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RESEARCH REACTOR CENTER

July 30, 2012

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Mail Station P1-37
Washington, DC 20555-0001

Reference: Docket 50-186
University of Missouri-Columbia Research Reactor
Amended Facility License R-103

On August 24, 2011, the University of Missouri-Columbia Research Reactor (MURR) submitted a request to amend the Technical Specifications appended to Facility License R-103. Enclosed is additional information that the U.S. Nuclear Regulatory Commission (NRC) requested via teleconference on June 6, 2012, regarding MURR's response to question No. 2 of the Request for Additional Information (RAI), dated April 12, 2012.

If you have any questions, please contact John L. Fruits, the facility Reactor Manager, at (573) 882-5319.

Sincerely,

Ralph A. Butler, P.E.
Director

RAB/djr

Enclosures

A020
NRR

1513 Research Park Drive Columbia, MO 65211 Phone: 573-882-4211 Fax: 573-882-6360 Web: www.murr.missouri.edu
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REFERENCE: Docket 50-186
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SUBJECT: Written communication as specified by 10 CFR 50.4(b)(1) regarding the response to the "University of Missouri-Columbia – Request for Additional Information, Re: License Amendment, Safety Limits (TAC No. ME7018)," dated April 12, 2012

By letter dated August 24, 2011, the University of Missouri-Columbia Research Reactor (MURR) submitted a request to the U.S. Nuclear Regulatory Commission (NRC) to amend the Technical Specifications (TSs), which are appended to Facility License R-103, because of an error that was discovered in the MURR Safety Limit (SL) Analysis while answering a relicensing Request for Additional Information (RAI) question.

On April 12, 2012, the NRC requested additional information and clarification regarding the proposed Amendment in the form of five (5) questions. By letter dated May 23, 2012, the MURR responded to those questions.

On June 6, 2012, via teleconference, the NRC requested additional information regarding the response to question No. 2, which asked, "*The new Safety Limit Analysis for MURR (application Attachment 11), Section F.4 assumes that the center test hole contains only moderator. It appears that this analysis does not address the effect of irradiation samples and experiment test tube canisters in the center test hole on the core heat flux. Please provide a summary of the effect of irradiation samples and canisters in the center test hole on the heat flux profile used for the hot channel factors of Table F.4.*"

Table 3-14 of MURR Technical Data Report TDR-0125, "Feasibility Analyses for HEU to LEU Fuel Conversion of the University of Missouri Research Reactor (MURR)," which was included in the response to question No. 2, provided a comparison of the hot stripe heat fluxes from an all fresh fuel element core to the worst-case mixed burnup cores for both highly-enriched uranium (HEU) and low-enriched uranium (LEU) fuel. The modeling also included two different flux trap configurations: "empty," i.e. only moderator, or "loaded with samples." The "loaded with samples" configuration consisted of the center test hole [The volume in the flux trap occupied by the removable experiment test tubes (TS 1.3)] filled entirely with samples that are "typically" irradiated weekly at MURR. The all-

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moderator configuration creates the highest moderation condition in the flux trap, which produces the highest thermal flux in fuel plate-1. Irradiation samples and the removable experiment test tubes (sample holder) in the center test hole both displace the moderator and absorb some of the neutron flux, which combine to reduce the thermal flux at fuel plate-1 and the corresponding power density. Therefore, the effect of irradiation samples and the sample holder inserted in the center test hole is a reduction in the hot channel power peaking factors used in the new MURR SL analysis.

The question that was raised during the June 6, 2012, teleconference was what if a fueled experiment or material with moderating characteristics better than light water was placed in the center test hole. Enclosed is the additional information that was requested based on that discussion.

If there are any questions regarding the attached response please contact me at (573) 882-5319. I declare under penalty of perjury that the foregoing is true and correct.

Sincerely,

John L. Fruits
Reactor Manager

ENDORSEMENT:
Reviewed and Approved,

Ralph A. Butler, P.E.
Director

xc: Reactor Advisory Committee
Reactor Safety Subcommittee
Dr. Robert Duncan, Vice Chancellor for Research
Mr. Alexander Adams, U.S. NRC
Mr. Craig Bassett, U.S. NRC

MARGEE P. STOUT
My Commission Expires
March 24, 2016
Montgomery County
Commission #12511436

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MARGEE P. STOUT
My Commission Expires
March 24, 2016
Montgomery County
Commission #12511436

The following response is additional information, as requested by the NRC, to MURR's initial response to the question below regarding placing a fueled experiment or material with moderating characteristics greater than light water in the center test hole.

2. *The new Safety Limit Analysis for MURR (application Attachment 11), Section F.4 assumes that the center test hole contains only moderator. It appears that this analysis does not address the effect of irradiation samples and experiment test tube canisters in the center test hole on the core heat flux. Please provide a summary of the effect of irradiation samples and canisters in the center test hole on the heat flux profile used for the hot channel factors of Table F.4.*

   As stated above, irradiation samples and the removable experiment test tubes (sample holder) in the center test hole both displace the moderator and absorb some of the neutron flux, which combine to reduce the thermal flux at fuel plate-1 and the corresponding power density. Therefore, the effect of irradiation samples and the sample holder inserted in the center test hole is a reduction in the hot channel power peaking factors used in the new MURR Safety Limit (SL) analysis.

   The irradiation samples that were modeled consisted of a configuration of "typical" samples that are irradiated weekly at MURR. Based on the discussion that occurred on June 6, 2012, additional MCNP runs were performed in which the samples consisted of a fueled experiment or material with moderating characteristics better than light water, such as paraffin.

   In addition to all of the reactivity and experimental limitations listed in Sections 3.1 and 3.6 of the Technical Specifications (TS), specifications that are specific to a fueled experiment include:

   1. TS 3.6.a – "Each fueled experiment shall be limited such that the total inventory of iodine isotopes 131 through 135 in the experiment is not greater than 150 Curies and the maximum strontium-90 inventory is no greater than 300 millicuries."

   2. TS 3.6.n – "The maximum temperature of a fueled experiment shall be restricted to at least a factor of two below the melting temperature of any material in the experiment. First-of-a-kind fueled experiments shall be instrumented to measure temperature."

   3. TS 3.6.o – "Fueled experiments containing inventories of Iodine 131 through 135 greater than 1.5 Curies or Strontium 90 greater than 5 millicuries shall be in irradiation containers that satisfy the requirements of specification 3.6.i or be vented to the exhaust stack system through HEPA and charcoal filters which are continuously monitored in radiation levels."

   Additionally, another specification of significance regarding a fueled experiment, which also applies to any experiment, is TS 3.6.h, which states, "Cooling shall be provided to prevent the surface temperature of a submerged irradiated experiment from exceeding the saturation temperature of the cooling medium." A conservative heat flux limit of 100 W/cm^2 has been established for samples irradiated in the center test hole in order to comply with this specification.

   Below is the applicable section of Table F.4, "Summary of MURR Hot Channel Factors," that was included in the revised Appendix F, "Safety Limit Analysis for the MURR," that provides the SL

nuclear peaking factors. The revised Appendix F was included in the original Amendment submittal, dated August 24, 2011.

<u>On Heat Flux From Fuel Plate-1</u> – **All-Moderator State in the Center Test Hole**

Power-related Factors	For mesh interval between the following inches down the fuel plate		
Mesh Interval Number	14(13-14")	18(17-18")	19(18-19")
Nuclear Peaking Factors			
Fuel Plate (Hot Plate Average)	2.215	2.215	2.215
Azimuthal Within Plate	1.070	1.070	1.070
Axial Peak	1.3805	1.2958	1.2266
Additional Allowable Factor	1.062	1.062	1.062
Engineering Hot Channel Factors			
Fuel Content Variation	1.030	1.030	1.030
Fuel Thickness/Width Variation	1.150	1.150	1.150
Overall Product	**4.116**	**3.863**	**3.657**

A fueled experiment with the following specifications and operating under the listed conditions was modeled in the center test hole:

a. **Mass**: 0.5 grams of UAl_x with 0.19 grams of highly-enriched uranium (93% enriched in the isotope ^{235}U)
b. **Irradiation container**: Standard 2-inch long aluminum sample can with a surface area of 45.622 cm^2 (excluding top and bottom for heat flux calculations)
c. **Irradiation time**: 150 hours (MURR typical weekly operating cycle)
d. **Total neutron flux**: 9.48E14 n/cm^2-sec (42% thermal)

Based on the above specifications and operating conditions, the fueled experiment would produce a total iodine inventory of 153 Curies, slightly greater than the limit of TS 3.6.a. The experiment would also produce a total power of 24.5 kW, which creates a surface heat flux of 537 W/cm^2 – more than 5 times the administrative limit of 100 W/cm^2, thus violating TS 3.6.h. Therefore, using these extremely conservative values, the nuclear peaking factors with a fueled experiment in the center test hole would be as follows:

<u>On Heat Flux From Fuel Plate-1</u> – **Fueled Experiment in the Center Test Hole**

Power-related Factors	For mesh interval between the following inches down the fuel plate		
Mesh Interval Number	16(15-16")	18(17-18")	19(18-19")
Nuclear Peaking Factors			
Fuel Plate (Hot Plate Average)	1.998	1.998	1.998
Azimuthal Within Plate	1.070	1.070	1.070
Axial Peak	1.3969	1.3200	1.2542
Additional Allowable Factor	1.062	1.062	1.062
Engineering Hot Channel Factors			
Fuel Content Variation	1.030	1.030	1.030
Fuel Thickness/Width Variation	1.150	1.150	1.150
Overall Product	**3.757**	**3.550**	**3.373**

As can be seen from the table, the overall product for each stated fuel plate-1 mesh interval with a fueled experiment modeled in the center test hole is much lower than the all-moderator configuration.

The center test hole was then modeled with liquid paraffin in all three tubes of the sample holder. The paraffin was placed in standard aluminum sample cans (4-inch long x 1.125-inch diameter) that filled the entire volume of each tube. Paraffin is defined as any chain of hydrocarbon. For the most conservative case, the best paraffin-type moderator would be the one with the highest hydrogen-to-carbon ratio, which is methane (CH_4). However, methane is a gas at room temperature and is not an effective moderator in this state. Although its boiling point is about 110K, methane was conservatively modeled in its liquid state with a density of 0.5 grams/cm^3 since detailed thermal neutron scattering cross-section data exists for this condition.

On Heat Flux From Fuel Plate-1 – **Liquid Paraffin in the Center Test Hole**

Power-related Factors	For mesh interval between the following inches down the fuel plate		
Mesh Interval Number	14(13-14")	18(17-18")	19(18-19")
Nuclear Peaking Factors			
Fuel Plate (Hot Plate Average)	1.8993	1.8993	1.8993
Azimuthal Within Plate	1.070	1.070	1.070
Axial Peak	1.3836	1.3043	1.2473
Additional Allowable Factor	1.062	1.062	1.062
Engineering Hot Channel Factors			
Fuel Content Variation	1.030	1.030	1.030
Fuel Thickness/Width Variation	1.150	1.150	1.150
Overall Product	**3.537**	**3.334**	**3.189**

Once again, as can be seen from the above table, the overall product for each stated fuel plate-1 mesh interval with liquid paraffin modeled in the center test hole is much lower than the all-moderator (i.e., light water) configuration. The hydrogen atom density of light water is 6.69E22 atoms/cm^3 whereas for paraffin it is 7.53E22 atoms/cm^3. However, the void effect from the amount of aluminum in the sample cans and the sample holder more than counteracts the moderating effect from a higher paraffin hydrogen atom density. Additionally, as required by irradiations procedure IRR-PSO-110, "Target Encapsulation," all sample cans that are placed in the reactor pool must meet minimum mass requirements to ensure negative buoyancy. The minimum mass is at least 15% above the equivalent water volume mass (i.e., volume x 1.15). The volume of a standard 4-inch long sample can is 65.1 cm^3. A minimum mass of 75.0 grams is required to ensure that the sample can will sink when placed in the pool. The density of liquid paraffin is approximately 0.5 grams/cm^3; therefore, a 4-inch long sample can would only have a mass of approximately 32.6 grams if filled entirely with paraffin. The addition of 42.5 grams of ballast that would be required to ensure negative buoyancy would then further reduce the amount of volume available for paraffin in the can.

In conclusion, based on these additional MCNP runs, the week 58 mixed core case at startup with no samples or sample holder inserted in the center test hole; i.e. only light water moderator, still produces the highest power peaking factors.