framatome

The ORFEO-GAIA and ORFEO-NMGRID Critical Heat Flux Correlations

ANP-10341Q3NP
Revision 1

Additional Information

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
2	Section 1.2	Sub-section "Application to non-limiting region" has been supplemented with the MSLB LOOP case analysis. Sub-section "Analysis of ORFEO-NMGRID correlation" has been supplemented with Figure 1-4. All changes are marked with revision bars.
1	All	Initial Issue

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Nomenclature

Acronym	**Definition**
AFA	AFA grid design
CHF	Critical Heat Flux
DNBR	Departure from Nucleate Boiling Ratio
EOHL	End of Heated Length
GAIA	Framatome's PWR fuel assembly grid design
HMP	HMP grid design
IGM	Intermediate GAIA Mixer
MSLB	Main Steam Line Break
LOOP	Loss of Offsite Power
NMGRID	Non-mixing grid design
ORFEO	Framatome's CHF correlation form for PWR fuel assemblies

1.0 ORFEO-NMGRID CORRELATION APPLICABILITY [ ]

1.1 *Purpose*

The ORFEO-NMGRID CHF correlation has been submitted for approval in [1]. In Section 6.2 of [2] a list of fuel / grid designs for the ORFEO-NMGRID correlation application is provided. Specifically, the ORFEO-NMGRID correlation is applicable to any grid span that *(i)* is located immediately downstream of a HMP grid on any fuel assembly and *(ii)* has the geometry as described in Table 2-6 of [1]. The range of applicability [

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The purpose of this supplement is to justify the ORFEO-NMGRID correlation applicability for [

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The request made in this supplement pertains only to the applicability of the ORFEO-NMGRID correlation downstream of HMP spacer grids. It does not impact the applicability of the ORFEO-NMGRID correlation to the mixing grid region of the GAIA fuel assembly, also described in Section 6.2 of [2].

The justification supporting this request is presented in Section 1.2. It consists of multiple independent arguments, which rely on evaluation of mixing test data, CHF test data and the ORFEO-NMGRID correlation.

Based on the justification in Section 1.2, Framatome proposes to update Table 2-6 in [1] to reflect the following markup.

Table 2-6 Geometry for ORFEO-NMGRID correlation (fuel assembly geometry)

[ ]

1.2 *Justification*

Previous CHF correlations

The BWC correlation development indicated that there is no corresponding [ ] This was also incorporated in the BWU-N CHF correlation [4]. Part of the CHF test data base used for BWC and BWU-N is also included in the ORFEO-NMGRID CHF test database.

Application to non-limiting region

[ ] of the ORFEO-NMGRID correlation is requested only for application to the non-mixing grid span of the fuel assembly. This is the lowermost spacer span on the fuel assembly, downstream of an HMP grid (Figure 2-1 of [1]). The local thermal-hydraulic conditions in this region are characterized by lower equilibrium quality compared to the downstream regions of the fuel assembly. Due to the lower equilibrium quality and typically low heat flux, the lowermost spacer span is usually non-limiting for the DNBR of the fuel assembly. The main steam line break (MSLB) with loss of offsite power (LOOP) can exhibit the MDNBR in the lowermost span. However, the MSLB LOOP is a non-limiting event.

A typical MSLB LOOP application case was analyzed with ORFEO-NMGRID and the lowermost spacer span (HMP) was investigated. Figure 1-1 shows the predicted CHF, local heat flux and resulting DNBR as a function of [ ]

[ ]

Figure 1-1
Predicted CHF, local heat flux and resulting DNBR as a function of [ ] for a typical MSLB LOOP case

[ ]

Analysis of turbulent mixing coefficient

The turbulent mixing coefficient is a measure of grid capability to promote fluid mixing downstream of the grid. The turbulent mixing coefficient is determined from mixing tests performed with CHF test assemblies. Values determined for grids without any mixing features are typically an order of magnitude lower than those for grids with mixing vanes. For example, the turbulent mixing coefficient for non-mixing grids is [ ] while the value for mixing grids (GAIA, IGM) is [ ] (Table 5-1 of [1]). In the axial direction of a subchannel, the level of turbulence induced by a grid decreases progressively as the fluid flows farther downstream of the grid. For non-mixing grids, which have very little fluid mixing capability, the induced turbulence dissipates quickly, with the region immediately upstream of the next grid being characterized by very little induced turbulence. [

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Analysis of "half-span" CHF tests

"Half-span" CHF tests have the distance between the uppermost grid and the end of heated length (EOHL) equal to half of the grid spacing (Figure 1-2). They are performed with uniform axial power profile [

] For "half-span" tests, there are two competing locations where the CHF detection can be expected to occur: EOHL and 2nd to last span (Figure 1-3). Two of the factors that influence the location of CHF are the local equilibrium quality and the local turbulence. Higher quality and lower turbulence lead to a decrease in CHF performance. At the EOHL (relative to the 2nd to last span) the quality is higher and the turbulence is higher due to the proximity of the upstream grid (half-span). At the 2nd to last span (relative to the EOHL) the quality is lower and the turbulence is lower because the upstream grid is a full-span away.

Grids without mixing vanes have a reduced capability to induce turbulence. Therefore, the distance from the upstream grid is expected to have little influence on the CHF performance and the majority of CHF detections will be located at EOHL because of the higher quality.

Figure 1-2
"Half-span" vs. "full-span" CHF test configurations

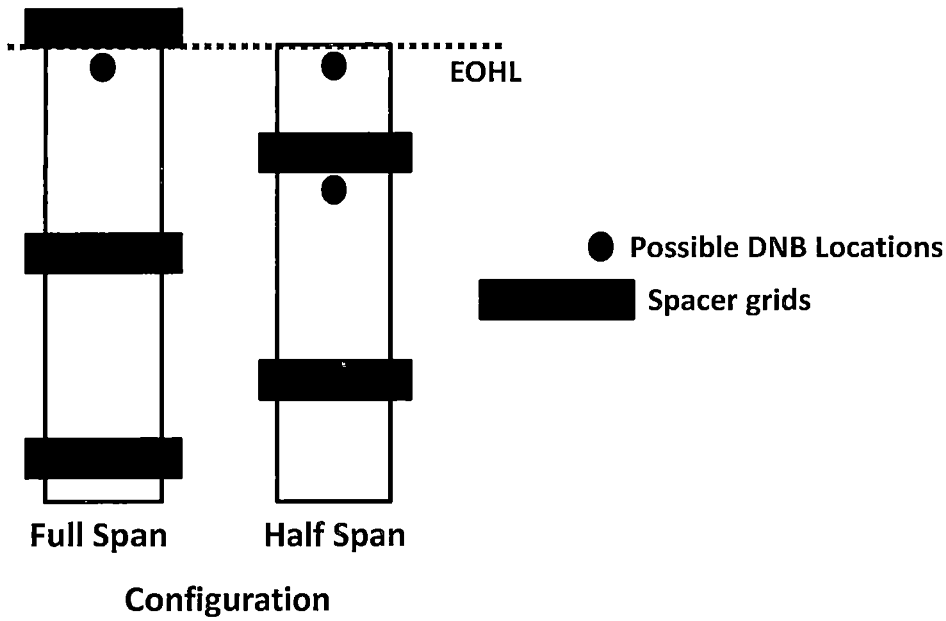
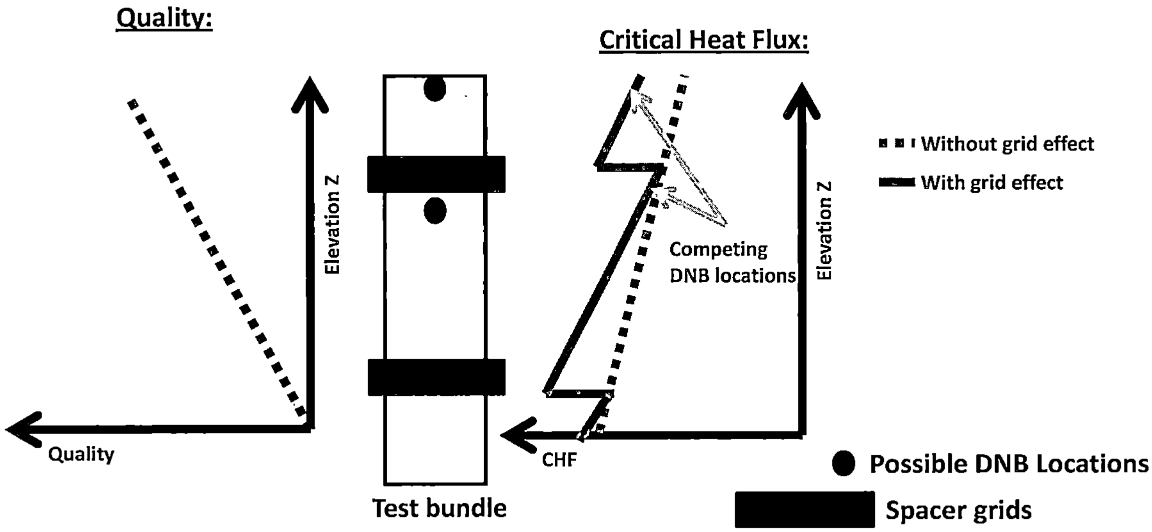


Figure 1-3
"Half-span" vs. "full-span" CHF detection locations



A summary of the "half-span" CHF tests that were analyzed is shown in Table 1-1. They comprise various grid designs (mixing and non-mixing) and multiple grid spacing values. Table 1-2 shows [

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[

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Table 1-1
Summary of "half-span" CHF tests

[ ]

Notes:

1. Tests analyzed for this particular grid design had different grid spacing values.

Table 1-2
Summary of CHF detection locations for "half-span" CHF tests

[ ]

Analysis of ORFEO-NMGRID correlation

The ORFEO-NMGRID correlation includes [ ] Calculations performed on ORFEO-NMGRID for various statepoints indicated that [ ] Figure 1-4 shows the relative variation in predicted CHF for [ ] The ORFEO-NMGRID predictions in Figure 1-4 are generated by changing [ ] while keeping the local thermal-hydraulic conditions constant.

Figure 1-4
Relative difference in CHF predicted by ORFEO-NMGRID as a function of [ ]

[ ]

Figures 7-27 and 7-28 of [1] show the M/P distribution of the ORFEO-NMGRID correlation as a function of distance-to-grid and grid spacing. [

]

For the purpose of this justification only, [

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Figure 1-5

[ ]

1.3 *Conclusion*

The justification presented in Section 1.2 demonstrates that the ORFEO-NMGRID correlation adequately predicts the CHF performance of spacer spans equipped with non-mixing grids of the HMP design for [

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2.0 REFERENCES

1. The ORFEO-GAIA and ORFEO-NMGRID Critical Heat Flux Correlations, ANP-10341P, Revision 0, AREVA Inc., August 2016.
2. Response to Request for Additional Information – ANP-10341P, ANP-10341Q1P, Revision 0, AREVA Inc., November 2017.
3. BWC Correlation of Critical Heat Flux, BAW-10143P-A, Babcock & Wilcox, April 1985.
4. The BWU Critical Heat Flux Correlations, BAW-10199P-A, FCF, August 1996.