Draft

SC&A'S RESPONSE TO NIOSH'S SUBGROUP 10A IMPACT ANALYSIS DATED NOVEMBER 1, 2011

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health or Advisory Board
DOE	U.S. Department of Energy
GDP	Gaseous Diffusion Plant
kg	kilogram
LEU	Low Enriched Uranium
MCA	Materials Control and Accountability
MgF_2	magnesium fluoride
MT	metric tons
NIOSH	National Institute for Environmental Safety and Health
NLO	National Lead of Ohio
PGDP	Paducah Gaseous Diffusion Plant
POOS	Plutonium Out Of Specification
ppb	parts per billion
RU	Recycled Uranium
SC&A	S. Cohen and Associates
SEC	Special Exposure Cohort
SRDB	Site Research Database
TRU	transuranic
UNH	Uranyl nitrate hexahydrate
UF_4	uranium tetrafluoride
UO_3	uranium trioxide

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1.0 INTRODUCTION

Recycled Uranium (RU) is uranium that had been previously used as reactor fuel or as target material in plutonium production reactors. After irradiation, the uranium was chemically purified to remove fission products and plutonium and other transuranics (TRU), and then shipped to the uranium enrichment, fabrication, and production plants for re-use. Because it is not possible to attain 100% product purity in chemical separation processes, quantities of several non-uranium isotopes remained following the uranium processing and posed a source of potential exposure to workers at Fernald.

On November 1, 2011, in response to tasking by the Fernald Work Group, the National Institute for Occupational Safety and Health (NIOSH) provided a focused analysis of the one remaining point of discussion regarding RU at Fernald. That analysis, entitled *Rationale for 400 ppb U Pu for 10A Process Stream at Fernald, Rev. 01* (NIOSH 2011c), is intended to provide quantitative evidence that the new proposed RU defaults provide a plausible upper bound for the group of workers who handled the most highly contaminated RU feed materials. This report provides SC&A's response to the NIOSH analysis. **It is important to note that this report provides SC&A's final technical position on the RU issue at Fernald.**

1.1 Historical Milestones Leading Up To This Report

The issue of worker exposures to contaminant radionuclides in RU at Fernald has involved several work group meetings and many white paper exchanges. To orient the reader, a brief historical summary of the discussions and white paper exchanges regarding the RU issue at Fernald is provided.

During the Fernald Work Group meeting held on October 28, 2008, SC&A was tasked with reviewing the NIOSH white paper on RU entitled, *Dose Reconstruction Considerations for RU Contaminants at Fernald* (NIOSH 2008). The direction provided by the Advisory Board on Radiation and Worker Health (ABRWH or Advisory Board) stated that SC&A should focus on the appropriateness of the default values selected for RU contaminants [Pu-239/240 (referred to herein as Pu-239), Neptunium-237 (Np-237), and Technecium-99 (Tc-99)], and whether the selected values are bounding for all workers for all time periods. SC&A's white paper on this issue, entitled *SC&A's Review of Issues Related to Reconstruction of Doses for Workers Exposed to Recycled Uranium at Fernald: Commentary on the NIOSH White Paper* (SC&A 2009), identified 11 deficiencies (findings) in the NIOSH white paper, which were the subject of extensive discussions at the January 29, 2010, Work Group meeting. During the January 2010 Work Group meeting, NIOSH stated that it was not prepared at that time to address the various issues raised, but agreed to prepare a response.

Prior to the November 9, 2010, Work Group meeting, NIOSH submitted the report, *Response to SC&A Findings related to the White Paper on Recycled Uranium at Fernald – October 2010*, (NIOSH 2010), which provided NIOSH's position on each of the 11 findings in SC&A (2009). The 11 findings and NIOSH's responses to those findings were the subject of intensive discussions at the November 9, 2010, meeting (ABRWH 2010). Two principal unresolved issues that emerged from that meeting prompted the Advisory Board's request for a second white

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paper. First, SC&A provided a compelling argument as to why the 19 subgroup process means derived in the U.S. Department of Energy (DOE) Ohio Field Office Report (DOE 2000) and reported in Table 5 of NIOSH (2008) do not provide a firm basis for bounding defaults for TRU and fission products. Second, SC&A's preliminary review of the dust collector data reported in Appendix B of NIOSH (2008) indicated that the NIOSH default values may not be bounding for some classes of workers in some facilities during the proposed Special Exposure Cohort (SEC) period.

SC&A's second white paper on recycled uranium, *SC&A Review of Issues Related to Reconstruction of Doses for Workers Exposed to Recycled Uranium at Fernald – A Second White Paper* (SC&A 2011a), was transmitted to the Work Group prior to the February 9, 2011, Work Group meeting. That paper identified nine new findings that supported our position regarding the questionable basis for NIOSH's proposed RU defaults, and that some categories of workers were exposed to TRU and fission product levels in excess of the NIOSH defaults. The issues were discussed in detail at the February 9, 2011, Work Group meeting. At that meeting, NIOSH was tasked to respond to SC&A (2011a) prior to the next Work Group meeting, scheduled for April 19, 2011. SC&A (2009) and SC&A (2011a) thoroughly describe SC&A's concerns regarding RU.

On April 13, 2011, SC&A transmitted Revision 1 of our second white paper on RU at Fernald (SC&A 2011b). That revision contained editorial corrections and a revised Table 2 that limited comparisons of organ doses from intakes of RU constituents to specific absorption classes. Note that Revision 1 did not result in changes to the findings in SC&A (2011a). Thus, unless otherwise indicated, all references in this document to SC&A's second white paper are to SC&A (2011b).

On April 17, 2011, NIOSH provided a response to SC&A (2011a) entitled, *NIOSH Response to Draft SC&A Review of Issues Related to Reconstruction of Doses for Workers Exposed to Recycled Uranium at Fernald – A Second White Paper – February 2011* (NIOSH 2011a). Because SC&A did not have time to prepare a detailed response to NIOSH (2011a) prior to the April 19th Work Group meeting, we prepared preliminary observations for discussion at the meeting. It is noteworthy that at the April 19th meeting, SC&A was not tasked to respond to NIOSH (2011a) or perform any additional work on the RU issue.

At the Advisory Board meeting held in St. Louis, Missouri, May 24–26, 2011, SC&A presented the status of our six main SEC findings regarding Fernald. Part of that presentation focused on our preliminary observations on NIOSH (2011a). At the conclusion of the presentation, SC&A was tasked by the Advisory Board to provide a formal response to NIOSH (2011a). On August 4, 2011, SC&A provided a response to NIOSH (2011a) entitled, *SC&A's Evaluation of NIOSH's Response Dated March 31, 2011, to SC&A's Second White Paper on Recycled Uranium (Sec Issue #3) at Fernald* (SC&A 2011c). On August 5, 2011, NIOSH submitted a paper entitled, *Issues Related to the Ability to Bound Internal Dose from Recycled Uranium Trace Level Contaminants at Fernald, Draft 01* (NIOSH 2011b), which outlined their position on RU default values.

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On August 11, 2011, the Fernald Work Group met and again discussed the RU issue, including the concerns raised in SC&A (2011c) and the position outlined in NIOSH (2011b). At that meeting, the Work Group agreed that the new proposed defaults for RU constituent radionuclides presented in NIOSH (2011b) probably provide plausible upper bounds for the most highly continuously exposed subgroup of workers, the Plant 5 metal production workers and associated Plant 1 millwrights during the period 1973–1989 (ABRWH 2011b). However, SC&A continued to express concern that another group of workers, those who handled the most highly contaminated feed materials on the front end of processing operations (Subgroup 10A in DOE 2000), might have experienced exposures at levels higher than the new defaults. NIOSH indicated that they believed that those workers were exposed to the highest concentrations only for brief intermittent periods and would, therefore, be covered by the new defaults. At the conclusion of the August 11, 2011, meeting, the Work Group tasked NIOSH to provide quantitative evidence that the new proposed RU defaults provide a plausible upper bound for the Subgroup 10A handlers and downblenders. On November 1, 2011, NIOSH provided their analysis (NIOSH 2011c). This report provides SC&A's response to the analysis in NIOSH (2011c)

2.0 SC&A'S SEC ISSUE #3 – RECYCLED URANIUM

SEC Issue #3 can be summarized by the following statement: **Default concentrations (on U mass basis) of Pu-239, Np-237, and other isotopes associated with RU at Fernald may not be bounding for some classes of worker activities, buildings, and time periods.**

3.0 NIOSH'S NOVEMBER 1, 2011, EVALUATION OF THE NEW PROPOSED DEFAULTS AS APPLIED TO GROUP 10A WORKERS

NIOSH 2011c is a focused analysis of the processes and time periods during which workers may have been exposed to the highly contaminated unblended subgroup 10A tower ash materials. The paper provides some processing data gleaned from the SRDB (Site Research Database) and assumptions based on those data, which are then used to justify the default contaminant values as bounding for all workers. Table 1 provides the NIOSH default values of Pu-239, Np-237, and Tc-99 for periods of time that generally correlate with levels of contaminants present in RU that could have exposed workers at Fernald. Note that for the period 1953–1960, prior to the introduction of RU into the process stream, NIOSH proposes defaults of zero. While SC&A believes that the exposure potential to RU at that time was low, we do not believe that defaults of zero represent a claimant-favorable position.

Table 1. Summary of Proposed NIOSH RU Default Values (1973–1989)

Radionuclide	1961–1972	1973–1989	Basis (DOE 2000)
Pu-239	100 ppb U	400 ppb U	Subgroup 8; MgF_2
Np-237	3,500 ppb U	11,000 ppb U	Subgroup 11; Waste Residues
Tc-99	9,000 ppb U	20,000 ppb U	Subgroup 6B; LEU* products

*low enriched uranium

The reader is referred to NIOSH 2011a, NIOSH 2011b, and SC&A 2011c for details regarding the basis for the default values in Table 1. SC&A wishes to reiterate that at the time of this draft report, the only remaining RU issue to be resolved is whether the new defaults in Table 1 for 1973–1989 provide plausible bounding values for subgroup 10A handlers and downblenders. The applicability of the proposed defaults for periods prior to 1973 has been agreed upon by the Fernald Work Group and is not addressed herein. Similarly, details regarding concentrations of contaminants in shipments of RU to Fernald over the operating life of the facility and the chemical processes that concentrated contaminants are described in SC&A 2011b.

The most highly contaminated subgroup 10A feed materials were received at Fernald in June 1980 from the Paducah GDP in 16 T-hoppers with a total mass of about 22.5 metric tons (MT). This material introduced about 25 grams of plutonium into the Fernald process stream, which essentially doubled the Pu inventory at the facility. Historically, this material was referred to as Plutonium Out Of Specification or "POOS." Table 2 is taken from a National Lead of Ohio (NLO) memorandum (NLO 1985a) and provides data on the amounts and plutonium concentrations in the 16 hoppers of most highly contaminated POOS feed materials.

Table 2. Recycled Feeds (Paducah Ash)

June 1980 Hopper	Uranium Mass (Kg)	Pu ppb (Uranium basis)	Pu ppb sample basis (MCA)	Pu ppb sample basis (NLO)
T-339	1,080	67	37	37
T-392	2,888	534	377	382
T-346	3,118	468	341	345
T-322	2,849	253	181	184
T-103	1,477	880	522	528
T-293	1,233	210	116	117
T-453	630	644	217	220
T-122	1,615	445	283	286
T-221	1,046	1,073	566	573
T-439	1,080	145	73	73
T-118	414	111	33	33
T-449	1,405	7,005	940	2,789
T-256	1,350	346	174	176
T-334	684	94	34	34
T-058	896	7,757	3,118	3,156
T-171	765	211	94	95

It is evident from Table 2 that the Pu content was highly variable among the hoppers (67 to 7,757 ppb Pu on a uranium mass basis), and that in at least one hopper (T-449), measured quantities varied by a factor of 3. The variability and uncertainty in these data were discussed in detail at the April 19 and August 11, 2011, Work Group meetings (ABRWH 2011a, ABRWH 2011b).

This 1980 shipment of 22.5 MT was sampled and stored primarily to develop blending material inventories and processes to accommodate this unusual shipment. It is important to note that this material was not immediately downblended upon receipt. After approximately a 2-year period, in April and May of 1982, five of the T-Hoppers with high contaminant levels were repackaged into large drums in Plant 4 to facilitate process needs in Plants 8 and 2/3 (Weidner 1982, *Air Sampling at Plant 4 During Repackaging of PGDP Wastes*, SRDB 33730). That is, repackaging into drums allowed for remote and semi-remote handling of the material during subsequent processing steps. Air sampling records associated with this repackaging are recorded, as well as the time required. Table 3 contains data on repackaging times from Weidner (1982).

Table 3. Repackaging Data – Subgroup 10A

Date	Shift	Hopper	PU ppb (U mass)*	Mass (Kg)	Shifts
4/19/1982	1	346	468	3,118	3
4/20/1982	1	346	468		
4/21/1982	1	346	468		
4/21/1982	2	392	534	2,888	8
4/21/1982	3	392	534		
4/22/1982	1	392	534		
4/23/1982	1	392	534		
4/26/1982	1	392	534		
4/27/1982	1	392	534		
4/28/1982	1	392	534		
4/29/1982	1	392	534		
4/30/1982	1	122	445	1,615	2
5/1/1982	1	122	445		
5/2/1982	1	449	7,005	1,405	4
5/3/1982	1	449	7,005		
5/4/1982	1	449	7,005		
5/5/1982	1	449	7,005		
5/6/1982	1	322	253	2,849	2
5/7/1982	1	322	253		
Totals				**11,875**	**19**

Though the information in Table 3 provides quantitative information on the time required to repackage some of the POOS material from hoppers into drums, neither NIOSH nor SC&A were able to locate quantitative information on the times required to process the subgroup 10A material after repackaging. NIOSH indicates that because the five hoppers identified in Weidner (1982) were those with the greatest concerns and difficulties, the times of repackaging could be used to estimate the repackaging times of other hoppers. They further assume that because subsequent processing steps such as calcining and blending involved semi-remote handling, the repackaging times would provide a sufficiently accurate and plausible bound on the time that any worker would have been exposed to unblended POOS material. NIOSH 2011c provides the following instructive excerpt regarding post-repackaging processing of the POOS material (NLO 1985a, pg. 50):

> *Paducah Feed Plant Ash was prepackaged from hoppers into drums in Plant 4. Drummed material was later blended with sump cake in the rotary kiln operation in Plant 8 producing seven lots of calcium uranate, which was used as feed for the*

> *refinery. Most of this material was converted to UO_3; a quantity remains as UNH in the refinery. UO_3, which was contaminated with the plutonium, remains on inventory at NLO. The remainder of the UO_3 was converted to UF_4 and blended with three parts of UF_4 produced from Hanford UO_3 in the metal reduction operations.*

The quote above indicates that the blended calcium uranate (now below the 400 ppb Pu (U) default level) was dissolved in Plants 2/3, resulting in liquid UNH. Again, the materials were stored until appropriate processing to UO_3 was available.

The next reference to processing of the subgroup 10A material is found in a 1985 NLO document entitled, *Processing 168 MTU of UO_3 Containing Recycle Contaminants*, (NLO 1985b). This document is instructive on several levels. First, it indicates that Pu and Np-237 concentrations in materials processed to UO_3 were about 34 and 662 ppb (U) respectively. This material was to be further blended with "clean UO_3" prior to fluorination to UF_4 in Plant 4, and again downblended prior to reduction to metal in Plant 5 with clean UF_4.

NLO 1985b also indicates that unblended POOS materials were occasionally processed through to metal:

> *…This represents a 26-fold increase in concentration, or a Pu content of 676 ppb. MgF_2 analyses to date have not yielded any results that high* ***even though materials with similar Pu content have been processed without conscious attempts at blending****.* [Emphasis added.]

This last statement is important because it indicates that pathways other than chemical concentration mechanisms resulted in the high concentrations observed in MgF_2 in the 1980s. The topic of whether the original defaults (e.g., 100 ppb Pu) would adequately bound Plant 5 metal production workers and associated Plant 1 millwrights who were exposed to high constituent concentrations in MgF_2 in the pre-1973 period was discussed in the April and August 2011 Work Group meetings (ABRWH 2011a, ABRWH 2011b). At that time, SC&A contended that if chemical concentration of downblended material was the sole mechanism that resulted in the high concentrations in MgF_2 documented in DOE 2000, then the higher defaults (e.g., 400 ppb Pu) would apply during the entire period of metal production employing RU, and not just after POOS receipts began in 1973. The discovery of NLO 1985b among the 49 new references identified in NIOSH 2011c was a key factor in SC&A's acceptance of the original defaults for the 1961–1972 timeframe. SC&A was also concerned about the high dust concentrations reported in Plant 1 mill areas that were reported in Appendix B of NIOSH (2008), because they may have resulted from milling of unblended materials in addition to recycled MgF_2. Given that unblended POOS materials were occasionally processed, SC&A's concerns in this regard appear to have been warranted.

Based on the information in Table 3 and several somewhat subjective assumptions, NIOSH concluded that any given worker continuously involved in POOS handling would have spent no more that about 8% of a year's work exposed to materials with concentrations greater than 400 ppb Pu. Thus, they determined that in aggregate, 400 ppb was inclusive for all workers. Assumptions included a 5-hour shift to account for documented respiratory protection and

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protective clothing, and that only the hoppers with Pu concentrations over 400 ppb were of concern.

SC&A used the data in Tables 2 and 3 and applied more conservative assumptions to calculate that about 14% of a worker's annual time could have been dedicated to unblended POOS handling, and that the weighted average Pu concentration experienced by the workers was less than 400 ppb. Our calculations were based on the following facts and assumptions.

- Average plutonium concentration in the 16 hoppers on a U mass basis was about 1,122 ppb (Table 2)
- Assumed baseline concentration for other than Plant 5 metal workers = 100 ppb
- Shift time = 8 hours (no reduction for protective measures and respirators)
- Average mass processed per shift = 11,875 kg/19 shifts = 675 kg/shift (Table 3)
- Given 8 hours per shift, it would take about 288 hours in 36 shifts to process all 16 hoppers
- Maximum percentage of annual time allotted to POOS handling = 288/2,080 = 13.86%

Weighted average Pu concentration over a year (Pu_{avg}):

$$Pu_{avg} = [(1{,}792 \text{ hours} \times 100 \text{ ppb}) + (288 \text{ hours} \times 1{,}122 \text{ ppb})]/2{,}080 \text{ hours} = \mathbf{242\ ppb}$$

In summary, SC&A agrees that the repackaging intervals provided in Table 3 can probably be used in conjunction with conservative assumptions regarding shift intervals to reasonably estimate a period during which workers could have been exposed to unblended POOS. While we may disagree with NIOSH over the choice of particular assumptions in determining the timeframe, our own calculations suggest that the new NIOSH defaults in Table 1 for 1973–1989 adequately bound exposures experienced by subgroup 10A workers.

Given that this was the last remaining Fernald Work Group issue to be resolved regarding RU exposures, we believe that the topic of RU exposures at Fernald can be moved to site profile discussions.

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