Demonstrating Compliance with 10 CFR 20 Exposure Limits for Radon-222 and Progeny

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NRC Staff Interest in Radon and Progeny (Daughters) and Compliance with 20.1301

- The NRC staff is continuing to improve the UR program.
- One aspect receiving attention is demonstrations of compliance with the public dose limit (10 CFR 20.1301), especially for exposures from radon and radon progeny.
- Staff thinking on this has been evolving.
- The goal of today's talk is to provide the staff's current thinking regarding future guidance on the subject of demonstrating compliance with 20.1301 for radon and progeny and to provide an opportunity for public input.

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NRC Staff Interest in Radon and Progeny (Daughters) and Compliance with 20.1301

- In reviews of new applications for ISRs, staff have had a number of RAIs related to methods for demonstrating compliance with the public dose limit, especially as it relates to radon and radon progeny.
- For existing licensees, DWMEP staff are re-evaluating demonstrations of compliance, especially related to exposures from radon and radon progeny.
- From both perspectives, staff has identified issues deserving further consideration.

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Radon and 20.1301—Issues

- Applicable to all licensed and to-be-licensed facilities: ISRs, conventional, heap leach.
- Licensees must account for dose from radon progeny.
- Considerations when comparing to Part 20, Appendix B, Table 2 for compliance (20.1302(b)(2) method): which Table 2 value to use; equilibrium factor adjustment.
- Considerations when performing dose assessment for compliance (20.1302(b)(1) method): equilibrium factor; dose conversion factor; occupancy factor.
- Considerations for background radon measurements.

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NRC Staff Evaluation of Licensee Methods

- NRC staff evaluated recent examples of licensee (ISR and conventional) reports showing methods for demonstrating compliance with public dose limit of 20.1301.
- Licensees have used inconsistent methods to demonstrate compliance.
- NRC staff is developing guidance to address these issues.

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Applicable to All Uranium Recovery Facilities

- Sources of radon releases are different for ISRs versus for conventional mills or heap leach facilities, but radon issues for compliance with 20.1301 are similar.

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Compliance Demonstration Must Account for Radon Progeny

- This issue was discussed at the UR workshop in November 2009.
- Dose from releases of radon is due primarily to the short-lived radon progeny. The noble gas radon does not substantially stay in the lung when inhaled; the progeny are particulates and a significant fraction will lodge in the lung. Once in the lung, alpha radiation from the progeny delivers dose to the lung (main dose is to bronchial epithelium).

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- Among others, the Statements of Consideration for the 1991 revision to Part 20 (56FR23374, May 21, 1991), in discussing public dose limit and 40 CFR 190 compliance, state:

"For uranium mills it will be necessary to show that the dose from radon and its daughters, when added to the dose calculated for 40 CFR part 190 compliance, does not exceed 0.1 rem." [emphasis added]

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- For exposure to radon for members of the public around UR facilities, staff knows of no cases where the progeny (daughters) have been removed. Thus, some level of progeny will generally be present.
- Conclusion: in complying with 20.1301, **licensees must account for dose from the radon progeny**.
  - unless it can be demonstrated that the progeny are not present or have been removed from the air to which members of the public are exposed.

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Compliance Using Part 20, Appendix B, Table 2

20.1302(b)(2):

(b) A licensee shall show compliance with the annual dose limit in §20.1301 by--

(1) …

(2) Demonstrating that--

(i) The annual average concentrations of radioactive material released in gaseous and liquid effluents at the boundary of the unrestricted area do not exceed the values specified in table 2 of appendix B to part 20; and

(ii) If an individual were continuously present in an unrestricted area, the dose from external sources would not exceed 0.002 rem (0.02 mSv) in an hour and 0.05 rem (0.5 mSv) in a year.

Rn-222 & 20.1301: Compliance using App. B, Table 2

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- Using Appendix B, Table 2, values is a simple, potentially conservative method to demonstrate compliance.
- Note that the Appendix B, Table 2, values are based on dose of 50 mrem/year.
- If licensees have other effluents (e.g., U or other particulates), the sum of fractions or unity rule must be followed (Part 20, Appendix B, Note 4).
- Previous talk discussed the issue of location of measurements relative to unrestricted area boundary.

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- Table 2 of Appendix B provides two values for Rn-222 in air: one "with daughters removed" and one "with daughters present."
- The Appendix B values represent potential radionuclide exposure conditions, not measurement conditions or methods.

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- Based on the dose being primarily delivered by the radon daughters and based on the Statements of Consideration for Part 20, NRC staff considers that **using the value for radon "with daughters removed" is incorrect** for exposures of public around UR facilities. **Licensees should be using the value for radon "with daughters present,"** unless it can be demonstrated that the progeny have been removed from the exposure pathway.
- Table 2 value for Rn-222 with daughters present, in air: 1E-10 µCi/mL = 0.1 pCi/L.

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Adjusting Appendix B Value for Equilibrium

- Statements of consideration for 1991 Part 20 (56FR23375, May 21, 1991) discuss difficulty in meeting this value:

The Commission is aware that some categories of licensees, such as uranium mills and in situ uranium mining facilities, may experience difficulties in determining compliance with the values in appendix B … , Table 2, for certain radionuclides, such as radon-222. Provision has been made for licensees to use air and water concentration limits for protection of members of the general public that are different from those in appendix B …, Table 2, if the licensee can demonstrate that the physicochemical properties of the effluent justify such modification and the revised value is approved by the NRC. For example, uranium mill licensees could, under this provision, adjust the table 2 value for radon (with daughters) to take into account the actual degree of equilibrium present in the environment. …

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20.1302(c):

Upon approval from the Commission, the licensee may adjust the effluent concentration values in appendix B to part 20, table 2, for members of the public, to take into account the actual physical and chemical characteristics of the effluents (e.g., aerosol size distribution, solubility, density, radioactive decay equilibrium, chemical form).

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- For radon, the equilibrium factor is the fraction of the maximum radon progeny concentration supported by the radon concentration, or the ratio of potential alpha energy concentration (in working level (WL), multiplied by 100) to radon-222 concentration (in pCi/L).
- The Appendix B, Table 2, value for Rn-222 with daughters present assumes progeny are present at 100% of equilibrium. This is a conservative assumption (because progeny will usually be present at less than 100% of equilibrium), and acceptable to NRC staff.

Rn-222 & 20.1301: Adjusting App. B value for equilibrium

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- Licensees may wish to adjust the Table 2 value to account for more realistic progeny equilibrium factor.
- Licensees must obtain approval from the NRC staff.
- Cannot adjust for occupancy other than 100% (NRC 1994, Q&A 68).

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Representative Equilibrium Factor

- 20.1301 limits TEDE "to individual members of the public from licensed operations." Doses to these actual members of the public may be received in multiple locations; licensees must evaluate exposures at locations where public are exposed.
- For public exposed at their residences, a substantial exposure may result from time indoors. Thus, exposures indoors must be accounted for.

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Indoor Radon and Equilibrium Factor

- Measuring the indoor radon concentration that is due to facility radon releases may be difficult, due to the difficulty in separating contributions from multiple sources of indoor radon (other sources may include soil under the building, background outdoor air, building materials, water supply).
- Simple model is that facility contribution to indoor radon concentration equals contribution to concentration outdoors at same location (Schiager 1974).

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- Representative value of the equilibrium factor may also be difficult to measure.
- RG 3.51 describes the basis for the radon daughter dose conversion factor which the NRC staff has used.
  - Describes a conversion factor of outdoor Rn-222 concentration (pCi/m^3) to indoor radon progeny (WL).
  - Also describes air concentration ratios assumed for individual progeny.
  - Consistent with an indoor equilibrium factor of 0.5.
  - (Also consistent with simple model of indoor radon concentration due to facility releases equaling the outdoor concentration due to facility releases.)

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Compliance Using Dose Assessments

20.1302(b)(1):

(b)A licensee shall show compliance with the annual dose limit in § 20.1301 by--

(1) Demonstrating by measurement or calculation that the total effective dose equivalent to the individual likely to receive the highest dose from the licensed operation does not exceed the annual dose limit; or

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- For cases where comparison with Appendix B, Table 2, is not practical or is not preferred by a licensee, performing dose assessments allows licensees more flexibility.
- Licensees must account for total dose from direct radiation, particulates, radon and radon progeny, and any other pathways, as applicable.
- Acceptable approximation to calculate dose as product of Rn-222 concentration (C), progeny equilibrium factor (F), dose conversion factor (DCF), and occupancy factor (T), for locations or conditions i:

$$D = DCF \sum_i C_i F_i T_i$$

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Dose Conversion "Factor" for Rn-222 with Progeny

- In this use, the dose conversion factor (DCF) is the dose from Rn-222 plus progeny in 100% equilibrium per concentration of Rn-222 (mrem/yr per pCi/L at 100% equilibrium).
- A DCF can be established based on Appendix B, Table 2, value.

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- Statements of consideration (56FR23387, May 21, 1991) for Part 20 revision, in discussing values of Appendix B for radon:

"The concentration limit for members of the general public is a factor of 300 lower and, like the other airborne concentration limits, represents an effective dose of 0.05 rem."

- 0.1 pCi/L value represents a dose of 50 mrem/year.
- So, DCF = 500 mrem/year per pCi/L Rn-222 at 100% equilibrium.

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- Note that this is not a true dose conversion factor.
  - There is no DCF to look up in the Federal Guidance Report 11 (which provides DCFs for all radionuclides other than radon) (EPA 1988).
  - FGR 11 states that the primary guide (usually 5 rem/year for other radionuclides) for radon is 4 WLM exposure per year.
  - In essence, the NRC considers the risk from 4 WLM exposure to radon progeny to be consistent with the risk from a 5 rem dose to workers.
  - ICRP term was dose conversion convention, to distinguish from true dose conversion factor.

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Occupancy Factor

- Occupancy factor of 1, while conservative, has often been used.
- More realistic occupancy factor may be determined.
- Public dose limit of 20.1301 applies to "individual members of the public," not to hypothetical individuals and not to groups of people.
- Thus, occupancy factors must address occupancy of the actual individuals.
- Factors developed for hypothetical groups should not be used.

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Considerations for Background Radon

20.1301(a)(1):

(a) Each licensee shall conduct operations so that -

(1) The total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem (1 mSv) in a year, exclusive of the dose contributions from background radiation, … [emphasis added]

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- Licensees may subtract background contributions.
- RG 4.14 recommends "a remote location representing background conditions."
- But, radon concentrations have significant spatial variability; determining representativeness can be difficult. In particular, there may be other radon sources nearby.
- Preoperational data can be a useful tool to assist determination of background location (by evaluating spatial and temporal variability in background radon) and then interpretation of background results.

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Questions?