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Fuel Designs Containing the Siemens Power Corporation High Thermal Performance Spacer and Intermediate Flow Mixer

Ref.: 1. ANF-89-060(P)(A) and Supplement 1, *Generic Mechanical Design Report High Thermal Performance Spacer and Intermediate Flow Mixer*, Advanced Nuclear Fuels Corporation, March 1991.

Ref.: 2. EMF-92-153(P)(A) and Supplement 1, *HTP: Departure from Nucleate Boiling Correlation for High Thermal Performance Fuel*, Siemens Power Corporation - Nuclear Division, March 1994.

This letter describes a design analysis condition that Siemens Power Corporation (SPC) has imposed on DNB analyses for fuel designs that contain SPC's High Thermal Performance (HTP) spacers. The local peaking factor distribution for the assembly used in the DNB analysis will be such that the minimum DNBR will occur on an interior rod. The rod power for the interior fuel rod will be at the technical specification limit on total rod average power, Fr (which is called $F_{\Delta H}$ for Westinghouse plants). This design analysis condition will ensure that the minimum DNBR is not calculated to occur on a fuel rod located in any exterior (peripheral) position of a fuel assembly.

Typically, DNB testing does not address exterior cells of the fuel assembly array. Exterior cells may differ from interior cells in flow area and in the presence of, or design of, DNB performance-enhancing devices. In the past, the greater flow area of exterior cells (due to the adjacent inter-assembly gap) combined with lower rod power peaking in these cells has ensured that no exterior cell is limiting with respect to DNB. The design of DNB performance-enhancing devices such as HTP flow nozzles or mixing vanes has therefore focused on the interior cells of the array, as shown in Reference 1.

The improvement in DNB performance which characterizes HTP fuel designs is achieved by using HTP spacers and, in some cases, IFMs. The HTP spacers and IFMs incorporate flow mixing nozzles designed to impart a swirling component to the flow downstream of a spacer or IFM. The arrangement of the nozzles around the fuel rods in the interior of an assembly forces the water to swirl clockwise or counterclockwise around a fuel rod.

The nozzle arrangement adjacent to the fuel rods on the exterior of an assembly is different from that surrounding the fuel rods on the interior of an assembly. An interior fuel rod has a nozzle on each of its four sides. An exterior fuel rod has nozzles on three sides. The side of the exterior fuel rod which faces the assembly side plate does not have a nozzle. However, the side plates have anti-hang-up tabs that extend into the region between each fuel rod. These anti-hang-up tabs impart a flow disturbance similar in nature to that caused by mixing vanes. The two nozzles perpendicular to the

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side plate point toward the assembly interior. The flow nozzle on the interior side of the perpendicular cell continues the pattern of the interior cells. This arrangement can be seen by looking at the HTP spacer and IFM drawings in Reference 1.

Following standard industry testing practice, SPC performed the DNB tests on a configuration representative of the arrangement for an interior fuel rod (Reference 2). Because the geometry of an exterior cell differs from that of an interior cell and because of the method used to perform the DNB tests, some have questioned whether the application of the HTP DNB correlation to the exterior fuel rods will result in a conservative calculation of the probability of DNB for any rod in the fuel assembly. SPC developed a condition report to evaluate this question.

The nozzle configuration adjacent to a fuel rod on the exterior of an assembly may result in a different DNB performance from that of an interior fuel rod for the same thermal-hydraulic conditions. The difference in DNB performance should be less than the in-test reproducibility of individual DNB data points. For HTP spacers and IFMs, the exterior cell flow nozzles and anti-hang-up tabs are expected to provide DNB performance at least as good as that provided by spacer designs using mixing vanes.

A review of all HTP fuel designs (and supporting analyses) that have been delivered and are operating in reactors indicates that the limiting DNBR occurs on a fuel rod in the interior of the fuel assembly. There are two reasons that the limiting DNBR always occurs on an interior fuel rod. First, the fuel rods on the exterior of an assembly receive more flow due to the gap between assemblies. This increased flow results in an increase in DNBR for the exterior fuel rods that is larger than the potential degradation in DNB performance due to the differing nozzle arrangement. Second, the maximum rod power peaking, Fr, has always occurred on an interior fuel rod for assemblies using the HTP spacer and IFMs. Therefore, all past DNB analyses have correctly calculated the minimum DNBR for the assembly.

Future assembly designs using HTP spacers may use multiple fuel rod enrichments to produce flatter local peaking distributions. These designs could have the highest local peaking factor located on an exterior fuel rod. SPC has performed evaluations that show that the calculated minimum DNBR for an interior fuel rod remains the limiting DNBR for the assembly as long as the power of the interior fuel rod is equal to or greater than the power of the exterior fuel rod. Even for cases where the peak Fr during reactor operation occurs on an exterior fuel rod the imposition of the design analysis condition that the limiting DNBR be calculated for an interior fuel rod position ensures that the technical specification limit on Fr will be based on a conservative calculation.

SPC concludes that the design analysis condition that has been imposed on the SPC DNB analysis for assemblies containing HTP spacers, or HTP spacers and IFMs, will result in a conservative determination of the minimum DNBR.

Very truly yours,

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