July 24, 2017

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 39 (eRAI No. 8841) on the NuScale Design Certification Application

REFERENCE: U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 39 (eRAI No. 8841)," dated May 26, 2017

The purpose of this letter is to provide the NuScale Power, LLC (NuScale) response to the referenced NRC Request for Additional Information (RAI).

The Enclosure to this letter contains NuScale's response to the following RAI Question from NRC eRAI No. 8841:

- 05.02.05-2

This letter and the enclosed response make no new regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions on this response, please contact Marty Bryan at 541-452-7172 or at mbryan@nuscalepower.com.

Sincerely,

Zackary W. Rad
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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 8841

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 8841

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 8841
Date of RAI Issue: 05/26/2017

NRC Question No.: 05.02.05-2

10 CFR 52.47(a)(2) requires that a standard design certification applicant provide a description and analysis of the structures, systems, and components (SSCs) of the facility, with emphasis upon performance requirements, the bases, with technical justification therefor, upon which these requirements have been established, and the evaluations required to show that safety functions will be accomplished.

RG 1.45, Regulatory Positions C.2.1 and C.2.2 provide guidance on leakage detection systems sensitivity and response time:

"Plant procedures should include the collection of leakage to the primary reactor containment from unidentified sources so that the total flow rate can be detected, monitored, and quantified for flow rates greater than or equal to 0.05 gal/min (0.19 L/min).

The plant should use leakage detection systems with a response time (not including the transport delay time) of no greater than 1 hour for a leakage rate of 1 gal/min (3.8 L/min)."

FSAR Tier 2, Section 9.3.6.3 states the following:

"Regulatory Positions C.2.1 and C.2.2, in RG 1.45 are satisfied in that:

- Leakage to the primary reactor containment from unidentified sources can be detected, monitored, and quantified for flow rates greater than or equal to 0.05 gpm using containment vessel (CNV) pressure or containment evacuation system (CES) sample tank level timing.
- Leakage detection response time (not including transport delay time) is less than one hour for a leakage rate greater than 1 gpm using CNV pressure or CES sample tank level timing."

Although, the CNV pressure and CES tank level timing are used indirectly measure leakage flow, FSAR Tier 2 does not indicate how CNV pressure and CES tank level timing are related to the reactor coolant leakage sensitivity and leakage detection response time.

The applicant is requested to clarify how RG 1.45, Regulatory Positions C.2.1 and C.2.2, are satisfied by addressing the following questions:

a. Clarify how the instrument output of CNV pressure and CES tank level timing correlate to reactor coolant leakage rate.
b. Demonstrate how the leakage sensitivity of 0.05 gpm and the leakage detection response time of one gpm within one hour are satisfied by using CNV pressure and the correlation.
c. Demonstrate how the leakage sensitivity of 0.05 gpm and the leakage detection response time of one gpm within one hour are satisfied by using CES sample tank level and the correlation.

NuScale Response:

a) The leakage into the containment vessel (CNV) can be calculated using pressure instruments by solving the ordinary differential equation for flow in a vacuum system (Equation 1) [Equation 2.28 of Reference 1] and solving for the leak rate. The leak rate is given as a quantity of gas entering the CNV (measured as pressure times volumetric flow).

$$\frac{dp}{dt} = Q - Sp \qquad \text{Eq. 1}$$

Where: p = pressure inside the CNV

t = time from leak initiation

Q = leak rate

S = vacuum pump speed (volumetric flow)

Equation 1 is solved for pressure, which gives containment pressure as a function of time given a constant leak rate. An initial pressure is assumed for the initial condition at time t = 0.

$$p(0) = p_o \qquad \text{Initial condition}$$

$$p(t) = \left[p_o - \frac{Q}{S} \right] e^{-\frac{t \cdot S}{v}} + \frac{Q}{S} \qquad \text{Eq. 2}$$

To obtain a volumetric flow rate, Equation 2 is solved for the leak rate, Q, and the ideal gas law is used to define the leak rate in terms of mass flow. This equation is then solved for the volumetric flow rate to get Equation 4.

$$p\dot{V} = \dot{n}R_u T = \dot{V}\rho RT$$ Ideal Gas Law

$$\therefore Q = p\dot{V} = \dot{V}\rho RT$$ Eq. 3

Where: $\dot{V}$ = volumetric flow rate

ρ = initial density of leak

R = specific gas constant of water vapor

T = initial temperature of leak

$$\dot{V} = \frac{S\left[p_o \cdot e^{-\frac{t \cdot S}{v}} - p\right]}{\rho RT\left[e^{-\frac{t \cdot S}{v}} - 1\right]}$$ Eq. 4

As the pressure goes to steady state over time (t → ∞), Equation 4 reduces to:

$$\dot{V} = \frac{Sp}{\rho RT}$$ Eq. 5

Thus, given a pressure reading, and assuming the leaking fluid is at RCS conditions, a volumetric flow rate for the leak can be calculated. The module control system will perform this calculation automatically.

Level Instrument Correlation to RCS Leak Rate

As leakage enters the CNV from the Reactor Coolant System (RCS), the fluid pressure goes below the vapor pressure and the fluid vaporizes. The CNV is held at a pressure below the vapor pressure associated with the lowest temperature surface within the CNV to preclude condensation. A single containment evacuation system (CES) vacuum pump operates continuously, so that vapor is constantly removed.

As the vapor passes through the vacuum pump, it is condensed back to liquid in the condenser. The CES sample vessel collects the liquid where its temperature, radioactivity, and vessel level is measured over time.

Given that the dimensions of the CES sample vessel are known, the volumetric flow rate can be calculated using Equation 6. The internal geometry of the vessel is assumed to be a vertical cylinder.

$$\dot{V} = f\frac{\pi r^2 h}{t}$$ Eq. 6

Where: $\dot{V}$ = volumetric flow rate

f = condenser bypass factor

r = internal radius of vessel

h = liquid level in vessel

t = time

The calibrated output of the level sensor is used to measure the liquid level in the CES sample vessel. The measurement begins at time t=0s with the CES sample vessel drain valve closing. As liquid accumulates, Equation 6 alone will give an average leak rate for the time it takes to cycle the CES sample vessel. However, real time leak rate trending can be performed by using instantaneous level and time. After the calculation is performed, the results can be correlated to volumetric leak rate at RCS conditions. A condenser bypass factor is also included to account for the fraction of vapor that is not condensed in the condenser stage; this factor is dependent on the condenser design.

$$\dot{V} = f\frac{\pi r^2 dh}{dt}$$ Eq. 7

b) Demonstration of 1 gpm Leak Sensitivity and Leak Detection Response Time - Containment Pressure

The leak detection sensitivity can be demonstrated by rearranging Equation 2 (with Equation 3 substituted for Q) to solve for time and substituting the pressure inside the CNV (p) for the initial pressure plus the instrument resolution. Once rearranged, this will calculate the instrument response time it takes for the containment atmosphere to change from its initial pressure to the initial pressure plus the minimum instrument resolution.

$$t = \frac{-v}{S}\ln\left[\frac{\left(p_i + p_{res}\right) - \left(\frac{\rho R T \dot{V}}{S}\right)}{p_i - \left(\frac{\rho R T \dot{V}}{S}\right)}\right]$$ Eq. 8

Where: p_{res} = pressure instrument resolution

With RCS conditions assumed to be nominal at 487°F and 1850 psia with an initial pressure of 0.001 psia, a 1 gpm leak with a vacuum pump operating at 283 ft^3/min will be a pressure instrument with a resolution of 0.1psi (which is much higher than a typical commercial vacuum pressure instrument) could detect a 1 gpm in well under an hour.

$$t = \frac{-6144\,ft^3}{283\,\frac{ft^3}{\min}} \ln\left[\frac{(0.001psia + 0.1psi) - \left(\frac{50.2\frac{lbm}{ft^3}\cdot 85.78\cdot\frac{ft\cdot lbf}{lbm\cdot R}\cdot 946.7R\cdot 0.134\frac{ft^3}{\min}}{283\frac{ft^3}{\min}}\right)}{0.001psia - \left(\frac{50.2\frac{lbm}{ft^3}\cdot 85.78\cdot\frac{ft\cdot lbf}{lbm\cdot R}\cdot 946.7R\cdot 0.134\frac{ft^3}{\min}}{283\frac{ft^3}{\min}}\right)}\right]$$

$$t \simeq 10\sec$$

While instrument loop uncertainty or signal processing time is not included in this calculation, it will not have a significant enough affect for the detection time to exceed 1 hour.

<u>Demonstration of 0.05 gpm Leak Sensitivity and Leak Detection Response Time - Containment Pressure</u>

To demonstrate the leak sensitivity of a 0.05 gpm leak, the same conditions are assumed.

$$t = \frac{-6144\,ft^3}{283\,\frac{ft^3}{\min}} \ln\left[\frac{(0.001psia + 0.1psi) - \left(\frac{50.2\frac{lbm}{ft^3}\cdot 85.78\cdot\frac{ft\cdot lbf}{lbm\cdot R}\cdot 946.7R\cdot 6.68\cdot 10^{-3}\frac{ft^3}{\min}}{283\frac{ft^3}{\min}}\right)}{0.001psia - \left(\frac{50.2\frac{lbm}{ft^3}\cdot 85.78\cdot\frac{ft\cdot lbf}{lbm\cdot R}\cdot 946.7R\cdot 6.68\cdot 10^{-3}\frac{ft^3}{\min}}{283\frac{ft^3}{\min}}\right)}\right]$$

$$t \simeq 212\sec$$

A 0.05 gpm RCS leak is detected in approximately 212 seconds (without measurement uncertainty or signal processing time). For a leak to go undetected by the pressure instrumentation, it would have to be insignificant enough to cause a pressure change inside containment of less than the instrument resolution.

c) <u>Demonstration of 1 gpm Leak Sensitivity and Leak Detection Response Time - CES Sample Vessel</u>

By rearranging Equation 6 to solve for time, t, a 1 gpm leak detection time can be calculated.

$$t = f\frac{\pi r^2 h_{res}}{\dot{V}} \qquad \text{Eq. 9}$$

Where: h_{res} = level instrument accuracy

As the level instrument is assumed to calibrated differential pressure sensor at the bottom of the sample vessel, an accuracy of 0.005 psi is assumed (based on typical industry differential pressure level instruments). To assume worst case CES condenser performance, it is assumed the water in the sample vessel is at 212°F and 1 atm. Thus, the minimum detectable level change in the vessel would be:

$$h_{res} = \frac{p_{res}}{\rho_{sample} g} = \frac{0.005\, psi}{59.8 \frac{lbm}{ft^3} \cdot 32.1 \frac{ft}{s^2}} \simeq 0.15 in \qquad \text{Eq. 10}$$

Using the level instrument accuracy and an assumed vessel radius of 4 inches, with a condenser bypass factor of 0.75 (25% of vapor is not condensed) the leak detection time for a 1 gpm leak is calculated.

$$t = 0.75 \frac{\pi (2in)^2\, 0.15in}{231 \frac{in^3}{\min}}$$

$$t = 0.37s$$

While instrument loop uncertainty, signal processing time or pipe transport time is not included in this calculation, it will not have a significant enough affect for the detection time to exceed 1 hour.

<u>Demonstration of 0.05 gpm Leak Sensitivity and Leak Detection Response Time - CES Sample Vessel</u>

Using Equation 9 for a 0.05 gpm leak, with the same conditions, the leakage detection time is approximately 7 seconds.

$$t = 0.75 \frac{\pi (2in)^2\, 0.15in}{11.6 \frac{in^3}{\min}}$$

$$t \simeq 7 \sec$$

While instrument loop uncertainty or signal processing time is not included in this calculation, it will not be significant enough to affect minimum leak detection performance of the CES Sample Vessel.

References:

1. Chambers, A., R.K. Fitch, and B.S. Halliday, Basic Vacuum Technology, 2nd Edition, Institute of Physics Publishing, Bristol, United Kingdom, 1998.

Impact on DCA:

There are no impacts to the DCA as a result of this response.