UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

June 5, 2019

Dr. Alan Cebula
Nuclear Reactor Facility Manager
Kansas State University
112 Ward Hall
Manhattan, KS 66506-5204

SUBJECT: KANSAS STATE UNIVERSITY – REQUEST FOR ADDITIONAL INFORMATION RELATED TO LICENSE AMENDMENT REQUEST FOR THE USE OF 12 WEIGHT PERCENT URANIUM FUEL ELEMENTS (EPID NO. L-2019-LLA-0092)

Dear Dr. Cebula:

By letter dated April 9, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12109A063), as supplemented by letter(s) dated April 28, 2014; October 5, 2016; May 2, 2017; September 23, 2017; and November 30, 2018 (ADAMS Accession Nos. ML16200A317, ML16291A498, ML17139C979, ML17319A305, and ML18347A209, respectively), Kansas State University (KSU) applied for an amendment to Facility Operating License No. R-88 for the KSU Training, Research, Isotopes, General Atomics (TRIGA) Mark-II Nuclear Reactor Facility. The requested licensing action would allow KSU to add up to four fuel elements that are 12 percent by weight uranium to its reactor core.

The U.S. Nuclear Regulatory Commission (NRC) staff identified additional information needed to continue its review of the amendment request, as described in the enclosed request for additional information (RAI). As discussed by telephone on May 16, 2019, provide a response to the RAI, or a written request for additional time to respond, including the proposed response date and a brief explanation of the reason, by October 7, 2019. Following receipt of the complete response to the RAI, the NRC staff will continue its review of the amendment request.

The response to the RAI must be submitted in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 50.4, "Written communications," and, per 10 CFR 50.30(b), "Oath or affirmation," be executed in a signed original document under oath or affirmation. Information included in the response that you consider sensitive or proprietary, and seek to have withheld from public disclosure, must be marked in accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding." Any information related to safeguards should be submitted in accordance with 10 CFR 73.21, "Protection of Safeguards Information: Performance Requirements."

Based on the response date provided above, the NRC staff expects to complete its review and make a final determination on the amendment request by December 31, 2020. This date could change due to several factors including a need for further RAIs, unanticipated changes to the scope of the review, unsolicited supplements to the application for amendment, and others. If the forecasted date changes, the NRC staff will notify you in writing of the new date and an explanation of the reason for the change. In the case that the NRC staff requires additional information beyond that provided in the response to this RAI, the NRC staff will request that information by separate correspondence.

If you have any questions regarding the NRC staff's review or if you intend to request additional time to respond, please contact me at 301-415-4067 or by electronic mail at Edward.Helvenston@nrc.gov.

Sincerely,

/RA/

Edward Helvenston, Project Manager
Research and Test Reactors Licensing Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket No. 50-188
License No. R-88

Enclosure:
As stated

cc:

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Test, Research and Training
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Attention: Amber Johnson
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Robert Seymour, Reactor Supervisor
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SUBJECT: KANSAS STATE UNIVERSITY – REQUEST FOR ADDITIONAL INFORMATION RELATED TO LICENSE AMENDMENT REQUEST FOR THE USE OF 12 WEIGHT PERCENT URANIUM FUEL ELEMENTS (EPID NO. L-2019-LLA-0092) DATE: JUNE 5, 2019

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ADAMS Accession No. ML19128A342 *concurrence via e-mail NRR-106

OFFICE	**NRR/DLP/PRLB/PM***	**NRR/DLP/PRLB/LA***	**NRR/DLP/PRLB/BC**	**NRR/DLP/PRLB/PM**
NAME	EHelvenston	NParker	GCasto	EHelvenston
DATE	5/14/19	5/14/19	6/5/19	6/5/19

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OFFICE OF NUCLEAR REACTOR REGULATION

REQUEST FOR ADDITIONAL INFORMATION

REGARDING AMENDMENT TO FACILITY OPERATING LICENSE

THE KANSAS STATE UNIVERSITY NUCLEAR REACTOR FACILITY

LICENSE NO. R-88; DOCKET NO. 50-188

The U.S. Nuclear Regulatory Commission (NRC) staff is continuing its review of Kansas State University (KSU)'s application for amendment to Facility Operating License No. R-88, for the KSU Training, Isotopes, General Atomics (TRIGA) Mark-II Nuclear Reactor Facility, dated April 9, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12109A063), as supplemented.

In the course of reviewing KSU's application, the NRC staff has determined that additional information or clarification is required to continue its review of the application, in support of the development of its safety evaluation. The application is primarily evaluated using the appropriate regulations in Title 10 of the *Code of Federal Regulations* (10 CFR), and the following guidance:

- NUREG-1537, Part 1, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Format and Content," issued February 1996 (ADAMS Accession No. ML042430055)

- NUREG-1537, Part 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Standard Review Plan and Acceptance Criteria," issued February 1996 (ADAMS Accession No. ML042430048)

- American National Standards Institute/American Nuclear Society, (ANSI/ANS)-15.1-2007 (R2013), "The Development of Technical Specifications for Research Reactors."

Requests for additional information (RAIs) 5 through 17, and 20 through 23, below are related to the proposed technical specifications (TSs) provided with KSU's application. TSs are fundamental criteria necessary to demonstrate facility safety and are required by 10 CFR 50.36, "Technical specifications," for each license authorizing operation of a production or utilization facility of a type described in 10 CFR 50.21, "Class 104 licenses; for medical therapy and research and development facilities." TSs are derived from the analyses and evaluation included in the safety analysis report (SAR) and submitted pursuant to 10 CFR 50.34, "Contents of applications; technical information." TSs for nuclear reactors will include items in the following categories: safety limits (SLs), limiting safety system settings, limiting conditions for operation (LCOs), surveillance requirements, design features, and administrative controls. The NRC guidance for TSs is provided in NUREG-1537, Part 1, Appendix 14.1, "Format and Content of Technical Specifications for Non-Power Reactors." This guidance relies significantly on ANSI/ANS-15.1-2007. The NRC staff takes the position that the statements in these documents provide acceptable guidance to licensees and, unless acceptable alternatives are justified by the licensee, should be utilized whenever appropriate.

RAI 1

The regulations in 10 CFR 50.30(b), "Oath or affirmation," require that license amendment applications, and each amendment to such applications, must be executed in a signed original by the applicant or duly authorized officer thereof under oath or affirmation.

The NRC staff notes that KSU's September 23, 2017, letter (ADAMS Accession No. ML17319A305), providing a supplement to its original April 9, 2012, license amendment request (LAR), does not appear to be signed.

Provide a signed version of the September 23, 2017, supplement (or a statement that the September 23, 2017, supplement is incorporated by reference into KSU's signed response to this RAI), or justify why no additional information is needed.

RAI 2

The regulations in 10 CFR 50.34(b)(2) require that applications contain 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 such requirements have been established; and the evaluations required to show that safety functions will be accomplished.

The guidance in NUREG-1537, Part 1, Section 4.5.1, states that licensees should provide a discussion of the safety considerations for different core configurations, including a limiting core configuration (LCC) that would yield the highest power densities and fuel temperatures available with the planned fuel. The guidance in NUREG-1537, Part 1, Section 4.5.2, states that licensees should present information on axial and radial distributions of neutron flux densities, and should validate calculations by comparing them with experimental measurements and other validated calculations.

In its response to RAI 10 submitted October 5, 2016 (ADAMS Accession No. ML16291A498), KSU provides the results of core design (neutronics) calculations that are updated and corrected from those in its original LAR and its April 28, 2014, RAI responses (ADAMS Accession No. ML16200A317).

a. The NRC staff notes that, based on the results illustrated in Figure 6 of KSU's response to RAI 10 submitted October 5, 2016, KSU's updated calculations appear to assume that the four 12 weight percent uranium (wt% U) elements are distributed at approximately equal intervals around the E-ring (previous calculations for 12 wt% U elements in the E-ring also appear to use a similar assumption, based on figures in the original LAR and the April 28, 2014, RAI responses).

   However, in its response to RAI 6 submitted May 2, 2017 (ADAMS Accession No. ML17139C979), KSU states that "MCNP results transmitted in the initial LAR and in previous RAI responses indicate that 12.5 wt% (max.) fuel in the E- and F-rings will be kept below the fission heating density (i.e., power) of the 9.0 wt% (max.) elements in the B-ring, even if placed adjacent to another 12.5%-loaded element."

   Given the discussion in KSU's response to RAI 6 submitted May 2, 2017, compared to the information in the LAR and previous RAI responses, it is not clear whether KSU's core design calculations consider the possibility of 12 wt% U elements being located near or adjacent to each other, or only consider 12 wt% U elements to be spaced at intervals from other 12 wt% U elements. The NRC staff notes that placing 12 wt% U elements adjacent to each other, or clustered together, in the E- and/or F-rings could result in higher power densities in those elements than if the elements were spaced at approximately equal intervals around the E-or F-ring.

Although proposed new TS 5.1.3(3) would prohibit placement of 12 wt% U elements adjacent to water channels, it would not prohibit placement of 12 wt% U elements adjacent to or near each other (see RAI 17).

Clarify whether KSU's core design calculations for its LAR, as supplemented, considered the possibility of 12 wt% U elements being near or adjacent to each other. If such situations were considered, discuss whether the maximum peaking factors in the 12% fuel elements in the E-and/or F-rings remained below the maximum peaking factor in 8.5 wt% U fuel in the B-ring. If such situations were not considered, provide calculations showing that placing 12 wt% U elements adjacent to each other or clustered together would not cause peaking factors in the 12 wt% U fuel to exceed the B-ring peaking factor, or discuss why such calculations are not necessary (for example, because TSs would prohibit the configurations that were not considered). Alternatively, discuss why no additional information is required.

b. The NRC staff notes that it is not clear how KSU's neutronics calculations have been validated for the KSU reactor, to ensure that the results of the calculations used to determine core characteristics (e.g., peaking factors) for proposed operation are suitably predictive. Discuss how KSU's neutronics calculations were validated, and provide appropriate supporting data (e.g., comparisons between control rod worths, etc., calculated with KSU's neutronics models for existing 8.5 wt% U fuel cores, and actual measured values). Additionally, discuss how KSU plans to verify that its neutronics models are also suitably predictive for proposed cores containing 12 wt% U fuel (e.g., by verifying that control rod worths, etc., measured for proposed cores are similar to predicted values). Alternatively, discuss why no additional information is required.

RAI 3

The regulations in 10 CFR 50.34(b)(2) require that applications contain a description and analysis of the SSCs of the facility, with emphasis upon performance requirements; the bases, with technical justification therefor, upon which such requirements have been established; and the evaluations required to show that safety functions will be accomplished.

The guidance in NUREG-1537, Part 1, Chapter 13, describes the types of research reactor accidents that licensees should analyze. These accidents include insertion of excess reactivity accidents. NUREG-1537, Part 1, Section 13.1.2, states that insertion of reactivity events include the rapid (or step) insertion of reactivity (e.g., due to rapid removal of a control rod or rods, rapid insertion of a fuel element into the core, or experiment malfunction), and the ramp insertion of reactivity (e.g., due to drive motion of a control rod or rods). NUREG-1537, Part 1, Section 13.2, describes how accidents should be analyzed, and states that licensees should base accident scenarios on a single initiating malfunction.

KSU's LAR, as supplemented, references analyses of a $3.00 pulse discussed in its license renewal SAR, as supplemented (and previously reviewed and approved by the NRC as documented in the NRC staff's March 13, 2008, safety evaluation report (SER) (ADAMS

Accession No. ML080580284)), and states that the $3.00 reactivity insertions previously analyzed would bound any inadvertent insertion of reactivity, for existing cores or proposed cores with 12 wt% U fuel.

a. The NRC staff notes that the existing analysis for a routine $3.00 pulse assumes that the reactor is initially at zero or very low power, such that the initial fuel temperature is low (27 degrees Celsius (degrees C) (81 degrees Fahrenheit (degrees F)). However, while routine pulses are typically performed from low power, when the fuel temperature is low, a rapid inadvertent insertion of reactivity (e.g., due to an experiment failure) could occur during proposed operation while the reactor is operating at full steady-state power and the initial fuel temperature is much higher.

   Existing KSU TSs 3.6.3(1) and 3.6.3(2) limit the worth of any individual reactor experiment, or total absolute worths of any two or more related experiments, to $2.00.

   The NRC staff notes that it is not clear whether a rapid insertion of up to $2.00 of reactivity from failure of any experiment, when the reactor is operating at full steady-state power (and the fuel is initially at its maximum calculated steady-state temperature) would be bounded by the $3.00 pulse analysis for proposed operation. Therefore, provide an analysis demonstrating that a rapid $2.00 reactivity insertion during full power steady-state reactor operation would not cause a SL to be exceeded, or justify why no additional information is required. For this analysis, the initial maximum fuel temperature at the onset of the rapid reactivity insertion event should be based on the updated steady-state thermal-hydraulic calculations in KSU's LAR, as supplemented. Additionally, if applicable, this analysis should consider the maximum time it could take the control rods to scram the reactor.

b. The NRC staff notes that the existing KSU TSs do not establish any specific limit on the rate at which reactivity may be inserted into the core (by control rods, or anything else) during steady-state operation. Additionally, the existing KSU TSs do not require that a short period scram be operable when the reactor is operating.

   The NRC staff notes that, for proposed operation, a control rod malfunction could cause a ramp insertion of reactivity that, in the absence of any short period scram, could cause the reactor core to reach an unacceptably high power level and temperature, given the time it could take the reactor to be shut down by one of the two existing TS-required high power scrams if the transient started from low power, considering the instrument delay and time it would take control rods to insert into the core once a scram occurred. The NRC staff notes that these types of transients (ramp reactivity insertions) could, potentially, bound any potential rapid (step) reactivity insertion transient or pulse.

   Therefore, provide an analysis demonstrating that any ramp reactivity insertion (reactivity being inserted at any rate), starting from any power level, with the reactor in its most restrictive initial condition, would not cause a SL to be exceeded (including due to a loss of flow stability); or, justify why no additional information is required. This analysis may use a Reactor Excursion and Leak Analysis Program (RELAP) computer model with point reactor kinetics, if appropriate. For this analysis, if applicable, the initial maximum fuel temperature at the onset of the ramp reactivity insertion event should be based on the updated steady-state thermal-hydraulic calculations in KSU's LAR, as supplemented. Additionally, if applicable, this analysis should consider the maximum time it could take the control rods to scram the reactor.

c. KSU's existing analysis for an inadvertent $3.00 pulse that occurs during reactor operation (although, as discussed in the NRC staff's March 13, 2008, license renewal SER, there is an interlock preventing pulsing when reactor power is above 10 kilowatts-thermal (kW(t)), there is no TS requirement for this interlock, and it is not credited) assumes that the peak reactor fuel temperature prior to the inadvertent pulse is 150 degrees C (302 degrees F). This temperature is based on a steady-state reactor power of approximately 100 kW(t) (well below the full licensed power). This is because KSU determined that, given that existing TS 3.1.3(1) limits maximum excess reactivity to $4.00, and the maximum allowed pulse is $3.00, the remaining $1.00 of excess reactivity would only allow the reactor to be operated up to a steady-state power of approximately 100 kW(t).

   Given that, in its LAR, as supplemented, KSU provided updated steady-state thermal-hydraulic analyses, it is not clear whether the inadvertent pulse analysis in KSU's license renewal SAR, as supplemented (including the 150 degrees C (302 degrees F) initial peak fuel temperature assumption), remains valid. Additionally, although KSU analyzed a scenario in which the reactor is operating at the highest power possible with $1.00 of excess reactivity, and the reactor is pulsed with the remaining $3.00 of excess reactivity, it is not clear whether this scenario would bound other possible combinations of reactivity for reactor operation and inadvertent pulsing. For example, the reactor could be operated at the maximum power level possible with $1.50 of excess reactivity, and the remaining $2.50 of allowed excess reactivity could be inserted in an inadvertent pulse.

   Therefore, discuss whether KSU's existing inadvertent pulse analysis is still valid for a scenario in which the reactor is operating at the highest power possible with $1.00 of excess reactivity, and the reactor is pulsed with the remaining $3.00 of excess reactivity. If it is no longer valid, provide an updated analysis that is based on the results of the updated steady-state thermal-hydraulic analyses in the LAR, as supplemented. Additionally, provide analyses, also based on the updated thermal-hydraulic analyses, demonstrating that other combinations of operation and pulsing (e.g., an inadvertent $2.50 pulse when the reactor is operating with $1.50 of excess reactivity) would be bounded by the inadvertent $3.00 pulse scenario (or other analyzed scenarios), or would otherwise not cause a SL to be exceeded. Alternatively, propose an LCO TS (and associated surveillance TS) on an interlock that would help ensure that the reactor would not be pulsed while operating at any power level that would cause the fuel temperature to be significantly above ambient; or, justify why no additional information is required.

<u>RAI 4</u>

(See also RAI 18.a in relation to this RAI.)

The regulations in 10 CFR 50.34(b)(2) require that applications contain a description and analysis of the SSCs of the facility, with emphasis upon performance requirements; the bases, with technical justification therefor, upon which such requirements have been established; and the evaluations required to show that safety functions will be accomplished.

The guidance in NUREG-1537, Part 1, Section 4.5.1, states that licensees should present information on core geometry and configurations, including the LCC (the core yielding the highest power density and fuel temperature using the fuel specified for the reactor), and other proposed operating core configurations that are demonstrated to be encompassed by the safety analysis of the LCC.

In its response to RAI 5 submitted May 2, 2017, KSU provided core design (neutronics) analyses to demonstrate the acceptability of its proposed new TS 3.4.3(3), which would allow reactor operation with any one control rod inoperable and fully inserted. KSU's calculations consider a core with all fresh 9.0 wt% U fuel elements and all rods fully withdrawn, and then consider how the peaking factor would change when each of the four control rods is fully inserted.

However, the core with all rods withdrawn that KSU considered appears to be a less limiting (lower peaking factor) core than the core considered for KSU's limiting core design calculations submitted in its October 5, 2016, RAI responses. Therefore, although KSU's calculations in its response to RAI 5 submitted May 2, 2017, show that having one rod inoperable and fully inserted would not cause a peaking factor to exceed 1.65 (the peaking factor calculated in KSU's bounding core design calculations submitted in its October 5, 2016, RAI responses), the calculations in RAI 5 submitted May 2, 2017, may not be based on a bounding core configuration.

KSU's calculations in its response to RAI 5 submitted May 2, 2017, also consider the effect on peaking factor of adding a single 12.3 wt% U element to the core (in position E-10) when each control rod is fully inserted, and show that the peaking factor would not still exceed 1.65. However, these calculations may also not be bounding given the core configurations assumed, including the use of only a single 12.3 wt% U element (instead of the four that would be allowed) and the location of that element.

Based on the above, the NRC staff notes that KSU's calculations do not appear to adequately demonstrate that any permissible core configurations, with up to four 12 wt% U fuel elements, and any one control rod fully inserted, would be bounded by KSU's limiting core design calculations. Therefore, provide additional calculations demonstrating that reactor operation with up to four 12 wt% U fuel elements located in any permissible locations, and any one control rod inoperable and fully inserted, will not result in a SL being exceeded. The calculations should assume that the reactor is operated at the full licensed power of 1,250 kW(t), even when one control rod is fully inserted, because although the inserted rod would reduce reactivity and could limit the power level that could be achieved, other core changes (e.g., addition of experiments) could compensate for some of this reduction in reactivity. Although the up to four higher U loading fuel elements that would be added to the core are nominally 12 wt% U, the calculations should also assume that the higher U loading elements have the highest U loading that would be allowed by proposed TS 5.1.3(1) (i.e., 12.5 wt%), if this would be bounding (see also RAI 23.a). Alternatively, revise proposed TS 3.4.3(3) and its associated action statement TS 3.4.4.B to require that all four control rods be operable (such that control rods can be banked during reactor operation, consistent with assumptions in the neutronics analysis in the LAR, as supplemented); or, justify why no additional information is required.

RAI 5

In its LAR supplement dated November 30, 2018 (ADAMS Accession No. ML18347A209), KSU provided a copy of the KSU reactor TSs, which includes KSU's proposed changes. However, the NRC staff notes that this copy of the proposed TSs appears to include changes that are not discussed in the LAR, as supplemented. Additionally, the change bars on this copy of the TSs do not appear to correspond exactly to all locations where changes have been made compared to the current TSs of record (i.e., some locations with change bars do not appear to have been changed, and vise-versa).

Provide TS change pages that only include changes that are specifically discussed and analyzed, as applicable, in the LAR, as supplemented; or, discuss and provide a basis for, as applicable, each change that is indicated in the change pages, including minor formatting or editorial changes. Additionally, provide the TS change pages with change bars that show all locations where changes have been made compared to the current NRC-approved TSs of record. The NRC staff recommends that, in addition to the TS change pages with change bars, KSU provide a separate, fully marked-up (i.e., with "tracked changes") version of the TS change pages, indicating all proposed changes to the current TSs. The NRC staff also recommends that, for TS change pages with change bars, and fully marked-up TS change pages, KSU only submit copies of those TS pages on which changes are proposed; a complete copy of the TSs including the pages with no changes does not need to be submitted. A recent submittal which may be useful as an example can be found at ADAMS Accession No. ML18109A039 (see Enclosures 3 and 4 for TS change pages). Alternatively, justify why no additional information is required.

RAI 6

In its LAR, as supplemented, KSU proposed to add TS 3.4.3(3) (and associated action statement TS 3.4.4.B), which would require operable control rods. However, although the title of current TS 3.4 includes "Control Rod Operability," the "Applicability" and "Objective" for current TS 3.4 only appear to address measuring and safety system channels, and do not address control rods. Propose a revised "Applicability" and "Objective" for current TS 3.4 such that they would be applicable to all specifications in proposed TS 3.4, or justify why no change is required.

RAI 7

The NRC staff notes that the current KSU reactor TSs, in general, use all capital letters to denote terms that are defined in the TS definitions (Section 1 of the TSs). However, the proposed TSs do not appear to use this formatting uniformly. For example (not an exhaustive list), proposed TS 3.4.4.B uses the term "control rod," which is defined in Section 1 of the TSs, but it is not in all capital letters, and proposed TS 5.1.3(1) uses "shall," but it is not in all capitals. Revise the proposed TSs (for any TSs in which changes are proposed) to consistently use all capital letters to denote defined terms, or justify why no change is required.

RAI 8

In its LAR, as supplemented, KSU proposed to add new TS 3.8.3(4), which would limit the reactor pool temperature to 37 degrees C (99 degrees F) when there is an experiment installed in an interstitial flux wire port. KSU stated that it proposed this limit (which is less than the 44 degrees C (111 degrees F) limit in proposed TS 3.8.3(1) when the ports are empty) because the presence of an experiment in these holes may reduce the temperature at which bulk boiling will occur. However, the LAR, as supplemented, does not appear to provide any basis or analysis supporting the specific choice of 37 degrees C (99 degrees F). Provide an adequate basis for the 37 degrees C (99 degrees F) limit in proposed new TS 3.8.3(4). The basis for this limit could consist of appropriate analyses demonstrating that when the interstitial flux wire ports are obstructed, a 37 degree C (99 degree F) pool temperature limit would ensure that a SL would not be exceeded (including due to a loss of flow stability), for any allowable condition of normal operation, or any credible accident scenario. Alternatively, justify why no additional information is required.

RAI 9

In its LAR, as supplemented, KSU proposed to add new TS 3.8.3(4), and an associated action statement which is designated as new TS 3.8.4.B. However, the NRC staff notes that proposed TS 3.8.4 appears to contain two items designated "B." Additionally, while proposed TS 3.8.3(4) is the fourth of the 4 specifications listed under proposed TS 3.8.3, the corresponding proposed TS 3.8.4.B is the second of 4 action statements listed under proposed TS 3.8.4.

Revise proposed TS 3.8.4 to correct the apparent editorial error, and clarify which action statement in proposed TS 3.8.4 corresponds to proposed TS 3.8.3(4) (for example, by re-designating the second action statement under proposed TS 3.8.4 as proposed TS 3.8.4.D, and moving it to the end of the list of action statements under proposed TS 3.8.4, if appropriate). Alternatively, justify why no change is required.

RAI 10

In its LAR, as supplemented, KSU proposed to add new action statement TS 3.8.4.B, which would state:

[CONDITION]	[REQUIRED ACTION]	[COMPLETION TIME]
B. Bulk water temperature exceeds 37°C with an experiment installed in an interstitial flux wire port.	B.1 ENSURE the reactor is SHUTDOWN AND B.2 Reduce bulk water temperature to less than 37°C. OR B.3 Remove experiment from flux wire port	B.1 IMMEDIATE B.2 IMMEDIATE B.3 IMMEDIATE

However, the NRC staff notes that the "and/or" logic in the center column of the action statement appears to be ambiguous. It is not clear whether both of items B.1 and B.2, *or* only item B.3, are required, or whether item B.1 *and* either item B.2 or item B.3 is required. Propose a revised TS 3.8.4.B which clarifies the "and/or" logic, or justify why no change is required.

RAI 11

Proposed LCO TSs 3.8.3(1) and 3.8.3(4) would impose limits on the bulk water temperature of the reactor pool. However, the proposed KSU reactor TSs do not appear to include an existing or proposed surveillance requirement for pool temperature. Propose a surveillance TS for pool temperature, or justify why no change is required.

RAI 12

In its response to RAI 2 submitted May 2, 2017, KSU proposed to add new TS 3.10, which would impose requirements on maximum steady-state power level and power level scram points. KSU stated that the purpose of the new TS 3.10 is, in part, to address the issue that the current reactor console instruments are not capable of reading up the full licensed power limit of 1,250 kW(t).

KSU's response to RAI 2 submitted May 2, 2017, also stated that "the upgraded control console instrumentation planned for installation in January 2018 is capable of reading 1.25 MW of power." Additionally, in a public meeting with the NRC staff on November 7, 2017 (see ADAMS Accession No. ML17319A064), KSU stated that it expected to complete its control console upgrade in 2018.

It is not clear to the NRC staff whether the upgraded control console instrumentation has been installed, or what the status of the planned installation is, or whether the KSU reactor instrumentation is still the original instrumentation discussed in KSU's response to RAI 2 submitted May 2, 2017. Discuss the status of the instrumentation upgrade, or justify why no additional information is required.

RAI 13

In its LAR, as supplemented, KSU proposed to add new TS 3.10.3(2), which would state, "[a] required reactor power level scram is set to a value no greater than 1,250 kWth." In its response to RAI 2 submitted May 2, 2017, KSU stated that the purpose of the new TS 3.10 is, in part, to address the issue that the current reactor console instruments are not capable of reading up the full licensed power limit of 1,250 kW(t). Additionally, KSU's corresponding action statement for proposed TS 3.10.3(2), which is found in proposed TS 3.10.4.B, requires that if "[a] required reactor power level scram is set to a value above 1,250 kW(t) or above the maximum readable value on a required channel," KSU must "[a]djust reactor power level scram setpoint to a readable value less than or equal to 1,250 kWth."

The NRC staff notes that proposed TS 3.10.3(2) requires that a power level scram be set at or below 1,250 kW(t) (the maximum licensed power of the KSU reactor), but does not appear to require that a power level scram also be set below the highest readable value of the scram channel. Therefore, the NRC staff notes that proposed TS 3.10.3(2) does not appear to be consistent with the purpose of proposed TS 3.10 (as discussed in KSU's response to RAI 2 submitted May 2, 2017), or with proposed action statement TS 3.10.4.B. The NRC staff also notes that existing TS 3.4.3(1) requires that two power level scram channels be operable, but proposed TS 3.10.3(2) only appears to require that one of the required scrams be set to an appropriate value. Additionally, the NRC staff notes that proposed TS 3.10.3(2) uses the language "is," which appears to be inconsistent with the existing TS definition of "shall" to denote a requirement.

Revise proposed TS 3.10.3(2) to be consistent with the stated purpose of proposed TS 3.10, and with proposed TS 3.10.4.B; to clearly require that both of the two power level scrams required by existing TS 3.4.3(1) be set to an appropriate value; and to be consistent with the TS definition of "shall." Alternatively, justify why no change is required.

RAI 14

Proposed new TS 3.4.3(3) would require that “[a] minimum of three CONTROL RODS must be OPERABLE. Inoperable CONTROL RODS must be fully inserted.” The NRC staff notes that proposed TS 3.4.3(3) uses the language “must” (2 instances), which appears to be inconsistent with the existing TS definition of “shall” to denote a requirement. Revise proposed TS 3.4.3(3) to be consistent with the TS definition of “shall,” or justify why no change is required.

RAI 15

Proposed new action statement TS 3.10.4.B, in the “COMPLETION TIME” column, appears to contain an extraneous “AND” that is inconsistent with the “COMPLETION TIME” columns for other existing and proposed action statement TSs. Revise proposed TS 3.10.4.B to correct the apparent editorial error by deleting the “AND,” or justify why no change is required.

RAI 16

The guidance in ANSI/ANS-15.1-2007, Section 4.2, recommends that TSs require that scram channels be checked for operability, including trip/shutdown action, every 24 hours or quarterly. The guidance in NUREG-1537, Section 1, Appendix 14.1, recommends that surveillance TSs require that channel tests of all scram and power measuring channels required by TSs, including scram actions with safety rod release, should be performed before each reactor startup following a shutdown of more than 24 hours, or following each secured shutdown.

Proposed new TS 3.10.3(2) would impose a requirement for the maximum setpoint of required reactor power level scrams (existing TS 3.4.3(1) requires that two reactor power level scrams be operable).

Existing TS 4.3.2 requires a daily channel test of the reactor power level measuring channels. However, existing TS 4.3.2 does not appear to require that the scram function of the power level measuring channels be verified to be operable. Therefore, the existing or proposed KSU TSs do not appear to include any surveillance TS to verify the operability of the required power level scrams, which could be needed to ensure that a SL is not exceeded if, for example, an unplanned reactivity transient occurred. Provide an appropriate surveillance TS for the operability of these scrams, or justify why no change is required.

RAI 17

Proposed new TS 5.1.3(3) would state:

> A maximum of four fuel elements with greater than 9.0 weight percent uranium may be installed in the core. These elements shall only be placed in lattice positions in the E-and F-rings of the core that meet the following condition: using a properly scaled top-view drawing of the reactor core grid plate, a line segment drawn from the center of any lattice position populated with a control rod or a water channel to the candidate lattice position must intersect the boundary of at least one additional lattice position.

Provide the following, or discuss why no additional information or TS changes are required:

a. Proposed TS 5.1.3(3) would require that 12 wt% U elements be placed in core positions not adjacent to “a water channel.” However, the NRC staff notes that it is not clear whether "water" channels mean only empty channels, or also other channels that are not "empty" but do not contain fuel (e.g., the neutron source holder position, or an experiment position such as a pneumatic transfer position). Revise proposed TS 5.1.3(3) to clarify what is meant by "a water channel."

b. Proposed TS 5.1.3(3) would provide criteria that would determine whether a lattice position would be considered to be adjacent to a control rod or a water channel, for the purposes of determining whether 12 wt% U fuel would be allowed in the lattice position. However, the NRC staff notes that the criteria appear to be ambiguous because it is not clear if the line segment would be drawn from "the center of any lattice position populated with a control rod or a water channel" to the center of the candidate position, or to any point on the candidate position. Revise proposed TS 5.1.3(3) to clarify which lattice positions would be considered to be adjacent to a control rod or water channel. To help ensure clarity, the NRC staff also recommends that KSU provide examples of locations where TS 5.1.3(3) would allow or not allow 12 wt% U fuel to be placed, based on a scale drawing of the grid plate.

c. The NRC staff notes that proposed TS 5.1.3(3) uses the language "must" which appears to be inconsistent with the existing TS definition of "shall" to denote a requirement. Revise the "must" language in proposed TS 5.1.3(3) to be consistent with the TS definition of "shall."

d. Proposed TS 5.1.3(3) would state that up to four fuel elements with greater than 9.0 wt% U may be placed in the core. However, the NRC staff notes that the proposed TSs, including proposed TS 5.1.3(3), would not appear to specifically prohibit more than four elements with greater than 9.0 wt% U from being placed in the core. Revise proposed TS 5.1.3(3) to clarify that more than four elements with greater than 9.0 wt% U shall not be placed in the core, consistent with the existing TS definitions and the analyses provided in the LAR, as supplemented.

RAI 18

The regulations in 10 CFR 50.34(b)(2) require that applications contain a description and analysis of the SSCs of the facility, with emphasis upon performance requirements; the bases, with technical justification therefor, upon which such requirements have been established; and the evaluations required to show that safety functions will be accomplished.

The guidance in NUREG-1537, Part 1, Section 4.5.1, states that licensees should present information on core geometry and configurations, including the LCC, and other proposed operating core configurations that are demonstrated to be encompassed by the safety analysis of the LCC. The guidance in NUREG-1537, Part 1, Section 4.6, states that licensees should present information on the thermal power density distribution in the fuel and heat fluxes into the coolant of each channel and along the channel, derived from fuel loading and neutron flux characteristics.

a. Figure 2 of KSU's response to RAI 1 submitted May 2, 2017, provides a plot of the heat flux along the axial length of the hot fuel element. This is the heat flux profile used in KSU's updated steady-state thermal-hydraulic analyses. Additionally, page 4-22 of the updated pages of KSU's SAR for its reactor, which KSU submitted with its LAR supplement dated November 30, 2018, states that the updated thermal-hydraulic analysis used "an appropriate axial power profile."

However, it is not clear how this axial power profile and corresponding heat flux profile assumed for the updated thermal-hydraulic calculations were determined, and whether or why they are appropriately conservative and bounding. Discuss how the axial power and heat flux profiles were determined and why they are appropriate for any calculations in which they are used (including analyses supporting KSU's ability to operate the reactor with one rod inoperable and fully inserted (see RAI 4)), or justify why no additional information is required.

b. In its RAI response dated October 5, 2016, KSU submitted neutronics calculations, which were updated and corrected in response to previous NRC staff RAIs. KSU's analyses demonstrated that when four 12 wt% elements are placed in designated locations in the E-ring in an 85 fuel element core, the power peaking factor (element-to-average) is approximately 1.65, and that this is similar to the peaking factor for an 85 element core with all 8.5 wt% elements (the peaking factor for the all 8.5 wt% core is slightly higher, but still approximately 1.65).

   Additionally, in its response to RAI 1 submitted May 2, 2017, KSU submitted updated steady-state thermal-hydraulic analyses. KSU's new thermal-hydraulic calculations appear to use a hot element peaking factor of 1.63, and a core thermal power of 1,250 kW(t) (corresponding to a hot element power of 24 kW(t) for an 85 element core).

   Given that KSU's steady-state thermal-hydraulic analyses appear to assume a lower peaking factor than the maximum peaking factor calculated for KSU's neutronics calculations (i.e., the peaking factor for the LCC), it is not clear whether KSU's steady-state thermal-hydraulic analyses are appropriately bounding. Provide revised steady-state thermal hydraulic analysis that assume a core power density (including element-to-average peaking factor) that is at least as conservative as the bounding power-density determined by KSU's neutronics calculations; discuss why KSU's steady-state thermal hydraulic analyses submitted in response to RAI 1 on May 2, 2017, are appropriately conservative; or justify why no additional information is required.

RAI 19

The regulations in 10 CFR 50.34(b)(2) require that applications contain a description and analysis of the SSCs of the facility, with emphasis upon performance requirements; the bases, with technical justification therefor, upon which such requirements have been established; and the evaluations required to show that safety functions will be accomplished.

The guidance in NUREG-1537, Part, 1, Chapter 13, describes the types of research reactor accidents that licensees should analyze. These accidents include loss-of-coolant accidents (LOCAs).

The guidance in NUREG-1537, Part 1, Appendix 14.1, states that to avoid compromising fuel integrity for stainless-steel clad TRIGA fuel, when the cladding temperature is greater than 500 degrees C (932 degrees F), the peak fuel temperature should not exceed 950 degrees C (1,742 degrees F). The NRC staff notes that the cladding temperature could exceed 500 degrees C (932 degrees F) during a LOCA.

In its response to RAI 7 submitted April 28, 2014, KSU discussed its justification for its determination that the LOCA analysis in its license renewal SAR, as supplemented, would continue to be bounding for existing cores or proposed cores with 12 wt% U fuel. KSU stated that its existing LOCA analysis would continue to be bounding because the maximum fission product density, and therefore decay heat and temperature, in the core would not increase beyond what was assumed for the LOCA analysis in the license renewal SAR, as supplemented.

However, the NRC staff noted that the existing LOCA analysis appears to use certain methodologies and assumptions which may not be appropriate and/or bounding for proposed operation. Specifically, the analysis assumes that the thermal resistance of the fuel cladding and gap is negligible, which may not be realistic. Additionally, the analysis appears to assume that the air temperature will be at ambient (27 degrees C (81 degrees F)) throughout the LOCA event, but the NRC staff notes that the air temperature could rise following the LOCA. The analysis also appears to assume that the initial fuel temperature is at ambient when the LOCA occurs, which may not reflect maximum reactor fuel temperatures for proposed operation. Also, the analysis only appears to consider the fuel temperature immediately after the LOCA occurs. The NRC staff notes that, for an instantaneous LOCA occurring simultaneously with reactor shutdown, the reactor fuel temperature generally increases for some period of time following the LOCA due to the decay heat produced in the fuel; therefore, the peak fuel temperature may occur after some time has elapsed since the core becomes uncovered. The analysis is also based on a decay heat curve which appears to indicate lower decay heat production following infinite reactor operation, compared to curves based on data from commonly used decay heat information sources (e.g. ANSI/ANS-5.1-2014, “Decay Heat Power in Light Water Reactors”), indicating that the decay heat curve used may not be appropriately conservative.

Therefore, provide an updated LOCA analysis that uses appropriate and conservative assumptions and methodologies, and is bounding for proposed operation. The initial maximum fuel temperature at the onset of the LOCA event should be based on the updated steady-state thermal-hydraulic calculations in KSU’s LAR, as supplemented, and the decay heat produced in the hottest element should be based on maximum element peaking factors. The LOCA analysis may use a RELAP computer model, if appropriate. As appropriate, the analysis may credit the time it would take to drain the reactor pool such that the core would be no longer be covered in water. The analysis should demonstrate that the maximum fuel temperature following a LOCA would not exceed 950 degrees C (1,742 degrees F).

Alternatively, discuss why the existing LOCA analysis would continue to be bounding, considering its methodologies and assumptions discussed above; or, justify why no additional information is required.

RAI 20

Proposed TS 3.10.3(1) would require that the “[m]aximum OPERATING thermal power SHALL NOT exceed 1,000 [kW(t)] in STEADY STATE MODE.” Proposed action statement TS 3.10.4.A would require that, if reactor power exceeds 1,050 kW(t) while the reactor is operating in steady-state mode, KSU must immediately reduce reactor power to a level no greater than 1,050 kW(t).

In its response to RAI 2 submitted May 2, 2017, KSU stated that although proposed TS 3.10 would establish a maximum steady-state power of 1,000 kW(t), it would not require KSU to take action to reduce power unless the power level reached 1,050 kW(t). The NRC staff notes that this would allow for the small fluctuations in power (above or below the steady-state power level) that would be expected to occur when the reactor is operating at a steady-state power level of 1,000 kW(t).

However, the NRC staff notes that while proposed TS 3.10.4.A indicates that no action is required until the reactor power reaches 1,050 kW(t), proposed TS 3.10.3(1), as written, appears to impose an absolute reactor power limit of 1,000 kW(t) (which would not allow fluctuations above 1,000 kW(t)), rather than a 1,000 kW(t) limit on steady-state reactor power (which would allow for small fluctuations above 1,000 kW(t)). Therefore, the wording of proposed TS 3.10.3(1) does not appear to be consistent with proposed TS 3.10.4.A, or the intent of proposed TS 3.10 as discussed in KSU's response to RAI 2 submitted May 2, 2017.

Revise proposed TS 3.10.3(1) to clarify that steady-state reactor power shall not exceed 1,000 kW(t) when the reactor is operated in steady-state mode. Alternatively, justify why no change is required.

RAI 21

In its response to NRC staff RAI 12 submitted October 5, 2016, and its response to RAI 5 submitted May 2, 2017, KSU proposed to add a new TS 3.4.3(3), which would require that a minimum of three control rods be operable when the reactor is operating in either steady-state or pulse mode. Additionally, KSU proposed to add new TS 3.4.4.B, which would delineate required actions if proposed TS 3.4.3(3) is not met. Proposed TS 3.4.4.B would require that, if a control rod is not operable, KSU must immediately either ensure that the inoperable control rod is fully inserted, or ensure the reactor is shutdown. Although the proposed TSs would allow one of the four total control rods to be inoperable, they would also require that, if a rod is inoperable, it be fully inserted.

However, the NRC staff noted that, while proposed action statement TS 3.4.4.B delineates required actions (i.e., shut down the reactor, or ensure the inoperable rod is fully inserted) if one control rod is in inoperable, it would not clearly delineate the required action (i.e., shut down the reactor) if more than one control rod is inoperable. Additionally, the NRC staff noted that the proposed TSs do not appear to contain a corresponding surveillance TS requiring verification that an inoperable control rod is fully inserted as required by proposed TS 3.4.3(3).

Revised proposed TS 3.4 to include an action statement TS delineating the required action if more than one control rod is inoperable. Additionally, provide an appropriate corresponding surveillance TS for proposed TS 3.4.3(3). Alternatively, justify why no changes are required.

RAI 22

The guidance in ANSI/ANS-15.1-2007 recommends that TSs include a definition of "reactor secured," which should specify that a reactor is secured when it meets certain conditions, including that all control rods are fully inserted.

However, the existing KSU TS definition of "REACTOR SECURED MODE" does not appear to require that all control rods be fully inserted for the reactor to be considered secured (when the reactor is considered secured under item 2 of the existing TS definition). Proposed TS 3.4.3(3) would require that control rods be operable or fully inserted when the reactor is in modes other than secured mode (i.e., steady-state mode or pulse mode), and the NRC staff notes that the status of the control rods should also be specified when the reactor is in secured mode.

Therefore, propose a revised TS definition that would require that all control rods be fully inserted when the reactor is secured, or justify why no change is required.

<u>RAI 23</u>

The proposed TS 5.1.3(1) would state:

> The high-hydride fuel element shall contain uranium-zirconium hydride, clad in 0.020 in. of 304 stainless steel. It shall contain a maximum of 12.5 weight percent uranium which has a maximum enrichment of 20%. There shall be 1.55 to 1.80 hydrogen atoms to 1.0 zirconium atom.

Provide the following, or justify why no TS changes or additional information are required:

a. Although proposed TS 5.1.3(1) would allow fuel containing up to 12.5 wt% U, the NRC staff noted that KSU's updated neutronics and thermal-hydraulics analyses submitted in its RAI responses dated October 5, 2016, and May 2, 2017, appear to assume that the higher-loading fuel elements added to the core would be 12.3 wt% U. KSU stated that the fuel elements are nominally 12 wt% U, but it used 12.3 wt% for these analyses, and used 12.5 wt% for proposed TS 5.1.3(1), to account for manufacturing variation in the fuel.

   Given the 0.2 percent difference in the U loading assumed for KSU's updated analyses, and the maximum loading that would be allowed by proposed TS 5.1.3(1), either justify this difference, or revise proposed TS 5.1.3(1) to be consistent with the updated analyses.

b. The regulation in 10 CFR 50.64, "Limitations on the use of highly enriched uranium (HEU) in domestic non-power reactors," requires, in part, that in general, non-power reactors shall not use highly-enriched U fuel, which is fuel that contains U enriched to 20 percent or greater in uranium-235 (U-235).

   The current reactor license conditions permit KSU to possess fuel elements containing U enriched to less than 20 percent in U-235, but not fuel elements containing U enriched to equal to (or greater than) 20 percent in U-235. In its LAR, as supplemented, KSU has not proposed to change portions of the reactor license conditions related to enrichment.

   Given the requirement of 10 CFR 50.64, and given that KSU's existing and proposed new 12 wt% U fuel elements contain U that is enriched to less than 20 percent in U-235, revise proposed TS 5.1.3(1) to clarify that KSU reactor fuel has an enrichment of less than, but not equal to, 20 percent.

c. The guidance in NUREG-1537, Part 1, Appendix 14.1, Section 2.1, states that to avoid compromising fuel integrity for stainless-steel clad TRIGA fuel, when the cladding temperature is greater than 500 degrees C (932 degrees F), the peak fuel temperature should not exceed 950 degrees C (1,742 degrees F); when the cladding temperature is less than 500 degrees C (932 degrees F), the peak fuel temperature should not exceed 1,150 degrees C (2,102 degrees F). NUREG-1537, Part 1, Appendix 14.1, Section 2.1, states that these recommended SLs are for fuel with a hydrogen to zirconium ratio of 1.65.

The guidance in NUREG-1537, Part 1, Appendix 14.1, Section 2.1, also states that for aluminum-clad TRIGA fuel with a hydrogen to zirconium ratio of 1.0, the peak fuel temperature should not exceed 500 degrees C (932 degrees F).

Existing KSU TS 2.1.3(1) states that the reactor fuel temperature shall not exceed 1,150 degrees C (2,102 degrees F).

i. Section 4.2.1.b of the updated SAR pages provided with KSU's September 23, 2017, LAR supplement states that the ratio of hydrogen to zirconium atoms in the current 8.5 wt% U reactor fuel is nominally 1.6.

   However, the LAR, as supplemented, does not appear to specify the hydrogen to zirconium ratio for the proposed new 12 wt% U fuel. The NRC staff notes that, for stainless-steel clad fuel with a hydrogen to zirconium ratio above approximately 1.65, which would continue to be permitted by proposed TS 5.1.3(1), it is not clear whether the temperature limits recommended in NUREG-1537, Part 1, Appendix 14.1, Section 2.1, would still be valid.

   Discuss the hydrogen to zirconium ratio for the proposed new 12 wt% U fuel, and clarify whether it is nominally the same as the existing 8.5 wt% U fuel. Additionally, revise proposed TS 5.1.3(1) to specify the actual nominal hydrogen to zirconium ratio for existing and proposed new KSU reactor fuel, and require that all fuel has a ratio that helps ensure that the SL temperature in existing TS 2.1.3(1) remains valid.

ii. Section 4.2.1.a of the updated SAR pages provided with KSU's September 23, 2017, LAR supplement states that "[t]hree instrumented aluminum-clad Mark II elements are still available for use in the core." Table 4.1 in this SAR section indicates that these aluminum-clad fuel elements have a hydrogen to zirconium ratio of 1.0.

   However, it is not clear from the LAR, as supplemented, whether any aluminum-clad instrumented TRIGA elements are actually proposed to be used in the core; and if these elements will be used in the core, whether this was considered in the updated analyses provided in the LAR, as supplemented. The NRC staff notes that the SL in existing KSU TS 2.1.3 would not be consistent with the NUREG-1537 recommended SL for aluminum-clad fuel.

   The NRC staff also notes that while proposed TS 5.1.3(1) would impose requirements related to high-hydride fuel (the stainless-steel fuel), it would not clearly require that only stainless-steel fuel be used in the reactor core.

   Clarify that aluminum-clad instrumented TRIGA elements (or any other aluminum-clad TRIGA elements) are not used or proposed to be used in the reactor core. Additionally, revise proposed TS 5.1.3(1) to clearly require that only stainless-steel-clad (high-hydride) fuel shall be placed in the core, and clarify that proposed TS 5.1.3(1) is applicable to all fuel elements (standard and instrumented elements).