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Dose Reconstruction Project for NIOSH

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02/07/2012	00	New document initiated for evaluation of external dose from ^{99}Tc at the Oak Ridge Gaseous Diffusion Plant (K-25), Paducah Gaseous Diffusion Plant, and Portsmouth Gaseous Diffusion Plant. Incorporates formal internal formal review comments. There were no comments as a result of formal NIOSH review. Training required: As determined by the Objective Manager. Initiated by Matthew H. Smith.

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ACRONYMS AND ABBREVIATIONS

cm	centimeter
cpm	counts per minute
DOE	U.S. Department of Energy
dpm	disintegrations per minute
g	gram
GDP	gaseous diffusion plant
hr	hour
in.	inch
keV	kiloelectron-volt, 1,000 electron-volts
mg	milligram
mm	millimeter
mrem	millirem
ORAU	Oak Ridge Associated Universities
PPE	personal protective equipment
SRDB Ref ID	Site Research Database reference identification (number)
TBD	technical basis document
yr	year

1.0 INTRODUCTION

External exposure to ^{99}Tc at the Paducah, Portsmouth, and Oak Ridge (K-25) gaseous diffusion plants (GDPs) has been discussed in varying detail in the external dose technical basis documents (TBDs) for those sites. The information for ^{99}Tc in those TBDs has been inconsistent, and the conclusions have been inadequate for the purpose of dose assignment.

This report provides guidance for the assignment of ^{99}Tc external dose to energy employees at the Paducah, Portsmouth, and K-25 GDPs. Due to its nonpenetrating characteristics – and the routine use of effective personal protective equipment (PPE) – the dose from ^{99}Tc is low. The assignment of ^{99}Tc dose in this report is based on information about work location, job title, and shallow dose data that can be used by dose reconstructors to identify energy employees that could have had exposure to ^{99}Tc.

2.0 BACKGROUND

Technetium-99 has been present at all three GDPs as a contaminant from the introduction of recycled uranium into the cascades. It is a long-lived fission product with a half-life of 213,000 years. It is a pure low-energy electron emitter with a maximum energy emission of 293.6 keV and an average energy of 84.6 keV (Shleien, Slaback, and Birky 1998). Although difficult to detect due to its low-energy electron emission, this same characteristic results in minimal external dose potential. Site exposure evaluation data indicate that the maximum range of ^{99}Tc electrons in air is approximately 24 in. At electron energies this low, even the effective depth of the dead layer of the skin (5 to 10 mg/cm^2) is a significant shield for the germinal layers of the skin. In addition, PPE such as coveralls and gloves afforded attenuation factors of 95% and 98%, respectively (Jenkins, Mitchell, and Baker 1961). These observations are corroborated by other studies that show the fraction of ^{99}Tc dose transmitted through two pairs of coveralls to be approximately 0.7% (Martz, Rich, and Johnson 1986). Further, an analysis of attenuation using the computer program VARSKIN 3 showed a transmission factor of less than 1% for a standard outer glove, which has a thickness of 0.45 mm and a density of 1.1 g/cm^3 as recommended in NUREG/CR-6918 (Durham 2006).

2.1 POTENTIAL FOR EXPOSURE

It is apparent from operational documents that the potential for dose from ^{99}Tc was known and addressed (Saraceno 1981):

> *However, when cascade equipment containing significantly high amounts of technetium is removed for replacement or maintenance, special precautions must be taken to protect workers from exposure to technetium as is the case for any toxic material.*

and

> *For most of the cascade, the same safety precautions implemented to avoid contamination of personnel by uranium are adequate to prevent the technetium exposure. In the upper cascade, where technetium tends to accumulate, more stringent measures are taken.*

In summary, the control measures in place to prevent contamination due to uranium and its progeny provided an even greater protection factor for ^{99}Tc exposure. Routine control measures included gloves and coveralls (Baker et al. 1978).

The work activities that could have resulted in ^{99}Tc contamination included:

- Technetium recovery operations,
- Removal of equipment from the cascade for routine maintenance, and
- Removal and replacement of cascade equipment during the Cascade Improvement Program and Cascade Upgrade Program.

Tables 2-1 to 2-3 list the facilities with ^{99}Tc exposure potential.

Table 2-1. Portsmouth GDP facilities with ^{99}Tc exposure potential (ORAUT 2006).

Building	Facility
X-326	Gaseous Diffusion Process Building
X-330	Gaseous Diffusion Process Building
X-333	Gaseous Diffusion Process Building
X-344	UF_6 Feed Manufacturing Plant
X-345	Special Nuclear Materials Storage
X-700	Maintenance Building
X-701B	Holding Pond
X-705	Decontamination and Cleaning Building
X-705E	Oxide Conversion Plant
X-720	Compressor Shop
X-744G	Smelter and Aluminum Recovery

Table 2-2. Paducah GDP facilities with ^{99}Tc exposure potential (ORAUT 2007a).

Building	Facility
C-409	Stabilization Building
C-410	Feed Plant
C-420	Oxide Conversion Plant
C-331	Gaseous Diffusion Process Building
C-333	Gaseous Diffusion Process Building
C-335	Gaseous Diffusion Process Building
C-337	Gaseous Diffusion Process Building
C-310	Purge and Product Withdrawal Building
C-710	Analytical Lab
C-400	Decontamination and Cleaning Building
C-720	Maintenance Building

Table 2-3. K-25 GDP facilities with ^{99}Tc exposure potential (BJC and Haselwood Enterprises 2000, DOE 2000).

Building	Facility
K-25 (K-310-3[a] and K-311-1)[a]	Gaseous Diffusion Process Building
K-27 (K-402-8[a] and K-402-9)[a]	Gaseous Diffusion Process Building
K-29	Gaseous Diffusion Process Building
K-31	Gaseous Diffusion Process Building
K-33	Gaseous Diffusion Process Building
K-631	Gaseous Diffusion Process Building
K-131	Feed Facility and Decontamination and Recovery
K-413	Product Withdrawal Facility
K-770	Scrap Metal Yard
K-1004-A, -B, -C, -E	Analytical Laboratory Facilities
K-1031	Power and Utilities Storage Facility
K-1131	Feed Manufacturing Plant
K-1231	Ash Pulverization and Uranium Recovery Facility

Building	Facility
K-1401	Maintenance Facility
K-1410	Decontamination and Plating Facility
K-1420	Decontamination Facility
K-1421	Incinerator Building

a. These were purge cascade units with high concentrations of Tc-99.

Energy employees with the job titles in Table 2-4 could have had exposure to ^{99}Tc while performing the above-listed activities while in facilities in Tables 2-1, 2-2, or 2-3. The highest exposure potential would have been to maintenance workers on the top purge cells or doing change outs of trapping media near the top purge cells.

Table 2-4. Job titles for GDP workers with ^{99}Tc exposure potential.

Cascade operators/workers
Feed plant operators
Maintenance mechanics
Chemical operators
Radiological workers
Construction trade workers
Decontamination and decommissioning workers

2.2 MAGNITUDE OF EXPOSURE

Site evaluations at Paducah assessed the potential for an external ^{99}Tc exposure problem from ^{99}Tc recovery operations and found that the likelihood of high exposure was low due to the following reasons (Baker et al. 1978):

- Gloves were worn routinely for all operations involving the handling of containers.
- All material was transferred remotely from point to point with one exception. When moved from one container to another, the transfer was done by pumping – the container was never dumped by hand.
- The solutions were dilute.
- Less than 20% of employee work time was spent at jobs with the potential to generate ^{99}Tc contamination.

Information about the magnitude of ^{99}Tc exposure is available in *Tc-99 Contamination* (Swinth 2004). A range of measured contamination exposure levels at Paducah (from 10,000 to 335,849 cpm/100 cm^2) were considered, which resulted in average dose rates to the skin (using VARSKIN to calculate dose rates) that ranged from 0.212 mrem/hr (on contact) to 0.013 mrem/hr (10 cm of distance in air. These rates include the use of coveralls with a density thickness of 28 mg/cm^2). To estimate the skin dose from a contamination event, a contamination level of 25,000 dpm/100 cm^2 was assumed (based on the action limit for ^{99}Tc contamination on work surface and hand tools) (PORTS 1963). The dose would be given by (Swinth 2004):

$$250 \text{ dpm/cm}^2 \times 0.081 \text{ mrem per dpm/cm}^2 = 20 \text{ mrem} \quad (2\text{-}1)$$

Note that the assumed contamination value is greater than the average contamination level (13,540 cpm/100 cm^2) identified by Swinth (2004). The value of 0.081 mrem per dpm/cm^2 derives from data in Swinth (2004), namely 1.6×10^{-3} mrem per dpm/cm^2 multiplied by a residence half-time of 1.5 days. A residence half-time of 1.5 days is assumed because ^{99}Tc can be difficult to remove from the skin (Swinth 2004).

Because the low-energy ^{99}Tc electrons would not have been detected by dosimetry, the potential unmeasured external electron dose can be estimated by assuming an ambient dose rate level of 0.2 mrem/hr, a technetium-to-uranium progeny ratio of 0.4, and a 2,000-hour work year (Bassett 1986):

$$0.2 \text{ mrem/hr (maximum ambient level)} \times 0.4 \text{ (Tc:U progeny ratio)} \times 2000 \text{ hr/yr} = 160 \text{ mrem/yr} \quad (2\text{-}2)$$

Since the facilities, processes, and contaminants were similar at all three GDP sites, the magnitude of exposure discussed here is likely valid for each site.

3.0 PROPOSED APPROACH FOR DOSE ASSIGNMENT

The three GDP external dose technical basis documents (TBDs) are not specific about how to assign dose due to ^{99}Tc exposure.

It is clear from review of the properties of ^{99}Tc and the site evaluations of control practices (which included the routine use of PPE as discussed in Sections 2.1 and 2.2), that automatic assignment of ^{99}Tc dose due to skin contamination is not warranted. Guidance for assignment of ^{99}Tc skin contamination dose on a case-by-case basis is given below. It is apparent, however, that external exposure to ^{99}Tc was unlikely to be measured by dosimetry due to its low-energy electron characteristics. In certain cases – as described below – an annual assignment of ^{99}Tc external dose should be included in the dose estimate under the Energy Employees Occupational Illness Compensation Program Act of 2000.

3.1 ASSIGNMENT OF EXTERNAL DOSE

External dose due to the presence of ^{99}Tc should be applied under certain circumstances for cancer sites involving the extremities (hands). Dose assignment is limited to the hands because the ^{99}Tc dose rate at distances beyond 30 cm is less than 0.08 mrem/hr and drops off rapidly at greater distances (ORAUT 2007b). The following conditions determine if a dose should be assigned:

1. Claimant has skin cancer on the hand(s); and
2. Claimant worked in a facility where ^{99}Tc was present (Tables 2-1 to 2-3); and
3. Claimant performed a job function that could have involved ^{99}Tc exposure (Table 2-4); and
4. Claimant dosimetry indicates a relatively high ratio (more than 2) of shallow to deep dose (NIOSH 2007).

If and only if all four of the above conditions are met, then the dose reconstructor should:

- **Assign an external electron dose of 8 mrem/yr**.

This value derives from an annual external dose of 160 mrem reduced by a protection factor of 95% to account for PPE.

3.2 ASSIGNMENT OF SKIN CONTAMINATION DOSE DUE TO RADIOLOGICAL CONTAMINATION INCIDENT

Skin contamination dose due to ^{99}Tc should be applied under certain circumstances for cancer sites where a documented skin contamination event occurred. The following conditions determine if a dose should be assigned:

1. Claimant has skin cancer on a potentially uncovered area of the skin; and
2. Claimant worked in a facility where ^{99}Tc was present (Tables 2-1 to 2-3); and
3. Claimant performed a job function that could have involved ^{99}Tc exposure (Table 2-4); and
4. Claimant records indicate a contamination incident involving the area of the skin cancer site.

If and only if all four of the above conditions are met, then the dose reconstructor should:

- **Assign a skin dose of 20 mrem per documented incident**.

4.0 SUMMARY AND CONCLUSIONS

The presence of ^{99}Tc as a contaminant at the GDPs was known to health physics personnel, and the protection measures in place to protect workers from exposure to uranium progeny also protected against ^{99}Tc exposure. Due to its low-energy electron characteristics, the potential for ^{99}Tc dose was very low, especially considering the high (95% or greater) attenuation factor afforded by the routine use of PPE such as coveralls and gloves.

Only the existing external technical basis document (TBD) for Portsmouth contains well-referenced dose calculations for skin contamination and external exposure scenarios for ^{99}Tc. However, it does not provide specific guidance about the assignment of dose values. This document provides guidance for the assignment of ^{99}Tc dose based on information about work location, job title, shallow dose data, and cancer type and location. The three GDP external TBDs should be revised to include the dose calculation information from this report. In addition, the methods for assignment of ^{99}Tc dose in Section 3.0 should also be included in each GDP external TBD document.

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