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

March 1, 2016

Dr. Ayman I. Hawari, Director
Nuclear Reactor Program
North Carolina State University
Department of Nuclear Engineering
Campus Box 7909
Raleigh, NC 27695-7909

SUBJECT: NORTH CAROLINA STATE UNIVERSITY PULSTAR RESEARCH REACTOR – REQUEST FOR ADDITIONAL INFORMATION REGARDING THE LICENSE AMENDMENT RELATED TO FUELED EXPERIMENTS USING ANY FISSIONABLE MATERIAL (TAC NO. MF5778)

Dear Dr. Hawari:

The U.S. Nuclear Regulatory Commission (NRC) staff is reviewing your application to amend Facility Operating License No. R-120, dated February 13, 2013 (available on the NRC's public website at www.nrc.gov under Agencywide Documents Access and Management System Accession No. ML13085A400, for the North Carolina State University (NCSU) Pulstar Research Reactor.

During our review, questions have arisen for which additional information is needed. The enclosed request for additional information (RAI) identifies the additional information needed to continue our review. We request that you provide responses to the enclosed RAI within 30 days from the date of this letter.

In accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 50.30(b), "Oath or affirmation," you must execute your response in a signed original document under oath or affirmation. Your response must be submitted in accordance with 10 CFR 50.4, "Written communications." Information included in your response that is considered sensitive or proprietary, that you seek to have withheld from the public, must be marked in accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding." Any information related to security should be submitted in accordance with 10 CFR 73.21, "Protection of Safeguards Information: Performance Requirements." Following receipt of the additional information, we will continue our review of your amendment request.

If you have any questions, or need additional time to respond to this request, please contact me at (301) 415-3724, or by electronic mail at Duane.Hardesty@nrc.gov.

Sincerely,

/RA/

Duane A. Hardesty, Senior Project Manager
Research and Test Reactors Licensing Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-297

Enclosure:
As stated

cc: See next page

cc:

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ADAMS Accession No.: ML15316A581 * concurrence via email NRR-088

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OFFICE OF NUCLEAR REACTOR REGULATION

REQUEST FOR ADDITIONAL INFORMATION FOR THE

LICENSE AMENDMENT RELATED TO FUELED EXPERIMENTS

USING ANY FISSIONABLE MATERIAL

NORTH CAROLINA STATE UNIVERSITY

LICENSE NO. R-120; DOCKET NO. 50-297

The U.S. Nuclear Regulatory Commission (NRC) staff is reviewing your application to amend Facility Operating License No. R-120, dated February 13, 2013, available on the NRC's public web site at www.nrc.gov under Agencywide Documents Access and Management System (ADAMS) Accession No. ML13085A400, for the North Carolina State University (NCSU) Pulstar Research Reactor. During our review of the NCSU License Amendment Request (LAR), the following questions have arisen for which additional information is needed. Provide responses within 30 days from the date of this letter.

1. The requested amendment to the NCSU License (ADAMS Accession No. ML13085A400) requests changes to the technical specifications (TSs) for conducting experiments using any fissionable material. NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the licensing of Non-Power Reactors, Format and Content," Part 1,Section 9.5, "Possession and Use of Byproduct, Source, and Special Nuclear Material," provides guidance that licensees should "clearly state the materials and areas of the facility requested to be authorized by the reactor license. The reactor license and TSs also will include regulatory conditions that apply to the management of such materials." The LAR does not provide any additional information related to the request regarding the types or quantities of additional materials regarding the receipt, storage, or use of these additional materials. Provide responses for the following:

    a. Describe any reviews and assessments of the NCSU licensed possession limits for the reactor license and indicate if the current possession limits and license conditions are adequate for the scope of the NCSU LAR, propose needed changes to the possession limits, or justify why no review is needed.

    b. Provide a description, which includes all of the additional licensed materials (as referenced in the NCSU LAR), the locations where the listed materials are to be stored or used, or justify why no description is needed.

    c. Discuss how radiation protection and any material control or security requirements will be met for the planned materials to be stored and used. Any information related to security requirements should be submitted in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 73.21, "Protection of Safeguards Information: Performance Requirements."

Enclosure

d. Describe any reviews and assessments of the NCSU facility broad scope license and reactor license and indicate if any additional license conditions need to be modified or incorporated within the scope of the NCSU Reactor License, R-120, or justify why no review is needed.

2. The following questions pertain to the "Assumptions and Data Sources" section on (page 3), of Attachment 1 to the NCSU LAR:

   a. The seventh assumption in the list states "Initially pure fissionable material is exposed, i.e., there is no initial inventory of fission products." Are all fueled experiments performed at the NCSU done so with initially pure fissionable material? Provide additional information/explanation for why fueled experiments, using previously irradiated material, were not considered for the accident analysis scenario for fueled experiments. Alternatively, provide a technical specification that limits fueled experiments to initially pure fissionable material.

   b. The eighth assumption states "Exposure times to personnel in the reactor building and to the public are estimated as 0.25 h and 24 h, respectively based on evacuation time from the reactor building and reactor building exhaust rates in the confinement mode." This assumption forms the basis for the accident analysis dose calculation and subsequent limiting fission rates.

      i. Provide documentation regarding the evacuation times at the NCSU reactor for personnel.
      ii. Provide documentation regarding the reactor building exhaust rates in the confinement mode.

   c. The fourteenth assumption in the list states "Buildup and fissions of transuranics is neglected," and assumption 15 states "Depletion by transmutation of fission products and fissionable materials (i.e., burnup) is neglected." Irradiation of a fueled experiment will result in higher dose calculation results when accounting for burned up material in the experiment. This may lead to a situation in which the limiting fission yields calculated for the accident analysis calculations actually varies as a function of operating time/burnup. Provide additional information/basis for why buildup of the fission products and transuranics in the fueled experiment was not considered in the accident analysis dose calculations. For example, plutonium produced in the irradiation of U-238 and U-232 produced in the irradiation of thorium.

3. The "Source Term" section of Attachment 1 to the NCSU LAR provides equations for N_i^0, $N_n(t)$, and $N_2(t)$ (page 7). Provide a reference for the equations listed on page 7 of Attachment 1.

4. The following questions pertain to possible typographical errors in the "Source Term" section of Attachment 1 to the NCSU LAR.

   a. On page 7, in equation Nn(t) should the symbol "pi" be replaced on the denominator of the summation of the Production Pi (1-e-kjt) term with a Product symbol (∏)

(kp-kj). Explain whether this was an editing error, or if it affects the calculated results.

b. On page 9 see equation N4(t) and note that a "+" may be missing at the end of the 2nd decay product, k2. Explain whether this was an editing error, or affects the calculated results.

c. On page 9, 7th line of equation, $N_4(t)$, the first term of $P_2B_2k_2B_{3m}K_{3m}B_3k_3[\ldots]$ equation may have a mistake in the denominator. Should the "k1" located in the denominator of the 1st equation be changed to "k2?" Explain whether this was an editing error, or affects the calculated results.

5. The "Source Term" section of Attachment 1 to the NCSU LAR provides equations for $N_3(t)$ and $N_4(t)$ (page 9 and page 10 respectively). Provide additional information regarding the solutions to the decay chain equations (e.g., $N_3(t)$ and $N_4(t)$). If taken from a reference, provide the reference.

6. The "Source Term" section of Attachment 1 to the NCSU LAR (page 14), states "Values of N for fission product decay chains for atomic masses from A = 66 to A =167 from the thermal and fast fission of various materials were determined as described above. The number of radionuclides evaluated was approximately 500." Provide a basis for the fission products that were analyzed in Attachment 1 including supporting analyses and references.

7. The "RELEASED (Dispersed) ACTIVITY" section of Attachment 1 to the NCSU LAR (page 20), states "Activity at end of time of production, A(t), is given by: $A(t) = \lambda N(t)$, where, t = time of production Decayed Activity, A(t + T) is given by: $A(t + T) = \lambda N(t + T)$." Provide units for the activity and the delayed activity equations on page 20.

8. The "External Dose Rates" section of Attachment 1 to the NCSU LAR (page 23), states "External dose rates from gamma radiation release from fissionable materials is a function of mass, fluence rate, and time. For radiological control purposes, external dose rates from gamma radiation is limited by facility procedures consistent with experimental limitations and conditions and 10 CFR 20 requirements including ALARA practices." Provide additional supporting analyses, procedures, and data to provide a more defensible basis for why external dose rates from gamma radiation are ignored. The use of all types of fissionable materials in the reactor during planned experiments may result in varied source terms of gamma radiation that may not have been accounted for in the existing shielding analysis. Provide additional analysis/basis for the external dose rates. Also, address non-gamma dose rates from fueled experiments, including radon released from uranium and thorium.

9. The "Experiment Limits" section of Attachment 1 to the NCSU LAR (page 24), provides a chart for the calculated dry and wet sample limiting fission rates versus irradiation time in black and white with similar types of symbols representing each data series. It is difficult to differentiate between the data series. Use a different symbol for the "All others" series of data in the calculated dry and wet sample limiting fission rates versus irradiation time in the graph or provide a colored graph.

10. The “Mass Limits” section of Attachment 1 to the NCSU LAR (page 26), states “For an incident uniform neutron fluence rate, the mass of the target may be determined from the limiting fission rate as follows:” Provide the value for the uniform fluence rate selected for the postulated accident analyses and a basis for the value selected.

11. The “Energy Release” section of Attachment 1 to the NCSU LAR (page 27), states “The energy release rate (RE) is calculated as follows:

    RE = (200 MeV per fission)(σφN) in MeV per second
    RE = (200 MeV per fission)(σφN) (1 watt / 6.243 E12 MeV per s), in watts
    Total energy release in Joules, J = (RE in watts)(Irradiation time in seconds).”

    Provide additional information regarding the calculation of the energy release rate (RE) such as the units for the fission rate (assumed to be fissions/sec). In addition, discuss whether the conversion from MeV/sec should be changed to show that
    1 W-s = 6.243E12 MeV.

12. The “Example Calculations” section of Attachment 1 to the NCSU LAR (page 30), states “N(t) evaluated at a production time, t, of 1.73 E5 seconds (or 2 days) gives:
    N(1.73E5s) = 4.30 E10 atoms of Sn-133
    N(1.73E5s) = 2.81E14 + 3.19E14 = 6.00 E14 atoms of Te-133
    N(1.73E5s) = 2.45 E16 + 3.59 E16 + 4.04 E16 = 1.01 E17 atoms of 1-133

    a. The explanation of the number of atoms of Te-133 on page 30 does not match the results provided in the table on page 31. Provide the additional information, correction, or explanation for this apparent discrepancy.

    b. Provide an additional explanation for how the resulting atom populations are calculated.

13. The regulation in 10 CFR Part 20, Appendix B, Table 1, “Occupational Values,” states that the value for Tellerium-133 is 9E-6 uCi/ml. The “Dry Sample (example)” section of Attachment 1 to the NCSU LAR (page 37), states “Te-133: Rem = [9.48E-4 uCi/ml *(1 – $e^{-0\ 966}$) * 5 rem] / [3.86 per h* 2000 h * 3E-5 uCi/ml] = 1.52 E-2 rem (effective).” The Table 1 DAC value for Tellerium-133 in 10 CFR Part 20, Appendix B, is 9E-6 uCi/ml which is much less than the 3E-5 uCi/ml value that is listed on page 37 of Attachment 1. Provide an explanation for this difference.

14. The “Example Calculations” section of Attachment 1 to the NCSU LAR (page 40), states “For the fission of 1 g of U-235 by thermal neutrons at a fluence rate of 1 E13 $cm^{-2}s^{-1}$, doses and f/s are calculated for times from t = 10s to t = 3E7s.:” Were the total fissions in the 8th column of the table on page 40 calculated or assumed values? Provide additional information for the selection or calculation of these values.

15. The “Detailed Calculation Results for the Thermal Fission of U-235” section of Attachment 1 to the NCSU LAR (page 42), shows a “Dry Rem Bay Thy” result of 1.55E+00 and on page 41, t=100 s, to T=0 s shows a “Dry Environment THY Rem” result of 1.43E+00. The value “Dry Rem Bay Thy” listed in the table on page 41 is not the same value as that listed on page 40 of the 3rd set of example calculations

(t=0 to t=100 s). Provide an explanation for this difference and if this difference affects the calculated results.

16. Attachment 1 to the NCSU LAR (page 44), shows calculated dose results for an example based on the 100 sec irradiation of 1 gram of U-235 material followed by 300 sec decay time. The dose conversion factors used to produce the calculated dose values are not provided anywhere in Attachment 1. Provide the dose conversion factors used to obtain these results.

17. As stated in the Regulatory Position section (page 2.2-3), of NRC Regulatory Guide 2.2, "Development of Technical Specifications for Experiments in Research Reactors," "The safety-oriented considerations from which technical specifications for experiments should be developed include (1) the physical conditions of the design and conduct of experiments, (2) the materials content of experiments, and (3) the administrative controls employed to evaluate, authorize, and carry out experiments."

    a. Provide or describe the procedure that specifies to researchers how the incident neutron flux in which the fueled experiment is to be irradiated is determined for input to the fission rate calculation.

    b. Provide an example calculation, in the form that it would be reviewed for approval by the NCSU review committee for each of the following, using the methodology in proposed Amendment 18.
        i. U-238/U-235 sample with no previous irradiation.
        ii. Thorium/U-233 sample with no previous irradiation.
        iii. If samples with previous irradiation history are permitted, provide sample calculations for each of the above with previous irradiation assumed.

    c. Provide or describe the procedure by which either:
        i. the actual irradiation history of the fueled experiment is determined to validate that limits were not exceeded during the irradiation, or
        ii. the fueled experiment is analyzed after irradiation to determine that limits were not exceeded.

18. The "Comparison of Atom and Activity Calculations to Nuclear Analysis 1.0" section of Attachment 1 to the NCSU LAR (page 55), provides a comparison of the results between the equations used in this calculation for the 4 and 6 pathway and the 4 pathway Nuclear Analysis 1.0 decay branching fractions for two cases. The section states "all of the above are in good agreement with the exception of Xe-133m and Xe-133. Nuclear Analysis 1.0 does not list a IT decay branching fraction for Xe-133m, which affects the atom calculations for both Xe-133m and Xe-133." For both Case 1 and Case 2 data, it appears that calculated I-133 results when compared to the I-133 results for Nuclear Analysis 1.0 do not closely agree. Provide an explanation of the disparity or provide a revision to the conclusions for this section.

19. Attachment 1 to the NCSU LAR (page 59), provides a comparison of fission rate limits between the current amendment request and amendment 17 to the NCSU technical specifications in a figure with similar symbols for each data series. Update the graph using a more easily discernible symbol for each series in the graph or provide a colored graph to make it easier to see the differences between the three sets of data.