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SUBJECT: UNIVERSITY OF MARYLAND – REPORT ON AR-41 MITIGATION AT UNIVERSITY OF MARYLAND TRAINING REACTOR; LICENSE NO. 70; DOCKET NO. 50-166

Enclosed please find report titled "Mitigation of Ar-41 at the University of Maryland Reactor" dated June 18, 2014 which addresses the solution to the Ar-41 at the University of Maryland Training Reactor (MUTR) in connection with the license renewal.

I declare under penalty of perjury that the foregoing and the enclosed documents are true and correct.

Sincerely,

Timothy W Koeth

Timothy W. Koeth, Assistant Research Professor and Director
University of Maryland Training Reactor & Radiation Facilities

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Mitigation of Ar-41 at the University of Maryland Reactor

June 16, 2014

Executive Summary. The University of Maryland Training Reactor (MUTR) was experiencing Ar-41 concentrations within the confinement that exceeded the annual Occupational Worker's Derived Air Concentration limit. Federal regulation requires that licensee shall use, to the extent practical, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are ALARA [10 CFR 20.1101] and when practical, use process or engineering controls to control the concentration of radioactive material in air to values below those that define an airborne radioactivity area [10 CFR 20.1701].

An investigation revealed the primary source to be crevices in the shielding of the MUTR thermal column. Several options for mitigation were explored, including sealing the thermal column joints or the installation of continuously run ventilation system. The engineering solution of sealing the crevices was selected. A subsequent battery of air-grab measurements now shows that the peak Ar-41 concentrations were reduced to 26% of the Occupational Worker's DAC limit. Very conservatively, assuming MUTR operation of 40 hours per week, 50 weeks per year at this peak concentration, the occupational dose to a worker present would be 1300 mrem. In reality, accounting for the linear build up of Ar-41 over an 8 hour shift and a maximum operating schedule of 3 shifts per week the effective concentration is reduced to 8% of the DAC, at the location of highest concentration; therefore, a more realistic expected dose to workers from exposure to Ar-41, would be 400 mrem. 400 mrem is less than 10% of the annual occupational dose limit of 5000 mrem.

Engineering Solution. Air gaps in the MUTR thermal column's intermediate shielding plug have been hermitically sealed to the reactor biological shield with RTV and the central experimental plugs have been sealed to the intermediate shield plug with a continuous strip of high-density compressible foam gasket.

Measurements. After the installation of the seals described above, a battery of Ar-41 measurements were made with the MUTR in the standard operating condition. Credible steps were taken to create the maximum possible Ar-41 concentration in the reactor bay (confinement). This included limiting entrance/egress to a single door on the second floor which is isolated from the confinement volume by an intermediate door. Additionally, maximum buildup was ensured by cessation of MUTR ventilation fan use during the entire run. The Ar-41 concentration measurements were performed with Marinelli air-grab samples and promptly counted on an absolutely calibrated High Purity Germanium (HPGe) detector.

The Ar-41 concentration was measured in the control room, on the experimental floor, and on the reactor bridge. Three separate air-grab samples were taken simultaneously at each measurement location at the end of an 8 hour shift of operating at 200 kW. (Although operating at 200 kW, our licensed operating power is 250 kW, thus a factor of 1.2 is applied to all reported % DAC limits below). A relative measurement of the Ar-41 concentration build up was monitor by a NaI(Tl) gamma ray spectroscopy system tuned to measure the 1294 keV Ar-41 line. A background subtracted argon signal is plotted in figure 1. The buildup monitor was installed on the Experimental Floor in a shielded lead chimney approximately ten feet from the MUTR thermal Column. A low volume "muffin" fan gently circulated the room air through the lead chimney ensuring a representative sampling of confinement air. The buildup measurement was performed twice which consistently showed an increase which, to first order, is approximated as linear.

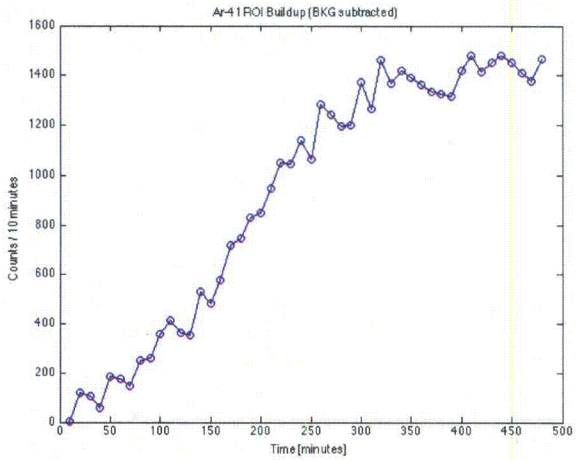

Figure 1. Relative Ar-41 buildup over 8 hour MUTR operation.

Occupational dose assessment. The following tables summarize the analyzed and reduced data from the MUTR confinement post-mitigation air-grab sampling. Table 1 is the overly conservative maximum hypothetical occupational dose assessment at MUTR, which assumes operation at 250 kW for five, eight hour shifts per week for 50 weeks per year, at peak Ar-41 concentration (neglecting Ar-41 buildup). Table 2 scales these, yet still conservative, values closer to real operation, which also includes Ar-41 concentration buildup.

Measurement Location	Measured Concentration [x10 $^{-7}$ uCi/ml]	Standard Deviation [x10 $^{-7}$ uCi/ml]	Max. Hyp. % DAC (Power Corrected)
Experiment Floor	6.64 ± 0.63	0.31	26.4
Reactor Bridge	5.44 ± 0.43	0.45	21.7
Control Room	Below MDA on all 3 samples (MDA: 5.5x10^{-8} uCi/ml)	-	2.2

Table 1. Summary of Maximum Hypothetical *Occupation Dose Assessment* at MUTR assuming operating at 250 kW, 40 hours per week, 50 weeks per year, at peak Ar-41 concentration.

Measurement Location	Average Concentration [x10 $^{-7}$ uCi/ml] (Power Corrected)	% DAC	Realistic Annual Occupational Dose to worker from Ar-41 (mrem)
Experiment Floor	3.98 x10 $^{-7}$ uCi/ml	13.3	399
Reactor Bridge	3.26 x10 $^{-7}$ uCi/ml	10.9	327
Control Room	Below MDA on all 3 samples (MDA: 5.5x10^{-8} uCi/ml)	1.1	33

Table 2. Summary of realistic *Occupation Dose Assessment* at MUTR assuming operating at 250 kW, 24 hours per week, 50 weeks per year, at average Ar-41 concentration.

Public dose assessment. The dose risk for members of the general public in uncontrolled areas due to Argon-41 was conducted using the software modeling program HotSpot (Version 2.07.1). HotSpot uses a detailed model to calculate the Total Effective Dose Equivalent (TEDE) to a receptor. For the total activity, the maximum hypothetical concentration of Argon-41, 6.64 x 10-7 uCi/ml, at the experiment floor was multiplied by the total volume of the facility, and included operating 5 days per week, 8 hours per day, 50 weeks per year. The MUTR does not run ventilation during normal operations; therefore a leakage of 5% of the total activity was used as the source strength to the uncontrolled area. The maximum dose received by a member of the general public was calculated to

be 0.84 mrem. 0.84 mrem is less than 10% of the 10 CFR 20.1101(d) constraint on air emissions of radioactive material to the environment, such that the individual member of the public likely to receive the highest dose will not be expected to receive a total effective dose equivalent in excess of 10 mrem.

Conclusion. Determining the thermal column as the primary source of Ar-41 in the MUTR confinement, and isolating it through the engineering solution of sealing air-gap crevices has brought the concentrations of Ar-41 to 26% of the occupational DAC limit in the maximum hypothetical case at the reactor experimental floor. When scaled to more realistic values, the concentration is approximately 8% of the DAC. The reactor bridge concentration was found to be 22% of the DAC. Finally, even in the maximum hypothetical case, the control room, where workers are stationed at all times during operation, the concentration is now 2.2% of the DAC, and under a more realistic operating schedule, would be less than 1% of the DAC. This engineering solution effectively reduced occupational and public exposures to ALARA.

It is worthwhile to note that the other mentioned mitigation solution, the installation of continuous flow ventilation, was quoted at $720,000 USD, making that option economically unfeasible. In contrast, the combine RTV sealant, gasket, and sealant material, approximately cost $72 USD. The existing MUTR ventilation system, when activated, ejects air from the confinement, creating a negative pressure that draws in un-conditioned air from outside through two louvers. Prolonged exposure to hot humid Maryland air will condense water on and cause damage to the reactor console and associated control components making routine operation of this ventilation system for Ar-41 mitigation impractical and ultimately detrimental to the facility.