ATTACHMENT 5

POST-ACCIDENT RADIATION MONITOR RESPONSE FOR CORE UNCOVERY

- Fleet Calculation RA-0078, Verification of Rad Monitor Response to Core Uncovery
- Calculation M2EP-04164R2, Verification of Rad Monitor Response to Core Uncovery

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Fleet Calculation RA-0078, Verification of Rad Monitor Response to Core Uncovery

The following pertinent information has been extracted from Calculation RA-0078, Verification of Rad Monitor Response to Core Uncovery. It is provided to assist technical reviewers that will be evaluating this license amendment request for MPS3, NAPS & SPS. (Note: MPS2 is analyzed in M2EP-04164R2).

Purpose:
The purpose of this calculation is to determine a single, common value for radiation monitor responses to core uncover for Millstone Unit 3, North Anna Units 1 & 2, and Surry Units 1 & 2. This analysis is only applicable when the reactor head is off of the vessel.

References:
1. ORNL/TM-2005/39, Version 6.2.2, "SCALE Code System."
2. LA-CP-14-00745, Rev. 0, "MCNP6 User's Manual, Code Version 6.1.1beta."
3. Calculation M3EP-04140R3 Rev. 0, "MP3 Rad Monitor Response to Core Uncovery."
4. MP-DWG-000-25212-27012 SH-00000000 Rev. 16, "Machine Location Cntmt Structure Plan El 51 Feet 4 Inches."
5. MP-DWG-000-25212-27013 SH-00000000 Rev. 13, "Machine Location Cntmt Structure Section 1-1 and 4-4."
6. MP-DWG-000-25212-27014 SH-00000000 Rev. 14, "Machine Location Containment Structure Section 2-2."
7. MP-DWG-000-25212-27015 SH-00000000 Rev. 12, "Machine Location Containment Structure Sect 3-3."
8. MP-DWG-000-25212-11060 SH-00000000 Rev. 9, "Plan Elevation 51 Feet 4 Inch Outline Containment Structure."
9. ETE-NAF-2014-0098 Rev. 0, "Millstone Unit 3 cycle 17 Nuclear Design Report."
10. M3AST-01942R3 Rev. 1, "Millstone 3 Alternate Source Term."
11. PNNL-15870 Rev. 1, "Compendium of Material Composition Data for Radiation Transport Modeling."
12. ET-NAF-06-0114 Rev. 0, "Dose Rate at the Containment Manipulator Crane Radiation Monitor Due to a Draindown Event Including Scatter from the air and Containment Dome."
13. PA-0227 Rev. 0, "Dose Rate at the Containment Manipulator Crane Radiation Monitor Due to a Draindown Event at North Anna or Surry."
14. MP-DWG-000-25212-11075 SH-00000000 Rev. 3, "Containment Structure Section 1-1."

Computer Codes Used:
SCALE 6.2 (Reference 1)
MCNP 6.1 (Reference 2)

Methodology:

Source Term

The LOCA core inventory source term will be decayed and converted to a photon spectrum using the ORIGEN code from the SCALE 6.2.2 code package.

Shielding Model

The core, refueling cavity, and containment will be modeled using MCNP 6.1. The fuel region of the core will be modeled as a single homogeneous zone containing fuel and water. The water level is modeled as being level with the top of the active fuel. The gamma source in the fuel is distributed axially to model a nominal axial fuel burnup.

This distribution is intended to capture the self-shielding in the fuel zone. The gamma source has a uniform radial distribution in the fuel region. Structures inside the containment dome are limited to the crane wall and concrete structures close to the radiation monitors. These structures should reasonably model the photon backscatter to the radiation monitors. The radiation monitors will be modeled as finite air volumes used exclusively to tally the dose rate.

Results and/or Conclusions:

Results from the MCNP output file provides an estimate of the average photon Mean Free Path (MFP) in each cell. An examination of these results indicates that the MFP in air varied between approximately 60 and 90 meters (197 and 295 feet). Given the distance between the operating floor and the containment dome, few photons interactions in air would occur during a photon's transit from the core to the containment dome and back to a radiation monitor.

Reference 3 also assumed that, other than air scatter, the primary contributor to radiation monitor dose rates was from photons that traveled vertically from the fuel through the air and scattered on the containment dome. This assumption was evaluated by modifying the MCNP input files to terminate any photon track that enters the refueling deck and refueling cavity concrete surfaces. The change was implemented by setting the importance of cell 10 to 0 (i.e. imp:p=0). The dose rates at the radiation monitors were reduced by ~69% at RE-05A and ~42% at RE-04A, bringing the results into reasonable agreement with the containment dome contributions calculated in Reference 3. Analysis shows much of the dose rates at the radiation monitors in this calculation are due to photons scattering on or transiting through the refueling cavity concrete. Thus, while photon scattering on the containment dome is a contributor to the dose rates, the primary contributor is attributed to other concrete surfaces.

It was found that a drain-down event earlier in a refueling outage could increase the count rates by a factor of three. This is consistent with the change in photon intensity.

In summary, containment radiation monitor dose rates at Millstone, North Anna, and Surry are expected to be between 3 R/hr and 40 R/hr, depending on the unit, time after

refueling, and radiation monitor location in containment. A value of 3 R/hr would be a conservative dose rate for use in identifying a potential drain-down event.

Calculation M2EP-04164R2, Verification of Rad Monitor Response to Core Uncovery

The following pertinent information has been extracted from Calculation M2EP-04164R2, Verification of Rad Monitor Response to Core Uncovery. It is provided to assist technical reviewers that will be evaluating this license amendment request for MPS2.

Purpose:
The purpose of this calculation is to calculate the radiological response of containment high range radiation monitors to core uncovery during refueling.

References:

1. M3EP-0414R3, Rev. 0, MP3 Rad Monitoring Response to Core Uncovery.
2. ANS/SD-76/14, "Handbook of Radiation Shielding Data," July 1976.
3. Calc. SFPGAMMA-04011R2, Rev. 0, "MP2 Gamma Heating Analysis," dated 4/4/2003.
4. MP2 Technical Specifications through Change # 318-01.
5. Not Used.
6. Not Used.
7. Dwg 25203-29531, Rev.1, Millstone 2 Fuel Assembly.
8. Dwg 25203-28014, Rev. 8, Instrument Location – Containment Plan El 14'-6" &38'-6".
9. Dwg 25203-27022, Rev. 6, General Arrgt– Containment & Aux Bldg Section B-B.
10. Dwg 25203-29141, Sh. 100, Rev. 1, Unit 2 – Reactor Arrangement Sectional Elevation Layout.
11. SCALE 4.4a Code File.

Computer Code Used:
SCALE Package / QADS

Method of Analysis:
EALs require the ability to measure gamma radiation from the reactor core while under conditions where the water level in the reactor vessel is at the top of the active core. Considering the location of the core relative to RM-8240 and 8241, there does not appear to be any direct, line-of-sight communication of radiation. This requires crediting of air and concrete scattered radiations from the core to the rad monitors. Based upon a review of detector location (14'6" elevation on SG shield walls), and the need to credit multiple scattering there does not appear to sufficient radiation to register on these detectors which have a low range limit of 1 R/hr. The insufficiency of radiation will be validated using RM-7891 which only requires a single scatter determination. RM-7891, the refuel floor rad monitor, is located adjacent to the refuel pool. No credit is taken for any radiation beyond single scattering.

The following scatter methods were validated in Reference 1. The methods are described in Reference 2 and applicable excerpts are retrievable as attachments to Reference 1.

Scattering by air is addressed by a method using a line beam response factor (LBRF) to evaluate the single scatter from direct radiation to a receptor located out of the direct beam. In the case of a reactor core, the gamma flux directly over the core at the elevation of the radiation monitors is determined using the QADS shielding code. This flux is converted to an equivalent line beam source by multiplying the flux by the horizontal surface area of the core. The line beam source is multiplied by the LBRF to get the dose rate at the rad monitor from air scattered radiation.

Scattering by the containment dome is addressed using a method that determines an appropriate albedo factor and appropriate dose rate response that reflects a single scatter from the containment structure above the core.
In this assessment, a lesser source term is more conservative to use (because it results in lower dose rates) and the twice burn, 5% enrichment provides a lesser source term than lower enrichments or single burns. The lesser source term results in a lower dose rate response ensuring that control room or SERO response to rad monitors used would be timely. In addition, since the core may be in a reduced inventory condition with containment closure not established, an assumption of 25 days decay will be assumed (this is roughly when draindown has occurred in order to put the reactor head back on the vessel).

This source term represents one fuel assembly decayed for 25 days using the ORIGENS code from the SCALE package (SQA Level 2). ORIGENS is a neutron depletion and decay code that will generate a source term that can be used in the QADS code with a multiplier to reach the equivalent of 217 assemblies. QADS is also from the SCALE package and is a point-kernel gamma shielding code. All of the fuel assemblies in a core will be modeled as a large cylindrical source. Receptor points will be located at the elevation of the rad monitors (for air scatter determination) and at the top of the containment dome (so that concrete/ steel scatter can be assessed).

Summary:
Dose rate at R7891 from a reactor vessel draindown condition to top of active core, with no reactor head in place, crediting scattered radiation and a 25 day decay time for fuel as determined by this calculation are:

	R7891, R/hr
Air Scatter	1.4
Dome Scatter	3.0
Total	**4.4**