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The 1991 Implementation of As Low As Reasonably Achievable (ALARA) Administrative Radiation Exposure Levels: Experiences and Lessons Learned

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1991 IMPLEMENTATION OF ALARA ADMINISTRATIVE RADIATION EXPOSURE LEVELS: EXPERIENCES AND LESSONS LEARNED

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BACKGROUND

As Low As Reasonably Achievable (ALARA) radiation exposure levels were implemented on January 1, 1991, by Westinghouse Hanford Company (WHC), a prime U.S. Department of Energy (DOE) contractor, located in Richland, Washington. This paper describes the radiation exposure levels which were implemented and the associated experiences and lessons learned.

The issue of a report from the Committee on Biological Effectiveness of Ionizing Radiation in 1989 prompted DOE to re-evaluate its position on radiation exposure limits and the resulting doses received by occupational radiation workers. DOE requested that all it's contractors determine the impacts to operations from reduced radiation exposure levels.

PRE-1989

Historically, at the Hanford Site, compliance monitoring of internal doses was based on DOE Order 5480.1B, *Environment, Safety, and Health Programs for Department of Energy Operations*, Chapter XI.

5 rem/yr	- whole body, red bone marrow, active blood-forming organs
30 rem/yr	- bone
15 rem/yr	- most other organs

The methodology for combining all internal doses with all external doses was not recognized by DOE before 1989. Documentation and tracking for compliance was simply calculated as the dose to a critical organ. The dose was then compared to a derived quantity called the maximum permissible body burden (MPBB). The MPBB was the maximum permissible amount of systemic uptake which would be expected to result in the critical organ receiving a dose equivalent equal to the DOE radiation protection standard (RPS).

A method was established at the Hanford Site in the early 1950's to administratively track workers with confirmed internal depositions. If additional confirmed intakes of radionuclides were incurred by the worker, their total deposition could then be readily calculated for compliance. Hanford Site practice was to place workers on a paper tracking system called the Hanford Deposition List, which contained two separate sections: the Hanford Systemic Uptake List, and the Critical Organ Dose List. Workers were added to a list if they received a confirmed internal deposition of radioactivity equal to, or exceeding, 1% of the applicable Department of Energy RPS, as contained in DOE Order 5480.1B Chapter XI.

Each Hanford Site contractor established it's own internal administrative radiation exposure level, to ensure that worker exposures were kept below the

DOE radiation protection standards. Reporting requirements were defined in DOE Order 5480.1A (1981) and DOE RL 5484.1, *Environmental Protection, Safety, and Health Protection Information Reporting Requirements* (1981). When the preliminary data indicated an uptake could exceed 5 times the RPS, immediate notification to DOE-Headquarters was made and a follow up Type A Investigation Report was prepared. If an uptake was expected to exceed the RPS, notification was required to be made within 72 hours and a Type B Investigation Report was prepared and submitted. Notification to the local DOE Richland Operations Office (DOE-RL) was required if a worker(s) was sent to the In Vivo Radiobioassay Facility for measurements following a potential intake of radioactive material. The DOE also required formal annual reporting of worker doses when the resulting internal dose exceeded 50% of the applicable RPS. Before 1989, only 18 workers from the entire Hanford Site exceeded 50 % of the MPBB. The last reportable intake under this criteria occurred in 1985. Any impact to workers from this system of administratively tracking and reporting of their internal doses was negligible.

The DOE-RL Manager issued a public information policy in 1985, requiring a press release to be prepared for "any confirmed personnel contamination exceeding 1/100 of the DOE prescribed internal or external levels." This was interpreted, with regard to internal dosimetry, as 1% of the MPBB attributed to a known occurrence. Any dose assessments performed as a result of an intake evaluated from a high routine bioassay measurement was not included.

POST- JANUARY 1989

January 1, 1989, DOE issued new requirements for the radiation protection of workers. This DOE Order 5480.11, *Radiation Protection for Occupational Workers*, required that annual effective dose equivalents be calculated for all intakes of radioactivity. For compliance monitoring, whole body annual effective doses were calculated and expressed in dose equivalent units (rem or mrem). These doses were compared to the 5 rem/yr RPS for effective dose. In addition, doses to single organs or tissues were required to be kept below the nonstochastic RPS of 50 rem/yr.

The effective dose concept allows the dose received by individual organs to be compared to a whole body radiation dose. This is accomplished by the use of organ specific weighting factors. All the weighted organ doses are then summed together to obtain the "effective dose." Computer codes are required to perform the many calculations required to arrive at effective dose.

Again, the DOE contractor administrative levels were established below the DOE standards to ensure over-exposures would not be incurred. The WHC radiation exposure level for whole body effective dose was 3 rem/year. There was also a weekly level of 300 mrem/week to accommodate a union/management contract agreement.

Following the issuance of WHC-CM-4-10, *Radiological Protection*, three administrative radiation exposure levels were initiated, incorporating new DOE recommendations for worker exposures. Workers who exceeded the WHC administrative radiation exposure level of 1 rem/year required authorization

to continue radiation area work from their immediate manager, their level 3 line-manager, and the level 3 manager from Environmental, Safety, Health and Quality Assurance (ESQ). For the next higher administrative level, 1.5 rem/year, radiological work authorizations were required from a worker's immediate manager, the level 2 line-manager, and the level 2 ESQ manager. These authorizations were documented and placed in the worker's personnel radiation history file.

The third administrative radiological exposure level, a 2 rem/year annual effective dose equivalent, required a worker to be placed under a "special control level" of 100 mrem/year annual effective dose equivalent, or consideration was made for alternate career opportunities (no further radiological area work). Documentation including signature authorization from the worker's immediate manager, the level 1 manager, the level 2 ESQ manager, and the level 1 Director of ESQ was a requirement.

WHC also implemented a lifetime dose (Age X 1 rem), based on recommendations contained in the International Commission on Radiological Protection (ICRP) publication 60. Before 1989, at Hanford, DOE contractors had not addressed the lifetime radiation dose concept.

During this period, the RLIP Order 5000.3A, *Occurrence Reporting and Processing of Operations Information*, provided categorization and notification requirements related to internal exposures. Any potential or confirmed intake whether from personnel or operating area contamination was defined as an Off-Normal Occurrence, requiring written notification to DOE within 24 hours of classification. Verbal notification was not required. If preliminary data indicated that any single or cumulative intake of radioactivity would result in a dose in excess of the annual RPS, the intake was classified as an Unusual Occurrence requiring oral notification to DOE within 2 hours of categorization, and written notification within 24 hours.

Calculating and tracking worker's internal doses was now considerably more complicated. Hanford Internal Dosimetry accomplished the tracking by use of a computerized data base "INTERTRAC". The internal component of the effective dose equivalent for each year, since 1989, was added to the Occupation Radiation Exposure (ORE) data base for use by all the Hanford contractors. Annual report cards provided a summary of the worker's effective dose equivalent on a calendar year basis.

DECEMBER 1992 - DOE N 5480.6, RADIOLOGICAL CONTROL MANUAL

A DOE Administrative Control Level of 2,000 mrem per year per person was established for all DOE radiological work activities. Approval by the Program Secretarial Official or designee shall be required prior to allowing a person to exceed 2,000 mrem. The Radiological Control Manual requirements are:

> An annual facility Administrative Control Level shall be established by the contractor senior site executive based upon an evaluation of historical and projected radiation exposures, work load and mission. The selection of the specific value shall be more restrictive than the

DOE Administrative Control Level. This control level should be reevaluated annually. The choice of a low level for 1 year should not preclude choosing either a higher or lower level in a subsequent year.

For most facilities, an annual facility Administrative Control Level of 500 mrem or less should be challenging and achievable. An annual Administrative Control Level above 1,500 mrem is in most cases not sufficiently challenging to meet the goals of this Manual.

No person shall be allowed to go above the facility Administrative Control Level without the prior approval of the contractor senior site executive.

To administratively control a worker's lifetime occupational radiation exposure, a Lifetime Control Level of N rem shall be established where N is the age of the person in years. Special Control Levels (Article 216) shall be established for personnel who have doses exceeding N rem. (The internal contribution to lifetime dose should continue to be reassessed as further bioassay results and improved methods for assessing internal dose become available)

Exposure Limits:

Whole Body	5 rem annual
Lens of the eye	15 rem annual
Organ or tissue (ex skin)	50 rem annual

Notes: Internal dose to the whole body shall be calculated as committed effective dose equivalent. The committed effective dose equivalent is the resulting dose committed to the whole body from internally deposited radionuclides over a 50-year period after intake. (declared pregnant workers and visitor exposure limits are also specified in the Radiological Control Manual.)

Internal (any 50-year committed effective dose equivalent, accounted for in the year of intake) and external whole body doses are added together as total effective dose equivalent (TEDE) and compared to the annual radiation exposure limits cited above. Annual contributions to dose and the "tracking" of those annual doses are no longer formally performed. Hanford Internal Dosimetry is continuing to calculate the annual doses and maintain the information in the worker's INTERTRAC file; however, the doses will not be reported to the workers, or their contractors (unless requested). All historical internal doses will be accounted for in the year of intake(s) and will no longer be used for administrative tracking relative to annual limits. The committed effective doses will be tracked by using the concept of lifetime dose.

EXPERIENCES

Three WHC workers exceeded the 2 rem/year level as a result of prior year intakes which required the third level of signature authorizations to be prepared and placed in their records. Meetings were scheduled with each one of the workers and their manager to discuss the new administrative exposure level, their specific radiation exposure records and the special administrative control level. All three workers were given the option to choose alternate career opportunities; each one chose to continue pursuing their current livelihood as radiation workers. In all three cases the workers had been informed of the internal depositions, had received regular updates of the internal doses and were willing to accept any additional risks involved in continuing to receive radiation exposure.

One of the three workers had exceeded his lifetime dose as a result of an intake years before and was not allowed to continue performing radiological work activities. The other two workers were allowed to continue working under a special control level of 100 mrem/year, with two additional caveats; no work activities involving a potential for plutonium intake, and restriction from any work activities requiring respiratory protection.

Currently, WHC administrative radiation exposure levels include: a 2 Rem/year DOE administrative radiation control level, a 1.5 Rem/year annual administrative radiation control level, and a 500 mrem/year facility administrative radiation control level. A special lifetime control level has also been initiated for any worker who exceeds their lifetime dose.

Table 1, *Changes in Administrative Radiation Dose Accountability*, parallels the three changes in the methodology of calculating and tracking doses at WHC. These changes are; (1) DOE Order 5480.11 *Radiological Protection for Workers*, (2) WHC *Radiological Protection Manual* (WHC-CM-4-10), and (3) DOE N 5480.6, *Radiological Control Manual*. In January 1989, annual, 50 year committed effective dose equivalent (CEDE) and annual effective dose equivalent (AEDE) were required. The internal dose contribution was simply called an annual dose. The CEDE was applied to the worker's record as an annual incremental internal dose contribution. Lifetime dose was not required by DOE Order 5480.11.

The WHC manual WHC-CM-4-10, *Radiological Protection*, required tracking of annual and 50 year CEDE as required by the DOE Order 5480.11, and also implemented the concept of lifetime dose. Although DOE Order 5480.11 did require lifetime dose as an official limit, a cumulative annual effective dose equivalent (CAEDE) was required to be calculated and provided to workers on an annual basis. The internal dose contributions were required to be summed only from January 1, 1989, forward.

DOE N 5480.6, introduced some major changes to administratively tracking radiation doses for workers. The radiation exposure limit remains 5 rem/year for internal and external whole body exposures, but there is a major change to the tracking of internal exposures. The internal dose contribution, CEDE is applied to the year of intake. Technically this system is misleading for long-term bone seeking radionuclides, like plutonium which delivers a dose

Table I
Changes in Administrative Radiation Dose Accountability

	DOE Order 5480.11 (1/1/89)			WHC Radiological Protection Manual (6/91)			DOE N 5480.6 (12/92)		
	1 Year	50 Years	Lifetime	1 Year	50 Years	Lifetime	1 Year	50 Years	Lifetime
Internal Dose Contribution	Annual	CEDE		Annual	CEDE		----	CEDE**	
External Dose	Annual			Annual			Annual	----	
Summed Effective Dose	Annual Effective Dose Equivalent (AEDE)		*	AEDE		"Cumulative" Annual Effective Dose Equivalent (CAEDE)	Total Effective Dose Equivalent		"Cumulative Annual Effective Dose Equivalent (CAEDE)

*5480.11 Cumulative Annual Effective Dose Equivalent = Internal Dose Contribution from January 1, 1989 forward plus all time external exposures.

**CEDE Applied to Year of Intake Only.

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over a long period of time. Administratively this system is misleading and extremely difficult to explain to workers.

Table 2, *Comparisons of Administrative Radiation Dose Accountability*, compares the administrative tracking of radiation dose under three separate systems for three actual WHC workers. Case 1, is an active WHC worker who incurred an internal deposition of plutonium as a result of a puncture wound in 1985. The worker's internal dose contribution under DOE Order 5480.11 was 2.0 rem for 1991, when he was 33 years of age. The CEDE was 13 rem through 1991. The cumulative annual effective dose equivalent included 5.9 rem from January 1, 1989 forward and 6 rem external effective dose, for a total of 11.9 rem. Lifetime dose was not required by DOE Order 5480.11.

Under the WHC-CM-4-10, the worker's lifetime dose was 19 rem, which includes all the annual internal dose contributions from 1985 through 1991 (13 rem) and the cumulative external effective dose (6 rem).

As of December 1992, the workers radiation dose is administratively handled much differently. The annual internal dose contribution no longer exists. The CEDE is applied to the year of intake and is no longer used to limit additional exposure. The lifetime dose (136 rem cumulative annual effective dose equivalent) did place this worker under restriction from any further radiological work, until the approval to continue under a "special control level" was obtained, documented and implemented. For Case 1, the worker was not allowed to work with plutonium/americium, wear respiratory protection, limiting addition internal intakes, or incur any additional external exposure. A "special radiation control level" was never allowed. Alternate career opportunity discussions are still on going.

Case 2, is a WHC worker who incurred a lung burden in 1978 resulting from an inhalation of plutonium oxide. In 1991, the worker was 53 years of age. His internal dose contribution for 1991 was 3 rem and his alltime external effective dose was 10 rem. The DOE Order 5480.11 cumulative annual effective dose equivalent was 19 rem, 9 rem from the cumulative internal dose equivalents January 1989 through 1991, and 10 rem, from the worker's alltime external effective dose. Under N 5480.6, the worker's lifetime dose is 120 rem. This worker was not allowed to work with plutonium/americium, or wear respiratory protection; however, a "special control level" of 100 mrem/year was allowed for radiological work activities.

Case 3, is a WHC retiree who at age 58 exceeded his WHC lifetime dose and was not allowed to continue radiological work as a consultant. Under DOE Order 5480.11, the worker's cumulative annual effective dose equivalent was 23 rem; 7 rem from internal dose contributions (1/1/89 - 1/31/91), and 16 rem alltime external effective dose equivalent. Under the WHC-CM-4-10, the worker's lifetime dose was 88 rem, and under the new N 5480.6, the worker's lifetime dose is 116 rem.

For occurrence reporting under DOE Order 5000.3B, *Occurrence Reporting and Processing of Operations Information*, external exposure is added to the 50-Year CEDE to determine the CAEDE and reporting requirements.

Table II
Comparisons of Administrative Radiation Dose Accountability (REM)

	Age (1991) (Years)	DOE Order 5480.11 (1/1/89)			WHC Radiological Protection Manual (6/91)			DOE N 5480.6 (12/92)		
		Annual	50 Year CEDE	Lifetime	Annual	50 Year CEDE	Lifetime	Annual	50 Year CEDE	Lifetime
Case 1	33									
Internal		2	13		2	13		----	130	
External		6			6			6		
Sum				11.9*			19			136
Case 2	53									
Internal		3	43		3	43		----	110	
External		10			10			10		
Sum				19*			53			120
Case 3	58									
Internal		2	72		2	72		----	100	
External		16			16			16		
Sum				23*			88			116

Note: Contractor Administrative Levels not included.

*DOE Order 5480.11 Cumulative Annual Effective Dose Equivalent. CEDE = Committed Effective Dose Equivalent.

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Where resulting doses (external plus 50-year CEDE):

- Exceeding 5 times the DOE Order 5480.11 limits are classified as an emergency,
- Exceeding the DOE limits would be classified as an unusual occurrence
- Effective dose equivalents greater than 100 mrem or 5 rem to any tissue or organ in the 12 month period following the uptake would be classified as an off-normal.

The internal dose contributions (CEDE) for the three cases identified in 1991 are shown in figures 1, 2, and 3. These figures show the internal dose contribution applied to the year of intake compared to the annual internal dose contributions up to age 75 years for each of the three cases. The average background dose over a 50 year period vs the total background dose applied to the first year reflected in Figure 4, is used at the Hanford Site to demonstrate the difference between and impacts of applying the dose to a single year vs the amount of dose for each 50 year increment. A comparison of the internal dose at the DOE radiation exposure limit over a 50 year period applied to the first year is reflected in Figure 5. The CEDE increment for each year is 0.1 rem.

LESSONS LEARNED

Accounting for total internal exposure in the initial year of intake increases the impact to workers and the administrative tracking of their exposures following incidents which involve long-lived radionuclides such as plutonium or strontium. As previously discussed, when a worker receives a dose assessment following an intake of this type, the internal dose will only be tracked during the calendar year in which the intake occurred.

Impacts to workers are more likely to occur as a result of the accounting of internal exposure in the year of intake than from a lifetime control level. If a worker exceeds the 5 rem/year annual dose limit they will not be able to perform as a radiological worker for the remainder of the calendar year. If the lifetime dose is exceeded, a special control level of 100 mrem/year is acceptable. Work restrictions based on a 5 rem annual dose limit using a 50 year CEDE from an intake of a long term bone seeking radionuclide are not technically defensible and are not practical from the workers point of view.

The real impact to workers will result from the addition of the 50-year CEDE to the year of intake for all "historically" documented internal doses. All workers who fall into this category and have exceeded their lifetime dose (Age X 1 rem) have been informed. Seventeen WHC workers are on work restriction/special control levels because of the new DOE lifetime control level. Documentation has been completed and initiation of a special control level of 100 mrem/year has been recommended. Since 1988, worker exposures at WHC have continually dropped. Workers who are above the 50 year age bracket are more seriously impacted by the implementation of a lifetime dose.

FIGURE 1

Internal Dose Contribution

Case 1, Projected Dose to Age 75 vs CEDE Applied to Year of Intake

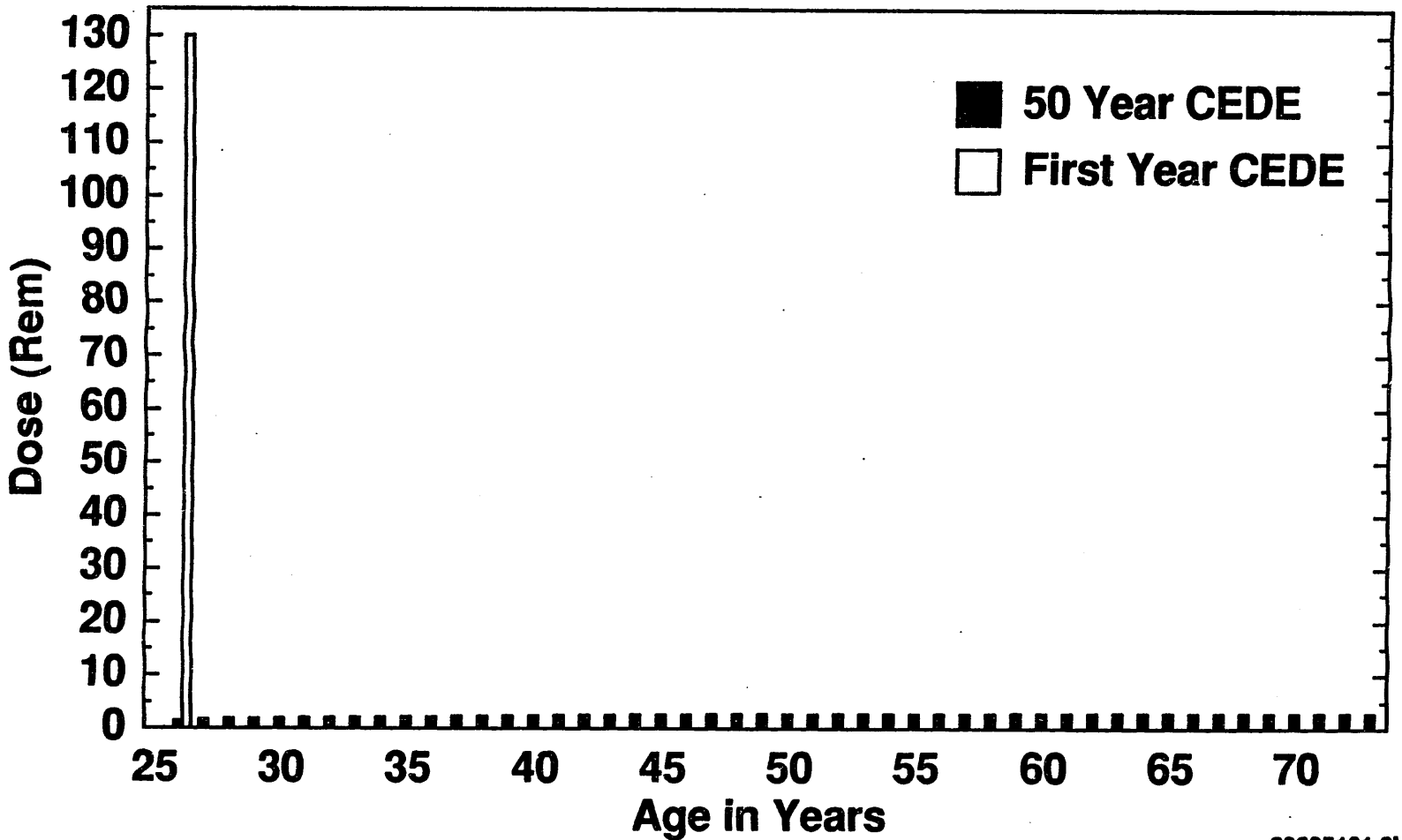

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Figure 2

Internal Dose Contribution

Case 2, Projected Dose to Age 75 vs CEDE Applied to Year of Intake

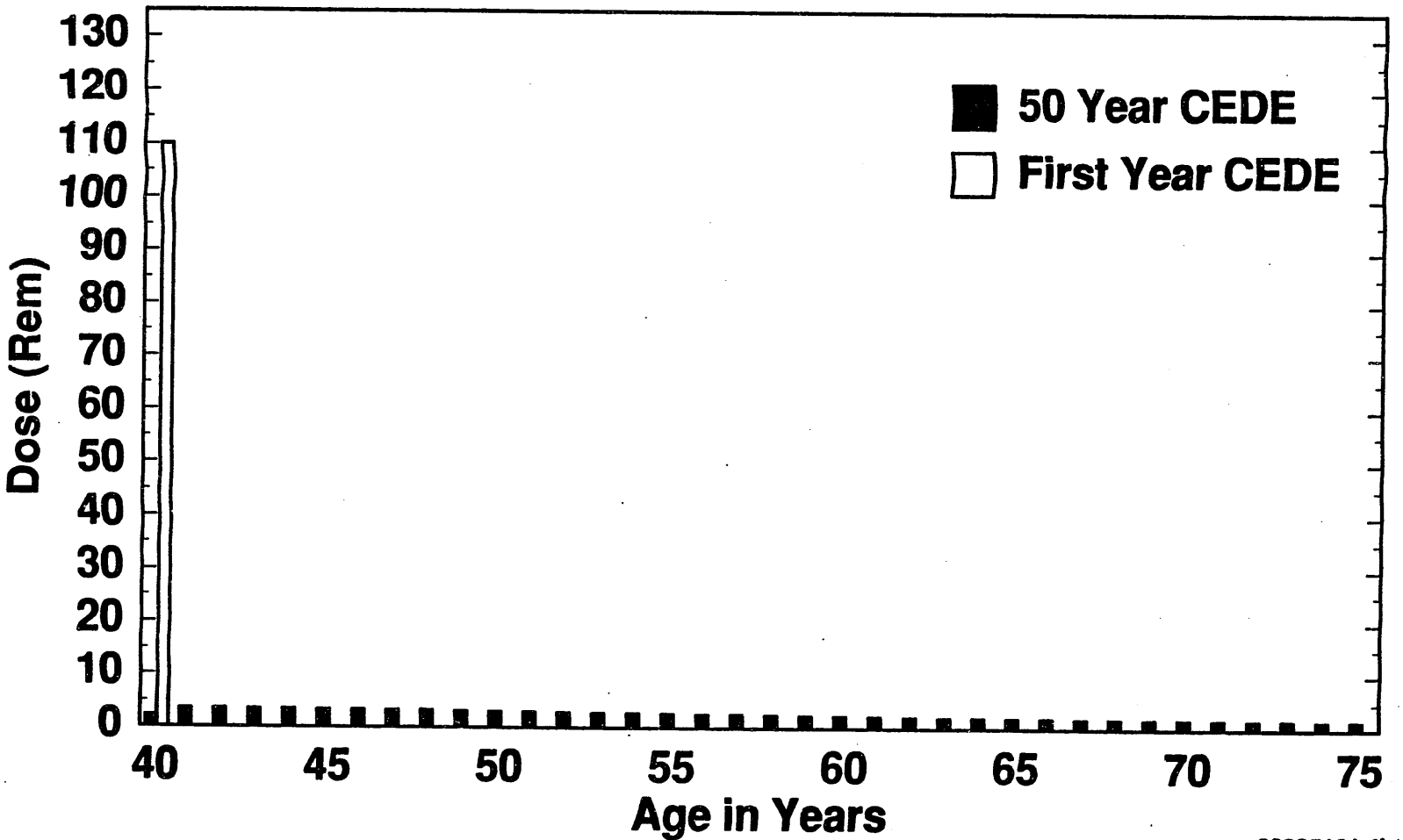

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Figure 3

Internal Dose Contribution

Case 3, Projected Dose to Age 75 vs CEDE Applied to Years of Intake

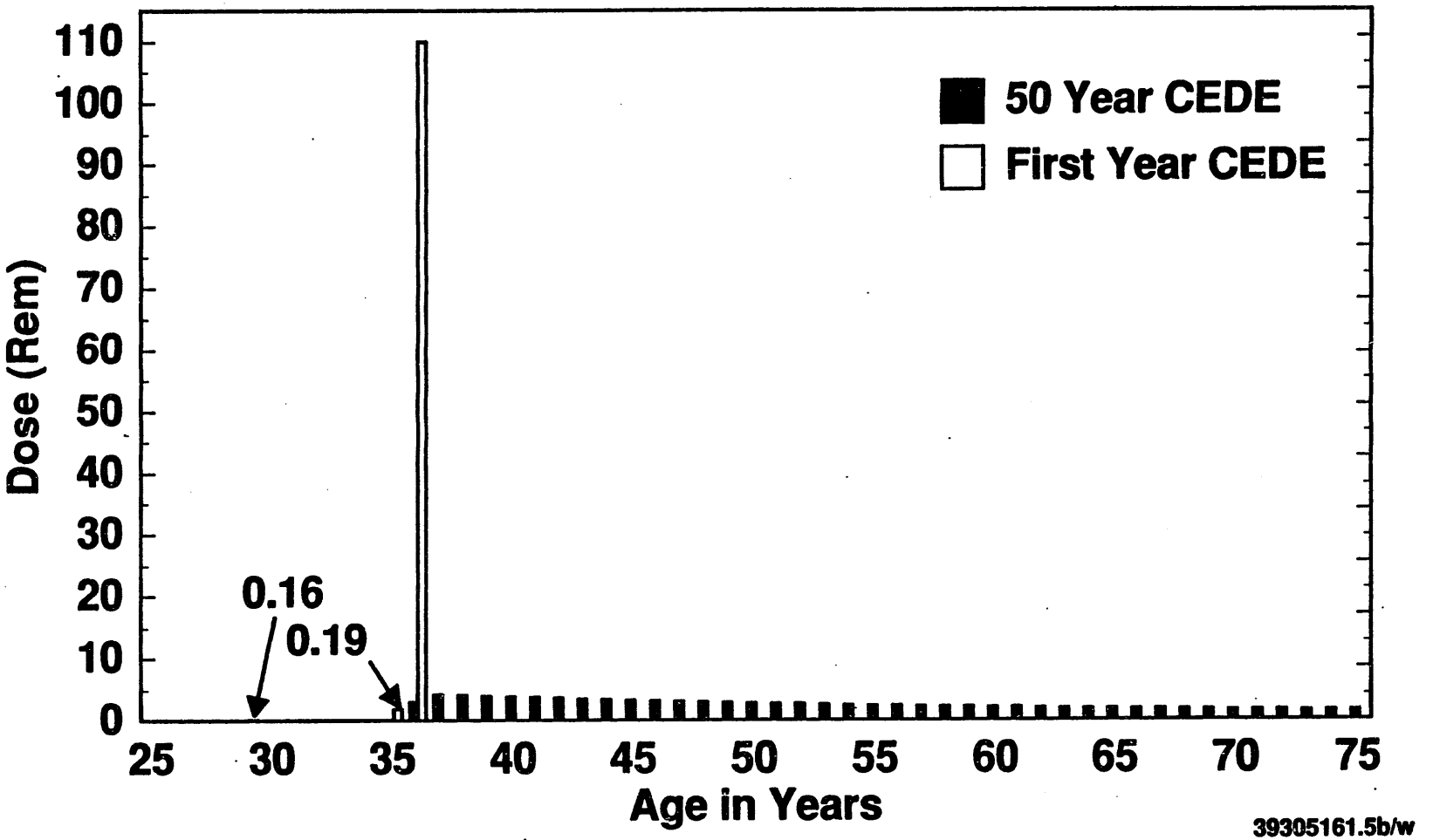

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Figure 4

Average Background Dose Over 50 Years vs Total Background Dose Applied to the First Year

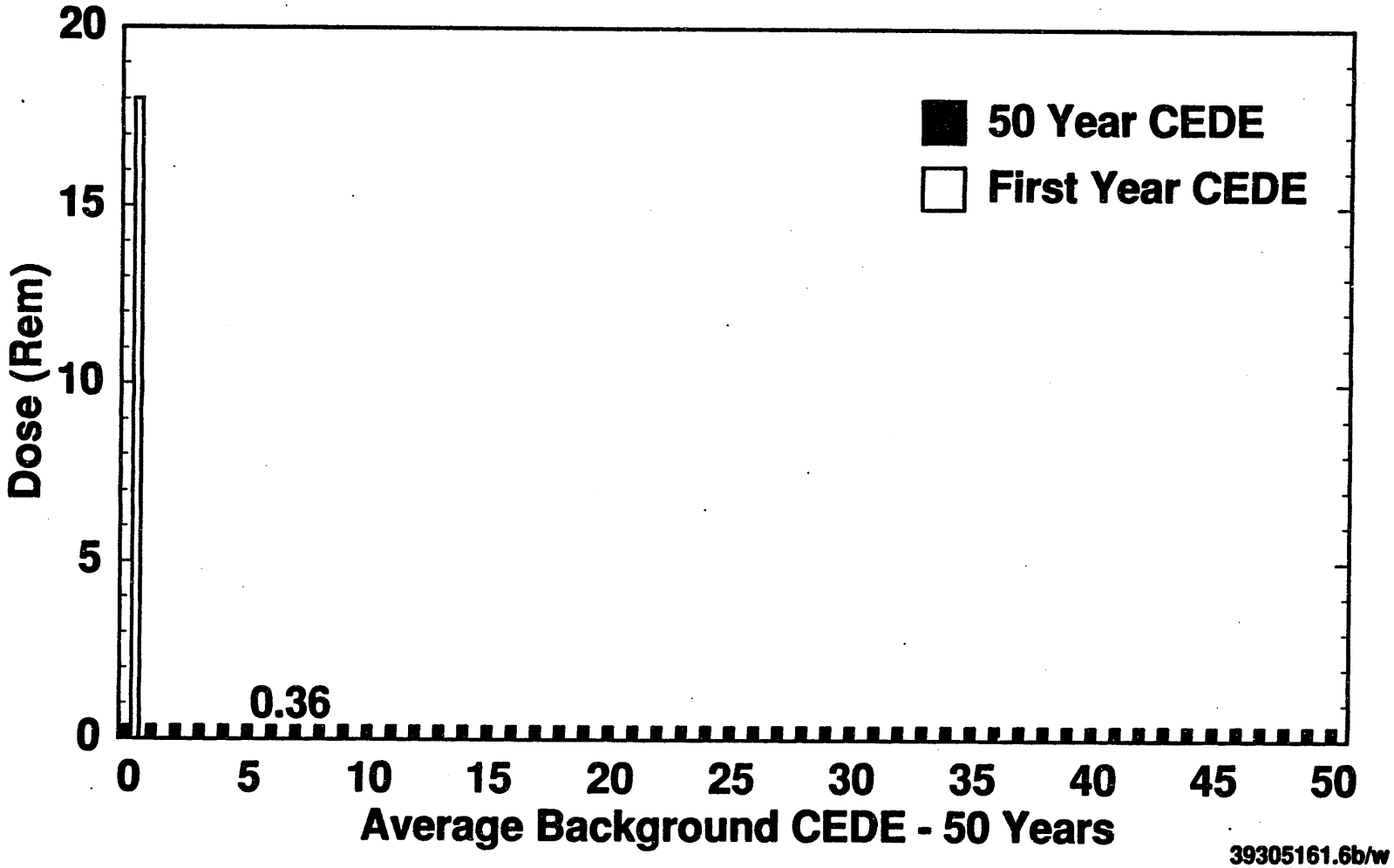

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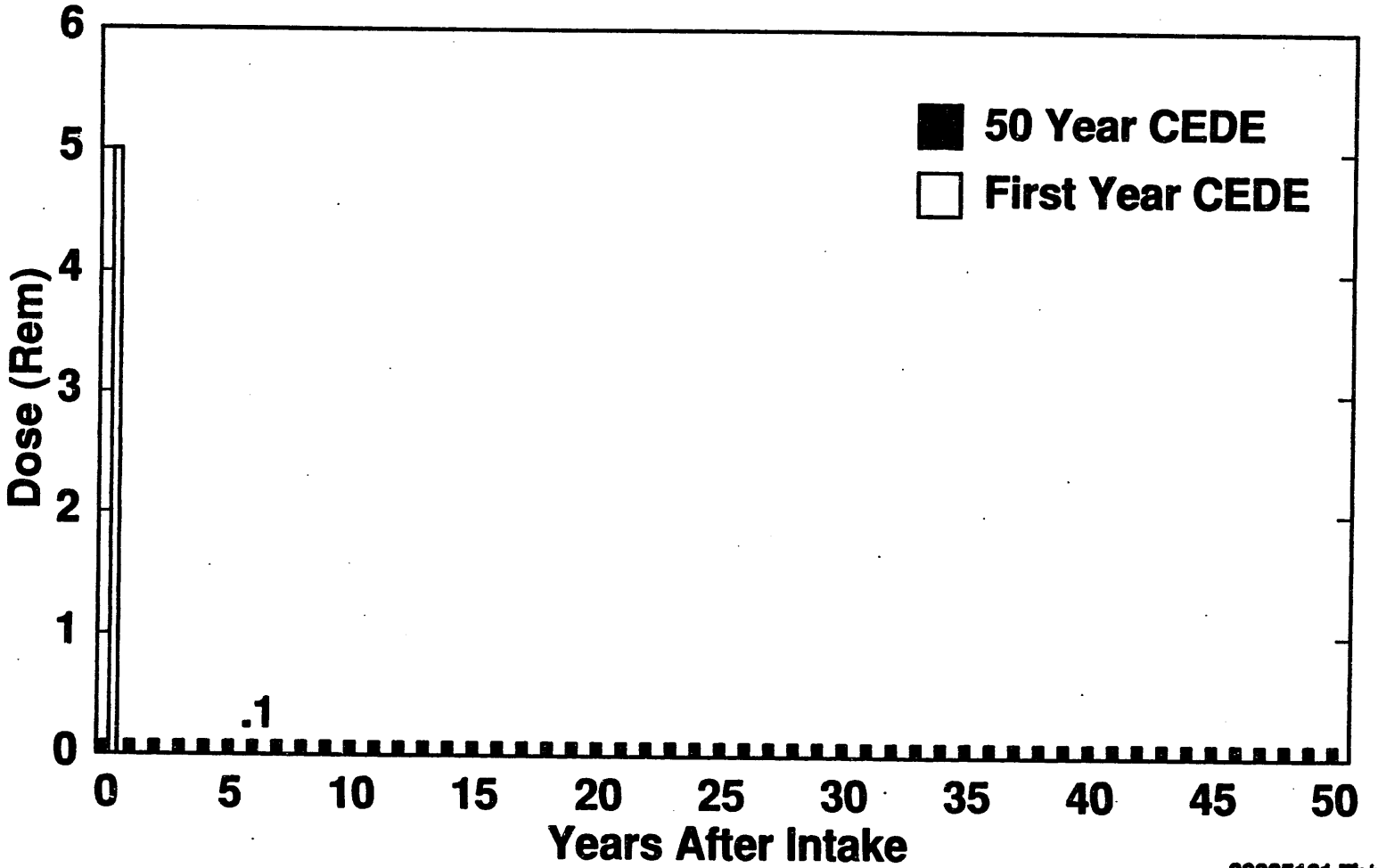
Figure 5

Annual vs CEDE for Plutonium



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The following three dilemmas remain to be solved:

- Does the worker have the right to maintain the same level of compensation if an alternate career must be imposed?
- Will the issue of a worker who has exceeded his lifetime dose while working at another employer - be addressed when hired by WHC?
- Will an individual who has exceeded their lifetime dose need to be replaced by additional workers to complete their assigned tasks?

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