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Addendum 1, Revision 1

HTP: Departure from Nucleate Boiling Correlation for High Thermal Performance Fuel, Addendum 1: Application at High Pressures or Low Qualities

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Nature of Changes

Item	Page	Description and Justification
1.	All	This document is a non-proprietary version of Revision 0.

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Tables

1.0 Introduction

The HTP DNB correlation (Reference 1) was approved for predicting the DNB performance of SPC High Thermal Performance (HTP) fuel in December of 1993 (Reference 2). The SER restricts the application of the correlation to the range of conditions listed in Table 1.1. Framatome ANP (FANP) desires to clarify the manner in which the lower limit on local quality and the upper limit on pressure are imposed for particular applications. FANP intends to observe these limits as described in this report.

Computation of DNBR for qualities below the lower quality bound and for pressures above the upper pressure bound is performed according to conservative methods, described herein. As described, the proposed applications have no safety significance.

Applications involving computed quality values below the HTP correlation lower limit are described in Section 2.0. Applications involving computed pressure values above the HTP correlation upper limit are described in Section 3.0. References are listed in Section 4.0.

Table 1.1 Range of Coolant Conditions Spanned by the HTP Correlation

Variable	Minimum Value	Maximum Value
Pressure (psia)	1775	2425
Local mass Flux (Mlb/hr/ft^2)	0.936	3.573
Inlet Enthalpy (Btu/lb)	382.3	649.9
Local Quality	-0.125	0.358

2.0 Lower Limit on Local Quality

FANP evaluates DNBR at every computational node in the assembly of interest, selecting the least value as the MDNBR. The MDNBR is sometimes calculated to occur in the lower part of the assembly for certain hypothetical, highly bottom-peaked axial power profiles. This result is due to the increasing conservatism of the HTP correlation axial power distribution factor as elevation decreases below mid-plane. The computed quality at the point of MDNBR may then be below the lower quality limit of the HTP correlation, because PWR applications are characterized by a highly subcooled inlet coolant state. FANP desires to clarify its practice for the computation of MDNBR in such cases.

The lower limit on local quality is now set at -0.125, the least value at which DNB was observed to occur in the [ ] data points of the HTP database. DNB did not occur for local qualities less than this value, even though local qualities less than this value were experienced in the lower test section for each DNB data point. Thus, the existing database demonstrates that DNB does not occur in the lower part of the assembly at local qualities less than -0.125 for the tested fuel designs, axial power profiles, and global fluid conditions.

FANP uses the XCOBRA-IIIC (Reference 3) code to evaluate local fluid conditions for input to the HTP correlation. In cases where the MDNBR is computed to occur at a quality below the lower quality limit of the HTP correlation, the MDNBR will be recomputed via the HTP correlation using the lower quality limit value. Thus, a quality higher than that computed by XCOBRA-IIIC is used. Because higher quality yields a lower value of DNB heat flux, a conservative MDNBR evaluation is obtained.

For clarity, the calculation process is outlined step-by-step:

- The MDNBR calculation is performed with the XCOBRA-IIIC code, the HTP correlation, and standard methodology.
- If the MDNBR is computed to occur at a quality within the quality limits of the HTP correlation, the computed MDNBR is accepted.
- If the MDNBR is computed to occur at a quality below the lower quality limit of the HTP correlation, then the MDNBR is re-evaluated using the same conditions of heat flux, pressure, and mass flux, but with a greater local quality value equal to the correlation lower limit on quality (-0.125).

The process ensures that the correlation is applied within its recognized range of applicability. A conservative DNBR is also assured. A message will be written to XCOBRA-IIIC output indicating that this process has been invoked.

3.0 Upper Limit on Pressure

The upper limit on pressure is 2425 psia, the maximum pressure at which DNB was observed to occur in the [ ] data points of the HTP database. In loss of load and other heatup event evaluations, pressure might potentially rise above 2425 psia to values as great as 2525 psia. FANP intends to implement the conservative application method described below to bound the DNBR in the pressure range between 2425 and 2525 psia.

For pressures above 2425 psia, the DNBR will be evaluated via the HTP DNB correlation. The computed transient statepoint will be conservatively biased for input to XCOBRA-IIIC by setting the pressure downward to 2425 psia, retaining the computed inlet coolant mass flux and temperature, and rod surface heat flux from the transient calculation. Thus, the present HTP limits on fluid conditions will be observed.

This method forces use of a conservatively high-biased value of local quality in the HTP correlation computation of the DNB heat flux. The effect of higher local quality is to reduce the computed DNB heat flux. An MDNBR is obtained that is lower than that which would be computed using the higher, computed statepoint pressure.

HTP DNB data show the DNB heat flux increasing with increasing pressure for the pressure range between normal operating pressure and the pressurizer relief valve setpoint*. This is true across the range of mass fluxes represented in the correlation, and accords with the observed behavior of DNB in this pressure range.

For clarity, the calculation process is outlined step-by-step:

- The transient plant response simulation is performed using standard methodology.
- If the pressure at the time of MDNBR is computed to be within the pressure limits of the HTP correlation, the MDNBR is computed using the XCOBRA-IIIC code with boundary conditions of pressure, temperature, heat flux, and mass flux taken as usual from the transient simulation.

* At pressures of 1800 and 2000 psia, it is sometimes observed that the DNB heat flux for the lower pressure will equal or exceed that of the higher pressure. This is attributed to a transition between flow regimes at these low pressures. No such behavior is observed at the pressures of interest in this application.

- If the pressure at the time of MDNBR is computed to be above the upper pressure limit of the HTP correlation, then the temperature, heat flux and mass flux boundary conditions will be taken as usual from the transient simulation. The pressure used in the XCOBRA-IIIC MDNBR calculation is the HTP correlation upper limit on pressure (2425 psia).

The HTP correlation will be applied within its recognized range of applicability. The DNB performance benefit of the higher pressure state over that at the correlation upper bound is conservatively neglected. Thus, a conservative MDNBR calculation is obtained.

4.0 References

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

2. Letter, Ashok C. Thadani (USNRC) to R. A. Copeland (SPC), "Acceptance for Referencing of Siemens Power Corporation Topical Report EMF-92-153(P), *HTP: Departure from Nucleate Boiling Correlation for High Thermal Performance Fuel*," December 28, 1993.

3. XN-NF-75-21(P)(A) Revision 2, *XCOBRA-IIIC: A Computer Code to Determine the Distribution of Coolant During Steady-State and Transient Core Operation*, Siemens Power Corporation, January 1986.

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