Draft

Review of NIOSH's White Paper:
Assessment of Sealed Radioactive Sources, and Fission and Activation Products as Radiological Exposure Sources in the Rocky Flats Plant Critical Mass Laboratory (Building 886 Cluster)

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Record of Revisions

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0 (Draft)	07/8/2015	Initial issue

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ABBREVIATIONS AND ACRONYMS

Bq	Becquerel
CML	Critical Mass Laboratory
DCAS	Division of Compensation Analysis and Support (formerly OCAS)
DOE	(U.S.) Department of Energy
FAP	fission and activation product
g U/L	grams of uranium per liter
IMBA	Integrated Modules for Bioassay Analysis
mrem	millirem
mW	milliwatt
µCi	microcuries
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH/OCAS Claims Tracking System
OCAS	Office of Compensation Analysis and Support (now DCAS)
pCi	picocuries
RFP	Rocky Flats Plant
SC&A	S. Cohen and Associates
SRDB	Site Research Database

1. INTRODUCTION

NIOSH provided a white paper on June 9, 2015, titled: *Assessment of Sealed Radioactive Sources, and Fission and Activation Products as Radiological Exposure Sources in the Rocky Flats Plant Critical Mass Laboratory (Building 886 Cluster).* It stated:

> *This white paper describes the Critical Mass Laboratory (CML) at the Rocky Flats Plant* [RFP] *and the programs and experiments conducted there. It discusses the radioactive materials present and their amounts and assesses these materials as radiological sources.*

After the introduction, the report is divided into the following sections:

- History of the critical mass laboratory
- Radioactive materials used in the CML
- Generation of fission and activation products
- Decommissioning and demolition
- Assessment of unmonitored radiation dose at the CML
- Summary and conclusions

2. RADIATION EXPOSURE POTENTIAL

NIOSH's white paper provided detailed information concerning the exposure potentials at the CML, which operated from 1964–1987, was in standby 1987–1997 (at which time all the fissile materials were removed), and was demolished in 2002. The major exposure potentials were from:

- **Sealed Sources** – Sealed radioactive check sources and neutron start-up sources
- **FAP –** Fission and activation products (FAP) generated in the fuels, test apparatuses, and building materials as a result of the nuclear criticality experiments conducted
- **Fuels –** Plutonium and uranium fuels (solids and liquids) used in the experiments

Sealed Sources

A summary of these sources is listed in Table 2 on page 4 of NIOSH's white paper.

FAP

Fission and activation products (FAPs) could be generated in the fuels, in the test apparatuses, and building materials as a result of the nuclear criticality experiments conducted. NIOSH's white paper (NIOSH 2015, pp. 4–11) provides an analysis of the potential FAP inventory in the fuel generated under the operating conditions at the CML; Table 5 on page 10 summarizes the dosimetrically important radionuclides generated from a series of 1-hour runs at 10 mW using highly enriched uranium concentration of 145.68 g U/L in each experiment. The largest amount of FAPs generated is in the neighborhood of 5E5 Bq, which corresponds to 14 µCi of activity. The FAPs generated in the fuel would be the controlling factor in this situation, since the activation of the test apparatuses and building structures would be far less than in the fuel, because the neutron flux is concentrated in the fuels and decreases rapidly with distance and through material.

Fuels

Plutonium and uranium fuels (liquids and solids) were used in the experiments; much of the solid fuels were not contained in a metal cladding. These fuels presented a potential for internal uptake during both normal operations and during incidents, such as spills.

3. SC&A'S EVALUATION OF NIOSH'S WHITE PAPER

Sealed Sources

External exposure – Sealed sources presented only potential external exposures. Workers were monitored for external exposures as required by the RFP badging policy when working in a radiation area containing radioactive sources; therefore, external doses should be accounted for in the worker's records.

Internal Exposure – Sealed sources, by definition, do not present an internal exposure hazard.

FAP

External Exposure – Workers were monitored for external exposures as required by the RFP badging policy when working in a radiation area containing FAPs; therefore, external doses should be accounted for in the workers' records.

Internal Exposure – Generally, subcritical and near-critical assemblies operating in the mW range do not produce significant FAPs; this is demonstrated in the NIOSH white paper. The potential intakes from the re-suspension of FAP contaminants is summarized in Table 6, page 19, of the NIOSH white paper. The maximum intakes over a 2-year period would in the neighborhood of 5 Bq, which corresponds to 135 pCi. The maximum committed organ doses from inhalation of FAPs for re-suspended contamination are summarized in Table 7 on page 20 of NIOSH's white paper. The doses range from 0.04 mrem to 0.1 mrem; these would not be significant doses for dose reconstruction purposes.

Fuels

External Exposure – Workers were monitored for external exposures as required by the RFP badging policy when working in a radiation area containing uranium and plutonium; therefore, external doses should be accounted for in the workers' records.

Internal Exposure – Plutonium and uranium fuels (liquids and solids) were used in the experiments; much of the solid fuels were not contained in sealed metal cladding. These fuels presented a potential for internal uptake during both normal operations and during incidents, such as spills. As can be seen from the current evaluation, the largest exposure potential at the CML was from the fuels, especially liquid fuels during incidents.

NIOSH's white paper (NIOSH 2015), Table 1, page 3, lists the uranium and plutonium fuels used at the CML; Table 3, page 5, provides some experimental uses of these fuels; and Table 8, page 17, lists the major spills over the operating history of the CML. NIOSH addressed potential internal uptakes from CML fuel on pages 15–17 of the white paper; in summary, it states:

> *…intakes of uranium or plutonium are accounted for by the RFP radiation dosimetry monitoring programs. Sufficient detail exists about both routine operations and incidents, as well as about the ambient radiation dose environment prior to decommissioning, that external doses to, and intakes of radioactive materials by, individual claimants could be reconstructed with sufficient accuracy if dosimetry records are unavailable.*

And on page 21:

> *The personnel dosimetry program also included periodic bioassay (urinalysis and body counts) that focused primarily on identifying uranium and plutonium intakes. The in-vivo bioassay, using gamma spectrometry, would be expected to easily detect most fission and activation products present in any significant amount except for radioisotopes like Sr-90, which emit beta radiation not detectable in a routine body count or in a urinalysis evaluated for alpha-emitters.*
>
> *Estimates of the total activity in fission and activation products from irradiation of high-enriched uranyl nitrate solution fuel (the fuel contributing most to contamination within the facility) indicate that only inconsequential amounts of these products* [such as Sr-90] *were available to contribute to radiation doses from re-suspension of residual contamination.*

To evaluate NIOSH's conclusions, SC&A searched some of the RFP claims on the NIOSH/OCAS Claims Tracking System (NOCTS) and found documentation for a few incidents in the claimants' files, but not a large number. Many of the incidents at the CML are recorded in a publication by Rothe (Rothe 2005). However, it is very difficult to quantitatively correlate the various incidents to potential intakes. Therefore, SC&A approached this issue by analyzing the CML workers' claim files for bioassay data.

Analyses of CML Claimants

SC&A obtained 25 names of CML workers from Rothe's publication (Rothe 2005) that had the most potential for exposure/uptakes, such as experimenters, technicians, and nuclear engineers. Four of these workers were claimants listed in NOCTS. SC&A analyzed these four workers' Department of Energy (DOE) files for bioassays that were performed while working at the CML; the employment years fell in the range of 1964–1982, which were the most active years for experimentation and incidents, according to NIOSH's white paper (Figure 2, page 9, and Table 8, page 17, respectively). SC&A looked for the frequency of bioassays (i.e., did the bioassays appear to be conducted on approximately an annual basis, or were they hit and miss), and also if there was an indication that bioassays were conducted more frequently than once per year, which would indicate special bioassays for an incident. SC&A noted that many of the original recorded bioassay results did not indicate the purpose of the bioassay; i.e., routine, special, etc.

Bioassay Results
A summary of the bioassay results is as follows:

Table 1. Summary of Four Claimant Bioassays 1964–1982

Case	Years at CML	No. of Bioassays 1964–1982	Average No. Bioassays per Year	Range of No. Bioassays/Year	No. years with ≥3 Bioassays/Year
A	17	38	2.2	0 to 9	5
B	4	10	2.5	1 to 3	2
C	5	7	1.4	0 to 2	0
D	18	58	3.2	1 to 11	8
Total:	**44**	**113**	**2.6**	-	**15**

While not conclusive, these results indicate that generally the workers at the CML received bioassays on an annual basis, and that there were years when the workers received above the normal number of bioassays (i.e., for 15 years out of 44 years, there were ≥3 bioassays performed per year on a given worker, which would be approximately 1/3 of the time), indicating possible monitoring for non-routine intakes.

SC&A performed some genetic Integrated Modules for Bioassay Analysis (IMBA) runs using urinalyses for Pu-239 and U-235 to determine if an acute intake occurring between routine bioassays might be missed (in case special bioassays were not taken after an incident). The results of these IMBA runs indicate that if the acute intake occurred midway between annual bioassays, the remaining radionuclide concentration in the urine bioassays would range from approximately 45% to 85% of the concentration just after the acute intake, depending on the radionuclide and solubility type. Therefore, significant acute or chronic intakes would most likely not go undetected if only routine annual bioassays were conducted.

SC&A Conclusion

The results of this analysis suggest that the external doses and internal intakes from potential exposures at the CML were monitored in a manner that would mostly likely not result in significant exposures going undetected for dose reconstruction purposes.

4. REFERENCES

NIOSH 2015. White Paper: *Assessment of Sealed Radioactive Sources, and Fission and Activation Products as Radiological Exposure Sources in the Rocky Flats Plant Critical Mass Laboratory (Building 886 Cluster)*, Rev. 0. National Institute for Occupational Safety and Health, Division of Compensation Analysis and Support (DCAS), Cincinnati, Ohio. June 9, 2015.

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