

The castellation/springs shall be arranged in such a way as to
The flow

mixing.

3.5.3 Anti-Hangup Design

The periphery of the HTP and IFM assemblies shall have provisions for avoiding hangup at grid spacer locations during fuel handling operations.

4.0 DESCRIPTION AND DESIGN DRAWINGS (STANDARD REVIEW PLAN - SECTION 4.2 B)

The HTP spacer is an all Zircaloy-4 grid structure welded at each strip intersection.

The IFM grid is an all Zircaloy-4 structure similar to the HTP.

Pages 9 - 16 have been deleted.

5.0 DESIGN EVALUATION (STANDARD REVIEW PLAN - SECTION 4.2 C)

5.1 Stress, Strain, and Load Limits

5.1.1 Clad Stress

The stress in the clad induced by the maximum spring force shall not exceed the maximum allowable stress intensity of the clad.

5.1.2 Fuel Rod Axial Friction Force

During differential thermal and irradiation induced expansion between the fuel rods and the fuel assembly cage, the fuel rod contact forces develop axial friction loads in the rods. These loads can cause creep bow of the fuel rods. The extent of bow must be projected in order to establish reactor operating thermal limits.

The spring force contact mechanism of the IFM grids will behave similarly to the HTP spacer springs. Rod bow will be less of a concern in assemblies with these grids because of their additional support of fuel rods in the fuel assembly.

5.1.3 Strength

The strength and rigidity of the structural component material must be adequate to provide the required fuel rod restraint for five years or more within the operating environment. Prototype spacers shall be tested to confirm the expected strength performance.

Lateral crush strength tests show that the HTP spacer is stronger than the ANF bi-metallic spacer it replaces.

5.1.4 Grid Attachment

The design of the grid assembly shall provide for attachment of the spacer to the fuel assembly skeleton. The attachment shall be designed to withstand the loads due to differential expansion between the fuel rods and the fuel assembly guide tubes. These loads are applied to the spacer through the frictional interaction between the fuel rods and the spacer cells.

To provide restraint of bowing (thermal and mechanical) and vibration, and to provide hydraulic and mechanical compatibility with co-resident fuel assemblies, the grid spacers must be appropriately spaced along the length of the fuel rods in each fuel assembly.

5.2 Fatigue

Cyclic stresses in the spacer to guide tube attachment are caused by changes in power. A fatigue evaluation using the design curve of O'Donnell and Langer(9) shall be performed to ensure the integrity of the attachment. The reduction in friction loads through life due to the relaxation of the Zircaloy channel spring forces may be considered in the evaluation.

5.3 Fretting Wear

To avoid fretting corrosion and the accompanying potential for fuel clad perforation throughout the design life of the fuel assembly, the grid spacer must limit fuel rod vibration and provide rod support such that fuel rod wear is minimized.

5.3.1 Clad/Spring Interaction

Figure 5.4 is an illustration of the fuel cladding and spacer spring in its unloaded and loaded condition.

Figure 5.5 describes the simplified clad/spring interaction where no relaxation of the spring is taking place. In this case, the spring's unloaded position remains unchanged. The spring will follow the cladding until it reaches maximum rod creepdown, at which time it will stop moving.

5.3.2 Spring Interference Analysis

5.3.2.1 Fluence

It is shown in Reference 11 that the relaxation of the HTP Zircaloy spring material is primarily a function of neutron fluence. Since the rod with the highest LHGR is also the rod with the greatest fluence, this rod is used in the gap analysis.

maximum clad creepdown.

5.3.2.2 Initial Spring Deflection

The minimum clad diameter and the maximum cell size are used to calculate the minimum initial spring deflection. These dimensions are determined from assembly production tolerances

5.3.2.3 Zircaloy Relaxation

5.3.2.4 Cladding Creep

The maximum clad diam [illegible] creepdown is calculated using RODEX2(10) with

5.3 Fuel Rod Fretting Wear

The ANF bi-metallic spacer design contains Inconel springs and Zircaloy dimples to restrain the fuel rod, Comparable fretting tests have been performed on HTP and IFM grids

5.4 Corrosion and Hydriding

The grid material must possess a high degree of resistance to local corrosion and stress corrosion cracking for five years or longer within the operating environment. Failure of structural components or connections can result in the loss of fuel rod restraint, which can result in local fretting corrosion. The same material and similar strip thicknesses to those used in the HTP and IFM designs have been used in other ANF spacer designs without corrosion problems.

5.5 Dimensional Requirements

5.5.1 Fuel Rod Alignment

Fuel rod alignment shall be maintained by both the HTP spacers and intermediate mixers.

5.5.2 Flow Mixing

5.5.3 Anti-Hangup Design

The HTP sideplates are equipped with top and bottom lead-in tabs to prevent catching on other reactor components and fuel assemblies during handling and refueling. The diagonal dimension of the grid is minimized and corner chamfers are provided so as to resist assembly interactions during handling.

Pages 29 - 38 have been deleted.

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RAC:006:90
January 18, 1990

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Dear Mr. Jones:

Subject: Response to NRC Questions on ANF-89-060(P)

References:
1. Letter, R. C. Jones (USNRC) to R. A. Copeland (ANF), "Request for Additional Information for ANF-89-060(P)," January 3, 1990.
2. Letter, R. A. Copeland (ANF) to Director of NRR (USNRC), "Transmittal of ANF-89-060(P)," April 11, 1989. RAC:021:89.

Attached are the responses to the NRC reviewer questions on ANF-89-060(P), "Generic Mechanical Design Report - High Thermal Performance Spacer and Intermediate Flow Mixer." These responses were requested in the Reference 1 letter. Please consider the responses to be proprietary to ANF. The affidavit enclosed with the Reference 2 letter provides the information required by 10 CFR 2.790(b) to support withholding the responses.

If there are any questions, or if further information is needed, please contact me at (509) 375-8290.

Sincerely,

Bob Copeland

R. A. Copeland
Manager, Reload Licensing

skm

Attachment

cc: Dr. S. L. Wu (NRC)
Mr. Carl Beyer (PNL)

ATTACHMENT

Responses To Questions About ANF-89-060(P), "Generic Mechanical Design Report High Thermal Performance Spacer and Intermediate Flow Mixer"

Question 1

What is the fabrication history of the Zircaloy-4 sheet stock that is used to make the channel strips of the high thermal performance (HTP) spacer and intermediate flow mixer (IFM)? How does the fabrication history and thickness of these strips compare to those Zircaloy strips used in the bi-metallic spacer designs?

ANF Response 1

The Zircaloy-4 sheet stock that is used for the HTP and IFM strip channels is made according to the same material and product specifications as those used for the ANF bi-metallic spacer strips.

Strips fabricated by this process have performed successfully in all of the PWRs supplied with ANF fuel.

Question 2

> What fuel assembly examination work is planned for the lead test assemblies that contain only the HTP spacers and those assemblies that contain both the HTP spacers and the IFMs? Are there any fuel batches that are currently scheduled with these new spacers and IFMs? If so, please provide their schedule for fuel loading.

ANF Response 2

The following table shows the lead fuel assembly programs currently under irradiation and the date the initial irradiation began. ANF intends to examine these assemblies. However, the schedule and scope of the examinations are dependent on the various reactor schedules and plans.

Question 3

The subject topical report has not addressed the impact of this design change on the seismic-LOCA analysis. How does ANF plan to address seismic-LOCA analysis for this design?

ANF Response 3

ADVANCED NUCLEAR FUELS CORPORATION

2101 HORN RAPIDS ROAD, PO BOX 130, RICHLAND, WA 99352-0130
(509) 375-8100 TELEX 15-2878

RAC:036:90
April 13, 1990

Mr. R. C. Jones, Chief
Reactor Systems Branch
Division of Engineering and System Technology
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Jones:

Subject: <u>Response to NRC Question on ANF-89-060(P)</u>

References: 1. ANF-89-060(P), "Generic Mechanical Design Report High Thermal Performance Spacer and Intermediate Flow Mixer," Advanced Nuclear Fuels Corp., April 1989.

2. Letter, R. A. Copeland (ANF) to Director of NRR (USNRC), "Transmittal of ANF-89-060(P)," April 11, 1989. RAC:021:89.

Attached are the responses to two additional questions asked by the reviewer of the Reference 1 topical report. He asked these questions during a telephone conversation on April 11, 1990. We intend to combine these responses with the (A) version of the report when that version is issued. Please consider the responses to be proprietary to ANF. The affidavit enclosed with the Reference 2 letter provides the information required by 10 CFR 2.790(b) to support withholding the responses.

If there are any questions, or if further information is needed, please contact me at (509) 375-8290.

Sincerely,

Bob Copeland

R. A. Copeland
Manager, Reload Licensing

/skm
Attachment

cc: Dr. S. L. Wu (NRC)
Mr. Carl Beyer (PNL)

RESPONSES TO ADDITIONAL COMMENTS AND QUESTIONS

ON ANF-80-060(P)

1. On page 5, Section 3.1.1, the cladding stress is limit is given as the ultimate strength of the tube. This limit is different than the previous limit. Please explain.

   Response

   The cladding stress from the spacer force is treated as a primary bending stress. Therefore, the limit should have been the yield strength or half the ultimate strength, as previously used, and should have been not the ultimate strength.

2. On page 21, Section 5.1.4, second paragraph, please provide additional description of the guide tube attachment for the large guide tube CE type designs.

   Response

ADVANCED NUCLEAR FUELS CORPORATION

2101 HORN RAPIDS ROAD, PO BOX 130, RICHLAND, WA 99352-0130
(509) 375-8100 TELEX: 15 2878

June 11, 1990
RAC:062:90

Dr. S. L. Wu
Reactor Systems Branch
Division of Engineering and System Technology
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Dr. Wu:

<u>Additional Information Supporting ANF-89-060(P)</u>

Reference: Letter, R. A. Copeland (ANF) to Director of NRR (USNRC), Transmittal of ANF-89-060(P)," April 11, 1989. RAC:021:89.

Attached are the responses to three additional questions asked by the reviewer concerning the topical report ANF-89-060(P). We intend to combine these responses with the (A) version of the report when that version is issued. Please consider the information in these responses to be proprietary to ANF. The affidavit enclosed with the referenced letter provided the information required by 10 CFR 2.790(b) to support withholding the responses.

If there are any questions, or if further information is needed, please contact me at (509) 375-8290.

Very truly yours,

R. A. Copeland
Manager, Reload Licensing

/skm

cc: Mr. R. C. Jones (USNRC)
Mr. Carl Beyer (PNL)

A Siemens Company

ATTACHMENT

Discussion of ANF-89-060, "Generic Mechanical Design Report, High Thermal Performance Spacer and Intermediate Flow Mixer"

Question 1

An assessment of the effect of the change from bi-metallic spacers (Inconel and Zircaloy-4) to all Zircaloy-4 high thermal performance spacers, on the fuel rod and assembly growth behavior is requested.

ANF Response 1

The differential expansion between fuel rods and fuel assembly guide tubes during reactor heatup and cooldown can introduce axial stresses in the fuel rods and guide tubes. These stresses are a function of the temperature difference between rods and guide tubes; the flexibility of clad, guide tubes, spacers and guide tube/spacer attachments; and the frictional force between the spacers and the fuel rods.

Pages 9 - 12 have been deleted.

Question 2

Shouldn't the maximum 95/95 wear rate be considered in design projections since no operational body of data exists for these spacers?

ANF Response 2

Pages 14 - 15 have been deleted.

ANF-89-060(NP)(A)

ANF-89-060(NP)(A)
Supplement 1

Issue Date: 3/25/91

GENERIC MECHANICAL DESIGN REPORT
HIGH THERMAL PERFORMANCE SPACER AND INTERMEDIATE FLOW MIXER

Distribution

RA Copeland/NRC(15)