RAIO-118038

July 20, 2022

Docket: 99902078

U.S. Nuclear Regulatory Commission
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**SUBJECT:** NuScale Power, LLC Response to NRC Request for Additional Information (RAI No. 9899) on the NuScale Topical Report, "Applicability Range Extension of NSP4 CHF Correlation," TR-107522, Revision 0

**REFERENCES:**
1. NRC Letter Final Request for Information eRAI 9899 (Proprietary), dated March 14, 2022, RAI# 9899
2. NuScale Topical Report Applicability Range Extension of NSP4 CHF Correlation, dated January 2022, TR-107522

The purpose of this letter is to provide NuScale's response to NRC Requests for Additional Information (RAI), RAI# 9899, noted in the References above. The responses to the individual RAI questions are provided in the attached Enclosures.

This letter contains NuScale's response to the following RAI Questions from NRC RAI# 9899:

- NTR-01
- NTR-02

Enclosure 1 is the proprietary version of NuScale's response to RAI #9899. Enclosure 2 is the non-proprietary version of NuScale's response to RAI #9899. NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The enclosed affidavits (Enclosure 3 and 4) support this request. Enclosure 3 pertains to the NuScale proprietary information, denoted by double braces (i.e., “{{ }}”). Enclosure 4 pertains to the Framatome Inc. proprietary information, denoted by brackets (i.e., “[ ]”). Enclosure 2 contains the nonproprietary version of the report.

Enclosures are grouped with all proprietary version responses first, followed by all nonproprietary version responses. NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The enclosed affidavit supports this request. The proprietary enclosures have 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 new regulatory commitments and no revisions to any existing regulatory commitments.

Please contact Thomas Griffith at 541-452-7813 or at tgriffith@nuscalepower.com if you have any questions.

Sincerely,

Mark W. Shaver

Mark Shaver
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Enclosure 1: NuScale Response to NRC Request for Additional Information RAI# 9899, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information RAI# 9899, nonproprietary

Enclosure 3: Affidavit of Mark Shaver, AF-118039

Enclosure 4: Affidavit of Morris Byram, Framatome Inc. AF-117384

**Enclosure 1:**

NuScale Response to NRC Request for Additional Information eRAI No. 9899, proprietary

RAIO-118038

**Enclosure 2:**

NuScale Response to NRC Request for Additional Information eRAI No. 9899, nonproprietary

## Response to Request for Additional Information
## Docket: 99902078

**RAI No.:** 9899
**Date of RAI Issue:** 03/21/2022

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**NRC Question No.:** NTR-01

Regulatory Basis:

Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, Section 47 and Section 79 require a final safety analysis report (FSAR) to analyze the design and performance of the structures, systems, and components (SSCs). Safety evaluations, performed to support the FSAR, include accident analyses to demonstrate that specified acceptable fuel design limits (SAFDLs) are not exceeded during normal operation, including the effects of anticipated operational occurrences (AOOs).

GDC 10, *Reactor design*, which requires that the reactor core and associated coolant, control, and protection systems be designed with appropriate margin to assure that SAFDLs are not exceeded during any condition of normal operation, including the effects of AOOs.

Issue:

In Supplement 1 to TR-0116-21012-P-A, Revision 1, NuScale provided NSP4 predictions for {{ }}2(a),(c)

Request:

{{ }}2(a),(c) in the same format as "Appendix A to Topical Report Entitled "Applicability Range Extension of NSP4 Critical Heat Flux Correlation: Supplement 1 to TR-0116-21012-P-A, Revision 1," TR-107522-P, Revision 0.

**NuScale Response:**

NSP4 predictions for the Stern C1 test have been added to Appendix A in the existing format. In addition, the C1 test data is incorporated into the assessment of the Stern database within Section 4 of TR-107522-P.

{{ [

] }}2(a),(c)

NSP4 predictions of the {{

}}2(a),(c)

{{ [

] }}2(a),(b),(c),ECI

Figure 1: Stern and K8500 Tests P/M vs. Local Mass Flux at the minimum CHFR location

{{ [

] }}2(a),(b),(c),ECI

Figure 2: Predicted vs. Measured Local Heat Flux by Test Series

Table 1: NSP4 Statistical Figures-of-Merit for K8500 Test

| Parameter {{ [ | | | |
|---|---|---|---|
| KATHY K8500 Uniform | | | |
| Mean | | | |
| Standard Deviation | | | |
| Non-parametric bounds | | | |
| Parametric Bound | | | ] }}2(a),(c) |

{{

}}2(a),(c)

Table 2: Local Conditions for NSP4 Prediction of K8500 Test

{{ [

] }}2(a),(c),ECI

Table 2: Local Conditions for NSP4 Prediction of K8500 Test

{{ [

] }}2(a),(c),ECI

Definitions:

| | |
|---|---|
| TEST | Test Identifier |
| POINT | Test point |
| $Z_{pred}$ | Elevation of CHF prediction from bottom of heated length, in. |
| P | Pressure, psia |
| $G_{in}$ | Approximate inlet mass flux (test matrix value), Mlbm/hr-ft$^2$ |
| $\Delta T_{sub}$ | Approximate inlet subcooling (test matrix value), °F |
| G | Local mass flux, Mlbm/hr-ft$^2$ |
| X | Local equilibrium quality |
| $Z_{boil}$ | Boiling length {{ }}2(a),(c) |
| {{ | }}2(a),(c) |
| {{ | }}2(a),(c) |
| q"($Z_{pred}$) | Predicted CHF, MBtu/hr-ft$^2$ |
| F-factor | Modified Tong F-factor |
| P/M | Predicted-to-measured CHF ratio |

**Impact on Topical Report:**

Topical Report TR-107522, Applicability Range Extension of NSP4 CHF Correlation, has been revised as described in the response above and as shown in the markup provided in this response.

Licensing Topical Report

# Applicability Range Extension of NSP4 Critical Heat Flux Correlation

Supplement 1 to TR-0116-21012-P-A, Revision 1, NuScale Power Critical Heat Flux Correlations

~~January 2022~~

Draft Revision 1

Docket: 99902078

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**Department of Energy Acknowledgement and Disclaimer**

This material is based upon work supported by the Department of Energy under Award Number DE-NE0008928.

# Licensing Topical Report

**List of Affected Pages**

| Revision Number | Page Number | Explanation |
|---|---|---|
| 0 | All | Initial Issue |
| 1 | All | Revised to address NRC Requests for Additional Information 9899 |
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## Abstract

The purpose of this topical report supplement is to provide the bases for Nuclear Regulatory Commission approval of an extension to the range of applicability in Tables 7-5 and 8-4 for the NSP4 critical heat flux (CHF) approved in topical report TR-0116-21012-P-A, Revision 1, "NuScale Power Critical Heat Flux Correlations." The correlation and correlation limit justified and approved in the topical report remain unchanged.

**Executive Summary**

The purpose of this report is to provide the bases for Nuclear Regulatory Commission approval to use the NSP4 CHF correlation in VIPRE-01, within its expanded range of applicability in Table 5-1, along with its associated correlation limit 1.21, for the NuScale safety analysis of the NPM with NuFuel-HTP2™ fuel.

This correlation conforms to acceptance criteria given by the NuScale Design-Specific Review Standard (DSRS) and the requirements of 10 CFR 50, Appendix A, General Design Criterion (GDC) 10.

~~Two independent~~The methods of justification {{

}}2(1),(c) ~~are provided:~~

~~{{~~

~~}}2(a),(c)~~

# 1.0 Introduction

## 1.1 Purpose

The applicable range of the NSP4 CHF correlation contained in TR-0116-21012-P-A, Revision 1 (Reference 6.1.1) was adequate for the NuScale Power Module (NPM) described in the Design Certification Approval (DCA). The range of applicability is expanded to ensure the NSP4 CHF correlation encompasses the operating domain of the NPM at higher rated power levels.

## 1.2 Scope

This supplement provides justification for extending the applicable range of the mass flux for the NSP4 critical heat flux (CHF) correlation (Reference 6.1.1).This supplement will assess the available CHF data, and justify an extension to the mass flux applicability range for the NSP4 critical heat flux correlation, while retaining the approved correlation limit of 1.21 for safety analysis evaluations of the NPM with NuFuel-HTP2™ fuel.

The numbering of Section 1 through 3 in this document follows that of TR-0116-21012-P-A, Revision 1 in order to assist the reader in relating this supplement to the original topical report. Section 4 provides a description of the ~~methodologies~~evaluation and assessment that ~~justify~~justifies the expanded applicability. Section 5 provides a summary of the results, along with the updated applicability range for the NSP4 CHF correlation. Appendix A provides the local thermal-hydraulic parameters for each of the evaluated test series with the NSP4 correlation.

## 1.3 Abbreviations and Definitions

This section is unchanged relative to the corresponding section of Reference 6.1.1.

## 2.0 Background

The NuScale topical report TR-0116-21012-P-A, Revision 1, "NuScale Power Critical heat Flux Correlations," presents the NSP2 and NSP4 critical heat flux (CHF) correlations that have been developed by NuScale to assess CHF performance for normal operation, anticipated operational occurrences (AOOs), and postulated accidents in the NuScale Power Module (NPM) with NuFuel-HTP2™ fuel. In particular, the NRC found the NSP4 CHF correlation acceptable for use in performing safety analyses of the NPM with NuFuel-HTP-2™ fuel, with its associated correlation limit 1.21, over the range of applicability provided in Table 8-4 of TR-0116-21012-P-A, Revision 1.

## 2.1 Regulatory Requirements

This section is unchanged relative to the corresponding section of Reference 6.1.1.

## 2.2 NuScale Power Module Fuel Assembly Design

This section is unchanged relative to the corresponding section of Reference 6.1.1.

# 3.0 Analysis and Experimentation

This section is unchanged relative to the corresponding section of Reference 6.1.1.

# 4.0 Extension of Mass Flux Range for NSP4 Critical Heat Flux Correlation

## 4.1 Overview of Mass Flow Range Extension

Two independentThe methods of justification {{

}}2(a),(c) are provided:

{{

}}2(a),(c)

### 4.1.1 Statistical Assessment

The first method consists of {{

}}2(a),(c)

Data are randomly generated for pressure, axial power shape, power level, inlet mass flux, and inlet temperature. Values for power level, pressure, and inlet mass flux are randomly selected from the uniform distribution on the ranges tabulated in Table 4-1. The inlet temperature data range is a function of the power level, which is used to accommodate the natural circulation design of the NPM, as given by:

| | |
|---|---|
| {{ | |
| | Equation 4-1 |
| }}2(a),(c) | |

{{

}}2(a),(c)

**Table 4-1 ~~Data Ranges for Random Parameter Generation~~**

| | ~~**Minimum**~~ | ~~**Maximum**~~ |
|---|---|---|
| ~~{{~~ | | |
| | | |
| | | |
| | | |
| | | ~~}}[2(a),(c)]~~ |

**Figure 4-1 ~~Axial Power Shapes~~**

~~A simple {{~~

~~}}[2(a),(c)]~~

**Figure 4-2 ~~Closed Channel Nodalization~~**

{{

}}2(a),(c)

~~The enthalpy at {{~~ }}2(a),(c)

| | | |
|---|---|---|
| $H_n = \frac{\sum_{i=1}^{n}[F_{z,i} \cdot \bar{Q}]}{G} + H_0$ | | Equation 4-2 |

{{

}}2(a),(c)

| | |
|---|---|
| {{ | |
| | Equation 4-4 |
| }}2(a),(c) | |

{{

}}2(a),(c) Values for CHF are calculated with the NSP4 CHF correlation (Reference 6.1.1; Equation 7-1)

The populations are compared using both the Wilcoxon rank sum test (Reference 6.1.2; Section 25.8) and the squared ranks test (Reference 6.1.2; Section 25.13), which test the median and variance of two samples, respectively.

**Wilcoxon rank sum test**

Let $\{y_{11},y_{12},\ldots,y_{1n}\}$ be a sample of size *n* from a population with median $\zeta_1$ and $\{y_{21},y_{22},\ldots,y_{2m}\}$ be an independent sample of size m from a population with median $\zeta_2$. The null hypothesis is $H_0$: $\zeta_1=\zeta_2$.

The test statistic for testing $H_0$ is the sum of ranks from the first sample:

| | |
|---|---|
| $W = \sum_{i=1}^{n} R(y_{1i})$ | Equation 4-5 |

For the alternative hypothesis, $H_1$: $\zeta_1 \neq \zeta_2$, $H_0$ is rejected if $W > w_{1-\alpha/2}(n,m)$ or if $W < w_{\alpha/2}(n,m)$. The critical values of the W statistic are calculated with:

| | |
|---|---|
| $w_q(m,n) = \frac{n(n+m+1)}{2} + z_q\sqrt{\frac{nm(n+m+1)}{12}}$ | Equation 4-6 |

where $z_q$ is the q[th] quantile of the standard normal distribution.

The test statistic and critical values are tabulated in Table 4-2. Since $w_{\alpha/2} < W < w_{1-\alpha/2}$ the null hypothesis is accepted and the two populations have the same median, and belong to the same distribution.

**Table 4-2 Wilcoxon Rank Sum Test for Mass Flux Range Variation**

| Parameter | Value | | |
|---|---|---|---|
| m | {{ | | |
| n | | | |
| W | | | |
| $w_{1-\alpha/2}$ | | | |
| $w_{\alpha/2}$ | | | }}2(a),(c) |

**Squared ranks test**

From Reference 6.1.2; Section 25.13, let $\{y_{11}, y_{12}, \ldots, y_{1n}\}$ and $\{y_{21}, y_{22}, \ldots, y_{2m}\}$ be independent samples of size *n* and *m* from two populations. The null hypothesis is $H_0$: $\sigma_1^2 = \sigma_2^2$. Calculate parameters $u_i$ and $v_j$ with:

$$u_i = |y_{1i} - \mu_1|, \; i = 1, 2, \ldots, n$$
$$v_j = |y_{2j} - \mu_2|, \; j = 1, 2, \ldots, m \qquad \text{Equation 4-7}$$

where: $\mu_1$ and $\mu_2$ are mean values for population 1 and 2, respectively, and *n* and *m* are the number of observations in population 1 and 2, respectively. Rank the *n+m* observations in the combined samples of $u_i$'s and $v_j$'s. If any values of $u_i$ or $v_j$ are tied, assign to each the average of the ranks that would have been assigned had there been no ties. Denote the ranks by $R(u_i)$ and $R(v_j)$. If there are no ties, the test statistic is:

$$T_1 = \sum_{i=1}^{n} R(u_i)^2 \qquad \text{Equation 4-8}$$

If there are ties, the test statistic is:

$$T_1^* = \frac{T_1 - n\bar{R}^2}{\sqrt{\frac{nm}{(n+m)(n+m-1)} \sum_{k=1}^{n+m} R_k^4 - \left(\frac{nm}{n+m-1}\bar{R}^2\right)^2}} \qquad \text{Equation 4-9}$$

where *n* and *m* are the number of observations in population 1 and 2, respectively,

$$\bar{R}^2 = \frac{1}{n+m}\left[\sum_{i=1}^{n} R(u_i)^2 + \sum_{j=1}^{m} R(v_j)^2\right] \qquad \text{Equation 4-10}$$

and

$$\sum_{k=1}^{n+m} R_k^4 = \sum_{i=1}^{n} R(u_i)^4 + \sum_{j=1}^{m} R(v_j)^4$$ Equation 4-11

For the alternative hypothesis, $H_1$: $\sigma_1^2 \neq \sigma_2^2$, $H_0$ is rejected if $T_1^* > w_{1-\alpha/2}(n,m)$ or if $W < w_{\alpha/2}(n,m)$. The critical values of the $T_1^*$ statistic are calculated with:

$$w_q(n,m) = \frac{n(n+m+1)(2n+2m+1)}{6} + z_q\sqrt{\frac{nm(n+m+1)(2n+2m+1)(8n+8m+1)}{180}}$$ Equation 4-12

where $z_q$ is the $q^{th}$ quantile of the standard normal distribution.

The test statistic and critical values are tabulated in Table 4-3. Since the null hypothesis is accepted and the two populations have the same variance, and belong to the same distribution.

**Table 4-3 Squared Rank Test for Mass Flux Range Variation**

| Parameter | | Value | |
|---|---|---|---|
| $H_1$ | {{ | | |
| $H_2$ | | | |
| $m$ | | | |
| $n$ | | | |
| $T_1$ | | | |
| $\bar{R}^2$ | | | |
| $\sum_{k=1}^{n+m} R_k^4$ | | | |
| $T_1^*$ | | | |
| $w_{1-\alpha/2}$ | | | |
| $w_{\alpha/2}$ | | | }}2(a),(c) |

Both the median and variance of the two populations are shown to belong to the same distribution. Therefore, extending the NSP4 CHF correlation from 0.635 to 0.700 Mlbm/hr-ft² can be justified based on the premise that using the correlation beyond its original bounds does not alter its predictive capability.

## 4.2 Stern CHF Data Evaluation

The Stern CHF database covers a much wider range of mass flux as shown in Reference 6.1.1, Table A-1. This data more than adequately covers the extended upper limit of mass flux desired in the NSP4 CHF correlation. The test assemblies for the Stern CHF tests (Reference 6.1.1, Table 3-2) are similar to the NuFuel-HTP2™ design (Reference 6.1.1, Tables 3-6, 3-7, 3-8, and 3-10) as illustrated in Table 4-4. The fuel rod pitch and outer diameter, guide tube diameter, and heated length are all identical between the two. The only difference lies with the spacer grids. Where NuFuel-HTP2™ uses a combination of Framatome HMP™ and HTP™ spacer grids that have built-in mixing features, the grids in Stern testing {{

}}2(a),(c) with NSP4 because the NSP4 CHF correlation is based on the HMP™ and HTP™ spacer grids. However, as pointed out in Reference 6.1.1; Section 3.1.2, "… *at low flows, such as those of the NPM, any mixing benefits provided by the HTP™ design decrease.*" So, the difference in grid spacer type is not expected to significantly affect results {{

}}2(a),(c) In addition, the spacer grid span is {{ }}2(a),(c) for the Stern tests than in the NuFuel-HTP2™ design. This difference is small enough that it will not affect results since there is no variable in the NSP4 CHF correlation accounting for grid span. Therefore, using Stern CHF data to support the justification of increasing the upper mass flux limit of the NSP4 CHF correlation is acceptable.

**Table 4-4 Geometry Comparison Between NuFuel-HTP2™ and Stern Test Assemblies**

| Parameter | NuFuel-HTP2™ | Stern | Difference |
|---|---|---|---|
| Fuel rod pitch (in.) | 0.496 | 0.496 | 0.0% |
| Fuel rod outer diameter (in.) | 0.374 | 0.374 | 0.0% |
| Guide tube outer diameter (in.) | 0.482 | 0.482 | 0.0% |
| Heated length (in.) | 78.74 | 78.74 | 0.0% |
| Spacer grid type | HMP™/HTP™ | {{ }}2(a),(c) | - |
| Spacer grid span (in.) | {{ | | }}2(a),(c),ECI |

Critical heat flux values are calculated for the Stern test local conditions (Reference 6.1.1, Table A-1) with the NSP4 CHF correlation using VIPRE-01. All VIPRE-01 inputs, including two-phase correlations and mixing coefficients, are used in a manner consistent with the approved NSP4 CHF correlation topical report.

Limiting CHF values (i.e., the CHF at the location of minimum CHFR) are used to form a population. {{

}}2(a),(c) because this is below the lower limit of the NSP4 CHF correlation applicability range. ~~Only t~~The {{

}}2(a),(c)

{{

}}2(a),(c)

The population is divided into twothree sub-populations:

- {{

  }}2(a),(c)

, the first including local mass flux values between 0.110 and 0.635 Mlbm/hr·ft², and the second including values greater than 0.635 Mlbm/hr·ft². The predicted-to-measured ratios for these sub-populations are plotted versus mass flux in Figure 4-3. From this figure, it is observed that these three sub-regions occur naturally based on visual trends of P/M versus mass flux. At higher mass fluxes the CHFPredicted-to-measured comparisonpredictions for {{

}}2(a),(c) and generally trending towards more conservative predictions (i.e., lower P/M ratios) than the rest of the data. The general trend in the predicted-to-measured plot in Figure 4-4 {{

}}2(a),(c) [ There is significant data scatter when compared to KATHY K9000 and K9100 test predictions with some points over-predicted. ] {{

}}2(a),(c) This indicates that the NSP4 CHF correlation under-predicts the measured data and is conservative. {{

}}2(a),(c) The measured-to-predicted trend for mass flux greater than 0.635 Mlbm/hr·ft² is comparable to that for mass flux less than this value, so predictions at higher mass flux are as reliable as those made at lower mass flux. Overall, trends predicted by the NSP4 CHF correlation for Stern data are generally conservative compared with the KATHY test data. The NSP4 CHF correlation conservatively predicts the Stern test data for the entire mass flux range.

**Table 4-5 Stern NSP4 Statistical Figure-of-Merits**

| **Parameter** | {{ | | | |
|---|---|---|---|---|
| | | | | |
| Mean | | | | |
| Standard Deviation | | | | |
| Non-parametric Bound | | | | |
| Parametric Bound | | | | |
| | | | | |
| Mean | | | | |
| Standard Deviation | | | | |
| Non-parametric Bound | | | | |
| Parametric Bound | | | | |
| | | | | |
| Mean | | | | |
| Standard Deviation | | | | |
| Non-parametric Bound | | | | |
| Parametric Bound | | | | }}2(a),(c) |

{{ }}2(a),(c)

**Table 4-6 ~~Stern NSP4 Statistical Parameters~~**

| | ~~Data~~ | ~~Set μ~~ | ~~Set σ~~ | |
|---|---|---|---|---|
| {{ | | | | |
| | | | | |
| | | | | |
| | | | | }}2(a),(c) |

**Figure 4-3 Stern Test P/M Versus Local Mass Flux Values at Minimum CHFR Location**

{{

}}2(a),(b),(c),ECI

**Figure 4-4 Stern Test Predicted Versus Measured Local Heat Flux Values**

{{

}}2(a),(b),(c),ECI

## 5.0 Summary and Conclusions

The upper end of the mass flux range for NSP4 CHF correlation is extended to a value of 0.75 Mlbm/hr·ft². The range extension is validated ~~in two ways: 1) {{ }}2(a),(c) and 2)~~ by using data from a separate CHF test program that contains data ranges greater {{ }}2(a),(c)

~~The first range extension validation is performed in Section 4.1.1. {{ }}2(a),(c) Therefore, it is appropriate that the NSP4 CHF correlation can be extended to an upper range limit of 0.7 Mlbm/hr·ft² with acceptable predictive capabilities.~~

~~The second range extension validation is performed in Section 4.2.~~ Local condition data from~~for~~ {{ }}2(a),(c) are generated using VIPRE-01 with the NSP4 CHF correlation. The measured and predicted values are compared and show that the {{ }}2(a),(c) which demonstrates the NSP4 design limit for the approved domain conservatively bounds the extended domain to 0.75 Mlbm/(hr-ft²). ~~{{ }}2(a),(c) which is conservative.~~

~~The CHF prediction population with mass fluxes greater than 0.635 Mlbm/hr·ft² have comparable mean and standard deviation as that from below 0.635 Mlbm/hr·ft². {{ }}2(a),(c)~~

~~Therefore, the NSP4 CHF correlation predicts Stern data conservatively and demonstrates it is applicable over the mass flux range 0.110 to 0.700 Mlbm/hr·ft².~~

The use of the NSP4 CHF correlation to an upper bound 0.75 Mlbm/(hr-ft²) is validated and appropriate.~~is validated by both the {{ }}2(a),(c) and with Stern data that is {{ }}2(a),(c)~~ The extended applicability range for the NSP4 CHF correlation is shown in Table 5-1.

 

**Table 5-1 NSP4 CHF Correlation Extended Applicability Ranges**

| Parameter | Units | Lower Limit | Upper Limit |
|---|---|---|---|
| Pressure | psia | 500 | 2,300 |
| Mass flux | Mlbm/hr·ft$^2$ | 0.110 | 0.750~~0.700~~ |
| Local quality | - | n/a | 95% |
| Inlet quality | - | n/a | 0% |

# 6.0 References

## 6.1 Referenced Documents

6.1.1 NuScale Power, LLC, "NuScale Power Critical Heat Flux Correlations," TR-0116-21012-P-A, Revision 1.

6.1.2 U.S. Nuclear Regulatory Commission, "Applying Statistics," NUREG-1475, Revision 1, March 2011.

# Appendix A Local Conditions

This appendix provides tabulated parameters for Stern test series U1, ~~and~~ U2, and C1 evaluated with the NSP4 CHF correlation.

Definitions:

| | |
|---|---|
| TEST | Test identifier |
| POINT | Test point |
| $Z_{pred}$ | Elevation of CHF prediction from bottom of heated length, in. |
| P | Pressure, psia |
| $G_{in}$ | Approximate inlet mass flux (test matrix value), Mlbm/(hr-ft$^2$) |
| $\Delta T_{sub}$ | Approximate inlet subcooling (test matrix value), °F |
| G | Local mass flux, Mlbm/hr-ft$^2$ |
| X | Local equilibrium quality |
| $Z_{boil}$ | Boiling length {{ }}$^{2(a),(c)}$ |

{{ }}$^{2(a),(c)}$

{{ }}$^{2(a),(c)}$

| | |
|---|---|
| $q''_{pred}(I_{chf})$ | Predicted CHF, MBtu/hr-ft$^2$ |
| F-factor | Modified Tong F-factor |
| P/M | Predicted-to-measured CHF ratio |

**Table A-1** ~~**Local Conditions for NSP4 Prediction of Stern U1 and U2 Tests**~~

{{

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
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**Table A-1 ~~Local Conditions for NSP4 Prediction of Stern U1 and U2 Tests (Continued)~~**

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**Table A-1 ~~Local Conditions for NSP4 Prediction of Stern U1 and U2 Tests (Continued)~~**

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**Table A-1 ~~Local Conditions for NSP4 Prediction of Stern U1 and U2 Tests (Continued)~~**

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**Table A-1 ~~Local Conditions for NSP4 Prediction of Stern U1 and U2 Tests (Continued)~~**

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**Table A-1 ~~Local Conditions for NSP4 Prediction of Stern U1 and U2 Tests (Continued)~~**

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**Table A-1 ~~Local Conditions for NSP4 Prediction of Stern U1 and U2 Tests (Continued)~~**

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**Table A-1 ~~Local Conditions for NSP4 Prediction of Stern U1 and U2 Tests (Continued)~~**

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**Table A-1 ~~Local Conditions for NSP4 Prediction of Stern U1 and U2 Tests (Continued)~~**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1** **Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1** Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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**Table A-1 Local Conditions for NSP4 Prediction of Stern U1, U2, and C1 Tests (Continued)**

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NUSCALE
Power for all humankind

# Response to Request for Additional Information
# Docket: 99902078

**RAI No.:** 9899
**Date of RAI Issue:** 03/21/2022

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**NRC Question No.:** NTR-02

Regulatory Basis:

Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, Section 47 and Section 79 require a final safety analysis report (FSAR) to analyze the design and performance of the structures, systems, and components (SSCs). Safety evaluations, performed to support the FSAR, include accident analyses to demonstrate that specified acceptable fuel design limits (SAFDLs) are not exceeded during normal operation, including the effects of anticipated operational occurrences (AOOs).

GDC 10, *Reactor design*, which requires that the reactor core and associated coolant, control, and protection systems be designed with appropriate margin to assure that SAFDLs are not exceeded during any condition of normal operation, including the effects of AOOs.

Issue:

In their February 18, 2022, submittal of supplement information, "CHF Topical Supplement, February 3, 2022, Clarification Call Summary", NuScale {{

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Request:

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**NuScale Response:**

Table 4-5 has been added to TR-107522 in order to provide a quantification of the conservatism and accuracy of the CHF prediction in the higher mass flux range using various figures-of-merit that all demonstrate {{

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Figure 1: Stern (U1/U2/C1) vs. KATHY (K9000/K9100/K9200/K9300) P/M for 'all data' test points binned by mass flux with 95% confidence intervals

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Figure 2: Stern (U1/U2/C1) vs. KATHY (K9000/K9100/K9200/K9300) P/M for 'like-for-like' test points binned by mass flux with 95% confidence intervals

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Figure 3: Stern vs. KATHY P/M absolute difference for ‘like-for-like’ test points

Table 1: Like-for-like statistical parameters comparing KATHY and Stern

| Parameter | KATHY | Stern | Bias |
|---|---|---|---|
| Average | {{ | | |
| Standard Deviation | | | |
| Non-Parametric Bound | | | |

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Figure 4: Predicted-to-Measured relative difference as a function of inlet mass flux between NSP4 applied to K8500 and K9100

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Figure 5: P/M relative difference as a function of inlet subcooling between NSP4 applied to K8500 and K9100

Table 2: Like-for-like statistical parameters comparing K8500 (non-mixing) and K9100 (mixing) tests

| Parameter | K8500 | K9100 | Bias |
|---|---|---|---|
| Average | {{ | | |
| Standard Deviation | | | |
| Maximum Bias | | | |

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Figure 6: Stern and K8500 Predicted CHF effects from Mass Flux terms in the NSP4 correlation

**Impact on Topical Report:**

Topical Report TR-107522, Applicability Range Extension of NSP4 CHF Correlation, has been revised as described in the response above and as shown in the markup provided in this response and as shown in the response to RAI Question NTR-01.

**Enclosure 3:**

Affidavit of Mark Shaver, AF-118039

**NuScale Power, LLC**

AFFIDAVIT of Mark Shaver

I, Mark Shaver, state as follows:

1. I am the Manager, Licensing 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 Request for Additional Information response reveals distinguishing aspects about the process by which NuScale develops its Applicability Range Extension of NSP4 Critical Heat Flux Correlation.

    NuScale has performed significant research and evaluation to develop a basis for this process 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 enclosed response to NRC Request for Additional Information eRAI-9899-NTR-01, NTR02. 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 July 15, 2022.

Mark W. Shaver

Mark Shaver

**Enclosure 4:**

Affidavit of Morris Byram, Framatome Inc. AF-117384

A F F I D A V I T

1. My name is Morris Byram. I am Product Manager, Licensing & Regulatory Affairs for Framatome Inc. (Framatome) and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the Document that is Enclosure 1 to the NuScale Power,LLC letter Number RAIO-118038, entitled “NuScale Power, LLC Response to NRC Request for Additional Information (RAI No. 9899) on the NuScale Topical Report, ‘Applicability Range Extension of NSP4 CHF Correlation,’ TR-107522, Revision 0,” and referred to herein as “Document.” Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by Framatome and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) “Trade secrets and commercial or financial information.”

6. The following criteria are customarily applied by Framatome to determine whether information should be classified as proprietary:

(a) The information reveals details of Framatome’s research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for Framatome.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for Framatome in product optimization or marketability.

(e) The information is vital to a competitive advantage held by Framatome, would be helpful to competitors to Framatome, and would likely cause substantial harm to the competitive position of Framatome.

The information in this Document is considered proprietary for the reasons set forth in paragraphs 6(a), 6(b), and 6(c) above.

7. In accordance with Framatome’s policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside Framatome only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. Framatome policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: (07/19/2022)

BYRAM Morris Digitally signed by BYRAM Morris
Date: 2022.07.19 14:16:30 -07'00'

(NAME)

Email: morris.byram@framatome.com
Phone: 434-221-1082