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December 4, 2014

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
11555 Rockville Pike
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SUBJECT: REQUEST FOR ADDITIONAL INFORMATION REGARDING THE RENEWAL OF FACILITY OPERATING LICENSE NO. R-84 FOR THE AFRRI TRIGA REACTOR FACILITY (TAC NO. ME1587)

Sir or Madam:

By letter dated May 16, 2014, the Nuclear Regulatory Commission requested additional information necessary to continue its review of the AFRRI application for the renewal of Facility Operating License No. R-84 Docket 50-170. Answers to those questions are enclosed. In addition, an amended response based on discussions with our license renewal project manager regarding Ar-41 production is included.

If you need further information, please contact Mr. Steve Miller at 301-295-9245 or stephen.miller@usuhs.edu.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge. Executed on December 4, 2014.

Stephen I Miller
Reactor Facility Director

A020
NRR

1a. In the proposed Technical Specifications (TS) 3.3., "Coolant Systems," Specification b., states that "[t]he reactor shall not be operated if the conductivity of the water is greater than 2 micromhos/cm (or less than 0.5 x10^6 ohms-cm resistance) at the output of the purification system, averaged over one week." Demonstrate with calculations and analysis that this value of conductivity will limit the potential of Hydrogen (pH) of the water at the output of the purification system to the range 5.5 and 7.5 at all times, or submit a modification to the TS, and a surveillance that will ensure the pH remains within that interval.

The limit for conductivity of water at the output of the purification system (TS 3.3., Specification b) shall be removed from the Technical Specifications. Additionally, the sentence: "The 2 micromhos/cm is an acceptable level of water contaminants in an aluminum/stainless-steel system of the type at AFRRI" shall be removed from the basis.

The basis for monitoring water quality as described in NUREG -1537 Section 5.2 is to "provide a chemical environment that limits corrosion of fuel cladding, control and safety rod surfaces, reactor vessels and pools, and other essential components." Therefore, the water quality of the bulk pool water is of primary importance; while the water quality at the outlet of the purification system does not provide a reliable indication of the conditions in the open pool. As discussed in the response to question 1b, water monitoring of the bulk pool water shall remain in the Technical Specifications to satisfy the need for maintaining a proper chemical environment.

As a result of this, TS 4.3. "Coolant Systems," Specification b., shall be removed.

1b. In the proposed TS 3.3., "Coolant Systems," Specification c., it states that "[t]he reactor shall not be operated if the conductivity of the bulk water is greater than 5 micromhos/cm (or less than 0.2 x 10^6 ohms-cm resistance), averaged over one week ..." Demonstrate with calculations and analysis that this value of conductivity will limit the pH of the bulk water to between 5.5 and 7.5 at all times or, submit a modification to the TS, and a surveillance that will ensure the pH remains within that interval.

Technical Specifications 3.3., "Coolant Systems", Specification c., shall read:

"The reactor shall not be operated if the conductivity of the bulk water is greater than 5 micromhos/cm, averaged over one week."

The Surveillance Requirement in TS 4.3. "Coolant Systems," Specification e., shall be removed from the Technical Specifications along with the sentence in the basis reading "[t]he pH limit serves to minimize the corrosive environment within the primary water system."

In order to minimize the corrosive environment within the reactor pool, limit the activation of contaminants in the primary coolant during and immediately following reactor operations, and maintain optical clarity within the reactor pool, the primary coolant is monitored for water quality and passed through a purification loop. Prior to entering the purification loop, the water quality is measured with a conductivity/resistivity meter. The tracking of bulk water conductivity at this location provides both a real-time indication of the water quality within the reactor pool, as well as a means of monitoring water quality trends over time. This conforms with ANSI 15.1 which in Section 4.3 "Coolant systems" Item 6 states "Conductivity or pH, or both: Weekly to quarterly." The statement "[c]onductivity or pH" references two common analytical means of measuring water quality in water systems. AFRRI has historically selected conductivity measurements as the primary means of quantifying water quality. The rationale for maintaining this method is outlined below:

Ultrapure water naturally dissociates into H^+ and OH^- ions in a reversible reaction. The presence of these ions within ultrapure water yields a conductivity of 0.055 micromhos/cm at 25°C, representing the lower limit of conductivity in water. The concentration of ions present in water is dependent on temperature, with a concentration of H^+ ions equal to 1×10^{-7} moles/L at 25°C. As temperature increases, the concentration of ions increases as well and therefore pH is reported with temperature or corrected for temperature effects to reflect the value at a standard 25°C. This concentration of H^+ can be used to calculate pH using the formula:

$$pH = -\log[H^+]$$

Therefore, in ultrapure water with no contaminants present the pH is equal to 7. While both conductivity and pH are common methods for quantifying water quality, it is important to note the differences in each measurement and the limitations that result in each method being used for a particular purpose in a particular circumstance.

Conductivity is a measure of the ability of water to pass an electric current. As mentioned earlier, the natural dissociation of water into ions yields a minimum conductivity in water at 25°C of 0.055

micromhos/cm. With an increase of ions within water, the conductivity increases. These ions can either be positively or negatively charged, and conductivity measurements alone cannot be used to determine the source of contamination. On the other hand, pH is a measure of the acidity or basicity of an aqueous solution. In the presence of acidic or basic contaminants in water, the pH will increase or decrease based on the type and concentration of contaminant in the solution. Briefly, both conductivity and pH provide an indication of the purity of the water. The benefit of pH, however, is that it is possible to gain more information about the source of contamination rather than just being alerted to its presence. With that in mind, it would appear that pH is a preferred method for determining water quality. However, a key limitation of pH measurements is that they are very challenging in low conductivity water where the low concentration of ions inhibits electron transport between the measuring and reference sides of a pH electrode. As a result of this, pH measurements of low conductivity water are often unreliable and highly susceptible to errors in sample handling. A relevant and important example of this is the exposure of ultrapure (0.055 micromhos/cm) water to air. As carbon dioxide (CO_2) is absorbed by the water, CO_2 is converted to carbonic acid. Carbonic acid then dissociates into bicarbonate and carbonate, yielding a pH of approximately 5.5. When left to equilibrate in air, ultrapure water conductivity increases from 0.055 to approximately 1 micromho/cm. Therefore, low conductivity water in an open pool environment similar to that of the reactor pool at AFRRI will naturally have a pH dominated by absorbed CO_2. Other sources of interference when measuring pH of low conductivity water include: contamination from sampling containers, electrolyte contamination from reference electrodes, and temperature correction. Given these uncertainties in measuring pH in low conductivity solutions, the American Society for Testing and Materials (ASTM) in Standard D1193 "Standard Specification for Reagent Water" states that "pH at 25°C is not applicable in higher resistivity waters." ASTM Standard D1293 "Standard Test Methods for pH of Water" describes the two methodologies of measuring water pH with glass electrode sensors and states "neither test method is considered to be adequate for measurement of pH in water whose conductivity is less than about 5 micromhos/cm." Therefore, this method of measuring pH is not applicable for measuring pH of reactor bulk pool water which sets the maximum conductivity limit at 5 micromhos/cm.

NUREG-1537 Part 2 Section 5.2 "Primary Coolant System" discusses the acceptance criteria for information on the primary coolant system and specifically outlines the necessity to maintain a "chemical environment that limits corrosion of fuel cladding, control and safety rod surfaces, reactor vessels or pools, and other essential components." The paragraph continues to state, "[e]xperience at non-power reactors has shown that the primary water conditions, electrical conductivity $\leq$ 5 micromhos/cm and pH between 5.5 and 7.5, can usually be attained with good housekeeping and a good filter and demineralizer system." Over the many years of monitoring reactor bulk pool water conductivity at AFRRI, the conductivities observed are in agreement with the above statement. And given the relationship between conductivity and pH, it is likely that the pH range is correct as well. However, when considering the information provided above about pH measurements in low conductivity water, it is understood that the most effective means of monitoring water quality in the primary coolant is by maintaining conductivity within the range specified in the Limiting Conditions of Operation.

One final note relating to NUREG-1537 is the mention of potential for oxide formation on aluminum-clad fuel resulting in decreased heat conductivity in relation to water quality. However, this is not applicable at the AFRRI reactor because, as stated in AFRRI TS 5.2.1. "Reactor Fuel", fuel used in the AFRRI TRIGA reactor shall have 304 stainless steel cladding.

2. In the proposed TS 6.1.3.2., "Operations," item b., states in part, that "[a]n SRO (Senior Reactor Operator) shall be present at the reactor during the following operations:

1. *All fuel and control rod relocations within the reactor core region;*
2. *Initial reactor startup and approach to power;"*

However, initial reactor startup is not defined. In the previous TS, submitted November 28, 2011 (ADAMS Accession No. ML11341A133), TS 1.10 "Initial Reactor Startup," was defined. Justify why a definition for initial reactor startup is not needed or resubmit the technical specifications with the definition.

The Technical Specifications shall be amended to include the following two definitions:

<u>INITIAL REACTOR STARTUP</u>

The first reactor startup and approach to power following fuel element relocation within the core and/or any significant (>$0.25) core configuration changes.

<u>REACTOR STARTUP</u>

Startup of the reactor and approach to power following a period when the reactor is shutdown or secured.

3. The Reactor Operator Requalification Program, Section C., "Periodic Evaluation," submitted with the license renewal package states that "[t]he operating test shall be administered annually, not to exceed 15 months, to each licensed operator except the RFD (Reactor Facility Director)." It also states "[a] written examination shall be administered once near the end of each 24-month requalification cycle to each licensed operator except the RFD." Furthermore, the plan states, "[a]s the senior supervisor in charge, the RFD shall not be required to take written examinations or operating tests."

Contrary to the requirement in the regulations, these sentences exempt the RFD indefinitely from requirements of taking a written examination and operating test. Please propose changes to the Reactor Operator Requalification Program to ensure that no one individual is permanently exempt from meeting the requirements of 10 CFR 55.59, "Requalification;" (e.g. through the addition of a requirement that exam preparation is rotated among the senior reactor operators).

Section C, "Periodic Evaluation" shall be amended to read:

"The operating tests shall be administered annually, not to exceed 15 months, to each licensed operator by the Reactor Facility Director (RFD). The operating test for the RFD shall be administered by a Senior Reactor Operator (SRO). Successful completion is left to the discretion of the individual administering the test."

"Written examinations shall be administered every two years, not to exceed 27 months, to each licensed operator. Written examinations shall be automatically generated from a question bank and graded by the RFD."

In addition, the following sentences shall be removed from Section 3:

"The RFD is the senior technical manager and, as such, shall oversee the administration of written examinations. Additionally, he will give senior staff members operating tests. These senior staff members may then administer the remaining operating tests. As the senior supervisor in charge, the RFD shall not be required to take written examinations or operating tests."

Ar-41 Dose to Radiation Workers in the Reactor Bay

During reactor operations, Ar-41 is generated by thermal neutron activation of Ar-40 dissolved in both the primary coolant and air found in dry tubes extending from the reactor core and terminating in the reactor bay (Room 3161). To ensure that the radiation workers within the reactor bay do not exceed the annual dose limit of 5 rem, the derived air concentration (DAC) limit from 10 CFR 20 App. B is established as 3×10^{-6} μCi/ml. Assuming a 2,000 hour working year, Ar-41 concentrations below this DAC limit will result in Ar-41-related doses less than 10 CFR 20 limits.

In order to determine the Ar-41 production rate from reactor operations, various measurements from the stack gas monitor (SGM) were collected while operating the reactor mid-pool at 1 MW for 30 minute intervals. The measured production rate at 1 MW was 0.5 μCi/sec.

Assuming equilibrium conditions with negligible decay time from activation near the core to exhausting from the reactor bay, the DAC is calculated by combining the 0.5 μCi/MW-sec production rate with the reactor bay exhaust rate (9.64×10^{7} ml/min). This yields an Ar-41 concentration of 3.1×10^{-7} μCi/ml. This concentration is approximately 10% of the 10 CFR 20 DAC limit.

It is important to note that the reactor bay is a Reactor Controlled Area and posted Radiation Area during reactor operations. Therefore, all individuals in the reactor bay during operations must be wearing dosimetry. While there are instances during experiments and maintenance activities that require personnel work within the reactor bay during operations, this is not a routine occurrence and certainly would never come close to the 2,000 hour assumption for the 10 CFR 20 DAC limit. Historically, the AFRRI reactor operates approximately 20 MWh per year.

Ar-41 Effluent Release to the Public

During reactor operations, Ar-41 is generated by thermal neutron capture of Ar-40 in air and dissolved in the primary coolant. Independent of reactor core location within the pool, Ar-41 is generated within the primary coolant, core experiment tube (CET) (if installed), and air-filled tubes associated with detectors, instrumented fuel elements, and any other core instrumentation. When positioned next to exposure room #1 (ER1) (position 250), there is additional Ar-41 generation from the air within ER1. When positioned next to exposure room #2 (ER2) (position 750), there is additional generation from the air within ER2, as well as the pneumatic transfer system (when installed). Therefore, the generation of Ar-41 is not only dependent of reactor power, but also the core position within the pool.

To quantify Ar-41 generation at various pool locations, Ar-41 effluent measurements from the stack were performed during reactor operations at different power levels and pool locations. For each sample point, reactor operations were sustained until Ar-41 saturation had occurred. The Ar-41 produced is inclusive of all sources (pool, instrumentation, experimental facilities, etc). The table below summarizes the Ar-41 production for each location:

Reactor Core Position*	Ar-41 Production Rate (mCi/kWh)
250	0.4
300	0.13
500	0.0024
700	0.57
750	1.89

*Position 250 is adjacent to ER1, position 750 is adjacent to ER2, positions 300 and 700 are approximately 12 inches from each respective exposure room, and position 700 is adjacent to the pneumatic transfer system.

It is important to note that design features of the exposure rooms have been utilized to decrease Ar-41 production. In both ER1 and ER2, the walls are painted with gadolinium oxide paint. The large thermal neutron cross section of gadolinium serves to capture thermal neutrons that would otherwise continue to scatter in the room. In ER1, the addition of a cadmium and gadolinium to the core projection restrict the entry of thermal neutrons into the exposure room from the core.

In accordance with Operational Procedure 8 Tab I "Daily Operational Shutdown Checklist", the reactor operations (integrated power and core location) are recorded in the Reactor Monthly Usage Summary (RMUS). At the conclusion of the month, the RMUS is reviewed against the operations logbook and filed. In accordance with Health Physics Procedure 2-5.D "Environmental Radioactivity Releases", the RMUS is collected on a quarterly basis by the Health Physics Department (HPD) so that the effluent releases can be determined (using the Ar-

41 production rates shown in the above table). A quarterly effluent release report is generated, filed with HPD and the reactor staff, and reviewed by the Reactor and Radiation Facilities Safety Subcommittee (RRFSS) at the semiannual meeting. Upon reviewing the quarterly effluent reports, the dose to a member of the public is calculated and compared against 10 CFR 20 limits. Future reactor operations for the year are projected and, along with the previous quarterly reports for the year, used to ensure that releases are within 10 CFR 20 limits. The quarterly reports are also compiled and submitted to the Nuclear Regulatory Commission (NRC) as part of the annual reactor operations report.

The dose to a member of the public due to Ar-41 effluent release is calculated using COMPLY v1.6. To ensure that no member of the public receives a dose greater than 10 mrem in a given year from routine reactor operations, COMPLY was utilized to determine the maximum quantity of Ar-41 released from the stack that would result in a dose a 9.9 mrem. This methodology establishes an upper limit for annual Ar-41 release from the stack. For compliance at level 2, the release of 313.5 Ci of Ar-41 would result in a 9.9 mrem dose per year (report attached). Therefore, restricting Ar-41 releases per year to less than 313.5 Ci will ensure that no member of the public receives a dose greater than 9.9 mrem from Ar-41 effluent release due to normal reactor operations.

It is important to note that the SGM is required to monitor radioactive effluent in stack during all reactor operations. This system is designed to alert the operator to the presence of radioactive material in the exhaust ventilation system. The reason Ar-41 releases are calculated based on integrated power rather than direct measurement is that an overwhelming majority of reactor operations are at low power (< 200 kW) for short periods (< 10 minutes). The Ar-41 generated during these low power, short duration operations is low enough that the Ar-41 readings from the SGM are below the limits of detection.

In addition to the quarterly effluent reports, a new surveillance requirement shall be added to the AFRRI Technical Specifications to prevent the inadvertent release of Ar-41 in excess of the annual 313.5 Ci limit. Ar-41 production is maximal in the ER2 (position 750) location. The production rate is 1.89 mCi/kWh, corresponding to 1.89 Ci of Ar-41 per hour at 1.0 MW. Thus, the 313.5 Ci release limit would be reached in 165.9 MWh of operation. Therefore, Ar-41 effluent release shall be analyzed at an interval not to exceed 20 MWh. With this limit in place, it is not possible to inadvertently release sufficient Ar-41 to exceed 10 CFR 20 limits between effluent report analyses. In other words, the maximum dose to the public between effluent report analyses is 1.2 mrem. Technical Specification 4.6 shall now read:

4.6. <u>EFFLUENTS</u>

<u>Applicability</u>

This specification applies to surveillance requirements for environmental monitoring.

Objective

The objective is to ensure the health and safety of the public through detection of any release of radioactive material to the environment.

Specifications

a. The unrestricted area outside of AFRRI shall be monitored by thermoluminescent dosimeters that shall be changed quarterly.

b. Samples of soil, vegetation, and water in the vicinity of the reactor shall be collected and tested for radioactivity quarterly.

c. A gaseous effluent release report shall be generated quarterly or every 20 MWh of reactor operation (whichever is first) to ensure radioactive effluent will not exceed the annual limit.

Basis

Experience has shown that quarterly environmental monitoring is sufficient to detect and quantify any release of radioactive material from research reactors. The requirement for gaseous effluent release reports will ensure that Ar-41 production from normal reactor operations does not exceed 10 CFR 20 annual dose limits to the public.

Technical Specification 3.5 shall now read:

3.5.2. EFFLUENTS: ARGON-41 DISCHARGE LIMIT

Applicability

This specification applies to the quantity of argon-41 that may be discharged from the TRIGA reactor facility.

Objective

The objective is to ensure the health and safety of the public are not endangered by the discharge of argon-41 from the TRIGA reactor facility.

Specifications

a. An environmental radiation-monitoring program shall be maintained to determine effects of the facility on the environs.

b. If calculations, which shall be performed at least quarterly but not to exceed 20 MWh of operation, indicate that an Ar-41 release in excess of 313.5 Ci to the unrestricted environment could be reached during the year as a result of reactor operations, reactor operations that generate and release measurable quantities of argon-41 shall cease for the remainder of the calendar year.

Bases

COMPLY analysis calculates that the release of 313.5 Ci from the stack to the unrestricted environment in one calendar year yields a dose to the public of 9.9 mrem. Therefore, limiting Ar-41 release to less than 313.5 Ci ensures that 10 CFR 20 limits on doses to the public are not exceeded. The upper limit of 20 MWh of reactor operation between gaseous effluent analyses ensures that even in the most conservative reactor core position, it is not possible to exceed 15% of the 10 mrem limit between reports.

313_5CI

40 CFR Part 61
National Emission Standards
for Hazardous Air Pollutants

REPORT ON COMPLIANCE WITH

THE CLEAN AIR ACT LIMITS FOR RADIONUCLIDE EMISSIONS

FROM THE COMPLY CODE - V1.6.

Prepared by:

Prepared for:

U.S. Environmental Protection Agency
Office of Radiation and Indoor Air
Washington, DC 20460

COMPLY: V1.6. 3/ 3/2009 6:01

SCREENING LEVEL 2

DATA ENTERED:

Nuclide	Release Rate (curies/YEAR)
AR-41	3.135E+02

Release height 13 meters.

Building height 10 meters.

The source and receptor are not on the same building.

Distance from the source to the receptor is 91 meters.

Building width 80 meters.

Default mean wind speed used (2.0 m/sec).

NOTES:

Input parameters outside the "normal" range:

None.

RESULTS:

Effective dose equivalent: 9.9 mrem/yr.

*** Comply at level 2.

This facility is in COMPLIANCE.

It may or may not be EXEMPT from reporting to the EPA.

You may contact your regional EPA office for more information.

********** END OF COMPLIANCE REPORT **********