NRC STAFF INTERIM GUIDANCE

EVALUATIONS OF URANIUM RECOVERY FACILITY SURVEYS OF RADON AND RADON PROGENY IN AIR AND DEMONSTRATIONS OF COMPLIANCE WITH 10 CFR 20.1301

Draft Report for Comment

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Protecting People and the Environment

COMMENTS ON DRAFT REPORT

The NRC staff is publishing the present guidance as a draft for public comment. Members of the public, licensees, and other interested parties are encouraged to submit comments. The NRC staff plans to publish a Federal Register Notice to formally notice the opportunity for public comment. The Federal Register Notice will provide a date for expiration of the public comment period; at this time, staff anticipates the public comment period to be 60 days. Interested parties are encouraged to contact the NRC staff (contact listed below) with questions about the comment period or about the technical content of this draft guidance.

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1 BACKGROUND

Based on a review of recent submittals to the NRC, the NRC staff has recognized that NRC guidance is insufficient regarding surveys of radon and determinations of dose to members of the public due to operations of licensed uranium recovery (UR) facilities.

This Interim Staff Guidance is intended to provide guidance currently lacking in other, existing NRC staff guidance documents. Specifically, this guidance addresses areas related to doses to members of the public from radon-222 and radon-222 progeny from UR facilities including: (1) surveys of environmental and effluent radon in air; and (2) radon-related aspects of demonstrations of compliance with the public dose limit of 10 CFR 20.1301. This guidance does *not* address (1) other aspects of public dose, including from external radiation and from particulates (such as uranium, Ra-226, Pb-210, etc.); (2) occupational exposures; and (3) compliance with NRC's constraint on air emissions provision (10 CFR 20.1101(d)) or EPA's fuel cycle standard (40 CFR 190).

Uranium recovery (UR) facility licensees, including in-situ recovery (ISR) facilities and conventional uranium mills, are required to perform surveys of radiation levels in unrestricted and controlled areas, and to perform surveys of radioactive materials in effluents released to unrestricted and controlled areas to demonstrate compliance with the dose limits for individual members of the public, in 10 CFR 20.1301.

The NRC regulations in 10 CFR 20.1301 and 20.1302 allow alternatives in appropriate surveys to demonstrate compliance with the public dose limit. This guidance addresses demonstrations of compliance with the public dose limit of 10 CFR 20.1301 for radon-222 and radon-222 progeny released from uranium recovery facilities (including ISR and conventional mills).

Note that in this document, the term "radon," without specifying the isotope, is generally used to mean radon-222, as that is generally the isotope of concern at the uranium recovery facilities currently licensed. As discussed later, radon progeny are addressed because most of the dose to people from releases of radon is actually due to exposure to the radon progeny. Here, radon progeny refers to the short-lived (half lives less than one-half hour) decay products of Rn-222, which are Po-218, Pb-214, Bi-214, and Po-214. This guidance uses the term "radon progeny;" other, especially older, documents may use the term "radon decay products" or "radon daughters" to refer to the same short-lived decay products of radon.

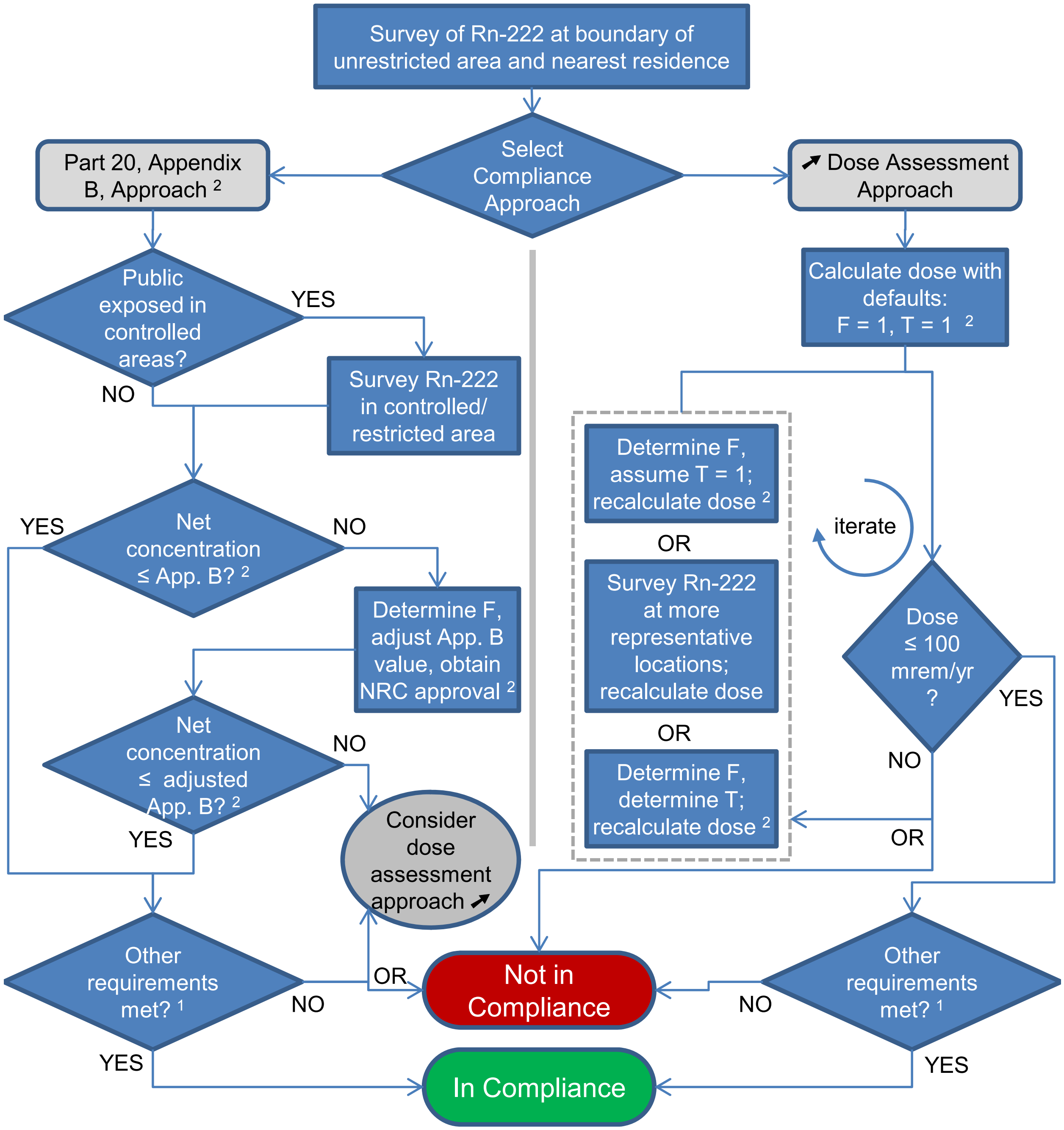
This guidance is intended for NRC staff, in performing reviews of radon and radon progeny aspects of licensee demonstrations of compliance with the public dose limit of 10 CFR 20.1301. This guidance may also be used in evaluating portions of license applications, renewals, or amendments dealing with radon and radon progeny surveys and compliance. As this guidance is focused only on compliance for radon and radon progeny in air, staff reviewers should refer to other documents for guidance on other aspects of compliance demonstrations.

Based on the review of recent submittals to the NRC, the NRC staff believes that certain issues related to radon surveys and compliance with the public dose limit deserve emphasis by staff reviewers. These key issues are highlighted below and discussed in more detail later:

Key Issues for Consideration by NRC Staff Reviewers In Evaluating Compliance with 10 CFR 20.1301 and 20.1302 for Radon and Radon Progeny

- Demonstration of compliance with §20.1301/1302 must account for radon *progeny*.
- When air concentrations are compared to values from 10 CFR 20, Appendix B, Table 2, for compliance with §20.1301/1302, the Table 2 value for radon with daughters present must be used.
- Demonstration of compliance with §20.1301/1302 must address members of the public who are most highly exposed, which may include public exposed onsite.
- When dose assessments are performed to show compliance with §20.1301/1302, licensees must address the total dose from all exposure pathways and all radionuclides (not just radon).
- When dose assessments are performed to show compliance with §20.1301/1302, the equilibrium factor for radon progeny is a key parameter. For exposure of residents, the assessment must address the equilibrium factor indoors for the occupancy time indoors.
- One acceptable survey method is to perform environmental measurements of radon in outdoor air at appropriate locations and to base an equilibrium factor value on generally acceptable values.
- Background concentrations of radon may be another important factor in the determination of dose to receptors; background may be subtracted but the determination of the background concentration must be done carefully.

The figure below provides a general flowchart showing a process licensees may wish to follow to determine the appropriate method for demonstrating compliance with 10 CFR 20.1301 for radon and radon progeny. This flowchart is intended to provide an overview of the process and flavor for the steps that may be considered by licensees in demonstrating compliance. Detailed information is provided in the later sections of this guidance.



[1] Other requirements include other limits and other radionuclides and external radiation.
[2] Note: App. B = Part 20, Appendix B, Table 2, Column 1. F = equilibrium factor. T = occupancy factor.

Flowchart of Radon and Radon Progeny Surveys and Compliance with §20.1301. This flowchart shows potential paths and considerations for licensees demonstrating compliance with 20.1301 for Rn-222 releases from uranium recovery facilities. NRC staff should note that licensees do not have to follow the exact sequence of evaluations. NRC staff should evaluate justifications for each step followed by the licensee. Detailed information on the steps is provided in later sections of this document.

2 ACCEPTANCE CRITERIA

2.1 Regulatory Requirements

10 CFR 20.1003	Definitions
10 CFR 20.1101	Radiation protection programs
10 CFR 20.1301	Dose limits for individual members of the public
10 CFR 20.1302	Compliance with dose limits for individual members of the public
10 CFR 40.65	Reporting requirements for effluents
10 CFR 40, Appendix A	Criterion 7: preoperational & operational monitoring programs Criterion 8: Airborne effluent releases ALARA

2.2 Regulatory Guidance

Regulatory Guide 3.51	Calculational models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations (March 1982)
Regulatory Guide 3.59	Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations (March 1987)
Regulatory Guide 4.14	Radiological Effluent and Environmental Monitoring at Uranium Mills (Revision 1, April 1980)
Regulatory Guide 4.15	Quality Assurance for Radiological Monitoring Programs (Inception through Normal Operations to License Termination) — Effluent Streams and the Environment (Revision 2, July 2007)
Regulatory Guide 8.37	ALARA Levels for Effluents from Materials Facilities (July 1993)
NUREG-1569	Standard Review Plan for In Situ Leach Uranium Extraction License Applications (Final Report, June 2003)
NUREG-1736	Consolidated Guidance: 10 CFR Part 20 - Standards for Protection Against Radiation (October 2001)

3 OVERVIEW OF METHODS FOR DEMONSTRATING COMPLIANCE WITH 10 CFR 20.1301

Licensees must comply with 10 CFR 20.1301, as specified in 10 CFR 20.1302:

> (a) The licensee shall make or cause to be made, as appropriate, surveys of radiation levels in unrestricted and controlled areas and radioactive materials in effluents released to unrestricted and controlled areas to demonstrate compliance with the dose limits for individual members of the public in § 20.1301.
>
> (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

(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.

(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).

For either of the two basic compliance methods (i.e., in §20.1302(b)(1) and 1302(b)(2)), licensees must address doses from all pathways of exposures and for the most exposed individual members of the public. In most cases, exposure pathways will include inhalation of radon and radon progeny, inhalation of uranium and other radionuclides in particulate form, and direct (gamma) radiation exposure. In some cases, other exposure pathways (e.g., ingestion of vegetables or meat from animals or ingestion of ground water contaminated from plant operations) must be included if they contribute significantly to dose.

Licensees must also address all sources, including point and diffuse or area sources, of radiation and radioactive effluents. Typical sources of effluents are described in Regulatory Guide 3.59 (NRC 1987) and Appendix D of NUREG-1569 (NRC 1997). However, in some cases, there may be unique situations resulting in additional sources of effluents. One example is the land application of water as a method of disposing of excess water from the production bleed at ISR facilities; other site-specific disposal practices may exist as well. Staff reviewers should evaluate whether licensees have addressed all sources.

There appears to have been confusion in the past about accounting for exposure and dose from radon progeny (the short-lived progeny). The radon progeny will be the principal contributor to radiation dose in most practical radon exposure situations. Therefore, the NRC staff concludes that determinations of radon-222 doses to the public must include the dose from radon progeny. See Section 4.7.1 and the Appendix for more detail on the need to account for radon progeny dose. (Lead-210 and Po-210, which are not considered radon progeny, may need to be evaluated separately; this guidance does not address evaluations of Pb-210 and Po-210.)

3.1 Compliance with 10 CFR 20.1301/1302 by Comparison to Part 20, Appendix B, Effluent Concentration Values

The licensee may comply with 10 CFR 20.1301 by demonstrating that concentrations in air at the unrestricted area boundary are no greater than the 10 CFR Part 20, Appendix B, Table 2, Effluent Concentration value for Rn-222 with daughters present. Surveys of radon concentrations in air should be performed as described later in this document.

3.2 Compliance with 20.1301/1302 by Performing Dose Assessment

The licensee may comply with 10 CFR 20.1301 by demonstrating that the dose (TEDE) to the individual likely to receive the highest dose from the licensed operation does not exceed 100 mrem/yr. Licensees need to provide the justification for assumptions about the radon-222 and radon progeny equilibrium, the dose conversion factor, and other parameters used to make the dose estimate.

3.3 Licensee Information to Be Reviewed for Demonstration of Compliance with 20.1301

NRC staff should review reports documenting licensees' demonstrations of compliance with 10 CFR 20.1301, the 100 mrem/yr (1 mSv/yr) public dose limit (such demonstrations may be included in annual ALARA review reports, semi-annual effluent monitoring reports, or other documents). The staff should review the methods used to survey concentrations of radon and radon progeny to which public receptors are exposed. The staff should review the methods used in calculating doses to members of the public from such concentrations. Staff should review the license for license conditions that may relate to these aspects. NRC staff reviewers should note that in some cases pertinent information will not be provided in a current report if that information has already been submitted to the NRC and is on the record. In these cases, licensees should refer to the previously submitted document.

NRC staff reviewers should not rely solely on reports of annual public dose or semi-annual effluent reports (sometimes referred to as 40.65 reports) for all information related to potential doses to members of the public. Staff reviewers should obtain a general knowledge of processes at the site, especially related to sources of radiation, effluent pathways at the site, waste disposal methods, and sampling methods.

Licensees must demonstrate compliance with the public dose limit of §20.1301 (i.e., addressing contributions from effluents and external sources of radiation). Licensee demonstration of compliance with the public dose limit must be performed on an annual basis. Licensees may submit the demonstration of compliance in different types of reports, in part dependent on license conditions. Some licensees will provide the demonstration in annual ALARA review reports. Other licensees may submit the demonstration as part of the semi-annual report for the second half of the year.

Licensees should provide a complete assessment of the dose to members of the public, with sufficient supporting information that the NRC staff could independently replicate the dose assessment. Specifically, licensees should address, or should reference, in the reports:

- Doses determined for the members of the public considered and a description of the methodology used.
- Evaluation of which members of the public are likely to be the most highly exposed due to licensed operations.
- Consideration of all sources of radiation and radioactive effluents under the control of the licensee.
- Consideration of doses from all pathways of exposures.
- Land use census to verify existing receptors and exposure pathways as well as identify potential new receptors and exposure pathways.

- Results of measurements and values for other parameters used in the assessment, along with associated uncertainties. Justification for parameter choices should be included.
- Discussion of the type of monitoring and analysis, as well as the sample collection frequency and lower limit of detection.
- Maps should be included, or referenced, which clearly identify licensed areas, restricted areas, unrestricted areas, controlled areas, nearest resident, and the location of monitoring points, as appropriate for the dose assessment.
- Meteorological data should be included or referenced, if used to determine monitoring locations or to calculate air transport of radionuclides.
- Although not required by regulations, licensees should include comparisons with previous reporting periods to identify any trends.

4 CONDUCTING A TECHNICAL REVIEW OF RADON COMPLIANCE ASSESSMENTS

NRC staff reviewers should review the information described under “Licensee Information to Be Reviewed for Demonstration of Compliance with 20.1301” (Section 3.3) above. For the determinations of dose from radon and radon progeny and demonstrations of compliance with the public dose limit, reviewers should review the dose calculation methods, parameter values, and compliance methods, as appropriate. Reviewers should ensure that licensees address doses from all pathways of exposures and for the most exposed individual members of the public. In most cases, exposure pathways will include inhalation of radon and radon progeny, inhalation of uranium and other radionuclides in particulate form, direct (gamma) radiation exposure (reviewers should note that only radon and radon progeny is discussed in this present document). In some cases, other exposure pathways (e.g., ingestion of meat from animals or ingestion of ground water contaminated from plant operations) must be considered if they contribute to dose.

NRC staff reviewers should be mindful of all the regulatory requirements in 10 CFR Part 20 that pertain to public dose limits, limit on dose rates from external sources in unrestricted areas, and dose constraint for airborne effluents (excepting radon and radon progeny).

1. 10 CFR 20.1301(a) requires that the TEDE does not exceed 100 mrem (1 mSv) in a year to individual members of the public from licensed operations exclusive of background contributions;

2. 10 CFR 20.1301(a) requires that dose from external sources do not exceed 2 mrem (0.02 mSv) in any one hour in any unrestricted area;

3. 10 CFR 20.1301(b) requires that doses to members of the public allowed access to controlled areas do not exceed 100 mrem/yr (1 mSv/yr);

4. 10 CFR 20.1101(b) requires licensees to establish a constraint on air emissions such that individual members of the pubic likely to receive the highest dose will not be expected to exceed a TEDE of 10 mrem/yr (0.1 mSv/yr) from air emissions of radioactive material exclusive of radon-222 and radon-222 daughters.

5. 10 CFR 20.1301(e) specifies that the EPA generally applicable environmental radiation standards in 40 CFR 190 must be met. The 40 CFR 190 requirements specify that the

annual dose equivalent not exceed 25 mrem (0.25 mSv) to the whole body, 75 mrem (0.75 mSv) to the thyroid, and 25 mrem (0.25 mSv) to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations.

Reviewers should ensure that licensees have evaluated which members of the public are likely to be the most highly exposed due to licensed operations. If the licensee allows the public access to controlled areas of the facility, then the licensee also needs to demonstrate that the dose to these members of the public does not exceed the 10 CFR 20.1301 limit. The NRC staff note that some licensees provide onsite residences for workers; while off-duty, these people are considered members of the public.

The public dose limit is a limit on the total effective dose equivalent (TEDE) to members of the public from licensed operations, and doses may be received in multiple locations. Thus, the compliance assessment must evaluate radon and progeny in locations where receptors are exposed. For example, for residents near a facility who spend time in their homes, the assessment needs to address indoor exposure.

Although the NRC regulations do not specifically require licensees to evaluate trends in their effluent quantities or public doses, NRC staff reviewers should evaluate potential trends in these quantities, as trends may provide indications of improvements or degradations in performance. NRC staff should consider obtaining reports from previous years, should plot data, and may consider performing statistical tests of trends, as appropriate.

4.1 Overview of Surveys of Radon and Radon Progeny in Air

Compliance with §20.1301 and 20.1302 requires that licensees must address radon and radon progeny. Compliance with the public dose limit, §20.1302(a) requires that licensees survey radioactive materials in effluents released to unrestricted and controlled areas. The definition of survey, in §20.1003, is an evaluation of radiological conditions that includes measurements or calculations of levels of radiation or concentrations or quantities of radioactive material present. As discussed in detail below, NRC staff reviewers should ensure that licensee evaluations address radon and radon progeny. In particular, staff should ensure that the licensee's survey or dose assessment addresses the dose contribution from radon progeny (see also Section 4.7.1 and Appendix for more detail).

4.2 Alternative Survey Approaches for Radon-222 in Air

The flexibility to perform measurements or calculations for surveys provides alternative methods for performing the surveys of radon in air necessary for compliance with §20.1301/1302. Three methods acceptable to NRC staff are described below and are considered adequate to demonstrate compliance with 10 CFR 20.1301/1302. Other options to demonstrate compliance may be acceptable if supported by an adequate justification or technical basis.

4.2.1 Measure Radon Outdoors at Unrestricted Area Boundary or Receptor Location

One approach to surveying Rn-222 in air is to measure radon concentration outdoors at the unrestricted area boundary or receptor location.

If receptors spend time indoors (e.g., at a residence), the indoor radon concentration can be calculated. For assessment of residential exposures, radon concentrations outdoors and indoors may be important. For indoors concentrations, it may be extremely difficult to distinguish the radon contributions from licensed operations from contributions from background (especially background due to infiltration into a house from the underlying soil). Schiager (1974) states that for buildings immediately adjacent to a tailings pile, the indoor radon concentration would be in equilibrium with (i.e., the same as) that found outdoors. This is a simplified model of infiltration of outdoor radon into buildings. Thus, measurements are usually made outdoors, and it is assumed that the indoor radon concentration due to licensee activities is equal to the outdoor concentration (at the same location) due to licensee activities (e.g., around the house). The NRC staff considers this assumption reasonable and acceptable.

If a more detailed analysis is necessary, the infiltration of outdoor radon could be modeled based on the air exchange rate between outdoor and indoor air. Such an infiltration modeling method is briefly described in UNSCEAR (1993). NRC staff believes that for most buildings with reasonable air exchange rates, this refinement would result in an estimated indoor radon concentration that is similar to assuming the indoor concentration equals the outdoor concentration.

4.2.2 Measure Operational Parameters

Another approach to surveying Rn-222 in air is to measure uranium recovery facility operational process parameters. Based on operational parameters, licensees could calculate a radon release rate or source term for vents, stacks, other release points, and wellfields. NRC Regulatory Guide 3.59 (NRC 1987) and Appendix D of NUREG-1569 (NRC 1997), provide guidance on methods that may be used for these calculations.

Based on the calculated radon release rates, the Rn-222 concentration at the unrestricted area boundary or receptor locations can be calculated using standard atmospheric dispersion calculations or an appropriate computer code (such as MILDOS-AREA (see NUREG-1569, Section 7.3)). Using a graded approach, NRC staff should ensure that the licensee has measured (or the applicant commits to measuring) radon in air or some other indicator sufficient to verify that the predicted concentrations are not exceeded.

4.2.3 Measure Radon in Stacks and Other Effluent Points

A third approach to surveying Rn-222 in air is to measure the radon released at vents or stacks by conventional stack monitoring, and measure the radon from wellfields using passive or dynamic radon monitors. Based on the measured radon release rates, the Rn-222 concentration at the unrestricted area boundary or receptor locations can be calculated using standard atmospheric dispersion calculations or an appropriate computer code (such as MILDOS-AREA (see NUREG-1569, Section 7.3)). Using a graded approach, NRC staff should ensure that the licensee has measured (or the applicant commits to measuring) radon in air or some other indicator sufficient to verify that the predicted concentrations are not exceeded.

Summary of Alternative Methods for Surveys (Combined Measurements and Calculations) of Radon in Air for Compliance with 10 CFR 20.1301/1302		
	Measurements	**Associated Calculations**
1	Measure radon concentration outdoors at the unrestricted area boundary or receptor location	When appropriate for receptors that spend time indoors (e.g., at a residence), calculate indoor radon concentration.
2	Measure operational process parameters.	Calculate radon release rates. Then calculate the Rn-222 concentration at the unrestricted area boundary or receptor locations. Verify with measurements of radon in air.
3	Measure the Rn-222 released at vents or stacks by conventional stack monitoring, and measure the Rn-222 from wellfields using passive or dynamic radon monitors.	Calculate the radon-222 concentration at the unrestricted area boundary or receptor location. Verify with measurements of radon in air.

4.2.4 Determining and subtracting background Radon-222 concentrations:

The public dose limit of 10 CFR 20.1301 specifically excludes dose contributions from background radiation. Thus, in surveying radon concentrations around facilities, NRC licensees may subtract the background radon levels from measured concentrations to determine net concentrations due to licensed activities. These net concentrations may be used in determinations of compliance with §20.1301/1302.

Establishing background locations for outdoor radon measurements is difficult in many situations, complicated by spatially and temporally varying concentrations; impact of varying geology on the natural emissions of radon from soil into air; effects of topography on wind patterns, especially on patterns of low speed winds (e.g., down valley drainage); and potentially other nearby radon sources, particularly for sites located in heavily mined areas. Licensees should carefully determine background locations on a case-specific basis. When feasible, preoperational monitoring may provide a more complete understanding of background radon concentrations. Regulatory Guide 4.14 recommends one year of preoperational monitoring. However, annual average background radon concentrations outdoors may vary considerably year-to-year.

For cases of background monitoring performed concurrently with operational monitoring, NRC staff reviewers should be aware of the complexities of determining an appropriate background outdoor radon concentration that is representative of the receptor (or other monitoring) locations. A background location would typically need to be close to the monitoring locations, with geology similar to the site geology, so that the background location is representative of the monitoring location. But the background location should also be far enough from the facility that the radon concentration is not significantly impacted by radon releases from the facility. If onsite meteorological data are available, the data can be used to help determine if background locations are unimpacted or minimally impacted by site operations.

Regulatory Guide 4.14 provides guidance on numbers and locations of preoperational monitoring locations. There may be conditions in which licensees may want to use more monitoring locations or a longer preoperational monitoring period than recommended, to provide a better understanding of the background radon concentrations and spatial and temporal variability around the proposed facility location. Some such conditions include:

- The location is known to have elevated radon concentrations.
- The location has significant topographic features such as valleys, mountains, buttes, or varying elevations.
- There are significant existing sources of radon nearby, for example old mine shafts, outcroppings of uranium-bearing minerals, or other uranium recovery facilities.

Background measurements should typically be made during the same time period as the measurements around the facility. Background radon concentrations may vary substantially, even when comparing annual average concentrations for different years. Thus, background measurements will be most representative of the time over which they are measured. NUREG-1501 (NRC 1994b) provides a general discussion of variability in background radiation that may be useful to reviewers.

Results of monitoring at background locations should also be compared to other locations, statistically if appropriate. NRC reviewers should carefully evaluate cases in which radon concentrations measured at the "background" location are consistently higher than concentrations at or around (especially downwind from) the facility. This situation may be an indication of a background location that is influenced by other radon sources or in other ways is not representative of the true background radon concentrations.

4.2.5 Types of Radon-222 Measurement Methods

The Standard Review Plan for In Situ Leach Uranium Extraction License Applications (NUREG-1569) refers to RG 4.14 for discussion of radon sampling methods. Regulatory Guide 4.14 recommends that samples for radon in air be collected continuously, or for at least one week per month. Specific methods are not provided in RG 4.14.

A.C. George has written two articles for AARST and the HP Journal (George 1996, 2005) that provide information on instruments and methods for measuring radon and radon progeny, and include information on sensitivity and accuracy of these instruments and methods. Also, the NCRP Report No. 97 (NCRP 1988) provides information on the measurement of radon and radon progeny in air.

Typically, passive alpha-track detectors are used to measure environmental levels of radon. These detectors are relatively sensitive, but the minimum detectable concentration (MDC) is a concern for demonstrating compliance using a comparison to the Part 20, Appendix B, effluent value (0.1 pCi/L with progeny in equilibrium). For certain of these detectors, MDC is given as an time-integrated concentration (i.e., an integrated product of concentration and time at that concentration, for example with units pCi-days/L). The length of deployment of detectors can be increased to improve the MDC and reduce the uncertainty of the measurements (e.g., 6 months exposure results in a lower MDC than does 3 months exposure).

Regulatory Guide 4.14 recommends an MDC (termed lower limit of detection in that Regulatory Guide) for Rn-222 in air of 0.2 pCi/L. The NRC staff notes that this Regulatory Guide was published before the 1991 update of 10 CFR Part 20, which reduced the Appendix B, Table 2 effluent concentration for Rn-222 by a factor of 30. The Regulatory Guide also recommends that the uncertainty associated with sample analyses should always be calculated and should take into account all significant sources of uncertainty, not just the counting statistics uncertainty. The MDC of 0.2 pCi/L (recommended in Regulatory Guide 4.14) would be applicable to measurements of background concentrations and gross concentrations at potential receptor locations. This MDC may be sufficient, but the uncertainty in net radon concentrations and dose to people is important. Thus, NRC staff should evaluate the overall uncertainty in the licensee's calculations of net (i.e., due to licensed operations) radon concentrations and doses to people, as appropriate. The overall relative uncertainty in these calculated results should be reasonable relative to the calculated doses.

If MDCs are insufficient (too high) or overall relative uncertainties are too high, licensees should evaluate improvements to monitoring techniques. Some detector vendors may make available analyses with improved MDCs (by analyzing a larger area of the alpha track material. Also, multiple detectors may be emplaced (at each location) to also reduce the statistical uncertainty of the overall measurement.

4.3 Radon-222 Measurements Locations:

Regulatory Guide 4.14 provides guidance on locations for monitoring radon in air around uranium recovery facilities: specifically at or near the site boundary and at the nearest residence or occupiable structure within 10 kilometers of a uranium mill. RG 4.14 recommends that the sampling stations be co-located with the air particulate monitoring stations, and that airborne particulate samplers be placed in locations with the highest predicted airborne radionuclide concentration.

The NRC staff reviewer needs to identify the restricted, controlled and unrestricted areas in the permit areas to determine if 10 CFR 20.1301 and 20.1302 requirements are met, because of the following considerations. The regulation of 10 CFR 20.1301 requires the dose to any member of the public be less than the limit. If the compliance method of comparing to the Appendix B values is used, 20.1302(b)(2)(i) requires that concentrations at the *boundary of the unrestricted area* do not exceed the Appendix B values. In addition, 20.1301(b) specifies that if members of the public have access to controlled areas, the public dose limit continues to apply to those individuals. The NRC staff notes that the recommendation of Regulatory Guide 4.14 may not be completely consistent with the Part 20 requirements, as the Regulatory Guide refers to the site boundary, and that may be different from the unrestricted area boundary and different from areas within the controlled areas to which members of the public may have access.

NRC staff reviewers should determine if licensees have evaluated which members of the public are likely to be the most highly exposed due to licensed operations. If the licensee allows the public access to controlled areas of the facility, then the licensee also needs to demonstrate that the dose to these members of the public does not exceed the 10 CFR 20.1301 limit or effluent concentration values. Additional monitoring locations inside controlled areas (i.e., in addition to the typical "fenceline" locations) may be appropriate to provide data to determine radon concentrations to which people who may access controlled areas may be exposed.

In determining monitoring locations, the licensee is also expected to take both point and diffuse or area sources into account. Diffuse sources include, for example, radon emanating from the wellfields at ISR facilities. Point sources may include, for example, radon from the ion exchange column captured by an exhaust system and released through a roof stack.

If passive alpha track detectors are used, these devices are relatively inexpensive. It may be beneficial for licensees to deploy detectors at additional locations to provide more comprehensive data about the variations in radon concentrations around a facility.

NRC staff reviewers should evaluate whether monitoring locations are representative and appropriate. If monitoring is performed at a limited number of boundary or fenceline locations, some of the locations should be chosen in directions of expected highest concentrations from facility releases. These directions can be determined based on meteorological data for the facility. If onsite meteorological data is not available, licensees should justify acceptability of using offsite, nearby data to represent site meteorology.

NRC reviewers should note that there may be difficulties in predicting locations of the expected highest radon concentrations. Many UR facilities are located in valleys where the air flows important to highest radon concentrations (least dispersion) may be upvalley (upslope) and downvalley (drainage) flows. These upslope and drainage flows are localized flows that set up in valley systems based on gravity (cool air at night is denser and thus drains downvalley while warm air during the daytime is less dense and tends to rise upslope) (Till and Grogan 2008). Shearer and Sill (1969) performed radon in air surveys around four uranium mill tailings sites and found that valley flows were important at two of the locations. Others have noted the significance of these valley flows for radon concentrations around tailings or other sources of radon releases. In many cases, the low speed, drainage winds that occur at night under relatively stable atmospheric conditions are the winds that may result in the highest radon concentrations and may contribute the most to annual doses. Thus, effects of topography should be considered when determining likely locations of highest radon concentrations.

It is unclear whether typical meteorological monitoring stations will adequately characterize the low wind speed drainage flows that may be critical for radon concentrations. One issue is that in areas of complicated topography, where these flows are important, it may be difficult to characterize the meteorology with a single monitoring station, because air flows will vary across and near the facility. Licensees and staff should be aware of these potential difficulties. Instead of using meteorology to guide monitoring locations, it may be reasonable to, at least initially, use a larger radon monitoring network (i.e., more monitoring locations) to provide reasonable assurance that the locations of expected highest radon concentrations are monitored. Or, it may be reasonable to model air dispersion using models that account for topography. The NRC staff does not have specific recommendations in this regard; this would need to be determined on a case-specific basis.

Another difficulty with locations for radon monitoring is distance from the release points. At some distance from a radon source, the air dispersion will reduce air concentrations of radon such that the concentrations are indistinguishable, statistically, from background or preoperational concentrations. Shearer and Sill (1969) studied radon concentrations around uranium mill tailings sites, in particular making measurements at 25 locations on and around the tailings pile in Grand Junction, Colorado. Based on the measurements around the Grand Junction tailings pile, their results showed that at a distance of one mile or more from the pile, none of the individual monitoring station averages could be considered statistically different (at 95% confidence level, based on standard t-test and analysis of variance techniques) from each other. At the time of the measurements, the tailings at the Grand Junction mill site were uncovered. In the current regulatory regime, tailings must meet a radon flux (fluence rate) standard, so radon releases are expected to be lower than in this study, and the distance to where measured radon concentrations would be indistinguishable from background may be less than one mile. That study around Grand Junction is just one study, and results could be different at different sites with different measurement methodologies. But it does point out that at some distance away from the source of radon emission, concentrations in air due to releases from the facility will be indistinguishable from the natural background concentrations. Thus, when feasible, there can be a benefit to performing monitoring close enough to the facility that differences from background are expected to be statistically significant.

4.4 Annual Average Concentrations May Be Used for Compliance

The public dose limit of §20.1301 is an *annual* limit. In addition, for using the Appendix B compliance method, §20.1302(b)(2)(i) specifies that *annual average* concentrations do not exceed the values of Part 20, Appendix B. Thus, in general, annual average concentrations should be calculated for use in dose calculations and compliance determinations. For certain specific purposes, averages over other time periods may be appropriate.

4.5 Radon Progeny Equilibrium Factor

For dose calculations, long-term average concentrations are typically most appropriate. For radon progeny in the environment, there are substantial difficulties in making appropriate long-term measurements of radon progeny (Jenkins 2010, George 1996). Passive methods for environmental measurements of radon progeny are not readily available. Based on the substantial variability in radon progeny concentrations (diurnal, longer-term, and other variability), making grab sample measurements with sufficient frequency to estimate long-term averages may be quite tedious and expensive.

Because of the difficulties in measuring radon progeny in the environment, the more typical approach is to measure radon concentration, determine an equilibrium factor (sometimes called equilibrium fraction), and then calculate the radon progeny concentration or the equilibrium effective concentration (EEC) of radon. If licensees intend to adjust the Part 20 Appendix B value for radon, for equilibrium factor other than 1.0, or intend to perform a dose assessment to demonstrate compliance with the public dose limit, determining the equilibrium factor is important. NRC reviewers should ensure that if licensees adjust the Appendix B, Table 2, value for radon, the licensee has obtained NRC approval.

The NRC staff reviewers should evaluate the licensee's approach to determining the equilibrium factor. The reviewer should determine that the licensee has used one of the three following approaches and has provided sufficient technical basis for the approach.

4.5.1 Conservative value:

The simplest approach to determining the equilibrium factor is to make the assumption that radon progeny are present in 100% equilibrium with radon, so an equilibrium factor of 1.0 is appropriate. This assumption would be conservative for all cases, for either compliance method. However, the licensee does not need to assume 100% equilibrium.

4.5.2 Generally Acceptable Radon Progeny Equilibrium Factors

To reduce conservatism in calculations, another approach to determining the equilibrium factor is to use equilibrium factor values that are generally accepted by the NRC staff. Equilibrium factors may be needed for indoors and outdoors exposures. A recent publication by the National Council on Radiation Protection and Measurements (NCRP) provides a summary of information on equilibrium factors.

The NCRP updated its report on the radiation exposure of the United States population, published as NCRP Report 160 (NCRP 2009). In this report, NCRP calculates average exposure to the U.S. population, based on average radon concentration and average equilibrium factors. The NCRP exposure model separates exposures into indoors at home, indoors away from home, and outdoors. NCRP used the same equilibrium factor for indoors at home and indoors away from home. NCRP summarized data on equilibrium factor from several sources. For indoor exposures, NCRP used a central value of 0.4, and considered the uncertainty range to be 0.3 to 0.5. (For perspective, NCRP considered the average background radon concentration indoors in homes to be 1.2 pCi/L.) For outdoor exposures, NCRP used a central value of 0.6, considered the typical values to be 0.5 to 0.7, and stated that a wider range of values can be found (0.2 to 1.0). (For perspective, NCRP considered the average background radon concentration outdoors to be 0.4 pCi/L.)

For outdoors exposures, previous NRC staff guidance does not provide a generally acceptable value of equilibrium factor. Therefore, the NRC staff considers use of values from NCRP 160 acceptable as follows. NCRP applied the central values to estimate exposures of the entire U.S. population. However, for compliance with the NRC public dose limit, exposures to individuals must be evaluated, so the NRC staff considers use of an overall average to be nonconservative for some individuals in the population. Thus, for outdoor exposures, the NRC staff would find acceptable use of the upper value of the NCRP's typical range, which is 0.7.

For indoors exposures, especially in houses, the equilibrium factor is primarily dependent on conditions of the building, due to typical air exchange rates less than 1 hr^{-1} (Nazaroff and Nero 1988). Schiager (1974) states that in determining the indoor radon progeny concentration, the critical factor, in addition to the radon concentration, is assessment of the mean residence time of the radon in the indoor atmosphere. For purposes of assessing indoors exposure to radon progeny, the NRC staff should assume that outdoor radon from a facility enters a home with very little progeny present (i.e., it is assumed most of the progeny plate-out on surfaces of the cracks through which the radon enters the home). The staff should assume that progeny ingrowth indoors is based on the characteristics of the home, especially the air exchange rate (which can be related to mean residence time of air). For indoors exposures, Regulatory Guide 3.51 provides a generally acceptable equilibrium factor. Appendix C of Regulatory Guide 3.51 provides technical basis information used by NRC staff for a radon progeny inhalation dose conversion factor. The appendix states that a ratio of 5×10^{-6} WL per pCi/m^3 of Rn-222 is established by the assumed indoor air concentration ratios of the individual radon progeny. The relationship between radon concentration, progeny concentration, and equilibrium factor is: progeny concentration (in WL) = radon concentration (in pCi/m^3) × equilibrium factor × (1 WL per 100 pCi/L radon at equilibrium) × (1×10^{-3} m^3/L). Based on this relationship, the value of progeny concentration per radon concentration in the appendix is equivalent to an assumption of an equilibrium factor of 0.5. Thus, for indoor exposures, the NRC staff would find acceptable an equilibrium factor of 0.5. The NRC staff notes that from the NCRP 160 assessment (NCRP 2009), the upper value of the uncertainty range on the *average* equilibrium factor for indoors was also 0.5.

For combined indoor and outdoor exposure of residents exposed at their residence relatively close to the facility, the NRC staff considers an equilibrium factor of 0.5 to be generally acceptable, based on the following. Distributions of exposure time indoors and outdoors are developed in NUREG/CR-5512, Vol. 3 (NRC 1999). At the 90th percentile, time spent indoors, outdoors, and gardening are 266, 58, and 7 days per year, respectively (values do not add to 365 due in part to an assumption that some time is spent offsite). If these times are used to weight the generally acceptable indoor and outdoor equilibrium factors, the weighted average equilibrium factor is 0.5. The NRC staff considers this value generally acceptable to use for typical cases of residential (indoors and outdoors, with majority of time spent indoors) exposure relatively close to the facility. This value should not be used in cases where it is known that outdoor exposure times are significantly more than described above and the travel time is long enough that the outdoor equilibrium factor from progeny ingrowth is expected to be significantly greater than 0.5.

4.5.3 Site-specific Radon-222 Radon Progeny Equilibrium Factor values:

To further reduce potential conservatism in the equilibrium factor, a third approach to determining the equilibrium factor is to base it on site-specific conditions. NRC reviewers should ensure that licensees have provided sufficient technical basis for this approach.

4.5.3.1 Outdoor equilibrium factor by travel time: For outdoors exposures, one site-specific approach acceptable to NRC staff would be to determine radon progeny in-growth time or the time that it takes radon to be dispersed to the unrestricted area boundary or the nearest resident (or other receptor) location. Fractional in-growth of progeny can be calculated for this travel time based on standard equations for in-growth of progeny. Two references that provide information on radon-222 progeny in-growth are the EPA CAP-88 PC Users Guide (EPA 2007) and a classic journal article (Evans 1969). Evans provides curves of radon progeny ingrowth as a function of time. If licensees use this method, NRC staff should evaluate applicability of the method. The method is more easily used for sources where the radon release is essentially pure radon gas, that is, where the equilibrium factor at time of release is essentially zero. In addition, the basis for the travel time used should be carefully considered. A single travel time calculated from the mean wind speed will differ from a mean of individual travel times calculated from the distribution of individual wind speeds. Travel time is inversely proportional to wind speed. The equilibrium fraction is a nonlinear function of travel time (though close to linear for short times). In addition, wind speeds are characterized by a distribution of wind speeds that is generally not close to a uniform distribution. Based on all these considerations, use of an *average* wind speed may *not* provide a reasonable basis for an estimate of travel time and determination of *average* equilibrium factor.

This method for determining equilibrium factor may be particularly appropriate for exposures of members of the public allowed access to outdoor controlled areas of the site (e.g., coal-bed methane workers routinely accessing controlled outdoor areas).

4.5.3.2 Indoor equilibrium factor by measurement. For indoors exposures, one site-specific approach would be to measure radon concentrations and radon progeny concentrations indoors at actual receptor locations, and calculate the equilibrium fraction. As mentioned above (Section 4.5.2), for indoors exposures, especially in houses, the equilibrium factor is primarily dependent on conditions of the building and the NRC staff should assume that outdoor radon from a facility enters a home with very little progeny present. The staff should assume that progeny ingrowth indoors is based on the characteristics of the home, especially the air exchange rate (which can be related to mean residence time of air). Thus, an equilibrium factor determined for a house should be applicable to the indoor radon that is due to facility releases. If licensees use this method, NRC staff should carefully evaluate details of the implementation. Radon and radon progeny are usually measured with different techniques that are not necessarily comparable. Both radon and progeny concentrations are expected to vary diurnally, but the two do not necessarily vary identically in time; therefore the equilibrium factor is expected to vary in time (diurnally). Thus, the radon and progeny measurements should be made at the same time and should be integrated over the same times (e.g., grab samples used for both measurements or integrated measurements made concurrently in time) so that it is reasonable to calculate an equilibrium factor. Ideally, the measurements should also be representative of the long-term average equilibrium factor, as the long-term average is what is appropriate for compliance purposes. Another issue to consider is whether substantial opening of doors (for personnel entering a house to make measurements) may affect the determination of the equilibrium factor indoors. If so, measurements should be timed to represent more typical equilibrium conditions.

4.5.4 Summary of acceptable Equilibrium Factor (F) values and approaches:

The table below summarizes acceptable values of and approaches to measuring the equilibrium factor. If receptors are exposed indoors and outdoors, it would be reasonable to use equilibrium factor values separately for indoor and outdoor exposure time (if appropriate to compliance method) or to use the more conservative of the two equilibrium factor values.

Acceptable values of and approaches to determining the equilibrium factor.			
Type of survey	**Receptor location**	**Equilibrium factor or approach**	**Notes**
Most conservative, always acceptable	Indoors or outdoors	1.0	
Generally acceptable	outdoors *	0.7	consistent with NCRP 160 approach
	indoors *	0.5	based on RG 3.51, consistent with NCRP 160 approach
	residential exposure	0.5	see text for conditions on use
Site-specific	outdoors *	ingrowth calculations based on travel time	
	indoors *	measure radon and progeny separately and calculate equilibrium factor	
* If receptors are exposed indoors and outdoors, it is acceptable to use separate equilibrium factor values for indoor and outdoor exposure time, or to use the more conservative equilibrium factor value.			

4.6 Compliance with 10 CFR 20.1301 and Assessment of Dose to Visitors

NRC staff reviewers should determine if licensees have evaluated which members of the public are likely to be the most highly exposed due to licensed operations. As stated by 10 CFR 20.1301(b), if the licensee allows the public access to controlled or restricted areas of the facility, then the licensee also needs to demonstrate that the dose to these members of the public does not exceed the 10 CFR 20.1301 limit. NRC staff note that some licensees provide onsite residences for workers; while off-duty, these people are considered members of the public.

The regulation of §20.1302(b)(2) describes a method to be used at the boundary of the unrestricted area. However, NRC guidance in NUREG/CR-6204 expands on this in the response to Question 104 in the NRC's Questions and Answers Based on revised 10 CFR Part 20 (NRC 1994a). This answer indicates that it would be acceptable to demonstrate compliance with the annual dose limit for members of the public in a controlled area by applying the effluent concentration criteria of §20.1302(b)(2) to the controlled area rather than to the restricted area boundary. To the extent that licensees establish controlled areas, this method may be used in such controlled areas.

4.7 Compliance with 20.1301/1302 by Comparison to Part 20, Appendix B, Effluent Concentration Values

4.7.1 10 CFR 20, Appendix B, Table 2, Value for Radon in Air:

There appears to have been confusion in the past about which of the two different values of effluent concentration in 10 CFR 20, Appendix B, Table 2, for radon-222 is applicable. Appendix B includes Table 2 values for radon-222 “with daughters removed” and for radon-222 “with daughters present.” The short-lived radon progeny will be the principal contributor to radiation dose in most practical radon exposure situations. The NRC staff does not envision cases at uranium recovery facilities where progeny (daughters) will have been completely removed from air to which the public is exposed. The Appendix provides discussion of the regulatory basis for NRC staff concluding that radon progeny will be present and that uranium recovery facilities are expected to use Appendix B, Table 2, values for radon with daughters present.

The NRC staff concludes that the correct Appendix B, Table 2, value for air for uranium recovery facilities is that for radon-222 “with daughters present,” which is 1×10^{-10} µCi/mL, or 0.1 pCi/L.

4.7.2 Adjusting Appendix B Value for Equilibrium Factor

The regulation of §20.1302(c) allows, with approval from the NRC, licensees to adjust the effluent concentration values of Part 20, Appendix B, to take into account actual physical and chemical characteristics of the effluents, including radioactive decay equilibrium. The Statements of Consideration to the 1991 Part 20 rule (*Federal Register*, 56FR23360, May 21, 1991, on page 23375) specifically discusses making such adjustments for the actual degree of equilibrium in the environment. This adjustment allows consideration of radon progeny equilibrium factor values other than 1.0 (100% equilibrium).

As noted, this adjustment requires NRC approval. If licensees request this approval, NRC staff should evaluate the requested adjustment following the guidance on equilibrium factor above in Section 4.5. In reviewing requests, NRC staff should note that §20.1302(c) allows only for adjustment based on physical or chemical properties of the effluents. In particular, adjustment for occupancy is not to be made when licensees use this method of demonstrating compliance.

4.8 Compliance with 20.1301/1302 by Performing Dose Assessment

The licensee may comply with 10 CFR 20.1301 by demonstrating that the dose (TEDE) to the individual likely to receive the highest dose from the licensed operation does not exceed 100 mrem/yr (1 mSv/yr). NRC staff reviewers should ensure that the licensee has provided the justification for assumptions about the radon-222 and radon progeny equilibrium, the dose conversion factor, and other parameters used to make the dose estimate.

Generally, licensees’ dose assessments should be straightforward, and could follow the simple equation:

$$D = DCF \sum_{i} C_i F_i T_i$$

where:

D = annual dose (TEDE) (mrem/yr);

DCF = dose conversion factor for Rn-222 in equilibrium (i.e., 100% equilibrium) with the Rn-222 progeny (mrem/yr per pCi Rn/L);

C_i = annual average concentration of Rn-222 in air (pCi/L) at the receptor location *i*;

F_i = radon progeny equilibrium factor (fraction) for receptor location *i*; and

T_i = occupancy time factor (fraction of a year) for receptor location *i*.

Here, the receptor locations *i* represent the different locations at which an individual is exposed. For example, if a person is exposed at their home indoors and outdoors, *i* would take two values to represent the indoor portion of exposure and the outdoor portion. If a person is exposed only outdoors, *i* would only take a single value, to represent that outdoor exposure.

Surveys of radon concentrations in air should be performed as described in Sections 4.1–4.4 above to determine the annual average radon concentration. Determinations of the radon progeny equilibrium factor should be performed following Section 4.5 above. The occupancy factor and dose conversion factor are discussed in the following sections.

4.8.1 Receptor Locations and Occupancy Factor

NRC staff reviewers should determine that licensees evaluated which members of the public are likely to be the most highly exposed due to licensed operations. If the licensee allows the public access to controlled areas of the facility, then the licensee also needs to demonstrate that the dose to these members of the public does not exceed the 10 CFR 20.1301 limit.

For nearest resident receptors (and other resident receptors), exposure may occur while indoors at home and while outdoors around the home. The dose assessment should either assess exposures both indoors and outdoors or should make conservative assumptions for parameter values (including equilibrium factor and occupancy factor) to address exposures indoors and outdoors. The NRC staff should ensure that simplifying assumptions are either realistic or conservative.

Use of an occupancy factor of 1 is conservative and bounding on realistic occupancy. Thus, use of an occupancy factor of 1 is acceptable to the NRC staff.

NRC staff reviewers should note that licensees do not have to make conservative assumptions about occupancy factors. If licensees use more realistic occupancy factors, NRC staff reviewers should evaluate the justification carefully. The public dose limit of §20.1301 applies to individual members of the public, not to hypothetical individuals or to groups of individuals. Thus, occupancy factors must address occupancy of the actual individuals. It would be *in*appropriate to apply occupancy factors that were developed to apply to groups of people (for example, a value intended to represent an average member of a critical group), as such a value may be nonconservative for certain individuals around the facility. One acceptable method that may be used to determine occupancy factors is to interview the potentially exposed people. Based on results of the interview, individual occupancy factors can be created based on each person's lifestyle.

If occupancy factors (other than 1) are used by licensees, NRC staff should consider the times of day that people are present at the receptor location. The air transport of radon from facility release points to receptor locations is dependent on meteorological conditions. The NRC staff is aware that meteorological conditions are highly dependent on time of day. Occupancy of homes is also typically dependent on time of day. This can be important to evaluations of exposures to radon. For example, during nighttime hours, most people are at their residence, so occupancy is high. Nighttime meteorological conditions are typically more stable, with lower wind speeds, and these conditions can result in significantly higher radon concentrations in air at night, due to the reduced dispersion. Thus nighttime occupancy may contribute substantially to the annual dose. Therefore, if occupancy factors (i.e., other than 1) are used by licensees, this potential relationship of occupancy times and radon concentrations should be considered and addressed appropriately.

In cases that licensees allow members of the public access to controlled areas, the access is usually for limited time (e.g., vendors visiting a site might typically only be in a controlled area a limited number of hours per month). In such cases, it is acceptable to NRC staff for licensees to determine an appropriate occupancy factor, *T*, for the members of the public that are less than 1; the determination should be based on a bounding estimate or on a realistic estimate of occupancy times.

4.8.2 Dose Conversion Factor for Radon at Equilibrium with Progeny

In general, a dose conversion factor based on the effluent concentration value in 10 CR 20, Appendix B, Table 2, for radon-222 with daughters present, and the associated annual dose for continuous exposure is acceptable to the NRC staff. Such a dose conversion factor is determined as follows.

First, the annual dose is considered. The text of Appendix B to Part 20, in the discussion about Table 2, states that the "concentration values given in columns 1 and 2 of table 2 are equivalent to the radionuclide concentrations which, if inhaled or ingested continuously over the course of a year, would produce a total effective dose equivalent of 0.05 rem (50 millirem or 0.5 millisieverts)." In addition, the Statements of Consideration for the 1991 Part 20 rule (56FR23360) include a response to a comment that the limits for occupational and nonoccupational exposure to radon-222 and its particulate daughters did not appear consistent with other radionuclides in terms of risk. The NRC response (on page 23387) stated, in part, that "the concentration limit for members of the general public …, like the other airborne concentration limits, represents an effective dose of 0.05 rem per year." The NRC staff considers the "concentration limit for members of the general public" to have meant the effluent concentration value from Part 20, Appendix B, Table 2.

The Appendix B, Table 2, value for radon with daughters present in air is based on the radon progeny being present at 100% equilibrium. The Appendix B value is 1×10^{-10} μCi/mL, which equals 0.1 pCi/L. The annual dose is 50 mrem/yr (0.5 mSv/yr). Therefore, the dose conversion factor for radon-222 with progeny at 100% equilibrium is determined as 50 mrem/yr (0.5 mSv/yr) divided by 0.1 pCi/L, or 500 mrem/yr (5 mSv/yr) per pCi Rn/L at 100% equilibrium. This value is acceptable to the NRC staff.

5. TRANSPARENCY AND DOCUMENTATION OF COMPLIANCE WITH 10 CFR 20.1301/1302

NRC staff reviewers need to assure that licensees document completely the assessments performed by licensees to demonstrate compliance, including:

- Measurement methods should be clearly described.
- Measurement locations used to represent background should be clearly described.
- Results of measurements should be provided, with associated uncertainties.

- Relation between potential exposed individuals and monitoring locations should be clear.
- The method used to demonstrate compliance should be clearly described, including method to account for dose from radon progeny.
- Methods used in calculations should be clearly and adequately documented.
- Licensee's choices of parameter values and all assumptions should be clearly described and licensees should provide a technical basis for all values and assumptions.
- NRC staff reviewers should be able to replicate calculated results from information documented by the licensee.

6. REFERENCES

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APPENDIX

REGULATORY STATEMENTS OF CONSIDERATION AND NRC STAFF CONCLUSIONS REGARDING PART 20 AND RADON PROGENY

There appears to have been confusion in the past about which of the two different values of effluent concentration in 10 CFR Part 20, Appendix B, Table 2, for radon-222 is applicable. Currently, Appendix B includes Table 2 values for radon-222 "with daughters removed" and for radon-222 "with daughters present."

In 1974, the Atomic Energy Commission proposed a revision to the occupational limit for exposure to radon-222 and its progeny (Federal Register, June 24, 1974, 39FR22428). The change was being proposed to conform AEC regulations to recommendations of the Environmental Protection Agency. In part, the AEC stated:

> "The limit for radon would be replaced by a limit on radon daughters because the daughters are the major health hazard."

The AEC also stated that the revised limit would be consistent with recommendations of the International Commission on Radiological Protection, in its Publication 2, and the National Council on Radiation Protection and Measurements. Both organizations had recommended the same Rn-222 concentration where the daughters "are assumed present to the extent they occur in unfiltered air." The rule was finalized by NRC in 1975 (Federal Register, October 31, 1975, 40FR50704) and the final limit, given in Table I of Appendix B to 10 CFR Part 20, was expressed as a concentration of Rn-222 (3×10^{-8} µCi/mL) where it was assumed the radon progeny were also present. The limit for public exposure, in Table II of Appendix B, while not changed, was expressed in the same terms. For both the occupational and public limits, the values could be replaced by concentrations of radon daughters expressed in working levels (one-third and one-thirtieth for the occupational and public limits, respectively). Thus, at that time, the NRC regulations recognized that the major health hazard was the radon progeny and the limits were based on radon progeny being present with the Rn-222.

The NRC did not change the limits for occupational or public exposure to radon in air until the major revision of Part 20 in 1991. The Statements of Consideration (SOC) for the 1991 final rule (Federal Register, May 21, 1991, 56FR23360) mentions this issue in context to uranium mills. In discussing the public dose limit and compliance with 40 CFR 190, the SOC state (page 23274):

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

The SOC also provide an example that uranium mills and ISR facilities may have difficulty in determining compliance with the values in Table 2 of Appendix B to 10 CFR Part 20 for Rn-222. In describing how licensees could adjust values in Appendix B, the SOC state (page 23375):

> "…For example, uranium mill licensees could, under this provision, adjust the table 2 value for radon (<u>with daughters</u>) [sic] to take into account…" [underline added here for emphasis]

Thus, the 1991 SOC indicate that NRC expected that uranium recovery facilities would use the value for radon-222 with daughters present to determine compliance.

The NRC staff concludes that the short-lived radon progeny will be the principal contributor to radiation dose in most practical radon exposure situations. The NRC staff does not envision cases at uranium recovery facilities where progeny (daughters) will have been completely removed from air to which the public is exposed. From the regulatory basis described above, the NRC expects that radon progeny will be present with Rn-222 and that uranium recovery licensees would be using the 10 CFR part 20, Appendix B, Table 2, value for Rn-222 with daughters present. Therefore, the NRC staff concludes that the appropriate value from 10 CFR Part 20, Appendix B, Table 2, for uranium recovery facility use, is the value for Rn-222 "with daughters present." The NRC staff also concludes that if a licensee performs a dose assessment to show compliance with 20.1301, the dose assessment must address the dose from radon progeny.