ATTACHMENT 3

Staff Analysis of the Dose Estimates In NUREG-1717 Related to Activities of the Interagency Jurisdictional Working Group

STAFF ANALYSIS OF THE DOSE ESTIMATES IN NUREG-1717 RELATED TO ACTIVITIES OF THE INTERAGENCY JURISDICTIONAL WORKING GROUP

Introduction

The staff reviewed the source material exemptions discussed in NUREG-1717, "Systematic Radiological Assessment of Exemptions for Source and Byproduct Materials." For those exemptions potentially impacted by the activities of the Jurisdictional Working Group (JWG) and for scenarios where the potential dose could exceed 100 mrem (1 mSv) per year, additional evaluations were conducted. Each evaluation is presented below. The analysis in NUREG-1717 was often based on conservative assumptions, as recognized in the report, because of uncertainties resulting from the lack of information about the subject industries. The NUREG analysis was based on the dose calculation methodology in International Commission on Radiological Protection Publications (ICRP) 26 and 30, which presents the dose methodology on which Part 20 is based. More specifically, the dose conversion factors in Federal Guidance Report 11 system, (FGR 11) were used. Additionally, the staff evaluated the doses for the impacted exemptions, if the use of ICRP 68+ dosimetry were to be applied instead of the dose conversion factors in FGR 11.

Background

NUREG-1717 presents a systematic assessment of potential individual and collective radiation doses associated with the current exemptions from licensing. The results of NUREG-1717 are intended to provide an assessment upon which the NRC can review and examine the radiological impact of current exemptions and determine if regulatory actions may be needed for ensuring public health and safety.

The staff review of NUREG-1717 identified three exemptions that could be impacted by the recommendations of the JWG. The sections from NUREG-1717 that cover the impacted exemptions are: Section 3.2, "Chemical Mixture, Compound, Solution, Alloy Containing <0.05 Percent by Weight of Source Material"; Section 3.3, "Unrefined and Unprocessed Ore Containing Source Material"; and Section 3.9, "Rare Earth Products Containing Less than 0.25 percent by Weight of Source Material." The specific exemptions are:

1. 10 CFR 40.13(a) [Section 3.2 of NUREG-1717], Source material in concentrations less than 0.05 weight-percent in any chemical mixture, compound, solution, or alloy: Zircon used in industry may cause doses estimated up to 4,000 mrem (40 mSv) per year. Use of Zircon sands in sandblasting may also cause a dose up to 300 mrem (3 mSv) per year. Use of slag materials in construction may cause dose up to 200 mrem (2 mSv) per year.

2. 10 CFR 40.13(b) [Section 3.3 of NUREG-1717], Source material in unrefined and unprocessed ores: The dose to a truck driver is up to 300 mrem (3 mSv) per year.

3. 10 CFR 40.13(c)(1)(vi) [Section 3.9 of NUREG-1717], Rare earth compounds containing less than 0.25 weight-percent source material. Doses up to 3,000 mrem (30 mSv) per year at a major processing facility.

The entries for these scenarios in Executive Summary Table from NUREG-1717 were expanded to include a breakout of the pathway contribution to the total dose, Table 1. These three exemptions were evaluated for the conservatism used in the NUREG-1717 analysis and the effect of the application of International Commission on Radiological Protection (ICRP)-68 dosimetry (which includes changes through ICRP-72) to the dose calculations.

Discussion:

The staff analyzed each of the scenarios for these exemptions evaluated in NUREG-1717 that had dose estimates in excess of 100 mrem (1 mSv) per year and that would be impacted by the recommendations resulting form the deliberations of the JWG. The analysis included review of the NUREG-1717 sections, identification of the dose pathways (ingestion, inhalation, or external dose), and a comparison of the doses in NUREG-1717 to the doses calculated using the ICRP 68 dosimetry system. The comparison to ICRP 68 was initiated to evaluate doses potentially received from source material, because ICRP 68 more accurately represents the actual dose. The zircon industry is currently using the ICRP 68 dosimetry system for evaluation of the doses from the materials currently covered under the exemption in § 40.13(a) and the development of their controls as recommended in their Materials Safety Data Sheet (MSDS) sheets.

1. **10 CFR 40.13(a)**, source material in concentrations less than 0.05 weight-percent in any chemical mixture, compound, solution, or alloy:

    a. **Zircon Flour Use**: Exposure pathways: NUREG-1717 identified two significant exposure pathways, the external dose [40 mrem (0.4 mSv) per year], and inhalation [4,000 mrem (40 mSv) per year].

    External dose: The external annual dose of 40 mrem (0.4 mSv) was calculated based on a 2000 hour per year worker exposure time. The calculated exposure rate using MicroShield and resulting dose to a worker was 40 mrem (0.4 mSv) per year. This assumes natural uranium in equilibrium with its short-lived progeny and Th-232 in equilibrium with its progeny. Higher measured exposure rates were reported in references noted in NUREG-1717, possibly from variations in actual uranium and thorium concentrations in the zircon product and contribution of uranium long-lived decay products. The assumption of full occupancy at 1 meter from bags of the zircon flour is considered conservative. The typical annual external dose will likely be lower than calculated. The contribution from external doses becomes of greater significance when the more realistic evaluations of inhalation doses under ICRP 68 methodology is used.

    Inhalation Dose: The rounded inhalation annual dose of 4,000 mrem (40 mSv) was calculated using an air concentration from personnel sampler data for a bagger operator, assuming 2000 hours of exposure, and the dose factors from FGR 11. Other dose calculations were cited which ranged from 200 mrem (2 mSv) to 3500 mrem (35 mSv) per year based on various air concentrations and particle sizes, all assuming a 2000 hour working year.

    The staff performed several dose calculations to bound the potential impacts of use of this material. The staff assumptions used were: (1) the Threshold Limit Value (TLV) dust concentration limit (10 mg/m^3) should bound the dust concentration, (2) the dust was assumed to contain uranium or thorium at the 0.05 weight-percent concentration level and in equilibrium with their progeny, (3) the FGR 11 dose factors were used, (4) the worker breathing rate of 1.2 m^3/hr was assumed, and (5) the duration of exposure was 2000 hours per year. For the uranium decay chains, the calculated dose is 2,610 mrem (26 mSv) per year, assuming 1 µm particle size. For the thorium decay chain, the dose is 1,965 mrem (20 mSv) per year. Information provided by the zirconium industry indicates that they maintain the dust levels below the TLV levels to ensure compliance with the Occupational Safety and Health Administration (OSHA) dust requirements. The staff is reporting the dust levels with caution since the measurements were conducted with techniques that may not be consistent with NRC sampling protocols. The dust concentrations used are total dust value which is the closest to the NRC dust value. The staff recognizes that the total dust values are conservative and will give dose values in excess of the actual doses received by the workers. The staff acknowledges that this calculation is conservative because the particle size of the dust in the zirconium industry is significantly larger than the assumed 1 µm particle size used in the calculation. Adjustments for the larger particle size would decrease the inhalation dose by up to a factor of 3 for 10 µm particle size.

Impact of ICRP-68: The staff conducted similar calculations using the ICRP-68 dosimetry. The staff calculations included use of 1, 5, and 10 µm particle sizes as well as the newer dosimetry. ICRP 68 recommends the use of the 5 µm particle size for occupational dose calculations. The other assumptions listed above were not changed. The resulting doses in mrem per year (for mSv divide by 100) were:

	Part 20 1 µm	ICRP 68 1 µm	ICRP 68 5 µm	ICRP 68 10 µm
Uranium @ 0.05 wt% and 10 mg/m^3	2,610	620	435	275
Uranium @ 0.05 wt% and 5 mg/m^3	1,305	310	220	160
Thorium @ 0.05 wt% and 10 mg/m^3	1,965	320	200	140
Thorium @ 0.05 wt% and 5 mg/m^3	985	160	100	70
U&Th @ 250 & 150 ppm @10 mg/m^3	1,900	410	280	180
U&Th @ 250 & 150 ppm @5 mg/m^3	950	205	140	90
U&Th @ 250 & 150 ppm @3 mg/m^3	645	125	85	55
U&Th @ 250 & 150 ppm @0.8 mg/m^3	155	35	25	15

The ratio of uranium to thorium in the latter entries is representative of the zirconium sands used in the U.S. industry and totals 0.04%, which is also representative of the U.S. zircon industry. The 0.8 mg/m^3 value was used as an example of the total dust level at a U.S. zircon sand plant. The respirable fraction at this plant was 0.22 mg/m^3. The ratio of total dust to respirable dust shows the large fraction of the total dust that is at, or greater than, the 10 µm particle size (the cutoff level for the respirable dust measurement technique). The larger actual particle size makes calculations based on total dust concentrations or dosimetry using smaller particle sizes conservative.

The dose calculations assumed no respiratory protective devices were worn by the workers. Several of the references in NUREG-1717 indicated that, in the dustier environments, respiratory protective equipment is provided and worn. Such equipment provides a protection factor of from 2 to 10 depending on the equipment used, which could further reduce inhalation doses.

Conclusion: For the zircon flour or sand industry, the doses from the nuisance radioactivity in the zircon flour and sand may cause doses in excess of 100 mrem (1 mSv) per year using the dosimetry on which 10 CFR Part 20 is based. However, if the NRC considers application of the ICRP-68 dosimetry, the particle size correction, or the lower actual occupancy times, the actual dose received by a worker could be, and most likely is, below 100 mrem (1 mSv) per year. These workers are covered under OSHA occupational exposure regulations since they are receiving an occupational dose. The OSHA occupational limit is 5 rem (50 mSv) per year.

b. **Use of Zircon sands in sandblasting may also cause a dose up to 300 mrem (3 mSv) per year**.

External dose: There was no significant external annual dose described in NUREG-1717.

Inhalation Dose: The inhalation annual dose of 300 mrem (3 mSv) was reported in NUREG-1717 (Section 3.2.4.2.2.1). The value was based on 2.5 pCi/g uranium-238, 5.5 pCi/g thorium-232, 10.4 mg/m^3 respirable air concentration, which was greater than the TLV, assuming 2000 hours of exposure, and the dose conversion factors from FGR 11. The staff ran the same input data and calculated a value of about 240 mrem (2.4 mSv) per year. The doses using the ICRP-68 dosimetry are 45, 30, and 20 mrem (0.45, 0.3, and 0.2 mSv) per year for 1, 5, and 10 µm particle sizes, respectively. NUREG-1717 stated that the doses could be lower by a factor of 5-10 if respiratory protective devices were worn.

Conclusion: The staff believes the doses will be more in the range of 20 to 50 mrem (0.2 to 0.5 mSv) per year, if respiratory protection is worn and more realistic assumptions are used in the dose assessment.

c. **Use of slag materials in construction may cause a dose up to 200 mrem (2 mSv) per year**.

External dose: The external dose pathway contributed the most to the total dose from slag materials (Section 3.2.3.4.2.1). The maximum doses from use in construction of streets and housing foundations are about 150 to 200 mrem (1.5 to 2 mSv) per year. The direct dose from storage and disposal of slags from minerals other than phosphate contributed 200 mrem (2 mSv) per year, and slags from phosphate contributed 100 mrem (1 mSv) per year to workers. NUREG-1717 also presented doses to on-site and off-site members of the public with annual doses up to 400 mrem (4 mSv) and 100 mrem (1 mSv), respectively. These numbers were taken from EPA report RAE-9232/1-2. The staff did not re-evaluate this assessment.

Inhalation Dose: The inhalation annual dose of 3 mrem (0.03 mSv) was reported in NUREG-1717. The staff did not evaluate this pathway any further.

Conclusion: As discussed in NUREG-1717, several States with phosphate industry have banned the use of phosphate slag as a building material. EPA is considering additional guidance and/or controls on the phosphate industry.

2. **10 CFR 40.13(b)**, source material in unrefined and unprocessed ores:

   External dose: The external dose pathway contributed the most to the total dose from uranium ore transport (Section 3.3.4.1.1). The NUREG-1717 assessment estimated an annual dose of 200 mrem (2 mSv) from the transport of uranium ores. This assessment used 0.3 cm for the thickness of steel between the ore and the driver of the haul truck. This thickness for the bed and cab of a large haul truck appears to be thin for this type of truck. A value of 0.9 cm for the thickness of the steel would appear to be a more realistic value to be applied. The 1000 hour exposure time is conservative since it does not allow for loading time and other down time for the trucks, where the driver of the truck would not be present and exposed to the uranium ores. The staff did not re-calculate the dose with less conservative assumptions. However, the staff believes that the actual external dose would be significantly lower.

   Inhalation Dose: The inhalation annual dose of 60 mrem (0.6 mSv) was reported in NUREG-1717 for uranium ore transport. The inhalation dose would be reduced significantly if less conservative assumptions and/or the ICRP-68 dosimetry (a factor of between 4 to 9) would be applied to the assessment.

   Conclusion: The staff believes that the actual total dose to uranium ore haul drivers is less than 100 mrem (1 mSv) per year.

3. **10 CFR 40.13(c)(1)(vi)**, Rare earth compounds containing less than 0.25 weight-percent source material.

   External dose: The external dose pathway contributes 40 mrem (0.4 mSv) per year and 80 mrem (0.8 mSv) per year for bastnasite and cerium bagging areas, respectively.

   Inhalation Dose: The inhalation annual dose for bastnasite and cerium concentrate were 1,000 mrem (10 mSv) and 3,000 mrem (30 mSv), respectively, in NUREG-1717. The staff calculated, using ICRP 68 dose system, annual inhalation doses of 170 mrem (1.7 mSv) and 500 mrem (5 mSv) for 1 µm particles, 100 mrem (1 mSv) and 300 mrem (3 mSv) for 5 µm particles, and 75 mrem (0.75 mSv) and 225 mrem (2.3 mSv) for 10 µm particles for bastnasite and cerium, respectively. NUREG-1717 identified that, if respiratory protection were worn in this dusty environment, the annual doses could be reduced by a factor of up to 10. The time of exposure was conservative for these calculations.

   Conclusion: The staff believes that the annual doses from this exemption are not actually in the 1,000 to 3,000 mrem (10 to 30 mSv) range based on: (1) the conservative nature of the assessment, (2) the reduced doses using the ICRP 68 dose system, and (3) the use of respiratory protective equipment in the dusty environment. Note also: the JWG indicated that there are very few remaining rare earth major processing facilities in the United States, and that most of the materials are imported.

Overall Summary and Conclusion

The staff reviewed the NUREG-1717 assessments for the industries that could be impacted by the recommendations resulting form the deliberations of the JWG. The staff found them to be conservative assessments and evaluated the impact of certain changes to those assessments. The significant changes considered were:

For External Dose:

1. The occupancy times were conservative, therefore, the doses were on the high side.
2. The thickness of material between the radioactivity and the exposed individual in one case was not appropriate for that assessment (0.3 cm vs 0.9 cm).

For Inhalation Dose:

1. The inhalation assessment was not always limited by the TLV's for a given material or the general limit for non-specified dust.
2. The occupancy time was conservative for the assessments.
3. The use of the 1 µm particle size was conservative and the actual doses could vary up to a factor of 3, if a larger particle size were to be used.
4. The use of the newer ICRP 68 dosimetry system would reduce the calculated doses in all of these cases. The NRC staff has approved the use of ICRP 68 in several cases for uranium licensees. The staff thought it was important to evaluate the change the ICRP 68 system would have on the doses from the uranium and thorium. The staff believes that the ICRP 68 dosimetry system more accurately represents the actual dose received from inhalation of uranium and thorium and their progeny.
5. The use of respiratory protection was not considered in the assessments even when NUREG-1717 specifically stated that respiratory protection was used by the workers in some cases.

The use of actual occupancy times, working conditions, and new dosimetry system would appear to bring the actual doses to near or below the 100 mrem (1 mSv) annual dose level. The areas that had the highest doses in NUREG-1717 were industrial workers that are also under the OSHA radiation protection standards. These workers would be within the OSHA limits for occupational radiation exposure, as originally evaluated. The OSHA occupational limit is 5 rem (50 mSv) per year.

Table 1. NUREG-1717 EXECUTIVE SUMMARY TABLE WITH DOSE PATHWAY BREAKOUT FOR EXEMPTIONS WITH THE HIGHEST DOSES[a]

Report Section	Source Material Exemption	Effective Dose Equivalent	Inhalation Dose	Ingestion Dose	External Dose
3.20	Chemical Mixture, Compound, Solution, or Alloy				
	Zircon Flour Use	4,000	4,000	0	140
	Zircon Sandblasting	300	300	0	0
	Construction (Slag)	200			200
3.30	Unrefined & Unprocessed Ore	300	60	0	200
3.90	Rare Earth Metals & Compounds, Mixtures, & Products	3,000	3,000	0	80

[a] The exemptions evaluated were selected based on their doses and whether they could be impacted by the recommendations of the JWG.