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November 25, 2014

US NRC
Document Control Desk
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SUBJECT: UNIVERSITY OF MARYLAND – REQUEST FOR ADDITIONAL INFORMATION RE: REVIEW OF THE ARGON-41 RADIOLOGICAL DOSE ASSESSMENT FOR LICENSE RENEWAL OF THE MARYLAND UNIVERSITY TRAINING REACTOR (TAC NO. ME1592) LICENSE NO. 70; DOCKET NO. 50-166

Enclosed please find the response to the RAI dated September 25, 2014 for the University of Maryland Training Reactor (MUTR), License No. R-70; Docket No. 50-166, regarding the radiological dose assessment from Ar-41.

I declare under penalty of perjury that the foregoing is true and correct.

November 25, 2014

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

A020
NRR

RAI 1A

Provide the leakage flow rate of Ar-41 from the restricted area to any outlying areas (hallways, classrooms, etc) and the environment. Provide any calculations, assumptions, and/or conservatism used to support the flow rate determination.

UMD response:

We have determined the leakage flow rates of Ar-41 from the restricted area to outlying areas (hallways, classrooms, etc) and to the environment through a detailed engineering assessment. The assessment includes a gap-analysis of MUTR penetrations, historical regional weather data, and air velocity measurements throughout the building. The 090 building HVAC system runs continuously placing the reactor bay at a negative pressure with respect to the neighboring hallways and classrooms. Table 1 provides leakage flow rates during normal conditions. The largest flow rate is from 1398 to 1308 at 87 CFM (cubic feet per minute), thus air flows from the unrestricted areas into the restricted area of the MUTR building. The subsequent leakage is out of the large roll-up door and adjacent personnel door into the restricted fenced area, as well as out of the louvers. Due to the dominant gap width of the rollup and personnel door, this is the primary contributor to leakage into an unrestricted area.

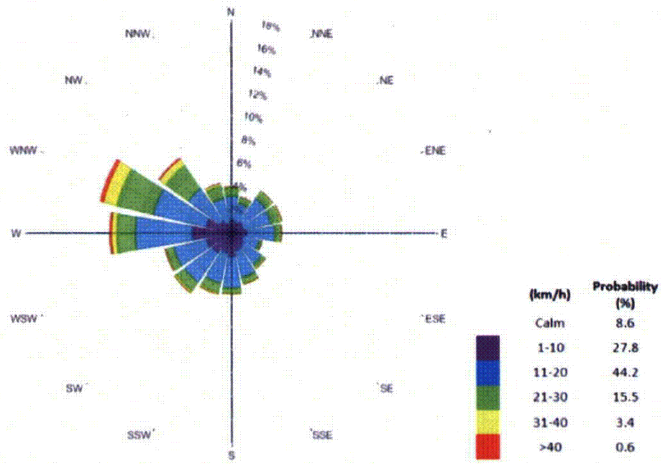

Figure 1. Baltimore-Washington Region Wind Rose [1954-2009]

Although building conditions and measurements indicate air flows from the unrestricted building hall ways into the MUTR and out the rollup door, the condition in which a North wind hits the roll up door, resulting in air flow into the MUTR and then into subsequent unrestricted hall ways was evaluated. In order to determine both the probability and magnitude of a North wind, blowing against the MUTR exterior roll-up door, a wind rose of the directional wind distribution in the Baltimore-Washington region during the period of 1954 to 2009 was consulted. See Figure 1. A weighted average of the wind speed blowing from the North-North-West, North and North-North-East found that during 10% of the year, an average wind of 1.6 miles per hour (MPH) will come from the northerly direction. Table 2 provides leakage flow rates under these conditions.

Table 1. MUTR Air Flow Analysis Normal Conditions

University of Maryland - Bldg 090 Chem Nuke

Reactor Leakage Analysis

Infiltration from Mechanical Equipment	Opeing H (Ft.)	Opening W (Ft.)	Door Perimeter (Ft)	Top Gap Width (FT)	Side Gap Width (FT)	Bottom Gap Width (FT)	Middle Gap (FT)	Gap Area (Sq. Ft.)	Gap Area (% of total)	Airflow (CFM)	Airflow (cu. m / sec)
Infiltration Double Door 1398 to 1308	7.0	4.9	28.60	0.010	0.010	0.042	0.021	0.54	0.6326	87.17	0.04114
Infiltration at 2308 to 2308D	6.6	2.4	17.99	0.014	0.014	0.042	0.000	0.32	0.3674	47.46	0.02240
								0.8612	1.0000	134.63	

Exfiltration	Opeing H (Ft.)	Opening W (Ft.)	Door Perimeter (Ft)	Top Gap Width (FT)	Side Gap Width (FT)	Bottom Gap Width (FT)	Middle Gap (FT)	Gap Area (Sq. Ft.)	Gap Area (% of total)	Airflow (CFM)	Airflow (cu. m / sec)
Garage Door	15.6	13.8	58.75	0.010	0.010	0.010	0.000	0.61	0.4404	59.29	0.02798
Exterior Door	6.6	2.9	18.98	0.010	0.010	0.010	0.000	0.20	0.1423	19.16	0.00904
Intake louver 1	2.5	3.0	11.00	0.010	0.010	0.010	0.000	0.11	0.0825	11.10	0.00524
Intake Louver 2	2.5	2.5	10.00	0.010	0.010	0.010	0.000	0.10	0.0750	10.09	0.00476
Louver Opening 1308A to 2308	3.0	2.0	10.00	0.010	0.010	0.010	0.000	0.10	0.0750	10.09	0.00476
Louver Opening 1308A to 2308B	3.0	2.0	10.00	0.010	0.010	0.010	0.000	0.10	0.0750	10.09	0.00476
Exhaust opening 1	2.4	2.2		0.008	0.008	0.008	0.000	0.08	0.0550	7.40	0.00349
Exhuast opening 2	2.4	2.2		0.008	0.008	0.008	0.000	0.08	0.0550	7.40	0.00349
Total								1.39	1.00	134.63	0.03556

Table 2. MUTR Air Flow Northerly Winds

University of Maryland - Bldg 090 Chem Nuke

Reactor Leakage Analysis — Revised : 10/13/2014 11:05

	Press Diff (In. WG)	Press Diff (PSI)	Door Height (FT)	Door Width (FT)	Door Perimeter (FT)	Top Gap Width (FT)	Side Gap Width (FT)	Bottom Gap Width (FT)	Gap Area (Sq. Ft.)	Airflow (CFM)	Airflow (cu. m / sec)
Infiltration at Garage Door	0.00	0.00	15.6	13.8	58.75	0.010	0.010	0.010	0.61	10.01	0.00472
Infiltration at Exterior Door	0.00	0.00	6.6	2.9	18.98	0.010	0.010	0.010	0.20	3.23	0.00153
Total									0.8	13.2	0.00625

	Opeing H (Ft.)	Opening W (Ft.)	Door Perimeter (Ft)	Top Gap Width (FT)	Side Gap Width (FT)	Bottom Gap Width (FT)	Middle Gap (FT)	Gap Area (Sq. Ft.)	Gap Area (% of total)	Airflow (CFM)	Airflow (cu. m / sec)
Double Door 1308 to 1398	7.0	4.9	28.60	0.010	0.010	0.042	0.021	0.54	0.3781	5.01	0.00236
Intake louver 1	2.5	3.0	11.00	0.010	0.010	0.010	0.000	0.11	0.0795	1.05	0.00050
Intake Louver 2	2.5	2.5	10.00	0.010	0.010	0.010	0.000	0.10	0.0723	0.96	0.00045
Louver Opening 1308A to 2308	3.0	2.0	10.00	0.010	0.010	0.010	0.000	0.10	0.0723	0.96	0.00045
Louver Opening 1308A to 2308B	3.0	2.0	10.00	0.010	0.010	0.010	0.000	0.10	0.0723	0.96	0.00045
Single Door from 2308D to 2308	6.6	2.4	17.99	0.014	0.014	0.042	0.000	0.32	0.2196	2.91	0.00137
Exhaust opening 1	2.4	2.2		0.008	0.008	0.008	0.000	0.08	0.0530	0.70	0.00033
Exhaust opening 2	2.4	2.2		0.008	0.008	0.008	0.000	0.08	0.0530	0.70	0.00033
Total								1.44	1.00	13.24	0.00625

RAI 1B

Provide a description of the release point(s) and any flow paths for the Ar-41 effluent from the restricted area to any unrestricted area(s).

UMD Response

The MUTR floor plans, Fig.1 bottom [experimental] floor and Fig.2 the upper [balcony] floor, are annotated with arrows depicting direction of airflow. The flow directions were determined by measurement with an airflow velocity meter and gap analysis of all penetrations of the reactor building and adjacent building. Note the Figure 2 also includes a n overlay to depict the reactor penthouse and its louver locations. As described in the previous section, the wind rose shows that 10% of the year, a northerly wind has the potential to reverse the flow direction. Under these conditions the greatest leakage will be from room 1308 to hallway 1398.

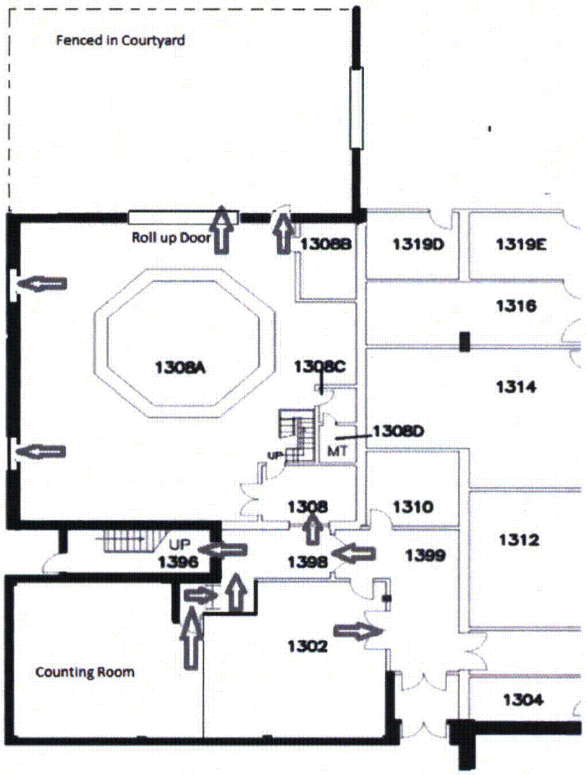

Figure 1. MUTR 1st floor

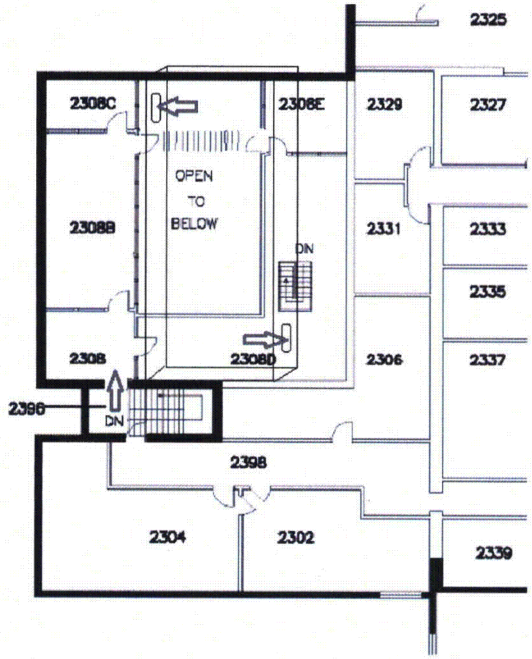

Figure 2. MUTR 2nd floor

RAI 1C

Provide the potential radiological dose to any members of the public from effluents that could leak from the MUTR confinement. Provide an analysis of the maximum exposure to an individual at the nearest unrestricted location such as permanent residence, classroom, campus dormitory, fence line, or other special interest space. Provide any assumptions used for this determination.

UMD Response:
Average MUTR concentration of Ar-41 was derived from the air grab measurements described in our letter dated June 18, 2014.

During the year, the maximum exposed individual member of the public is considered to be at the fence line, a distance 6.096 meters from the rollup door, for 8760 hours per year while operating the reactor 365 days per year at full licensed power. The EPA COMPLY code (attached) shows the maximum exposed individual member of the public receives 6.6 mrem per year.

Approximately 10% of the year, northerly prevailing winds, averaging 1.6 mph, may overcome the pressure differential and air will flow from reactor building to unrestricted areas. Based on the engineering assessment and measurements, the largest leakage rate will occur from 1308 to the unrestricted hallway 1398. During this time of reversed air flow, accounting for the dilution of the reactor air concentration with a measured air exchange rate in the hallway, the dose assessment to a member of the public spending 8760 hours per year in hallway 1398, while running the reactor continuously 365 days per year at maximum licensed power will result in 16 mrem per year. The following details the calculations which arrives at this result.

Using Federal Guidance Report 12 (FGR 12), EPA-402-R-93-081 External Exposure to Radionuclides in air/water/soil the dose to the Maximally Exposed Individual (MEI) member of the public due to effluent leaking during normal operations from the Maryland University Training Reactor (MUTR), can be calculated. The calculation and terms are as follows:

$$D = DCF\ x\ C\ x\ k$$

Where
D = Dose in rem yr^{-1};

DCF = Dose Conversion Factor for Ar-41 in [Sv Bq^{-1} s^{-1} m^3];

C = Concentration in the location of interest in [Ci m^{-3}],
For example C_{1398} is the concentration in hallway 1398, etc...;

k = Conversion factor in [Bq Ci^{-1} s yr^{-1} rem Sv^{-1}]

The equation governing the concentration in any location of interest is:

$$C = \frac{G}{VxQ}$$

G = Generation rate of Ar-41 in the reactor in [Ci s^{-1}];
V = Volume in 1398 in [m^3], and
Q = Ventilation rate from 1398 in [s^{-1}];

For the MEI in room 1398, C = C_{1398} and

$C_{1398} = \{C_{Rx} \text{ x } AF_{Rx \rightarrow 1398}\} / \{(V_{1398} \text{ x } (R_{1398})\}$

Where:
$G = C_{Rx} \text{ x } AF_{Rx \rightarrow 1398}$ in [Ci s^{-1}];
C_{Rx} = Ar-41 concentration in reactor;

$V = V_{1398}$ [m^3];

Q = ventilation rate, $R_{1398} + \lambda$ in [s^{-1}];
where R_{1398} is the air changes per time in 1398
and λ is the decay rate of Ar-41

$AF_{Rx \rightarrow 1398}$ = air flow from the reactor to 1398;

The decay rate λ of ^{41}Ar is as follows:

λ = (0.693/108 min) x (1 min/60 sec)

λ = 1.07 E-4 s^{-1}

The MEI is calculated given the following:

C_{Rx} = 6.64E-7 Ci m^{-3};
V_{1398} = 42m^3;
Q = 0.00167 s^{-1} + 0.00011 s^{-1}
$AF_{Rx \rightarrow 1398}$ = x 0.00236 m^3 s^{-1};
Wind rose percentage (0.10);

DCF = 6.5 E-14 Sv Bq^{-1} s^{-1} m^3;

k = 3.7E10 Bq Ci^{-1} x 3.15E^7 s yr^{-1} x 100 rem Sv^{-1};

The concentration is:

$$C_{1398} = \frac{\{6.64E\text{-}7\ Ci\ m^{-3} \times 0.00236\ m^3\ s^{-1}\}}{\{(42\ m^3) \times (0.00167\ s^{-1} + 0.00011\ s^{-1})\}}$$

$$C_{1398} = 2.1036E\text{-}8\ Ci\ m^{-3}$$

And the MEI dose to an individual in 1398 10% of the year is:

$$D_{MEI\ 1398} = 6.5\ E\text{-}14\ Sv\ Bq^{-1}\ s^{-1}\ m^3 \times (0.10) \times 2.1036E\text{-}8\ Ci\ m^{-3}$$

$$\times\ 1.167E20\ Bq\ Ci^{-1}\ s\ yr^{-1}\ rem\ Sv^{-1}$$

$$D_{MEI\ 1398} = 1.59E\text{-}2\ rem\ yr^{-1}$$

RAI 1D

In the letter dated June 18, 2014, MUTR stated the highest concentrations of Ar- 41 exist on the experimental floor. Describe how access is controlled to this area during reactor operations. Describe how radiation monitoring is accomplished to provide protection to a worker from an unanticipated Ar-41 exposure when experimental facilities are being utilized or in the event of a failure such as the thermal column seal.

UMD Response:

The experimental floor is within the reactor's restricted area, therefore access is limited to reactor staff and other occupational workers or otherwise escorted individuals whose time is minimized to maintain their dose ALARA.

Prior to sealing the Thermal Column, the highest Ar-41 concentration under the worst case scenario conditions, the MUTR Experimental floor was at 260% DAC ($3x10^{-6}$ uCi/mL is 100% DAC). In a 2000 hour work year, 100% DAC would give a radiation worker 5 Rem.

Occupational dose calculations under "MUTR Worst Case Scenario": Operating at 260% DAC $\Longrightarrow$ $13\ Rem/yr$

$$\frac{5\ Rem/yr\ limit}{13\ Rem/yr} = 0.38\ years = 760\ hours\ of\ 2000\ hour\ work\ year$$
$$= 19\ weeks\ before\ hitting\ 5\ Rem$$

Per our Tech Specs, our reactor bay air grab interval is 4 weeks nominally, not to exceed a maximum of 6 weeks.

Thus, in 6 weeks of non-stop operation an occupational working remaining motionless in the highest concentration would receive:

$$\frac{6\,Weeks}{19\,weeks/5\,Rem} = 1.6\,Rem \approx 32\%\ of\ allowed\ occupational\ dose$$

Per our Tech Specs we will continue with calibrated HPGe Ar-41 air grab concentration measurements on a 4-week interval not to exceed 6 weeks (12/yr) unless changes are made to shielding plugs at which time Ar-41 sampling will be performed to asses if Ar-41 concentrations have changed and actions will be taken to remain below regulatory limits. This sampling frequency, will in a worst-case scenario of a 6-week period during which thermal column seal is fully removed, result in the occupational worker loitering full-time in the highest concentration spot to receive ~ 32% of the occupational worker dose before being alerted by the air grab sampling. Further, both environmental and personnel dosimetry are cycled 6 times per year, which would also alert the reactor group to unusually high doses from Ar-41.

11/24/14

6:15

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, VERSION 1.4

Prepared by:

University of Maryland
MUTR
College Park, Maryland

Professor Timothy Koeth, Director

Prepared for:

U.S. Environmental Protection Agency
Office of Radiation Programs

Washington, D.C. 20460

11/24/14

6:15

Ar41 Fenceline Dose Assessment

SCREENING LEVEL 2

DATA ENTERED:

Nuclide	Release Rate (curies/SECOND)
AR-41	2.500E-08

Release height 0 meters.

Building height 0 meters.

The source and receptor are not on the same building.

Distance from the source to the receptor is 6 meters.

Building width 12 meters.

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

NOTES:

Input parameters outside the "normal" range:

Building is unusually SHORT.
Release height is unusually LOW.

RESULTS:

Effective dose equivalent: 6.6 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 **********