PRELIMINARY DOSE ANALYSIS FOR CLEARANCE OF NICKEL FROM MSC

A. Background:

In a letter dated October 25, 1999, Congressmen John Dingell, Ron Klink, and Edward Markey raised concerns about the Tennessee Department of Environmental Conservation (TDEC) approving the release of 6,000 tons of contaminated nickel from a waste processing facility -- Manufacturing Sciences Corporation (MSC) -- and that NRC licensees may also use that type of facility for materials releases. The TDEC licensing action was viewed as the establishment of a release standard for volumetrically contaminated radioactive nickel.

This analysis provides information on the projected doses from releasing nickel with surficial and volumetric radiological contamination.

B. Source Term

The licenses held by MSC provide limits for both volumetric contamination as well as surficial contamination of materials that are to be released from control. The pertinent license conditions (LC), from the TDEC licenses, are LC 32 of License R-01078-L00, Amendment 19, and LC 30 of License S-01046-L00, Amendment 57, both dated July 13, 1999. These conditions both contain the following:

> "...Nickel metal from the U.S. D.O.E. shall be decontaminated in accordance with procedures approved by the Department and unrestricted release of the decontaminated metal will be based on currently accepted removable surface contamination release criterion (U.S. N.R.C. Regulatory Guide 1.86) with an additional volumetric contamination release for 99Tc of an average of 3 Bq/g (180 dpm beta/g or 81 pCi/g) in a single shipment of nickel not to exceed 20 tons and with no single ingot in the shipment to exceed 6 Bq/g (360 dpm beta/g or 162 pCi/g). The release criteria for uranium (inclusive of 234U, 235U, and 238U, all of which are considered in total) will be an average of 0.3 Bq/g (18 dpm beta/g or 8.1 pCi/g) in a single shipment of nickel not to exceed 20 tons and with no single ingot in the shipment to exceed 0.6 Bq/g (36 dpm beta/g or 16.2 pCi/g)."

From the above license condition wording, the limits for removable surface activity and volumetric contamination are applied independently. An interpretation of the license conditions is that nickel would be permitted to leave the MSC facility with surface contamination at the acceptable limit plus volumetric contamination at the acceptable limits. The staff has requested clarification from the TDEC staff on this interpretation.

Based on knowledge of the process to be used at the MSC facility, it appears likely that contamination would be uniformly distributed throughout the volume of the nickel ingot. Because the TDEC specifies both surficial and volumetric limits, the analysis below accounts for the possibility of both surficial contamination and volumetric contamination at the levels allowed in the cited license condition.

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C. Technical Approach for NRC Staff Dose Calculations

The NRC staff has reviewed NUREG-1640 (NRC 1999) and other documents that evaluate potential doses from the unrestricted release or clearance of metals contaminated with low concentrations of radioactivity. The documents reviewed have compiled results from numerous studies, for a range of exposure scenarios. The staff has only used values that were considered appropriate for the potential uses of the contaminated nickel slabs that may be released from the MSC facility. Scenarios that appeared unrealistic were not considered further.

All studies to date have considered scenarios involving the use of contaminated steel, copper, and aluminum, but not nickel. In this preliminary analysis, the staff used the scenarios developed for steel to analyze the case for nickel. This is believed to be appropriate because nickel and steel have very similar metallurgical and radiation interaction characteristics, and both metals are frequently used by the same facilities to produce nickel-steel alloys. This analysis considered the relevant exposure pathways which would be expected for each scenario associated with the release of solid materials.

The dose calculation assumes the total uranium activity is from the isotopes (U-234, U-235, U-238) and their short-lived daughters (hereafter referred to as uranium).

D. Volumetric Contamination

1. NUREG-1640 (NRC 1999)

This draft report evaluated the clearance of 3 metals (steel, copper, and aluminum) and concrete; it did not evaluate nickel. Based on the information for steel contained in NUREG-1640, the following may be stated:

a. For nickel with Tc-99 contamination, the critical group is identified as an offsite dose through the ground-water pathway stemming from the slag-storage scenario. The dose conversion factor is 1.9E-1 uSv/a per Bq/g.

b. The TDEC-approved Tc-99 contamination levels are 6 Bq/g for any ingot and 3 Bq/gm averaged over a 20-ton shipment. Therefore, the calculated Tc-99 doses from the slag storage scenario are:

~ @ 6 Bq/g: 1.9E-1 uSv/a per Bq/g x (6 Bq/g) = 1.14 uSv/a = 0.114 mrem/y.
~ @ 3 Bq/g: 1.9E-1 uSv/a per Bq/g x (3 Bq/g) = 0.7 uSv/a = 0.07 mrem/y

c. For nickel with uranium contamination, the critical group is based on the scrap handling scenario. The steel dose conversion factor is 3.3E+1 uSv/a per Bq/g.

d. The TDEC-approved uranium-series contamination level for 0.6 Bq/g for any ingot and 0.3 Bq/gm averaged over a 20 ton shipment. Therefore, the calculated uranium doses from the slag storage scenario are:

~ @ 0.6 Bq/g: 3.3E+1 uSv/a per Bq/g x (0.6 Bq/g) = 19.8 uSv/a = 2.0 mrem/y.
~ @ 0.3 Bq/g: 3.3E+1 uSv/a per Bq/g x (0.3 Bq/g) = 9.9 uSv/a = 1.0 mrem/y

2. US EPA Technical Support Document (1997)

The EPA's draft report evaluated the clearance of scrap steel; it did not evaluate nickel. The report evaluated over 60 different categories of individuals that have the potential to receive some level of exposure from residual radioactivity contained in the scrap. The EPA determined within each category the doses to Reasonably Maximally Exposed Individuals (RMEI).

Applying the dose factors for steel contained in the EPA report, the following may be stated:

a. For nickel with Tc-99 contamination, the RMEI is based on the "cutting scrap" scenario. The steel dose conversion factor is 2.1E-5 mrem/y per pCi/g. This is equivalent to 5.7E-3 uSv/a per Bq/g.

b. The TDEC-approved Tc-99 contamination level for 6 Bq/g for any ingot and 3 Bq/gm averaged over a 20 ton shipment. Therefore the calculated Tc-99 doses from the slag storage scenario are:

~ @ 6 Bq/g: 5.7E-3 uSv/a per Bq/g x (6 Bq/g) = 0.03 uSv/a = 0.003 mrem/y.
~ @ 3 Bq/g: 5.7E-3 uSv/a per Bq/g x (3 Bq/g) = 0.02 uSv/a = 0.002 mrem/y

c. For nickel with uranium-series contamination, the RMEI is based on the slag pile worker scenario. The dose conversion factor is 3.3E-1 mrem/y per pCi/g. This is equivalent to 8.9E+1 uSv/a per Bq/g.

d. The TDEC-approved uranium-series contamination level for 0.6 Bq/g for any ingot and 0.3 Bq/gm averaged over a 20 ton shipment. Therefore the calculated total uranium doses from the slag storage scenario are:

~ @ 0.6 Bq/g: 8.9E+1 uSv/a per Bq/g x (0.6 Bq/g) = 53.4 uSv/a = 5.3 mrem/y
~ @ 0.3 Bq/g: 8.9E+1 uSv/a per Bq/g x (0.3 Bq/g) = 26.7 uSv/a = 2.7 mrem/y

3. European Commission (EC)

The EC's 1998 report recommends radiological protection criteria for recycling and direct reuse of metals from decommissioning. This report, as well as other international publications on this topic, differs from NUREG-1640 in its use of clearance terminology. In this report, the term "recycle" means metals that will be used for the production of new metal, whereas the term "reuse" means metals that could be used in the same (direct reuse) or modified form (but not remelted). For the staff's analysis of the proposed MSC nickel releases, the staff used dose factors for recycle only because the nickel would not be reused in this sense. See section F for more information on international dose factors and recommended clearance criteria.

The EC report recommended dose factors for recycling of steel for a number of exposure scenarios. The following may be stated:

a. For nickel with Tc-99 contamination, based on limited information contained in this report, the scenario resulting in the maximum dose was the occupancy of a disposal site with slag. The dose conversion factor is 2.6E-1 uSv/a per Bq/g.[1]

b. Additional assumptions: Amount of recycled scrap steel is 10,000 MT/a; carbon steel from electric arc furnaces is 4000 MT/a; stainless steel from induction furnaces 2000 MT/a; only 10 % of the scrap has nuclear origin.

c. The TDEC-approved Tc-99 contamination level for 6 Bq/g for any ingot and 3 Bq/g averaged over a 20 ton shipment. Therefore the calculated Tc-99 doses from the slag storage scenario are:

~ @ 6 Bq/g: 2.6E-1 uSv/a per Bq/g x (6 Bq/g) = 1.6 uSv/a = 0.2 mrem/y.
~ @ 3 Bq/g: 2.6E-1 uSv/a per Bq/g x (3 Bq/g) = 0.8 uSv/a = 0.1 mrem/y

d. For nickel with uranium-series contamination, the scenario is release of slag as ground cover in a public area. The steel dose conversion factor is 3.2E0 uSv/a per Bq/g.[2]

e. The TDEC-approved uranium-series contamination level for 0.6 Bq/g for any ingot and 0.3 Bq/g averaged over a 20 ton shipment. Therefore the calculated uranium doses from the slag storage scenario are:

~ @ 0.6 Bq/g: 3.2E+0 uSv/a per Bq/g x (0.6 Bq/g) = 1.9 uSv/a = 0.2 mrem/y
~ @ 0.3 Bq/g: 3.2E+0 uSv/a per Bq/g x (0.3 Bq/g) = 1.0 uSv/a = 0.1 mrem/y

4. International Atomic Energy Agency TECDOC-855

The IAEA's 1998 report recommends clearance levels for radionuclides in solid materials, including recycling, direct reuse, and disposal of various radioactively contaminated materials. As in the previous section on the EC report, the terms "recycling" and "reuse" differ from NUREG-1640 in its use of these clearance terms. Consistent with the above calculation, the staff's analysis of the proposed MSC nickel releases applied dose factors for steel only. See section F for more information on international dose factors and recommended clearance criteria.

The IAEA dose factors for clearance of steel are based on the analyses of an unspecified number of scenarios (between 1 and 50). Based on the dose factors for steel contained in this report, the following may be stated:

a. For steel with Tc-99 contamination, based on limited information contained in this report, the scenario resulting in the maximum dose was disposal at a landfill. The dose

[1] This is based on slag from an induction furnace disposed into a landfill. The receptor is a child; with inhalation, ingestion, and irradiation pathways. From Radiation Protection 89. EC 1998. The 0.26 µSv/a per Bq/g comes from Table 6-8, p. 20 of the EC report.

[2] This is based on a soccer player where the field is slag from an induction furnace and the pathway is inhalation. The dcf is from Table 6-8 p. 20 for U-234, which is more conservative but within the uncertainties almost identical to the other uranium isotopes.

conversion factor is 2.5E-1 uSv/a per Bq/g (based on Table 1.1 value).[3] This calculation used a different value from the one equivalent to that provided in Table 2.6 of NUREG-1640 (0.03 uSv/a per Bq/g).

b. The TDEC-approved Tc-99 contamination level for 6 Bq/g for any ingot and 3 Bq/g averaged over a 20 ton shipment.

~ @ 6 Bq/g: 2.5E-1 uSv/a per Bq/g x (6 Bq/g) = 1.5 uSv/a = 0.2 mrem/y.
~ @ 3 Bq/g: 2.5E-1 uSv/a per Bq/g x (3 Bq/g) = 0.8 uSv/a = 0.1 mrem/y

c. For nickel with uranium-series contamination, the scenario is a recycling (production as a new metal) scenario, but is not specified by the IAEA. The steel dose conversion factor is 5.0 E+1 uSv/a per Bq/g (Table I.3).[4] This calculation used a different value from the one equivalent to that provided in Table 2.6 of NUREG-1640 for the reported IAEA result (33.3 uSv/a per Bq/g). *

d. The TDEC-approved uranium-series contamination level for 0.6 Bq/g for any ingot and 0.3 Bq/gm averaged over a 20 ton shipment.

~ @ 0.6 Bq/g: 5.0E+1 uSv/a per Bq/g x (0.6 Bq/g) = 30 uSv/a = 3.0 mrem/y
~ @ 0.3 Bq/g: 5.0E+1 uSv/a per Bq/g x (0.3 Bq/g) = 15 uSv/a = 1.5 mrem/y

5. Summary of Volumetric Results

Table 1 is a summary of the potential doses from the volumetric contamination of the proposed release of nickel. The results from Tc-99 and uranium have been summed to provide potential total doses.

[3] The Tc-99 number is based on 1000 MT/a scrap being recycled; for landfill the percentage of radioactive material ranges from 2-6% and for incineration 3%. For recycling, the percentage can be as high as 50% depending on the scenario. Ref. TECDOC-855 Jan. 1996.

[4] From TECDOC-855, Table I.3 for recycling the uranium isotopes are based on 1000 MT/a scrap being recycled; the doses are adjusted to the relevant concentrations (conservative). For recycling the percentage can be as high as 50% depending on the scenario.

Table 1. Summary of Potential Doses: Volumetric Contamination[5]

Calculation method	Potential dose (mrem/year)					
	Based on single ingot limit			Based on shipment limit		
	Tc-99	Uranium isotopes	Total	Tc-99	Uranium isotopes	Total
NUREG-1640	0.1	2	2	0.07	1	1
EPA	0.003	5	5	0.002	3	3
EC	0.2	0.2	0.4	0.1	0.1	0.2
IAEA	0.2	3	3	0.1	2	2

E. Surficial Contamination

1. Historical Analyses

a. Regulatory Guide (RG) 1.86

No dose analysis was performed when RG 1.86 was issued in 1974.

b. NRC Inspection & Enforcement (IE) Circular 81-07

Referenced a dose of about 5 mrem/year for residual radioactivity levels associated with RG 1.86.

2. Current NRC Staff Dose Analysis Approach

The MSC license conditions (see above) refer to removable surface contamination limits provided in RG 1.86. The RG 1.86 limits being applied are: (1) for Tc-99, 1000 dpm/100 cm^2 and (2) for uranium isotopes, 1000 dpm/100 cm^2 - these limits are equal to 0.17 Bq/cm^2 (4.6 pCi/cm^2).

For the surficial contamination analysis, the staff has chosen to use the same reports used for the above dose analysis for volumetric contamination. The reports (NRC 1999, EPA 1997, EC 1998, IAEA 1996, IAEA 1992, and IAEA 1988) were reviewed to obtain dose factors and to determine the scenarios that are considered representative and reasonable for potential uses of nickel or steel. The previous assumption that nickel processing would be generally similar to steel processing is also applied in this analysis. The table below shows the dose factors and the scenarios from each study.

[5] In some cases, the total doses are summed over different scenarios; either to provide a degree of conservatism or else because of absence of data.

Table 2. Dose Factors (uSv/a per Bq/cm^2) for Surface Contamination

	Tc-99		Uranium isotopes	
Information Source	Scenario	Dose conversion factor	Scenario	Dose conversion factor
NUREG-1640	slag storage - nonworker	1.4E-1	scrap handling - worker	2.5E+1
EPA	n/a	n/a	n/a	n/a
EC	recycle - scrap processor[6]	9.6E-3	recycle - scrap processor[7]	2.0E+1
IAEA[8]	reuse - commercial product	2.2E-3	reuse - commercial product[9]	2.7

It should be noted that although EPA discusses surficial contamination monitoring strategies, they do not provide dose factors for surficially-contaminated steel.

From the IAEA report (1992), only reuse scenarios addressed surficial contamination of metals. This differs from the recycle scenarios in that the form of the metal is not changed substantially before use. These values are included in the calculations for comparison purposes. The potential doses are calculated by NRC staff as the product of the source term (surface contamination level) and the dose factor. These calculated potential doses are shown in Table 3.

Table 3. Summary of Potential Doses from Surficial Contamination

Calculation Method	Potential dose (mrem/year) Based on single ingot limit		
	Tc-99	Uranium isotopes	Total
NUREG-1640	0.002	0.4	0.4
EPA	n/a	n/a	n/a
EC	0.0002	0.3	0.3
IAEA	0.00004	0.05	0.05

F. Total Potential Doses from Nickel Ingots

[6]This is taken from Table 6-8 and is primarily an inhalation pathway from using a torch on the contaminated metal.

[7]This is also from Table 6-8 and is primarily an inhalation pathway from using a torch on the contaminated metal.

[8]This is taken from IAEA 1992, Table III.96, for tools and equipment, based on 600 hr. of exposure. Based on a resuspension factor of 10^{-6} m^{-1}, a secondary ingestion rate of 10^{-4} m^2/h, and a surface transfer rate of 10^{-2}.

[9]The dcf for U-238 was used for this calculation; dcfs for other U-isotopes were not provided in IAEA 1992.

The following table combines the doses calculated from Tables 1 and 3.

Table 4. Total Potential Doses from Surficial and Volumetric Contamination

Calculation Method	Potential dose from single ingot (mrem/year)		
	Tc-99	Uranium isotopes	Total
NUREG-1640	0.1	2	2
EPA*	0.003	5	5
EC	0.2	0.5	0.7
IAEA	0.2	3	3

* The 1997 EPA report did not provide surficial contamination dose factors.

For the dose estimates corresponding to the shipment average, the following table is provided for comparison purposes.

Table 5. Total Potential Doses from Surficial and Volumetric Contamination[10]

Calculation Method	Potential dose from per shipment average (mrem/year)		
	Tc-99	Uranium isotopes	Total
NUREG-1640	0.07	1	1
EPA*	0.002	3	3
EC	0.1	0.4	0.5
IAEA	0.1	2	2

* The 1997 EPA report did not provide surficial contamination dose factors.

G. Further Explanation of International Values

The international reports (of the EC and IAEA) presented dose factors or clearance levels for individual scenarios. To develop recommended clearance levels, these reports show a range of clearance levels for each radionuclide and scenario. This range of clearance levels could span a few orders of magnitude. Based on these diverse ranges, the radionuclides were grouped by the order of magnitude of the clearance level. Finally, for each radionuclide, a single clearance level was recommended that was a central measure to represent the order of magnitude range. For the EC report, the recommended clearance levels were rounded to orders of magnitude of 1, 10, 100, 1000, etc., whereas for the IAEA report, these levels were rounded to orders of magnitude of 0.3, 3, 30, 300, etc.

The recommended clearance levels were not used by the NRC staff for the above analyses because of this grouping and the order of magnitude rounding. The levels used by the staff for

[10] This Table uses the shipment volumetric concentrations and the surficial 1000 dpm/100cm^2 concentrations.

the above calculations provided an envelope of possible doses, based on individual exposure scenarios, rather than the reference values recommended in the international reports.

H. References

U.S. Environmental Protection Agency; 1997: "Evaluation of the Potential for Recycling of Scrap Metals from Nuclear Facilities"

European Commission; 1998: "Radiation Protection 89 - Recommended Radiological Protection Criteria for the Recycling of Metals from the Dismantling of Nuclear Installations"

International Atomic Energy Agency; 1996: "Clearance Levels for Radionuclides in Solid Materials, Application of Exemption Principles" IAEA -TECDOC 855.

International Atomic Energy Agency; 1988: "Principles for the Exemption of Radiation Sources and Practices from Regulatory Control," Safety Series No. 89.

International Atomic Energy Agency; 1992: "Application of Exemption Principles to the Recycle and Reuse of Materials from Nuclear Facilities," Safety Series No. 111-P-1.1.

U.S. Nuclear Regulatory Commission; 1999: "Radiological Assessments for Clearance of Equipment and Materials from Nuclear Facilities" NUREG-1640; Draft.