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National Institute for Occupational Safety and Health

A Review of NIOSH's Program Evaluation Report DCAS-PER-079, "Pinellas Plant"

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
ALARA	as low as is reasonably achievable
C	carbon
DOE	U.S. Department of Energy
DR	dose reconstruction
GE	General Electric
GENDD	GE Neutron Devices Department
^{3}H	tritium
IREP	Interactive RadioEpidemiological Program
keV	kiloelectron volt
Kr	krypton
MeV	mega-electron volt
mrem	millirem
Ni	nickel
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH Claims Tracking System
ORAUT	Oak Ridge Associated Universities Team
PER	program evaluation report
POC	probability of causation
Pu	plutonium
PuO_2	plutonium oxide
RTG	radioisotope thermoelectric generator
SEC	Special Exposure Cohort
SPR	Subcommittee for Procedure Reviews
SRDB	Site Research Database
TBD	technical basis document
TLD	thermoluminescent dosimeter
U	uranium
WG	work group

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1 Statement of Purpose

To support dose reconstruction (DR), the National Institute for Occupational Safety and Health (NIOSH) and the Oak Ridge Associated Universities Team (ORAUT) assembled a large body of guidance documents, workbooks, computer codes, and tools. In recognition of the fact that all supporting elements in DR may be subject to revisions, provisions exist for evaluating the effect of such programmatic revisions on the outcome of previously completed DRs. Such revisions may be prompted by document revisions due to new information, misinterpretation of guidance, changes in policy, and/or programmatic improvements.

A program evaluation report (PER) provides a critical evaluation of the effects that a given issue or programmatic change may have on previously completed DRs. This includes a qualitative and quantitative assessment of potential impacts. Most important in this assessment is the potential impact on the probability of causation (POC) of previously completed DRs with POCs less than 50 percent.

During a teleconference by the Advisory Board on Radiation and Worker Health (Board) Subcommittee for Procedure Reviews (SPR) on March 14, 2024, the Board tasked SC&A to review DCAS-PER-079, revision 0, "Pinellas Plant TBD Revision" (NIOSH, 2020; "PER-079"). In conducting a PER review, SC&A is committed to perform the following five subtasks, each of which is discussed in this report:

- **Subtask 1:** Assess NIOSH's evaluation and characterization of the issue addressed in the PER and its potential impacts on dose reconstruction. Our assessment intends to ensure that the issue was fully understood and characterized in the PER.

- **Subtask 2:** Assess NIOSH's specific methods for corrective action. When the PER involves a technical issue that is supported by documents (e.g., white papers, technical information bulletins, procedures) that have not yet been subjected to a formal SC&A review, subtask 2 will include a review of the scientific basis and/or sources of information to ensure the credibility of the corrective action and its consistency with current/consensus science. Conversely, if such technical documentation has been formalized and previously subjected to a review by SC&A, subtask 2 will simply provide a brief summary and conclusion of this review process.

- **Subtask 3:** Evaluate the PER's stated approach for identifying the universe of potentially affected DRs and assess the criteria by which a subset of potentially affected DRs was selected for reevaluation. The second step may have important implications where the universe of previously denied DRs is very large and, for reasons of practicality, NIOSH's reevaluation is confined to a subset of DRs that, based on their scientific judgment, have the potential to be significantly affected by the PER. In subtask 3, SC&A will also evaluate the timeliness of the completion of the PER.

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- **Subtask 4:** Conduct audits of DRs affected by the PER under review. The number of DRs selected for audit for a given PER will vary. (It is assumed that the Board will select the DRs and the total number of DR audits for each PER.)

- **Subtask 5:** Prepare a written report that contains the results of DR audits under subtask 4, along with our review conclusions.

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2 Relevant Background Information Pertaining to Facility Operations, Source Terms, and Worker Monitoring Protocols

2.1 Facility operations

Information on the Pinellas Plant is found in the current site profile TBDs (ORAUT, 2011a, 2011b, 2011c, 2011d, 2016, 2017). Details of the plant's history, building and equipment layout, manufacturing and other processes, radioactive source types and locations, and potential for personnel exposure are primarily in the site description technical basis document (TBD) (ORAUT, 2011b), with elaboration as appropriate in the other TBDs.

The plant, formerly located on a 100-acre site in Clearwater, Florida, was constructed in 1956 by the General Electric Company to manufacture neutron generators for the U.S. nuclear weapons program and expanded after 10 years of operation to include other specialized electronic and support components. Prominent among them from a radiological standpoint were radioisotope thermoelectric generators (RTGs). There was one large building, Building 100, which contained many areas designated for manufacturing, engineering, and administrative functions, and 17 smaller, surrounding buildings and structures, which themselves also contained different areas and rooms.

At peak operations, the plant employed approximately 2,000 people (GENDD, 1986). The plant operated from 1957 through September 1994, with subsequent decontamination and decommissioning activities from October 1994 through 1997 and remediation activities in 1999, 2008, and 2009. Pope (2007) provides further information on the plant's closing, which was prompted by the U.S. Department of Energy's (DOE's) efforts in the late 1980s to close several nuclear weapons complex plants and transfer their essential functions to other plants. As part of that process, fabrication of neutron generators passed from Pinellas to Sandia National Laboratories.

Over the plant's long history, Pinellas has gone by many names, including, but not limited to, the 908 Plant, General Electric (GE) X-ray Division Florida, GE Neutron Devices Department (GENDD), GE Neutron Devices, GE Pinellas Plant, General Electric Temporary Plant, GE Aerospace Neutron Generators, and Pinellas Peninsula Plant. These names occur throughout the literature and employee statements but are generally understood to refer to the same facility. Throughout this review, the plant is referred to as Pinellas, the Pinellas Plant, or the plant.

2.2 Sources of radiation

Section 2.4 of the Pinellas site description TBD (ORAUT, 2011b) discusses the radiation sources at the plant and categorizes them as either radioactive materials that continuously emit radiation through radioactive decay, or radiation-generating devices that produce radiation only when they are operating. In the radioactive materials category, the TBD lists several products containing radionuclides, such as:

- miniature linear accelerator-type neutron generators (containing tritium targets) used to initiate nuclear fusion reactions

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- RTGs containing plutonium oxide heat sources that arrived at the plant as triply encapsulated units
- borosilicate glass structures containing uranium
- leak-testing systems containing krypton (Kr)-85
- tritium storage systems
- instrumentation and dosimeter calibration and check sources
- analytical standards for laboratory analyses

The TBD asserts that: "With the exceptions of radionuclides used as analytical standards, tritium (^{3}H), ^{14}C [carbon-14], and ^{85}Kr were the only dispersible radionuclides normally encountered at the Pinellas Plant. All other radionuclides at the Plant were in nondispersible forms (plated sources, containerized sources, encapsulated sources, solid metal sources, etc.)" (ORAUT, 2011b, p. 14).

In addition to the radioactive materials, which always emit radiation, certain devices also generated radiation only when they were operating. Table 2-1 of the Pinellas site description TBD (ORAUT, 2011b) lists radiation-generating devices with their quantities and types. The primary product of the plant was neutron generators (containing very small linear accelerators enclosed in vacuum tubes) used in the triggering mechanism of nuclear weapons, which accelerate deuterons into either a tritium target or a deuterium target resulting in the emission of either 14.1 mega-electron volt (MeV) or 2.5 MeV neutrons, respectively, from the nuclear fusion reactions. Ion accelerators were used for ion implantation and target assessment, materials analysis, and other purposes and could also generate radiation.

X-ray diffraction and electron-beam equipment contained electron-producing sources and could only have directly exposed workers in the vicinity if the equipment containments were compromised. Various large and small sealed sources were also radiation emitters. The plant laboratories also contained an assortment of low-activity sources used as instrument check sources, etc. SC&A investigation of personnel exposures at Pinellas has not revealed any monitored external doses that were positive associated with these sources of radiation. Finally, the plant conducted onsite personnel occupational medical x-ray examinations.

Three types of radiation, arising from decay of radioactive materials or generated in a radiation-producing device, could have caused external exposures to plant workers: electron (beta), photon, and neutron. Several sources produced a mixture of different types of radiation.

Tritium (a low-energy beta emitter with 5.7 kiloelectron volt (keV) average energy, 18.5 keV maximum energy, and a 12.32-year half-life) occurred at Pinellas in four forms: tritiated water

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(tritium oxide), tritium gas, organically bound tritium, and metal tritides.[1] Although tritium represented the principal source of electron radiation at Pinellas, it did not pose a significant external radiation hazard due to the low energy of the beta particle, which would not allow it to penetrate the top layer of skin.

Kr-85, a beta-emitting noble gas (251 keV average energy, 687 keV maximum energy, and a 10.756-year half-life), poses a greater external electron exposure hazard than tritium because its beta particles have sufficient energy to cause a skin dose through exposure to a cloud of the gas. The plant used Kr-85 in leak detection systems, and although the plant recovered most of the gas after each leak test, some of it might have escaped into the environment despite the two leakage detection systems being surrounded by ventilation shrouds. However, SC&A's investigation of documented incidents at Pinellas found no instances of a cloud release of Kr-85.

Plutonium (Pu) (as Pu-238, 87.7-year half-life, and Pu-239, 24,110-year half-life) is an alpha particle emitter (not a concern to external exposures due to their very short path lengths) and x-ray emitter but might also produce neutrons and gamma rays from spontaneous fission events. Plutonium fission and daughter products, in turn, also emit radiation as they decay. NIOSH maintains that available evidence supports the assertion that there was no free plutonium in the plant as all of it was triply encapsulated as the heat source in the RTGs.

Uranium (U), in the form of natural and depleted uranium, was also present. The uranium isotopes (U-234, U-235, and U-238) emit alpha particles and x-rays when they undergo radioactive decay, and some of their decay chain progeny also emit alpha, beta, and gamma radiation as they, in turn, decay. Depleted uranium (lower U-235 isotopic percentage than in natural uranium), in a containerized configuration, was primarily used to store tritium in storage beds (depleted uranium hydrogen getter). Natural uranium was used as a dopant in borosilicate glass structures that were received by Pinellas in a sealed form. A 1992 Pinellas summary of natural uranium glass concerns noted that the plant used borosilicate glass containing 1.5 percent by weight of naturally occurring uranium oxide (Pinellas Plant, 1992–1994, PDF p. 2). As part of plant operations, this glass was cut and chemically etched. Site health physicists evaluated the exposure risk and determined that the conservative highest whole body external dose expected from work with the glass was 15 millirem (mrem)/year and the highest dose to the extremities was 75 mrem/year. These are well below the DOE limits at that time of 5 and 50 rem, respectively.

C-14 is a beta-emitting radionuclide (49 keV average energy, 156 MeV maximum energy, and 5,730-year half-life) used in small amounts in the plant as a radioactive label in some laboratory

[1] A note on nomenclature: Metal tritides also go by alternate names, including stable metal tritides, insoluble metal tritides, and insoluble tritium compounds; it is assumed here that all refer to the same forms.

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solvents.[2] Its beta energy is sufficiently high to potentially constitute an external electron hazard; however, the amount of C-14 that was at the plant is considered negligible.

Nickel (Ni)-63, a beta emitter (17.425 keV average energy, 66.977 keV maximum energy, and 101.2-year half-life), is used in krytrons (sealed, gas-filled glass tubes that were used as very high-speed switches in nuclear weapons). ORAUT (2017) states that Pinellas received the electroplated Ni-63 from an external supplier but might have been involved with creating and sealing assemblies into glass tubes. It should be noted that the emitted beta particle energy is quite low.

2.3 Worker exposures and monitoring at Pinellas

Since PER-079 is concerned only with the occupational external dose TBD, this discussion on worker radiation monitoring and exposures will also focus only on external dose aspects as they appear in the latest revision (revision 02) of the external dose TBD (ORAUT, 2017).

2.3.1 Electron radiation

The TBD concludes that, since tritium decay produces only low-energy betas, which cannot penetrate the skin, there is no external electron hazard at the plant.

> The only potentially significant sources of electron radiation with sufficient energy to penetrate the skin are ^{85}Kr that is used with the two leak detection systems . . . . Electron radiation exposures were also possible for X-ray diffraction and electron beam devices if containment of the beams was compromised. However, it was more probable that any exposures from these devices would have been from X-rays or bremsstrahlung production and not from a free electron beam. The exposures, if diffuse, would have been monitored by film badge or TLD. [ORAUT, 2017, p. 12]

2.3.2 Photon radiation

Section 6.2.2.1 of ORAUT (2017, p. 12) states that "the majority of the photon radiation exposures in the neutron generation production area were from the testing of neutron tubes and neutron generators. In the RTG production areas (Building 400), the majority of the photon radiation exposures were [*sic*] from the plutonium oxide ($^{238}PuO_2$) heat sources."

Table 6-1 of ORAUT (2017) gives electron and photon energies and percentages and process types producing the radiation in different plant locations. The listed electron-producing areas are Building 100, Area 109, associated with the Kr-85 leak detection system, and Building 800, associated with calibration and ion accelerator activities. The photon-producing areas are Buildings 100, 200, and 300, associated with neutron generator production; Building 100, Area

[2] NIOSH (2011b) notes that, "A 1983 environmental assessment indicated that small quantities of ^{14}C labeled solvents were used in a laboratory testing operation (DOE 1983). No other documentation was found to indicate other uses of ^{14}C" (p. 16).

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109, associated with the Kr-85 leak detection system; Building 400, associated with RTG production; and Building 800, associated with calibration and ion accelerator activities.

2.3.3 Neutron radiation

Section 6.2.2.2 of ORAUT (2017) states that potential neutron exposures at the Pinellas plant could have come from either radiation-generating devices, such as the neutron generators, or from the sealed $^{238}PuO_2$ heat sources, which were used in the RTGs. When activated, the neutron generators accelerated deuterium ions into deuterium- or tritium-containing targets and, through nuclear fusion processes, produced 2.5 MeV or 14.1 MeV neutrons, respectively. The $^{238}PuO_2$ sealed sources were manufactured by Los Alamos National Laboratory and not Pinellas. The plutonium in the RTGs also produced neutrons from fission initiated by (alpha, neutron) reactions, but continuously rather than intermittently as is the case with the neutron generators. The Pinellas 1990 ALARA report (Harder, 1991) states that the plutonium heat sources were the only measurable sources of neutrons at the plant.

Table 6-2 of ORAUT (2017) gives neutron energy groups and percentages and process types producing the radiation in different plant locations. Building 100 had several neutron generator production areas, Building 400 had several areas associated with RTG production, and Building 800 contained an ion accelerator that produced neutrons peripherally.

2.3.4 Monitoring techniques

Section 6.2.3 of ORAUT (2017) (pp. 15–22) gives information on external radiation dosimetry technology as it evolved over the years of the plant's operations. Table 6-3 reports on historical dosimetry events (e.g., changes in dosimetry equipment) from 1957 through October 1994 when the primary mission of Pinellas transitioned from defense production to cleanup activities.

Tables 6-4 through 6-7 of ORAUT (2017) summarize the monitoring techniques and describe the Pinellas dosimeters known or thought to be used by year. The table topics are as follows:

- Table 6-4: Whole body beta-gamma dosimeters, 1957–1997
- Table 6-5: Whole body neutron and beta-gamma-neutron dosimeters, 1957–1991
- Table 6-6: Wrist beta-gamma dosimeters, 1974–1997
- Table 6-7: Ring beta-gamma dosimeters, 1957–1997

Section 6.2.4 discusses dosimeter performance and calibration.

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3 Subtask 1: Identify the Circumstances that Necessitated DCAS-PER-079

3.1 Chronology of events

According to PER-079, NIOSH produced the current version (revision 02) of the Pinellas occupational external dose TBD (ORAUT, 2017) in response to several SC&A and SPR reviews and discussions that were conducted since the previous version (revision 01) of the TBD (ORAUT, 2011e). "The effect of issuing revisions to the TBD on previously completed claims is the subject of this PER" (NIOSH, 2020, p. 1). Specifically, PER-079 (p. 1) lists two revisions to the TBD:

- Eliminating the assignment of onsite ambient external dose and replacing it with the more favorable unmonitored dose.
- Monitored and unmonitored tritium doses increased for all years.

PER-079 states the consequences of the TBD revisions: "These changes mean all previously completed claims are affected and none can be eliminated from further evaluation based on the changes. Additional changes did occur, but it is unnecessary to itemize them here since all claims must be evaluated" (NIOSH, 2020, p. 2).

3.2 SC&A's comments

SC&A has assessed NIOSH's evaluation and characterization of the issue addressed in PER-079 and its potential impacts on DR. (An overview of the TBD review process appears in section 4 of this report.) SC&A concurs with NIOSH's determination that changes to the occupational external dose TBD from revision 01 to revision 02 affect all DRs with POCs less than 50 percent completed at the time.

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4 Subtask 2: Assess NIOSH's Specific Methods for Corrective Action

According to PER-079, NIOSH searched the NIOSH Claims Tracking System (NOCTS) database as well as other sources to identify an initial population of claims. Starting with a set of 529 cases, some factors, such as claims that already had a POC greater than 50 percent, caused those claims to be eliminated since a recalculation under the revised TBD would only increase their assigned external doses and thereby their POCs even more. This winnowing process resulted in 380 claims with POCs less than 50 percent requiring further evaluation.

NIOSH recalculated doses for those 380 claims using the revised TBD as well as then-current procedures and found that 379 claims had a POC less than 45 percent. One claim had a POC between 45 percent and 50 percent. NIOSH ran the Interactive RadioEpidemiological Program (IREP) 30 times with 10,000 iterations per run for that case, and the POC for that claim remained less than 50 precent. Hence, the increase in external dose using revision 01 of the occupational external dose TBD did not change the status of any of the claims.

4.1 Overview of SC&A's previous reviews of the Pinellas site profile TBDs

A summary of the history and status of Pinellas review activities will provide context for this PER-079 review. SC&A had previously reviewed all Pinellas site profile TBDs, and its findings were discussed and responded to in several Pinellas Work Group (WG) meetings and by NIOSH and SC&A papers, beginning in 2004 with worker outreach activities. SC&A had reviewed the original site profile TBDs produced by NIOSH/ORAUT in 2005 and 2006 (ORAUT, 2005a, 2005b, 2005c, 2005d, 2005e, 2006) and submitted its assessment to the Board in 2006 (SC&A, 2006). That assessment identified 11 primary and eight secondary issues.

Responding to SC&A's assessment and several technical exchanges between NIOSH, SC&A, and the Pinellas WG, NIOSH/ORAUT revised the TBDs beginning in 2011 (ORAUT, 2011a, 2011b, 2011c, 2011d, 2011e, 2016, 2017), where (ORAUT, 2011e) is revision 01 and (ORAUT, 2017) is revision 02 of the occupational external dose TBD, the subject of PER-079. After further reviews and discussions, the WG concluded that all TBD issues had been resolved.

In addition to the TBD assessments, Pinellas Special Exposure Cohort (SEC)-00256 is currently under active review. After several petition revisions, NIOSH qualified the final revised petition for evaluation on October 20, 2020, but modified the class definition to:

> All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Pinellas Plant in Clearwater, Florida for the period from January 1, 1957 through December 31, 1990. [NIOSH, 2021, p. 20]

NIOSH submitted its SEC evaluation report (NIOSH, 2021) on October 13, 2021. SC&A subsequently submitted an interim review report (SC&A, 2023), followed by a NIOSH response (NIOSH, 2023).

NIOSH's (2021) petition evaluation report concludes the following about the Pinellas facility:

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> NIOSH concludes that it has access to sufficient information to estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could be incurred in plausible circumstances by any member of the class under evaluation. Therefore, NIOSH does not recommend adding the NIOSH-evaluated class to the SEC. [NIOSH, 2021, p. 21]

The ongoing SEC review is considering several issues brought by SC&A, the WG, and the petitioners; its final disposition could potentially affect the TBDs and determination of worker compensation recommendations.

4.2 Recommendations in SC&A's review of the external dose TBD

As discussed in section 4.1 of this report, SC&A had reviewed revision 02 of the occupational external dose TBD (ORAUT, 2017) and determined, with the concurrence of the Pinellas WG, that all issues were resolved. Hence, SC&A has no further recommendations.

4.3 SC&A's comments

The first bulleted point in section 2.0, "Issue Evaluation," of PER-079 implies that: "Eliminating the assignment of onsite ambient external dose and replacing it with the more favorable unmonitored dose" is a factor that increased the assigned external dose to a worker when performing a DR. SC&A revisited the applicable section of ORAUT (2017) and found that the PER is following the guidance in section 6.5.1 and attachment B. The TBD assumes that workers with potential for external exposures were monitored and those with little potential for exposure were not monitored, implying that whatever dose the unmonitored workers might have received was less than received by the monitored workers. The TBD assigns a claimant-favorable annual unmonitored external dose of 100 mrem (all photons) and provides justification for it in attachment B. In addition, it is assumed that the unmonitored external dose should be assigned only as 100 percent 30–250 keV photons.

SC&A believes that, considering the previous reviews and discussions and acceptance by the WG of revision 02 of the occupational external dose TBD (ORAUT, 2017), it is acceptable to use its methodologies and data in performing DR reviews.

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5 Subtask 3: Evaluate the PER's Stated Approach for Identifying the Number of DRs Requiring Reevaluation of Dose

5.1 NIOSH's selection criteria

As recounted in section 4 of this report, NIOSH looked at all 529 previously completed DRs, eliminated those that already had POCs greater than 50 percent as well as a few others for various reasons, and reevaluated all the remaining 380 claims to determine if any rework resulted in a POC greater than 50 percent. NIOSH found that all still had POCs less than 50 percent. PER-079 (p. 2) provides details of the claim elimination process, summarized as follows:

- 529 previously completed DRs identified.
- 16 claims removed by the Department of Labor from DR for various reasons, including compensation under an SEC class.
- 7 claims were "active at NIOSH" after being returned for various reasons and would receive a new DR using the revised TBD.
- 76 claims were eliminated because the previous POC was greater than 50 percent and a further evaluation would not be required.
- 4 claims met the criteria for compensation under an SEC (for a site other than Pinellas) and no longer need a DR.
- 39 claims had no Pinellas employment or visits. The DR reports for those claims mentioned Pinellas for other reasons.
- 3 claims were eliminated from further evaluation because they had been completed after the TBD was revised.
- 4 claims were returned to NIOSH prior to this evaluation and will be revised based on the revised TBD.
- 149 claims were removed in total, leaving 380 claims to consider.

5.2 SC&A's comments

Although SC&A does not have access to NOCTS to review the data used to identify and quantify those cases that qualify for reevaluation, the selection criteria used by NIOSH for previously completed DRs that required reevaluation under DCAS-PER-079 are valid, i.e., NIOSH evaluated all affected noncompensated claims. There are no findings associated with subtask 3.

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6 Subtask 4: Conduct Audits of a Sample Set of Reevaluated DRs Mandated by DCAS-PER-079

Previous sections of this report described changes introduced in revision 02 of the Pinellas occupational external dose TBD (ORAUT, 2017) that raised the assigned external doses. NIOSH considered all previously performed DRs and, after reducing the population for various considerations, ended up with 380 claims to reevaluate. That process found that none of the claims with POCs originally less than 50 percent now had POCs greater than 50 percent.

SC&A recommends the Board select for additional evaluation two DRs with POCs less than 50 percent after NIOSH reworked them, with one case being the DR that originally had a POC between 45 percent and 50 percent and required running IREP 30 times with 10,000 iterations per run and one case where the worker was unmonitored or partially monitored externally (to test the 100 mrem application).

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