
Draft

Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

A Review of NIOSH's Program Evaluation Report DCAS-PER-051, "Weldon Spring Plant"

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SC&A, Inc. technical support for the Advisory Board on Radiation and Worker Health’s review of NIOSH dose reconstruction program

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
DCAS	Division of Compensation Analysis and Support
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DR	dose reconstruction
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
mrem	millirem
NA	not applicable
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
PER	program evaluation report
pCi/mg	picocurie per milligram
POC	probability of causation
Ra	radium
Rn	radon
RU	recycled uranium
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	technical basis document
Th	thorium
U	uranium
UF ₄	uranium tetrafluoride
WLM	working-level-month
WSP	Weldon Spring Plant
WSRP	Weldon Spring Raffinate Pits
WSQ	Weldon Spring Quarry

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 these supporting elements in DR may be subject to revision, 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) critically evaluates 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.

On February 16, 2023, the Advisory Board on Radiation and Worker Health (Board) tasked SC&A to review DCAS-PER-051, “Weldon Spring Plant” (NIOSH, 2015; “PER-051”). 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 DR. 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 behalf of subtask 3, SC&A will also evaluate the timeliness of the completion of the PER.
- **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.

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

The following information was obtained from the most current revisions of the Weldon Spring technical basis documents (TBDs) to present the relevant background for this report. Older versions of the TBDs will be referred to as applicable in the appropriate sections of our review of PER-051.

2.1 Facility operations

The facilities covered under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) are the Weldon Spring Plant (WSP), Weldon Spring Quarry (WSQ), and the Weldon Spring Raffinate Pits (WSRP). In this document, the term “WSP site” is used when it is unnecessary to distinguish between the plant, the quarry, and the raffinate pits. The WSP site was operated for the U.S. Atomic Energy Commission as a feed materials plant to process uranium and thorium ore by the Uranium Division of Mallinckrodt Chemical Works.

There were four periods for the WSP site:

1. site acquisition and development, 1954–1957
2. operational, 1957–1966
3. the U.S. Department of Energy (DOE) did not control WSP during the period 1967–1985 and WSRP and WSQ during the period 1967–1974; the U.S. Department of Defense (DoD) controlled those Weldon Spring facilities during these periods
4. remediation, 1985–2002

WSP employment is covered under EEOICPA only during the operational (1957–1966) and remediation (1985–2002) periods, when the U.S. Atomic Energy Commission, the U.S. Energy Research and Development Administration, and DOE had contractors and radioactive materials at WSP.

WSQ and WSRP employment is covered during the operational period (1957–1966), the period 1975–1984, and the remediation period (1985–2002).

2.2 Source terms

The radionuclides of concern are those that make up 95 percent of the potential internal dose. According to the TBD for internal dose, ORAUT-TKBS-0028-5, revision 04 (ORAUT, 2017), the radionuclides of concern at the WSP site for DR are the naturally occurring isotopes of uranium ((U)-234, U-235, and U-238), their decay products (primarily thorium (Th)-230 and radium (Ra)-226), isotopes of natural thorium (Th-228 and Th-232) and their decay products, and recycled uranium (RU).

2.2.1 Uranium

ORAUT-TKBS-0028-5 (ORAUT, 2017) recommends that, for the purposes of DR, it be assumed that all uranium processed at the WSP site was natural uranium from 1957 through

1962, with a specific activity of 683 picocuries per milligram (pCi/mg). After 1962, all uranium is assumed to be enriched to 1 percent, with a specific activity of 973 pCi/mg.

2.2.2 Radon and thoron

The three radon isotopes generated during the decay of U-235, U-238, and Th-232 are radon (Rn)-219, Rn-222, and Rn-220, respectively. Due to the limited amount of enriched uranium (which contains U-235) processed at the WSP site, there was no large source of Ra-223 and, in turn, Rn-219. The risks associated with Rn-219 were insignificant due to its extremely short half-life (4 seconds) and small source term. Therefore, ORAUT-TKBS-0028-5, revision 04 (ORAUT, 2017), considers only the inhalation intakes for Rn-222 (radon) and Rn-220 (thoron) to be potentially significant.

2.2.3 Recycled uranium

It should be assumed that all the uranium that the WSP site processed beginning in 1961 was RU. For the periods that include RU (i.e., after 1960), RU contaminant mass concentrations are provided in section 5.6.1.3.3 of ORAUT-TKBS-0028-5, revision 04 (ORAUT, 2017).

2.3 Internal and environmental monitoring

The following summarizes the internal intake monitoring at the WSP site. SC&A obtained this information from ORAUT-TKBS-0028-4, revision 04 (ORAUT, 2020), and ORAUT-TKBS-0028-5, revision 04 (ORAUT, 2017).

2.3.1 Operational period, 1957–1966

Urine bioassay was the primary method of determining uranium intakes during the production phase. There has been no indication so far that a routine urine sampling program was implemented for thorium. No urine bioassay data for thorium have been found in the worker files.

2.3.2 DoD period, 1967–1985

There did not appear to be DOE contractor personnel present during the DoD period. No bioassay monitoring records have been located for this period.

2.3.3 Remediation period, 1985–2002

An extensive bioassay monitoring program was conducted from 1991 to 2001 to detect intakes greater than 100 millirem (mrem) committed effective dose equivalent.

2.4 External and ambient monitoring

The following summarizes external monitoring methods at the WSP site. SC&A obtained this information from ORAUT-TKBS-0028-4, revision 04 (ORAUT, 2020), and ORAUT-TKBS-0028-6, revision 01 (ORAUT, 2013e).

2.4.1 Operational period, 1957–1966

Employees who worked in radiological areas were monitored, and their exposures should be accounted for in their normal dosimetry results. However, documents obtained to date do not

contain monitoring data that describe the ambient exposure rate at the WSP site during the operational period.

2.4.2 DoD period, 1967–1985

There did not appear to be DOE contractor personnel present during the DoD period, and no external monitoring records have been located for this period. In addition, there are no records of site surveys being conducted until 1982, except for a 1975 aerial radiological survey.

2.4.3 Remediation period, 1985–2002

Personnel external monitoring was provided as needed during the remediation period. External ambient exposure monitoring was conducted at the site beginning in 1982 by perimeter monitoring, as detailed in section 4.3.2 and summarized in table 4-6 of ORAUT-TKBS-0028-4, revision 04 (ORAUT, 2020).

3 Subtask 1: Identify the Circumstances that Necessitated DCAS-PER-051

3.1 Chronology of events that necessitated PER-051

3.1.1 ORAUT-TKBS-0028-3: Occupational medical dose

NIOSH issued revision 00 of ORAUT-TKBS-0028-3 on June 24, 2005 (ORAUT, 2005a), and revision 01 on January 30, 2013 (ORAUT, 2013a). NIOSH reevaluated all noncompensated claims using the current version of the TBDs; therefore, PER-051 did not address specific changes in revision 01 compared to revision 00 that could lead to an increase in assigned dose.

3.1.2 ORAUT-TKBS-0028-4: Occupational environmental dose

NIOSH issued revision 00 of ORAUT-TKBS-0028-4 on June 28, 2005 (ORAUT, 2005c), and revision 01 on May 17, 2013 (ORAUT, 2013b). NIOSH reevaluated all noncompensated claims using the current version of the TBDs; therefore, PER-051 did not address specific changes in revision 01 compared to revision 00 that could lead to an increase in assigned dose.

3.1.3 ORAUT-TKBS-0028-5: Occupational internal dose

NIOSH issued revision 00 of ORAUT-TKBS-0028-5 on June 28, 2005 (ORAUT, 2005d), revision 01 on March 15, 2013 (ORAUT, 2013c), and revision 02 on May 21, 2013 (ORAUT, 2013d). NIOSH reevaluated all noncompensated claims using the current version of the TBDs; therefore, PER-051 did not address specific changes in revisions 01 and 02 compared to revision 00 that could lead to an increase in assigned dose. However, PER-051 did list some general changes that could impact assigned internal dose:

- change in assumed isotopic ratios for uranium ore concentrates
- addition of a thoron exposure dose
- change in RU contaminate fractions
- an increase in the radon exposure estimate

3.1.4 ORAUT-TKBS-0028-6: Occupational external dose

NIOSH issued revision 00 of ORAUT-TKBS-0028-6 on June 24, 2005 (ORAUT, 2005e), and revision 01 on February 6, 2013 (ORAUT, 2013e). NIOSH reevaluated all noncompensated claims using the current version of the TBDs; therefore, PER-051 did not address specific changes in revision 01 compared to revision 00 that could lead to an increase in assigned dose. However, PER-051 did list some general changes that could impact assigned external dose:

- addition of a neutron-to-photon ratio
- addition of a geometry correction factor for external dose

3.1.5 DCAS-PER-051

On March 4, 2015, NIOSH issued DCAS-PER-051 (NIOSH, 2015) for the WSP site, which addressed changes in DR procedures using the latest 2013 revisions of the Weldon Spring TBDs, as given in sections 3.1.1–3.1.4.

3.2 SC&A's comments

SC&A reviewed the sequence of revisions of the Weldon Spring TBDs and PER-051. SC&A found that PER-051 addressed the changes in the TBDs that could potentially result in increases in internal and external dose assignments by (1) reevaluating all noncompensated Weldon Spring claims and (2) reworking the applicable claims using the latest version of the TBDs as of the PER-051 date of March 2015.

SC&A reviewed the changes in the 2013 revisions of the TBDs. The following subsections summarize the changes that have the potential to increase assigned dose.

3.2.1 ***ORAUT-TKBS-0028-3: Occupational medical dose***

Revision 01 of ORAUT-TKBS-0028-3 (ORAUT, 2013a) includes the following changes that may increase assigned occupational medical dose:

- Includes skin doses for all areas of skin (refer to tables 3-2 and 3-3).
- Recommends using revision 04 of ORAUT-OTIB-0006, "Dose Reconstruction from Occupational Medical X-ray Procedures" (ORAUT, 2011), whereas ORAU-TKBS-0028-3, revision 00, recommended using ORAUT-OTIB-0006, revision 03 (ORAUT, 2005b).

3.2.2 ***ORAUT-TKBS-0028-4: Occupational environmental dose***

Revision 01 of ORAUT-TKBS-0028-4 (ORAUT, 2013b) includes the following changes that may increase assigned occupational environmental dose:

- Added factors for calculation of RU contaminant activity based on parts per billion or picocurie of uranium in section 4.2.2.1, page 11.
- Added table 4-1, page 20, for annual median intake values for WSCP, WSRP, and WSQ.
- Added table 4-2, page 22, for maximum sitewide median intake values to comply with ORAUT-PROC-0031, "Site Profile and Technical Basis Document Development," revision 04 (ORAUT, 2012).
- Revised sections 4.2.1, page 9, and 4.2.2.1, pages 9–11, to more specifically target the radionuclides of concern and source terms that contribute to 95 percent of the potential internal dose.
- Revised section 4.2.3.1, pages 11–16, concerning the approach for determining annual intake of radionuclides during the operational period to optimize the use of available site-specific monitoring data.
- Added table 4-3, page 23, consisting of the annual median values for environmental external onsite ambient dose during the operational period.
- Added section 4.4, pages 27–28, as a summary of environmental doses for use by dose reconstructors and provided tabulated inhalation intakes and ambient dose default values.

3.2.3 ***ORAUT-TKBS-0028-5: Occupational internal dose***

Revision 01 of ORAUT-TKBS-0028-5, March 15, 2013 (ORAUT, 2013c), and revision 02 of ORAUT-TKBS-0028-5, May 21, 2013 (ORAUT, 2013d), include the following changes that may increase assigned occupational internal dose:

- The specific activity for slightly enriched (1 percent) uranium in section 5.2.1 of revision 01, page 13, was adjusted to agree with the formula in DOE's "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities" (DOE, 2001).
- Section 5.2.2 of revision 01, pages 13–14, related to uranium decay products, was edited to reflect the fact that the early uranium mills may not have been effective in removing thorium, and therefore the dose reconstructor should increase the amount of Th-230 and daughters used in DR calculations.
- The maximum concentrations for certain decay products at the WSRP and WSQ were eliminated in section 5.2.2 of revision 01, pages 13–14.
- A discussion was added in section 5.2.3 of revision 01, page 14, on potential intakes from thoron.
- Site-specific ratios of Th-230 to other contaminants were developed in section 5.6.1.1 of revision 01, pages 38–39, for DR applications during the period of initial uranium processing.
- Daily weighted-average concentrations for thorium dust measurements were added as attachment A of revision 01. These values were used to create table 5-22, page 41, of thorium intakes in section 5.6.1.2. Thoron guidance was also added to this section.
- A statement was added in section 5.6.1.1 of revision 01, page 38, to use Friday urine sampling data statistics to avoid underestimating intakes.
- The estimated annual exposure from radon was increased in section 5.6.1.3 of revision 02, pages 42–43, to 12.4 working-level-months (WLMs) per year.
- Section 5.2.4 of revision 01, page 16, concerning RU contaminants, was updated.
- Th-232 intake rates were updated in section 5.6.1.2 of revision 01, page 40, to reflect an 8-hour workday normalized to a calendar year for each of the years of Th-232 operations.
- Equations were included in the text in section 5.6.1.2 of revision 01, page 40, regarding calculation of the median and 95th percentiles of the Th-232 intake rates.
- The indoor radon equilibrium factor was modified from 0.5 to 0.7 in section 5.6.1.3 of revision 02, page 43. This increased the radon intake value from 8.8 WLM per year to 12.4 WLM per year.
- Table 5-23, page 44, was added in section 5.7 of revision 01, and revised in revision 02, to provide the dose reconstructor with a summary of intake information for DR that reflects the major changes outlined here.

3.2.4 ORAUT-TKBS-0028-6: Occupational external dose

Revision 01 of ORAUT-TKBS-0028-6 (ORAUT, 2013e) includes the following changes that may increase assigned occupational external dose:

- Section 6.3.11, page 30, includes a correction factor of 2.1 to account for worker-radiation source geometry to be applied to the measured and missed photon doses for operators, material handlers, and trade workers to avoid underestimating dose. Organs most affected by this are those in the lower torso (stomach, pancreas, ovaries, etc.).

Observation 1: Use of neutron-to-gamma ratio

Section 2.0 of PER-051 (NIOSH, 2015, p. 1), states that the revisions to the TBDs included the addition of a neutron-to-photon ratio. However, it appears that revision 00 of ORAUT-TKBS-0028-6 (ORAUT, 2005e) contains the same neutron-to-photon ratio recommendations as revision 01 (ORAUT, 2013e), as follows.

ORAUT-TKBS-0028-6, revision 00, section 6.2.4.2, states:

Using the results of gamma and neutron dose rate measurements performed on depleted and low enriched UF₄ [uranium tetrafluoride] drums, a neutron-to-gamma ratio was developed. Natural uranium was addressed as well. The results of this analysis were that a neutron-to-gamma ratio of 0.1, lognormally distributed with a geometric standard deviation of 1.71 and an upper 95% ratio limit of 0.23, should be applied in those areas where there is the potential for neutron dose from uranium fluoride compounds. [ORAUT, 2005e, p. 19]

ORAUT-TKBS-0028-6, revision 01, section 6.3.4.2, states:

Using the results of gamma and neutron dose rate measurements performed on depleted and low-enriched UF₄ drums, a neutron-to-gamma ratio was developed. The results of this analysis were that a neutron-to-gamma ratio of 0.1, lognormally distributed with a geometric standard deviation of 1.71 and a 95th percentile ratio of 0.23, should be applied in those areas where there is the potential for neutron dose from uranium fluoride compounds. [ORAUT, 2013e, p. 24]

SC&A has previously reviewed¹ the WSP TBDs and the revisions made to the TBDs.

¹ SC&A's WSP TBD review reports can be found on the *Weldon Spring Plant* page of the NIOSH website at <https://www.cdc.gov/niosh/ocas/weldonsp.html>.

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

NIOSH initially released revision 00 of sections 3–6 of the Weldon Spring TBD in June 2005 (ORAUT, 2005a, 2005c, 2005d, 2005e). NIOSH released revision 01 of sections 3–6 and revision 02 of section 5 of the Weldon Spring TBD between January 30 and May 21, 2013 (ORAUT, 2013a, 2013b, 2013c, 2013d, 2013e). These revisions to the Weldon Spring Plant TBD included several changes that would cause an increase in calculated doses. NIOSH did not find that a detailed list of changes made to the TBD was necessary because all four sections were revised, and the changes cover all operational time periods and job types. Therefore, as a corrective action, NIOSH did not exclude any Weldon Spring claim from further evaluation based on job type or employment period but reevaluated all previous Weldon Spring claims with POCs <50 percent.

SC&A had previously reviewed revision 00 of sections 3–6 of the Weldon Spring TBD in 2009 (SC&A, 2009). However, revision 01 of sections 3–6 and revision 02 of section 5 of the Weldon Spring TBD had not been reviewed by SC&A. Therefore, subtask 2 of PER-051 included 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 as described in the following section.

4.1 Overview of SC&A's review of Weldon Spring site profile

SC&A reviewed revision 01 of sections 3–6 and revision 02 of section 5 of the Weldon Spring 2013 TBD to determine if they contained technically correct methodology and information and referred to appropriate references as needed. SC&A analyzed changes that could decrease or increase assigned dose. SC&A did not identify any findings or observations concerning sections 3–6 of the Weldon Spring 2013 TBD. SC&A summarized the changes that have the potential to increase assigned dose in section 3.2 of this report and had two observations there concerning PER-051, but there were no findings or observations involving the revised TBDs.

4.2 SC&A's comments

SC&A confirmed that the revisions incorporated into Weldon Spring ORAUT-TKBS-0028-3, ORAUT-TKBS-0028-4, ORAUT-TKBS-0028-5, and ORAUT-TKBS-0028-6 were scientifically sound. Since NIOSH reevaluated all Weldon Spring noncompensated claims and reworked the applicable claims using the revised TBDs, SC&A finds NIOSH's corrective actions to be appropriate.

SC&A has no findings associated with subtask 2.

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

According to section 3.0 of PER-051, NIOSH created a database to search for all claims using the search terms "Weldon Spring Plant," "Weldon Spring Raffinate Pits," and "Weldon Spring Quarry" to develop a list of all claims that may have had employment at the Weldon Spring site. The original search resulted in 286 potentially affected claims. Claims were excluded from reevaluation based on the following:

- Four claims were removed because the DRs were completed using the revised TBDs.
- Five claims had been pulled from dose reconstruction by the U.S. Department of Labor (DOL) and were removed from the list.
- 112 claims were removed because the previous DR resulted in a POC of 50 percent or greater.
- 46 of the claims also had employment at Mallinckrodt and were part of the Special Exposure Cohort (SEC) at that facility.
- Two claims were excluded because they had no verified Weldon Spring employment and the Weldon Spring TBDs were not used in the DR.
- Two claims were excluded because the employment only included the construction period prior to the start of any radiological operations.
- Three claims were removed prior to being evaluated further. One was determined to meet the Mallinckrodt SEC criteria. A DR for this claim was done prior to the designation of the Mallinckrodt SEC, but no DR would now be necessary for a compensation decision. The second was removed because the employment was outside the covered period for the site. The third claim was returned to NIOSH for a new DR for other reasons. That claim will be revised using the current revision of the TBDs.

This resulted in 112 claims remaining for reevaluation. Dose for the remaining 112 claims was recalculated using the current revisions of the TBDs and any other applicable documents. The following is a summary of the reevaluation of 112 remaining claims:

- The resulting POC for 101 of the claims was below 45 percent.
- Eight of the claims resulted in a POC greater than 50 percent.
- Three claims had a POC between 45 percent and 50 percent. For those three claims, the Interactive RadioEpidemiological Program was run 30 times at 10,000 iterations per NIOSH procedures, and the resulting POC was still less than 50 percent for each of those claims.

PER-051 states that NIOSH will provide the DOL with the list of all the claims evaluated under this PER. Further, NIOSH will request that DOL return the eight claims that would now result in a POC greater than 50 percent.

5.2 SC&A's comments

The selection criteria used by NIOSH for previously completed DRs that required reevaluation under PER-051 are reasonable. SC&A had no findings but did have an observation associated with subtask 3.

Observation 2: Eliminating claims due to being reevaluated under an SEC

PER-051 indicates that 46 of the claims were removed from the reevaluation list because the energy employees also had employment at Mallinckrodt and were part of the SEC at that facility. However, a claim may also have a non-SEC cancer that would need to be reevaluated using the revised Weldon Spring documents for medical coverage. How does NIOSH assure that a claim does not have additional non-SEC cancers before removing it from consideration under a PER?

6 Subtask 4: Conduct Audits of a Sample Set of Reevaluated DRs Mandated by DCAS-PER-051

Previous sections of this report described changes introduced in revisions of WSP TBDs that could increase the dose assigned for the periods covered for the WSP site.

For SC&A to satisfy its commitment under subtask 4, SC&A suggests that two or three DR claims be selected for review from the WSP site during the operational period (1957–1966). Instead of a focused review of the claims, SC&A suggests that SC&A perform a complete DR review of the claims, since the TBDs have undergone major revisions with many changes. SC&A does suggest that the selection process should attempt to include the following criteria to address some of the major changes in the TBDs:

1. occupational medical x-rays with skin cancer(s)
2. environmental intakes consisting of exposure to uranium, thorium, and RU contaminants
3. environmental external ambient exposure
4. internal intakes consisting of exposure to uranium ore concentrates, thorium, RU contaminants, thoron, and radon
5. external photon dose for an operator, material handler, or trade worker

7 References

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