The Ohio State University
Nuclear Reactor Laboratory

1298 Kinnear Road
Columbus, OH 43212

Phone 614-688-8220
Fax 614-292-2209

28-Sep-2007

Daniel E. Hughes, Project Manager
Research and Test Reactors Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

RE: REQUEST FOR ADDITIONAL INFORMATION REGARDING THE OHIO STATE
        UNIVERSITY RESEARCH REACTOR APPLICATION FOR RE-LICENSING
        (TAC NO. MA7724)

Mr. Hughes,

Please find enclosed the remainder of our response to your letter dated 05-July-2007 requesting additional information to supplement the OSURR re-licensing application. If you have any questions, please contact Andrew Kauffman at 614-688-8220 or kauffman.9@osu.edu.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on 28-Sep-2007.

Sincerely,

Thomas E. Blue

Thomas Blue, Director
OSU Nuclear Reactor Lab
The Ohio State University
(License R-75, Docket 50-150)

c.   W.A. "Bud" Baeslack III, Dean, College of Engineering
     Andrew C. Kauffman, Associate Director, OSU Nuclear Reactor Lab

A020

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Proposed Update to Assumptions Used for OSU-NRL Safety Analysis Report (SAR) Section 8.4.4

Note: References in this document to Section 8.4.4 of the SAR include both the information submitted on 15-Dec-1999 with the Relicensing Application as well as supplemental information submitted on 21-Aug-2002 as a part of a response to a Request for Additional Information.

In the current version of Section 8.4.4, which analyzes the results of a hypothetically damaged fuel plate, there are two overly conservative assumptions:

1) A power peaking factor in the core of 2.75. This appears to have been calculated by dividing the *Maximum Thermal Neutron Flux* in Table 4.1 of the SAR by the *Average Thermal Neutron Flux* in the same table. As can be seen in the figures showing flux profiles in Chapter 4 of the SAR, this is overly conservative in that the maximum flux occurs in the Central Irradiation Facility, not in fuel. A better but still conservative number to use is the value of 1.8 given for *Total Power Peaking Factor* in Table 4.1 of the SAR. This value is conservative because it includes radial and axial peaking. However, only the radial peaking should affect the source term, as release from the fuel plate will be from across the entire length of the plate.

2) The entire inventory of fission-fragment noble gases and iodine are assumed to be released from a fuel plate. According to **NUREG 1537 (Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors) Part 2** Section 13, for the Maximum Hypothetical Accident (MHA) for a low-power (< 2 MW) MTR fuel reactor, the recommendation is analysis of results from cladding stripped from one face of one fuel plate. In the document **Analysis of Credible Accidents for Argonaut Reactors** (NUREG/CR-2079), it is suggested that only fission fragment gases within recoil range of the surface of fuel will escape for such a scenario. The value given for fission fragment recoil range for aluminum matrix fuels is 1.37×10^{-3} cm. Therefore, only the fraction of noble gases and iodine within 1.37×10^{-3} cm of one surface of one fuel plate should be considered for escape from the fuel for our analysis.

Given these two corrected assumptions, results calculated for source terms in SAR Section 8.4.4 need to be adjusted. The first adjustment factor is the ratio of peaking factors to account for the formerly over-conservative peaking factor.

$$\frac{1.8}{2.75} = 0.654$$

The second factor is the ratio of fission fragment recoil range to fuel thickness to account for the formerly over-conservative release fraction. The fuel thickness is given in Table 4.1 of the SAR as 0.020", which is equal to 0.0508 cm. This gives:

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$$\frac{1.37 \times 10^{-3} \, cm}{0.0508 \, cm} = 0.0270$$

Calculated values for source-term activities should be scaled by these two factors to get better (but still conservative) estimates. Because calculated doses will scale linearly with activity, calculated dose values can be directly scaled by these two factors.

With the exhaust fan on, Table 8.19 of the SAR currently shows that the maximum direct dose from the building received by someone standing next to the building is 3.63 rem. If we scale by the two correction factors above, this value is reduced to 64.2 mrem. Likewise, the maximum submersion dose listed in Table 8.17 for someone standing next to the building with the exhaust fan on is currently listed as 0.877 rem. When scaled by the correction factors, this is reduced to 15.5 mrem. Therefore, if the exhaust fan was left running for such a hypothetical release, members of the general public should not receive more the limit of 100 mrem.

With the exhaust fan off, Table 8.18 of the SAR currently shows that the maximum direct dose from the building received by someone standing next to the building is 37.64 rem. If we scale by the two correction factors above, this value is reduced to 665 mrem. Likewise, the maximum submersion dose listed in Table 8.16 for someone standing next to the building with the exhaust fan off is currently listed as 0.0433 rem. When scaled by the correction factors, this is reduced to 0.8 mrem. Therefore, if the exhaust fan was turned off for such a hypothetical release, members of the general public could theoretically receive a dose greater than the limit of 100 mrem. This is unlikely, given that to get such a dose would require occupancy next to the building for a significant period of time. In the event of a radionuclide release, the fence surrounding the building would be used to establish a controlled area that would keep members of the general public away from the building. Therefore the hypothetical dose at this boundary needs to be estimated to determine if it is within 10-CFR-20 limits for the case of the exhaust fan off.

To model direct dose at the controlled-area boundary, we used spherical shapes once again to simplify the calculations via symmetry. As was shown in Section 8.4.4.5 of the SAR, the value of dose from a spherical cloud of an isotope of radius R can be estimated as the dose from an infinite cloud of that isotope multiplied by μR, where μ is the gamma absorption coefficient in air for that isotope. Therefore, the dose from a cloud of radius R_1 is $D_\infty \mu R_1$, where D_∞ is the dose from an infinite cloud. Likewise, the dose from a cloud of radius R_2 is $D_\infty \mu R_2$, and the dose from a spherical shell extending from R_1 to R_2 is $D_\infty \mu (R_2 - R_1)$. The hypothetical maximum dose (dose at the nearest point to the building at the boundary of the controlled area) was modeled as the center of spherical shells, and the reactor building was modeled as sections of the total solid angles of two shells, as seen from the center of the sphere. The size of these sections was determined by the ratio of the areas of building faces by the areas of spheres with radii equal to the distances to the building faces, and the thickness of the shell sections was calculated to make the section volumes equal the building volume. The center of the spherical shells was chosen at the east fence surrounding the building, as that is the

closest point from between building and fence. The figures below show the spherical shell sections superimposed on the building. The solid lines show the outline of the building, and the hatched area show the model's volumes. As can be seen in the figures, this simplification is conservative in that the average distances from the modeled volumes are closer to the point of interest at the fence than the average distance from the actual volume of the building to the fence.
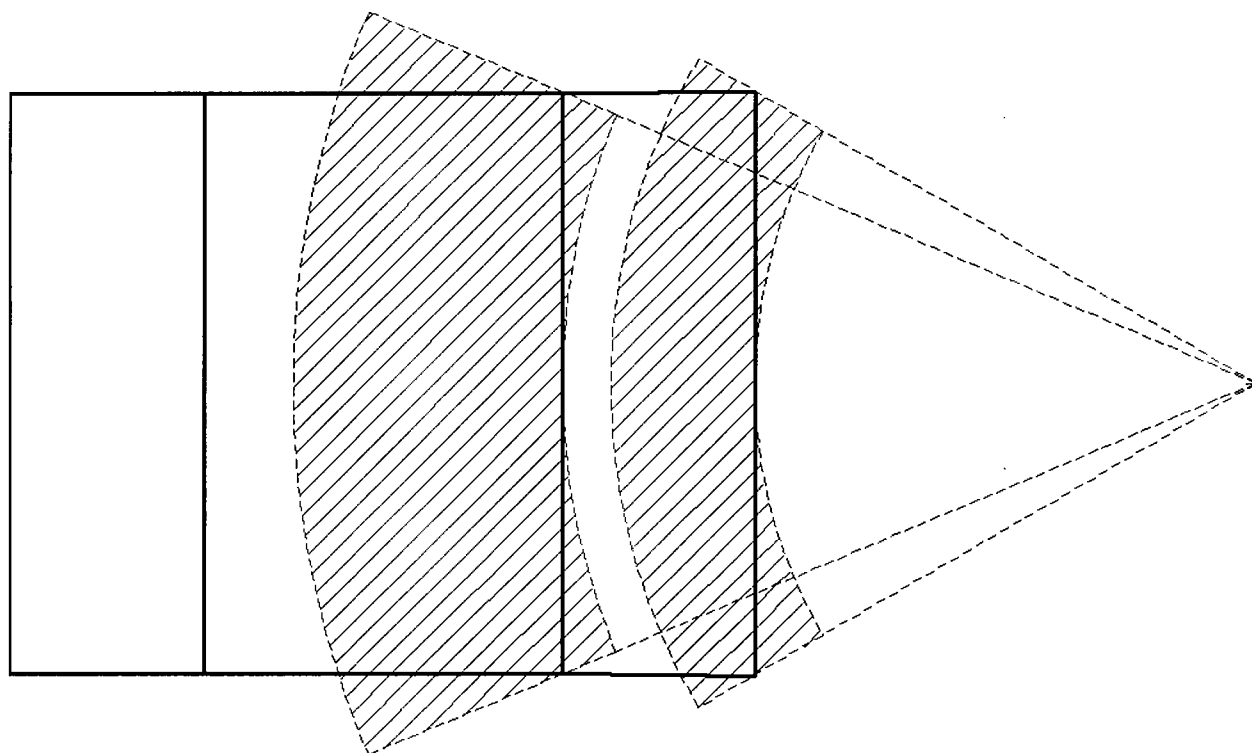
Top View
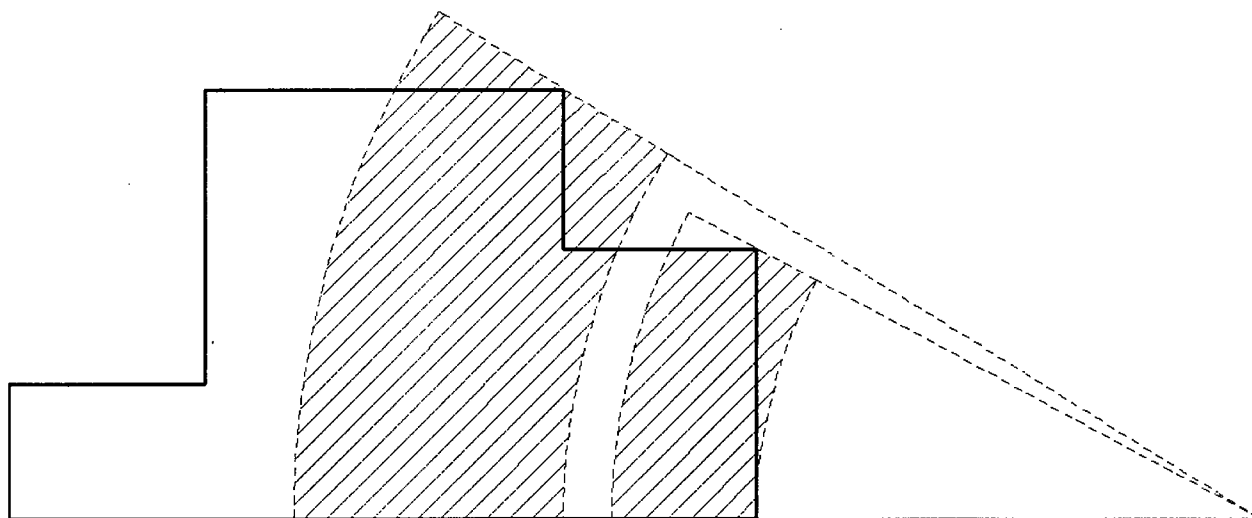
Side View (from the South)

To calculate the dose from isotope 'i' from the shell section closest to the controlled-area boundary, we use an equation similar to those used in previous estimates in Section 8.4.4.5 of the SAR. The activities used for this calculation must have been scaled by the two factors discussed above so that we use proper source-term activities.

$$D_i = \frac{A_i}{\rho \cdot V} \frac{1 - e^{-(\lambda_i + \Lambda)t}}{\lambda_i + \Lambda} E_i \cdot F_1 \cdot F_2 \cdot F_3 \cdot F_4 \cdot F_5 \cdot F_8 \cdot \mu \cdot (R_2 - R_1)$$

where
A_i = source term activity in Ci
ρ = density of air = 1.293 kg/m^3
V = building volume = 1.982x10^3 m^3
λ_i = nuclide decay constant in seconds^{-1}
Λ = building volume leakage constant in seconds^{-1}
t = time after source release in seconds
E_i = gamma energy in MeV per tranformation
F_1 = factor to convert Ci to transformations/sec = 3.7x10^{10}
F_2 = factor to convert MeV to J = 1.6x10^{-13}
F_3 = factor to convert J/kg to rad = 100
F_4 = factor to convert rad to rem = 1
F_5 = factor to account for stopping power of tissue $\approx$ 1.1
F_8 = factor to account for fraction of total solid angle
μ = gamma absorption coefficient in air (m^{-1})
R_1 = inner radius of shell (m)
R_2 = outer radius of shell (m)

To determine the fraction of total solid angle, we divide the surface area of the facing building wall by the surface area of a sphere with the radius of the inner shell

$$F_8 = \frac{\text{height} \cdot \text{width}}{4\pi R_1^2} = \frac{6.7m \cdot 14.6m}{4\pi(12.5m)^2} = 0.0500$$

To determine the outer radius for this shell section, we can integrate the calculated fraction of solid angle between the two radii and set this equal to the desired volume. The volume of the portion of the building being modeled as the inner shell is 471 m^3, so this integral is:

$$471\,m^3 = \int_{R1=12.5m}^{R2} 0.0500 \cdot 4\pi r^2 \cdot dr$$

This equation is solved to yield R_2 = 16.1 m.

Likewise, to calculate the dose from isotope 'i' from the shell section farther away from the controlled-area boundary, we use the same equation shown above, but with different values for F_8, R_1, and R_2.

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The fraction of solid angle for this section is

$$F_8 \quad = \frac{\text{height} \cdot \text{width}}{4\pi R_1^2} = \frac{10.7\text{m} \cdot 14.6\text{m}}{4\pi(17.3\text{m})^2} = 0.0415$$

The outer radius is determined using the remaining volume of the building of 1511 m^3.

$$1511\,\text{m}^3 = \int_{R1=17.3\text{m}}^{R2} 0.0415 \cdot 4\pi r^2 \cdot dr$$

This yields an outer radius of 24.0 m for the outer shell section.

Using the values calculated above in addition to those provided in SAR Section 8.4.4, we can calculate the doses from the two shell sections for each isotope and add them together to estimate the total direct dose from the building at the boundary of the controlled area. Results of these calculations are shown below in the table. As is seen in the table, the estimate of maximum direct dose from all isotopes from the building received by someone standing at the nearest point at the controlled-area boundary is 98.4 mrem. When this is added to the submersion dose calculated previously of 0.8 mrem, the total dose is still below the limit of 100 mrem. This estimate is close to the limit, but because it is conservative the limit will not be exceeded. In addition to the conservatism resulting from the distance of the modeled shell sections to the point of interest, there is also conservatism from the fact that no dose attenuation is accounted for from the building or the large concrete reactor structure. Also, as was mentioned previously, the estimates for source term activities are conservative, even after being scaled as discussed above. Pending approval of this methodology for estimate of dose at the boundary of the controlled area, we propose to add this information to Section 8.4.4 of the SAR.

Integral Whole-Body Gamma Doses From Direct (From the Building) Dose At the Controlled-Area Boundary Assuming a Leakage Fraction of 0.0042 Hr^{-1} (Purge Fan Off)

	Dose In Rem									
Isotope symbol	Exposure Times									
	5 Minutes	10 Minutes	15 Minutes	30 Minutes	60 Minutes	2 Hours	24 Hours	48 Hours	168 Hours	720 Hours
^{131}I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{132}I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{133}I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{134}I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{135}I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
^{85m}Kr	0.0	0.0	0.1	0.1	0.2	0.4	1.4	1.5	1.5	1.5
^{87}Kr	0.1	0.2	0.3	0.6	1.0	1.6	2.4	2.4	2.4	2.4
^{88}Kr	0.5	1.1	1.6	3.0	5.7	10.2	25.4	25.5	25.5	25.5
^{131m}Xe	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.8
^{133m}Xe	0.0	0.0	0.0	0.0	0.0	0.1	0.8	1.3	2.1	2.3
^{133}Xe	0.0	0.1	0.1	0.2	0.5	0.9	9.7	17.4	37.7	46.8
^{135m}Xe	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4
^{135}Xe	0.1	0.2	0.4	0.7	1.4	2.8	16.1	18.4	18.8	18.8
TOTALS	0.9	1.8	2.6	5.0	9.2	16.3	56.3	67.1	88.9	98.4