NuScale Power™

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U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Submittal of Changes to Subchannel Analysis Methodology Topical Report, TR-0915-17564

REFERENCES:
1. NuScale Power Topical Report, "NuScale Power Critical Heat Flux Correlations," TR-0116-21012, Revision 1, dated November 2017 (ML17335A089)

2. NuScale Power Topical Report, "Subchannel Analysis Methodology," TR-0915-17564, Revision 1, dated February 2017 (ML17046A333)

In Reference 1, NuScale Power, LLC submitted a change to the Critical Heat Flux (CHF) Correlations topical report to incorporate a new CHF correlation, NSP4. This submittal provides conforming changes to the Subchannel Analysis Methodology topical report (Reference 2). The Enclosure to this letter provides a mark-up of the topical report pages incorporating revisions in redline/strikeout format. NuScale will include these changes as part of a future revision to the Subchannel Analysis Methodology topical report.

Enclosure 1 is the proprietary version of the Subchannel Analysis Methodology topical report mark-ups. NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The enclosed affidavit (Enclosure 3) supports this request. Enclosure 2 is the nonproprietary version of the Subchannel Analysis Methodology topical report markups.

The proprietary enclosure has been deemed to contain Export Controlled Information. This information must be protected from disclosure per the requirements of 10 CFR § 810.

This letter makes no regulatory commitments or revisions to any existing regulatory commitments.

Please feel free to contact Darrell Gardner at 980-349-4829 or at dgardner@nuscalepower.com if you have any questions.

Sincerely,

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Enclosure 1: Changes to “Subchannel Analysis Methodology,” Topical Report, TR-0915-17564, proprietary version
Enclosure 2: Changes to “Subchannel Analysis Methodology,” Topical Report, TR-0915-17564, nonproprietary version
Enclosure 3: Affidavit of Zackary W. Rad, AF-1217-57511

Enclosure 1:

Changes to “Subchannel Analysis Methodology,” Topical Report, TR-0915-17564, proprietary version

Enclosure 2:

Changes to “Subchannel Analysis Methodology,” Topical Report, TR-0915-17564, nonproprietary version

The subchannel methodology presented in this report is not dependent on a specific CHF correlation as long as the CHF correlation satisfies the following applicability criteria. The CHF correlation may only be used for design analysis that implements this subchannel methodology if:

- The application must explicitly state that an approved CHF correlation is used.
- The CHF correlation is used within its applicable parameter ranges.
- Local conditions are simulated with VIPRE-01 to predict the CHF test data.
- The same two-phase flow model options are used for local condition simulations.
- The CHF correlation is applicable to the fuel design (including spacer grids) being analyzed.

~~A~~Two CHF correlations for NuScale, referred to as NSP2 and NSP4, ~~is~~are presented in Reference 8.2.7. The NSP2 and NSP4 correlations are applicable to the NuFuel design. The CHF 95/95 limit is the design limit on MCHFR which meets the acceptance criterion and is used for all thermal margin calculations. The 95/95 correlation limit for the NSP2 CHF correlation is 1.17. The correlation limit takes into account the uncertainties associated with the correlation development. For conservatism a design limit of 1.19 is used in subchannel analyses. The 95/95 correlation limit for the NSP4 correlation is 1.21. In order for CHF correlations to be used within their applicable parameter ranges, they are developed to be valid for an extended range of parameters. For example, the EPRI CHF correlation is valid up to 70 percent quality and a lower pressure limit of 600 psia. Parameter ranges applicable to the NSP2 CHF correlation are even wider and are presented in Table 3-1. These parameter ranges are much wider than the limiting local conditions of the reactor to ensure that the CHF correlation remains valid for a wide range of off-normal conditions. For example, the NSP2 correlation remains valid down to a system pressure of 300 psia and up to ~~95~~ 90 percent local equilibrium quality, while the NuScale core is not expected to operate at more than 20 percent quality. Example NuScale operational ranges are provided for the NSP2 correlation in Table 3-1 for comparison. The NSP4 ranges are provided in Reference 8.2.7.

Table 3-1. Parameter ranges for example (NSP2) CHF correlation

Parameter	Lower Limit	Upper Limit	Example NuScale Range (Normal / Off-Normal)
pressure, psia	300	2300	1,700 – 2,200
local mass flux, $Mlb_m/hr\text{-}ft^2$	0.110	0.700	0.1 – 0.5
local equilibrium quality, %	-	≤ ~~95~~90~~%~~	< 20~~%~~
inlet equilibrium quality, %	-	≤ 0	-40 to -10

The effect of increasing pressure resulting in a reduced CHFR is discussed in more detail in the CHF topical report (Reference 8.2.7).

3.4 Thermal Margin Results Reporting

The key results for subchannel analyses are CHF margin and MCHFR; the latter is a direct output from VIPRE-01 calculated for all modeled fuel rods and channels. The MCHFR is the limiting ratio calculated for any rod or channel in the core. For transients, MCHFR is calculated for each time step. CHF margin is reported as a percentage or CHF points above the CHF analysis limit as indicated below:

$$\text{CHF margin }(\%) = \frac{\text{MCHFR}_{\text{VIPRE}} - \text{CHF}_{\text{Analysis Limit}}}{\text{CHF}_{\text{Analysis Limit}}} * 100$$

$$\text{CHF margin (CHF points)} = (\text{MCHFR}_{\text{VIPRE}} - \text{CHF}_{\text{Analysis Limit}}) * 100 \qquad \text{Eq. 3-3}$$

where

$\text{MCHFR}_{\text{VIPRE}}$ = minimum CHFR from VIPRE-01 calculation

$\text{CHF}_{\text{Analysis Limit}}$ = CHF limit incorporating margin applied to the design limit

The incorporation of uncertainties or biases to produce a conservative subchannel methodology is performed in two places: (i) within VIPRE-01 inputs prior to MCHFR calculation, and (ii) outside the VIPRE-01 calculations, but as an increase on the MCHFR design limit. The derivation of the penalties and conservative bias determine whether the penalty is applied within the VIPRE-01 input model or external to the calculation as an increase in the correlation limit. The biases and penalties are presented throughout Section 3.0 of this report and are summarized in Section 3.13. When an external penalty is needed (e.g., rod bowing, F_Q^E, etc.), the following equation is used to modify the 95/95 CHF design limit (e.g., 1.17 from Section 3.3) for margin reporting:

$$\mathrm{CHF}_{\text{Analysis Limit}} = \mathrm{CHF}_{95/95\text{ Limit}} \cdot (1+\gamma_a) \cdot (1+\gamma_b) \cdot \ldots \cdot (1+\gamma_i) \qquad \text{Eq. 3-4}$$

where

$\mathrm{CHF}_{95/95\text{ Limit}}$ = 95/95 CHF design limit (NSP2 = 1.17 or 1.21 for NSP4)

γ_i = penalty, fraction

Figure 3-2 shows the MCHFR limits and the example margins in the MCHFR calculation.

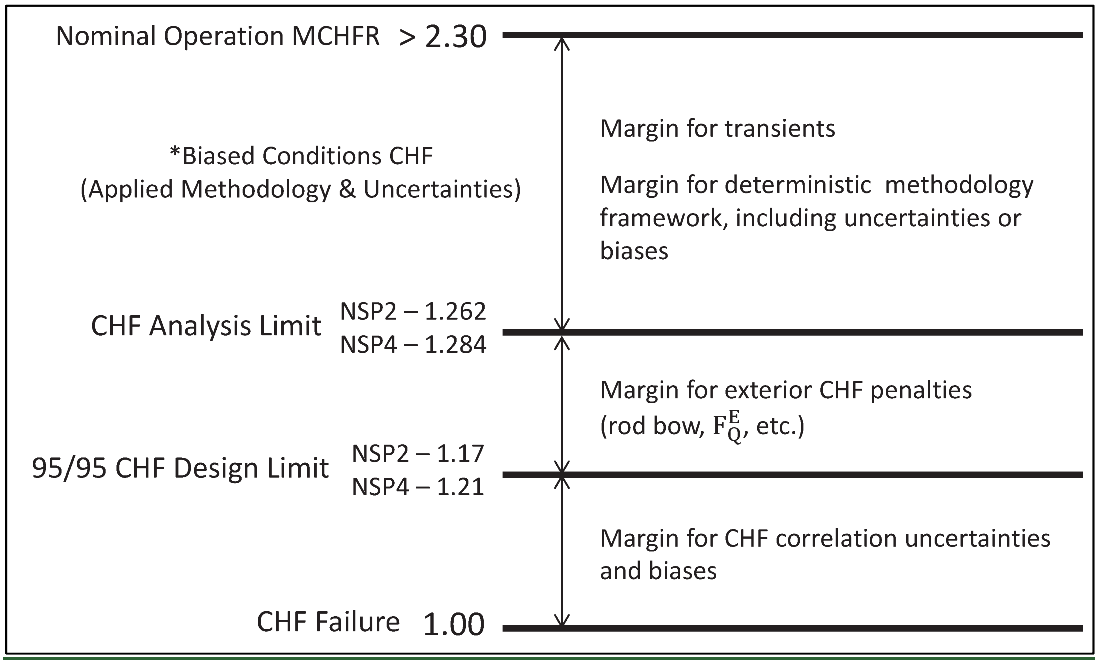

Figure 3-2. Example thermal margin pictorial

3.5 Geometry Design Input

The geometry for the radial and axial dimensions must be defined to develop the inputs for the subchannel basemodel. Geometry may be input for 'cold' conditions, meaning the dimensions are the measured values at room temperature (approximately 70 degrees F), or for 'hot' conditions, which are traditionally the dimensions that are thermally expanded using a material-specific equation evaluated at the core average temperature.

The NuScale subchannel analyses use 'cold' geometry conditions. This assumption allows the use of dimensions directly from the reference fuel design document and maintains consistency with the pressure drop information. The grid spacer form loss and bare rod friction losses are evaluated with flow areas consistent with 'cold' conditions. To remove any conversions required for the inputs based on the bare rod flow areas, the inputs are simplified to assume 'cold' conditions. The thermal expansion for fuel and where

ABETA = turbulent mixing coefficient

S = Flow gap width

$\overline{G}$ = Average axial mass flux velocities among adjacent subchannels

~~The value of ABETA is determined from thermal mixing tests in Reference 8.2.7. An example value for NuScale is {{ }}$^{2(a),(b),(c),ECI}$. This value is fuel-design specific; however, this is a conservatively low value representative of non-mixing vane grid fuel assemblies. This modeling value is further justified from parametric sensitivity analysis in Section 6.4.~~The value of ABETA is determined from thermal mixing tests described in Reference 8.2.7. The testing that was used to develop the NSP2 correlation resulted in an ABETA value of {{ }}$^{2(a),(c),ECI}$; the testing for NSP4 resulted in an ABETA value of {{ }}$^{2(a),(c),ECI}$. These values are fuel-design specific; with the {{ }}$^{2(a),(c),ECI}$ value being representative of non-mixing vane grid fuel assemblies and the {{ }}$^{2(a),(c), ECI}$ value being representative of mixing vane fuel assemblies. An example ABETA value of {{ }}$^{2(a),(c),ECI}$ is used for all MCHFR example calculations in the remainder of this report.

The turbulent enthalpy mixing parameter used in VIPRE-01 is derived for subchannels. Lumped channels, as used in the VIPRE-01 basemodel (Section 3.7), require a reduction in the mixing coefficient ABETA. The mixing coefficient ABETA is reduced by dividing the standard subchannel example value, {{ }}$^{2(a),}$~~$^{(b),}$~~$^{(c),ECI}$, by the ratio of the centroid distance to the fuel rod pitch. This equates to non-lumped subchannel gaps having the {{ }}$^{2(a),}$~~$^{(b),}$~~$^{(c),ECI}$ mixing coefficient while the lumped channels are reduced in proportion to the centroid distance differences for each gap. The effect from reducing the turbulent mixing coefficient has negligible impact in the lumped basemodel because the value of ABETA is small already.

The value for the turbulent momentum parameter is not measured and is justified based on parametric sensitivity analysis in Section 6.4. The sensitivity study results demonstrate that NuScale basemodel is not sensitive to this value and {{ }}$^{2(a),(c),ECI}$ is suitable.

3.10 Radial Power Distribution

The radial power distribution for the core is characterized by $F_{\Delta H}$, which is the enthalpy rise hot channel factor describing the integrated rod power for a particular rod. This peaking parameter is variable depending on the cycle design as the exposure, fuel composition, burnable poison loading, operational history, and thermal-hydraulic conditions all affect the power distribution. As a result, the location of the peak $F_{\Delta H}$ fuel rod changes throughout an operating cycle.

A one-eighth core basemodel is used in the subchannel analysis as discussed in Section

Table 3-2. Example methodology parameter biases for subchannel MCHFR analyses

Parameter	Conservative Bias Direction	Example Bias	Location Applied	Reference Section
reactor power measurement uncertainty	increase	~~{{~~ 2%	subchannel or transients input	Section 3.12.2
core inlet flow rate uncertainty	decrease	0%* ~~}}$^{2(a),(c),ECI}$~~	subchannel or transients input	n/a
core exit pressure	increase	case dependent	subchannel or transients input	Section 3.12.2
core inlet temperature	increase	+5 °F	subchannel or transients input	Section 3.12.2
core inlet flow distribution uncertainty	decrease	5%	VIPRE-01 model hot assembly	Section 3.12.9
$F_{\Delta H}^{U}$ uncertainty	increase	{{	hot rod peak (RSS)	Section 3.12.2
$F_{\Delta H}$ rodded peaking	increase		limiting assembly peak	Section 3.10.5
$F_{\Delta H}^{E}$ engineering uncertainty	increase	}}$^{2(a),(c),ECI}$	hot rod peak (RSS)	Section 3.12.4
$F_{\Delta H}$ augmentation for asymmetric events	increase	varies, %	hot rod peaking	Section 3.10.1
F_{Q}^{E} engineering uncertainty	increase	{{ }}$^{2(a),(c),ECI}$	CHF analysis limit	Section 3.12.5
fuel rod bowing	increase	3%	CHF analysis limit	Section 3.12.8
fuel assembly bowing	n/a	none	n/a	Section 3.12.8
radial power distribution uncertainty	n/a	none	n/a	Section 3.12.7
core exit pressure distribution	n/a	none	n/a	Section 3.12.10

*This bias is indicated as ~~{{~~ zero ~~}}$^{2(a),(c),ECI}$~~ because the minimum design system flow rate accounts for uncertainties throughout the RCS loop. System transient simulations include the implementation of the flow loss uncertainties.

The boundary conditions input uncertainties in Table 3-2 are applied on the values calculated from transient analysis and subsequently input into VIPRE-01. The hot rod peaking is inclusive of all $F_{\Delta H}$ peaking factors, including the augmentation factor if needed. The basemodel radial power distribution includes all peaking values, except the augmentation factor. The inlet flow distribution penalty is applied to the entire assembly containing the hot rod. The basemodel already includes the Figure 3-7 distribution from Section 3.8.5; however, the fully-detailed model case will need to be applied appropriately as discussed in Section 3.8.5. The penalties that are applied on the CHF design limit use Eq. 3-4.

is determined as a ratio relative to the HFP core operating limit value. This augmentation factor is applied to all rods in the central assembly using Eq. 3-4 (which preserves the peak-to-average ratio for hot assembly) and reduced from the outer assembly using Eq. 3-5. This augmentation factor is only in reference to the increased allowable peaking for the core operating limit value, which is different than the augmentation factor for SRP Section 15.4 events.

It should be noted that for the example cases in this topical report, the full power $F_{\Delta H}$ is 1.50, and after including uncertainties it is {{ }}$^{2(a),(c),ECI}$. The limiting 95/95 CHFR is 1.17 but with the penalties that are applied is 1.262 for the example NSP2 correlation.

Table ~~3-3~~4-1 summarizes the axial and radial power distribution assumptions used in the Chapter 15 analyses. Each of the event categories are discussed in more detail in subsequent section.

Table ~~3-3~~4-1. Radial and Axial Power Distribution Assumed in Chapter 15 Event Subchannel Analysis

Event	FSAR	Radial Shape	Axial Shape
Decrease in FW Temperature	15.1.1	Bounding	Bounding
Increase in FW Flow	15.1.2	Bounding	Bounding
Increase in Steam Flow	15.1.3	Bounding	Bounding
Open SG Relief	15.1.4	NA	NA
Steamline Break (pre-trip)	15.1.5	Bounding	Bounding
Steamline Break (post-trip)	15.1.5	No Return to Power	No Return to Power
Loss of Containment Vacuum	15.1.6	Bounding	Bounding
Loss of Electrical Load	15.2.1	Bounding	Bounding
Turbine Trip	15.2.2	Bounding	Bounding
Loss of Condenser Vacuum	15.2.3	Bounding	Bounding
Closure of MSIV	15.2.4	Bounding	Bounding
Steam Pressure Regulator Failure	15.2.5	Bounding	Bounding
Loss of AC Power	15.2.6	Bounding	Bounding
Loss of Normal Feedwater	15.2.7	Bounding	Bounding
Decrease in Flow	15.3	NA	NA
CRA or Bank Drop	15.4.3	Bounding + Augmented	Shape at pre-event power
CRA Misalignment	15.4.3	Bounding + Augmented	Shape at pre-event power
Single CRA Withdrawal	15.4.3	Bounding + Augmented	Shape at post-event power
Fuel Assembly Misload	15.4.7	Bounding + Augmented	Shape at full power
Uncontrolled Bank Withdrawal – at power	15.4.2	Bounding at pre-event power	Shape at pre-event power
Uncontrolled Bank Withdrawal – at zero power	15.4.1	Bounding for zero power	Bounding for zero power
Rod Ejection	15.4.8	Separate Methodology	Separate Methodology
Increase in RCS Inventory	15.5	Bounding	Bounding
Decrease in RCS Inventory	15.6	No CHF Assessment	

Additionally, presented in this section are transient-specific methodologies, such as fuel

The four combinations of the VIPRE-01 two-phase flow models shown above were evaluated at several operating conditions that span NuScale normal and off-normal conditions, including full power, extreme elevated power (MCHFR=1), low power, low pressure, and high pressure. Displayed in Table 5-3 are results for the full-power conditions in which MCFHR is effectively identical. These results are based on the NSP2 correlation. At more extreme conditions, larger differences in MCHFR and local conditions are observed, as expected, with the general trends consistent across all sets of operating conditions.

Table 5-3. Comparison of two-phase flow correlations at NuScale full-power conditions

Name	**MCHFR**	**Diff. (CHF Points)**	**Axial Level (in)**	**Mass Flux at MCHFR**	**Equil. Quality at MCHFR**
EPRI-EPRI-EPRI	{{				
LEVY-HOMO-HOMO					
LEVY-ZUBR-HOMO					
LEVY-ARMA-ARMA					}}$^{2(a),(c),ECI}$

The EPRI-EPRI-EPRI combination (above) is used for licensing analysis, with the requirement that the same combination be used for the following purposes:

- CHF correlation analysis
- Mixing parameters
- Pressure loss coefficient development

A comparison of the heat transfer correlation data base range to NuScale operating conditions is presented in Table 5-6. As stated above, the data base range is just one indication of applicability. Code-to-code benchmarking, including with experimental comparison evaluations (Section 5.9) provides an additional strong basis to holistically demonstrate applicability to the safety analysis of the NuScale design. For additional perspective, the computer codes for core thermal-hydraulics simulation currently used in the industry use correlations that are approximately representative of the parameter ranges of interest for the codes. This is acceptable due in part to the comprehensive process in which the qualification of a code to the application occurs. Other than the CHF correlations, most models, such as VIPRE-01 two-phase flow correlations, are used outside the ranges characterizing their databases.

Table 5-6. Comparison of heat transfer correlation database ranges to NuScale

Correlation	Pressure (psia)	Mass Flux (Mlbm/hr-ft^2)	Heat Flux (Mbtu/hr-ft^2)	Equilibrium Quality (%)
THSP	750 - 2,000	0.77 - 2.80	<0.5	n/a
COND	-	"High Flow"	-	-
G5.7	490 - 500	0.590 - 3.0	-	10 – 90
Example NuScale (Normal/Off-Normal)	1,700 - 2,200	0.1-0.5	< 0.029	< 20

The EPRI single phase forced convection correlation (Dittus-Boelter) is traditionally utilized over a broad range of conditions.

5.6 Summary of Two-Phase and Heat Transfer Correlations Used

A summary of the correlations qualified for NuScale use as described in Sections 5.4 and 5.5 is provided in Table 5-7. For NuScale subchannel applications, all licensing calculations are performed with these correlation options. These correlations are identical with those used in the derivation of the NSP2 and NSP4 CHF correlations (Reference 8.2.7), which ties the prediction of CHF, along with thermal margins, to the underlying CHF test data. This further strengthens the applicability of these correlations for application to the NuScale design.

Table 5-7. Two-phase flow and heat transfer correlation selection for VIPRE-01

Correlation Option	Description
EPRI	EPRI subcooled void correlation
EPRI	EPRI void/flowing-quality correlation
EPRI	EPRI two-phase friction multiplier
EPRI	EPRI single phase forced convection heat transfer
THSP	Thom nucleate boiling correlation (plus single-phase correlation)
THSP	Thom nucleate boiling correlation (plus single-phase correlation)
COND	Condie-Bengtson transition boiling correlation
G5.7	Groeneveld 5.7 film boiling correlation

5.7 Fuel Rod Conduction Model

The VIPRE-01 conduction model solution has been verified in Reference 8.2.5. In this reference, the VIPRE-01 conduction equation results were benchmarked to test data as well as analytical problems, demonstrating that the fuel rod temperature predictions radially and axially were acceptable. To provide additional assurance that the temperature predictions for the VIPRE-01 fuel rod conduction model are suitable for NuScale applications, VIPRE-01 temperature predictions are calibrated against fuel

6.0 Example Calculation Results

Calculation analyses and results are presented in this section to demonstrate the application of the methodology described in this report. These results are for illustrative purposes only. NuScale design values are provided in the FSAR. Results are provided in this section for steady-state and transient simulations. All MCHFR results in this section are calculated using the NSP2 CHF correlation.

6.1 General Inputs

In addition to the example inputs provided throughout the report, namely Table 3-2 and Table 5-7, tabulated inputs utilized for the analyses are provided in Table 6-1 and Table 6-2.

Table 6-1. Tabulated inputs for example calculations

Description	Units	Value
core power at 100% power	MW	160
system flow at 100% power	kg/s	537.3
inlet temperature at 100% power	°F	486.6
nominal system pressure	psia	1850
core average axial power shape	relative	top-peak
core average axial power peaking	factor	1.3
fuel rod pitch	In.	0.496
active core height	In.	78.740
rod outer diameter	In.	0.374
rod inner diameter	In.	0.326
guide tube outer diameter	In.	0.482
pellet outer diameter	In.	0.3195
fuel rod length	In.	85.00
total bypass flow (of system flow)	%	8.5
turbulent mixing factor	factor	{{ }}$^{2(a),}$~~$^{(b),}$~~$^{(c),ECI}$
lateral resistance factor	factor	0.5
turbulent momentum factor	factor	{{ }}$^{2(a),(c),ECI}$

Table 6-2. Example loss coefficients [K=A*Re^B+C]

Grid	A	B	C
bottom nozzle + grid	{{		
middle grids			
top nozzle + grid			
axial friction			}}$^{2(a),(c),ECI}$

Table 6-13. Sensitivity case summary

Case Name	Description	Core Power (% Rated)	Pressure (psia)	Core Inlet Temperature (°F)
100	Hot Full Power	100	1,850	497
120	Higher Power/Flow	120	1,850	492
80	Lower Power/Flow	80	1,850	502
lo_pr	Low Pressure	100	1,700	Min (420)
hi_pr	High Pressure	100	2,200	Max (525)
min	Minor Importance	100	1,850	497

Table 6-14 presents the inputs sampled for the sensitivity analysis utilizing uniform distributions. Engineering judgment is utilized for minimum and maximum bounds of an input for those inputs in which tolerances are not currently available. For those inputs in which minimum and maximum bounds, or a tolerance, is documented this basis is provided. The sampling of transient input forcing functions is not performed.

Table 6-14. Summary of sampled input

Description	Units	Nominal	Uncertainty	Min	Max
Core Power at 100% Power	MW	160	2%	156.8	163.2
System Flow at 100% Power	kg/s	587	12.5%	513.6	660.4
Inlet Temperature at 100% Power	°F	496.1	5	491.1	501.1
System Pressure	psia	1850	35	1815	1885
Pitch Assembly	in	8.466	0.005	8.461	8.471
Pitch Rod	in	0.496	0.002	0.494	0.498
Rod Diameter	in	0.374	0.002	0.372	0.376
Guide Tube Diameter	in	0.482	0.002	0.480	0.484
Axial Power	-	1.3	0.2	1.1	1.5
F-delta-H Bias	-	1.0	-	1.00	1.12
Lateral Resistance Factor	-	0.5	0.4	0.1	0.9
Turbulent Momentum Factor	-	{{ }}$^{2(a),(c),ECI}$	-	{{	}}$^{2(a),(c),ECI}$
Turbulent Mixing Factor	-	{{ }}$^{2(a),}$~~$^{(b),}$~~$^{(c),ECI}$	-	{{	}}$^{2(a),}$~~$^{(b),}$~~$^{(c),ECI}$
Frictional Loss Coefficient	-	0.204	20%	0.163	0.245
HMP Spacer Grid Loss Coefficient	-	{{	20%	{{	
HTP Spacer Grid Loss Coefficient	-	}}$^{2(a),(c),ECI}$	20%		}}$^{2(a),(c),ECI}$

Utilizing the general sensitivity analysis criteria defined previously to analyze the results of the seven cases, a number of observations are made. As described, the quadratic regression, PRCC, and adjusted R^2 values are the main basis for these observations. In all cases, the adjusted R^2 indicated fair performance with quadratic values ranging approximately from 0.7 to 0.85. A review of all the sensitivity results indicates that this fair performance is likely a combination of (i) a cubic relationship between MCHFR and axial power shape and (ii) the number of total inputs perturbed. It is judged that it is unlikely that the roughly 0.7 adjusted R^2 is caused by non-linear effects and the resulting sensitivity analysis is judged to be fairly reliable.

The quadratic regression criteria consistently aligned across all cases and with the PRCC rankings. As a result, eight inputs for the steady-state cases are classified as the most important. As mentioned earlier, a positive PRCC value means that the effect of input on the output is the same. As an example, the axial shape PRCC value is always positive. As the axial shapes are sorted from top (1) to bottom (4), an increase in shape number (more bottom peaked) results in an increased MCHFR. Stated the other way, a decrease in shape number (more top peaked) results in a decreased MCHFR.

The one main exception is that of system pressure in which the bias direction is not consistent across all cases. This is due to the unique features of the NSP2 and NSP4 correlations as defined in Reference 8.2.7. As a result, case dependent bias directions on pressure should be utilized to ensure a conservative calculation of MCHFR. The turbulent moment parameter does exhibit one instance of an inconsistent bias direction; however, the calculated PRCC and incremental R^2 values are sufficiently small such that it may be discounted as statistical noise. Table 6-15 presents rankings the key parameters (as defined by the quadratic regression criteria) for steady-state full power results. The resulting relative importance and bias directions are in alignment with expectations. In all but the low pressure case, the rankings of importance, based on the magnitude of PRCC values, are identical. In this case, there are minor differences in the relative rank of the top four parameters and the addition of pressure into the top eight.

- Smaller turbulent mixing factor is both significant and limiting.
- System pressure is not consistent across all cases due to unique features of the NSP2 correlation as defined in Reference 8.2.7. As a result, case dependent bias directions on pressure should be utilized to ensure a conservative calculation of MCHFR.

Table 7-1. The quality assurance procedures required for usage with VIPRE-01 are described in SER Requirement #5.

Table 7-1. Summary of NuScale modeling assumptions

Topic for Justification	Value	Section in the Topical Report
CHF correlations and limits	NSP2, 1.17, NSP4, 1.21 (examples)	3.3
turbulent mixing coefficient	{{ }}$^{2(a),}$~~$^{(b),}$~~$^{(c),ECI}$ (example)	3.9
turbulent momentum factor	{{ }}$^{2(a),(c),ECI}$	3.9
crossflow resistance factor	0.5	5.8.1
axial friction losses	Blasius formulation	3.6, 5.3
choice of particular two-phase flow correlations	EPRI correlations	5.4
heat transfer correlations	EPRI, THSP, COND, G5.7	5.5
fuel rod modeling	calibration to fuel performance data	5.7
slip ratio	not used	n/a
grid loss coefficient (fuel-design specific)	fuel-dependent	6.1 (example)
axial friction loss coefficient (fuel-design specific)	fuel-dependent	6.1 (example)
run control parameters	default options or guidance specified	3.11

7.2 Criteria for Establishing Applicability of Methodology

The generalized methodologies presented in this topical report are based upon modeling assumptions. For completeness, the following set of criteria for establishing the applicability of these methodologies is provided. An applicant or licensee that uses the methodology of this topical report must satisfy these criteria in order to establish applicability. Any deviation from these criteria must be explicitly defined and justified.

7.2.1 General Criteria

The following criteria are required for a valid MCHFR calculation:

- The local mass flux, equilibrium quality, and pressure at the location and time of MCHFR is within the correlation applicability range.
- The MCHFR must occur in a channel geometry for which there is a valid CHF correlation (a unit or guide tube or instrument tube cell).
- The MCHFR must not occur on a peripheral subchannel of an assembly when using the fully-detailed one-eighth core model.

8.0 References

8.1 Source Documents

8.1.1 American Society of Mechanical Engineers, *Quality Assurance Program Requirements for Nuclear Facility Applications*, NQA-1-2008, NQA-1a-2009 Addenda, New York, NY (endorsed by Regulatory Guide 1.28, Revision 4).

8.1.2 *U.S. Code of Federal Regulations*, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Facilities,” Appendix B, Part 50, Chapter 1, Title 10, “Energy,” (10 CFR 50).

8.2 Referenced Documents

8.2.1 “Safety Evaluation by the Office of Nuclear Reactor Regulation Relating to VIPRE-01 Mod 02 for PWR and BWR Applications,” EPRI-NP-2511-CCM-A, Revision 3, October 30, 1993.

8.2.2 Stewart, C.W., et al., NP-2551-CCM-A, Volume 1, Mathematical Modeling, Revision 4.5, “VIPRE-01 A Thermal-Hydraulic Code for Reactor Cores,” Computer Code Manual, February 2014.

8.2.3 Stewart, C.W., et al., NP-2511-CCM-A, Volume 2, User’s Manual, Revision 4.5, “VIPRE-01 A Thermal-Hydraulic Code for Reactor Cores,” Computer Code Manual, February 2014.

8.2.4 Stewart, C.W., et al., NP-2511-CCM-A, Volume 3, Programmer’s Manual, Revision 4.5, “VIPRE-01 A Thermal-Hydraulic Code for Reactor Cores,” Computer Code Manual, February 2014.

8.2.5 Stewart, C.W., et al., NP-2511-CCM-A, Volume 4, Applications, Revision 4.5, “VIPRE-01 A Thermal-Hydraulic Code for Reactor Cores,” Computer Code Manual, February 2014.

8.2.6 Stewart, C.W., and J.M. Cuta, NP-2511-CCM, Volume 5, Guidelines, “VIPRE-01: A Thermal-Hydraulic Code for Reactor Cores,” Computer Code Manual, March 1988.

8.2.7 NuScale Power, LLC, “NuScale Power Critical Heat Flux Correlations~~ NSP2~~,” TR-0116-21012, Revision 1~~0~~, ~~October ~~November ~~2016~~2017.

8.2.8 NuScale Power, LLC, “Nuclear Analysis Codes and Methods Qualification,” TR-0616-48793, Revision 0, August 2016 (ML16243A517).

8.2.9 NuScale Power, LLC, “Applicability of AREVA Fuel Methodology for the NuScale Design,” TR-0116-20825, Revision 1, June 2016 (ML16187A017).

Enclosure 3:

Affidavit of Zackary W. Rad, AF-1217-57511

NuScale Power, LLC

AFFIDAVIT of Zackary W. Rad

I, Zackary W. Rad, state as follows:

(1) I am the Director of Regulatory Affairs of NuScale Power, LLC (NuScale), and as such, I have been specifically delegated the function of reviewing the information described in this Affidavit that NuScale seeks to have withheld from public disclosure, and am authorized to apply for its withholding on behalf of NuScale

(2) I am knowledgeable of the criteria and procedures used by NuScale in designating information as a trade secret, privileged, or as confidential commercial or financial information. This request to withhold information from public disclosure is driven by one or more of the following:

(a) The information requested to be withheld reveals distinguishing aspects of a process (or component, structure, tool, method, etc.) whose use by NuScale competitors, without a license from NuScale, would constitute a competitive economic disadvantage to NuScale.

(b) The information requested to be withheld consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), and the application of the data secures a competitive economic advantage, as described more fully in paragraph 3 of this Affidavit.

(c) Use by a competitor of the information requested to be withheld would reduce the competitor's expenditure of resources, or improve its competitive position, in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

(d) The information requested to be withheld reveals cost or price information, production capabilities, budget levels, or commercial strategies of NuScale.

(e) The information requested to be withheld consists of patentable ideas.

(3) Public disclosure of the information sought to be withheld is likely to cause substantial harm to NuScale's competitive position and foreclose or reduce the availability of profit-making opportunities. The accompanying report reveals distinguishing aspects about the analytical method by which NuScale performs its subchannel analysis.

NuScale has performed significant research and evaluation to develop a basis for this analytical method and has invested significant resources, including the expenditure of a considerable sum of money.

The precise financial value of the information is difficult to quantify, but it is a key element of the design basis for a NuScale plant and, therefore, has substantial value to NuScale.

If the information were disclosed to the public, NuScale's competitors would have access to the information without purchasing the right to use it or having been required to undertake a similar expenditure of resources. Such disclosure would constitute a misappropriation of NuScale's intellectual property, and would deprive NuScale of the opportunity to exercise its competitive advantage to seek an adequate return on its investment.

(4) The information sought to be withheld is in the enclosure entitled Changes to "Subchannel Analysis Methodology," Topical Report. The enclosure contains the designation "Proprietary" at the top of each page containing proprietary information. The information considered by NuScale to be proprietary is identified within double braces, "{{ }}" in the document.

(5) The basis for proposing that the information be withheld is that NuScale treats the information as a trade secret, privileged, or as confidential commercial or financial information. NuScale relies

upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC § 552(b)(4), as well as exemptions applicable to the NRC under 10 CFR §§ 2.390(a)(4) and 9.17(a)(4).

(6) Pursuant to the provisions set forth in 10 CFR § 2.390(b)(4), the following is provided for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld:

(a) The information sought to be withheld is owned and has been held in confidence by NuScale.

(b) The information is of a sort customarily held in confidence by NuScale and, to the best of my knowledge and belief, consistently has been held in confidence by NuScale. The procedure for approval of external release of such information typically requires review by the staff manager, project manager, chief technology officer or other equivalent authority, or the manager of the cognizant marketing function (or his delegate), for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside NuScale are limited to regulatory bodies, customers and potential customers and their agents, suppliers, licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or contractual agreements to maintain confidentiality.

(c) The information is being transmitted to and received by the NRC in confidence.

(d) No public disclosure of the information has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or contractual agreements that provide for maintenance of the information in confidence.

(e) Public disclosure of the information is likely to cause substantial harm to the competitive position of NuScale, taking into account the value of the information to NuScale, the amount of effort and money expended by NuScale in developing the information, and the difficulty others would have in acquiring or duplicating the information. The information sought to be withheld is part of NuScale's technology that provides NuScale with a competitive advantage over other firms in the industry. NuScale has invested significant human and financial capital in developing this technology and NuScale believes it would be difficult for others to duplicate the technology without access to the information sought to be withheld.

I declare under penalty of perjury that the foregoing is true and correct. Executed on December 08, 2017.

Zackary W. Rad