Document Title:	Document Number:	ORAUT-OTIB-0002
	Revision:	02
Maximum Internal Dose Estimates for Certain DOE Complex Claims	Effective Date:	02/07/2007
	Type of Document:	OTIB
	Supersedes:	Revision 01

Subject Expert(s): Eugene M. Rollins and Elizabeth M. Brackett

Site Expert(s): N/A

Approval:	Signature on File John M. Byrne, Document Owner	Approval Date:	01/12/2007
Concurrence:	Signature on File Edward F. Maher, Task 5 Manager	Concurrence Date:	01/26/2007
Concurrence:	Signature on File Kate Kimpan, Project Director	Concurrence Date:	01/24/2007
Approval:	Brant A. Ulsh Signature on File for James W. Neton, Associate Director for Science	Approval Date:	02/07/2007

☐ New ☒ Total Rewrite ☐ Revision ☐ Page Change

FOR DOCUMENTS MARKED AS A TOTAL REWRITE, REVISION, OR PAGE CHANGE, REPLACE THE PRIOR REVISION AND DISCARD / DESTROY ALL COPIES OF THE PRIOR REVISION.

PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
11/07/2003	00	New document to establish Technical Information Bulletin for Maximum Internal Dose Estimates for Certain DOE Complex Claims. First approved issue. Initiated by Eugene M. Rollins.
01/10/2004	01	Approved Issue of Revision 01. Initiated by Eugene M. Rollins.
01/23/2004	01 PC-1	Added information on pages 8 and 9 regarding the employee's initial hire date after 1969 and revised hire date for Hanford employees. Deleted the following information: The covered employee's initial hire date was 1970 or later. For Hanford employees, the covered employee's initial hire date was 1953 or later. See Attachment B for discussion. Approved issue of page change. Initiated by Eugene M. Rollins.
05/07/2004	01 PC-2	Lists additional organs to Table 3.1.1-4 on page 8. Adds information on page 9 regarding conditions to determine the potential for internal exposure – for covered employee's initial hire date after 1952 and not participating in a bioassay program prior to 1970 and the covered employees initial hire date prior to 1970 with an evaluation of working conditions. Initiated by Pam Olsen.
02/07/2007	02	Approved Revision 02 revised for biennial review. Constitutes a total rewrite of the document. Formatting and terminology changes were made to make the document consistent with current practices. Attachment A and associated references from Rev. 01 were deleted as they are no longer used. No changes occurred as a result of formal internal review. Incorporates NIOSH formal review comments. This revision results in no change to the assigned dose and no PER is required. Initiated by Elizabeth M. Brackett.

TABLE OF CONTENTS

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

CFR	Code of Federal Regulations
d	day
DOE	U.S. Department of Energy
dpm	disintegrations per minute
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
g	gram
hr	hour
IMBA	Integrated Modules for Bioassay Analysis
L	liter
MDA	minimum detectable activity
mg	milligram
mL	milliliter
MPBB	maximum permissible body burden
MPC	maximum permissible concentration
mrem	millirem
nCi	nanocurie
NIOSH	National Institute for Occupational Safety and Health
NTS	Nevada Test Site
TIB	technical information bulletin
U.S.C.	United States Code
wk	week
yr	year
µCi	microcurie
µg	microgram
µm	micrometer
§	section or sections

1.0 INTRODUCTION

Technical information bulletins (TIBs) are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historic background information and guidance to assist in the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). TIBs may be used to assist NIOSH staff in the completion of individual dose reconstructions.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy (DOE) facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [42 U.S.C. § 7384l(5) and (12)].

2.0 PURPOSE

The purpose of this TIB is to provide a method to facilitate timely processing of claims under the EEOICPA that involve cancer to an organ with little or no reported dose from internally deposited radionuclides that might be associated with work at DOE complex sites.

3.0 BACKGROUND

Title 42, Part 82 of the Code of Federal Regulations (CFR) dictates the methods to be used for radiation dose reconstruction under the EEOICPA; 42 CFR 82.10(k) summarizes the general philosophy to be adopted:

> *Research and analysis will be determined sufficient if one of the following three conditions is met:*
>
> *(1) From acquired experience, it is evident the estimated cumulative dose is sufficient to qualify the claimant for compensation (i.e., the dose produces a probability of causation of 50% or greater);*
>
> *(2) Dose is determined using worst case assumptions related to radiation exposure and intake, to substitute for further research and analyses;*
>
> *(3) Research and analysis indicated under steps described in paragraphs (f) - (j) of this section have been completed.*
>
> *Worst-case assumptions will be employed under condition 2 to limit further research and analysis only for claims for which it is evident that further research and analysis will not produce a compensable level of radiation dose (a dose producing a probability of causation of 50% or greater), because using worst-case assumptions it can be determined that the employee could not have incurred a compensable level of radiation dose.*

Worst-case assumption is defined in 42 CFR 82.5(r) as:

> *A term used to describe a type of assumption used in certain instances for certain dose reconstruction conducted under this rule [42 CFR 82]. It assigns the highest*

reasonably possible value, based on reliable science, documented experience, and relevant data to a radiation dose of a covered employee.

A number of EEOICPA claims have been submitted that can be expedited based on paragraph (2) above. These cases involve cancer of an organ that does not concentrate any of the primary radionuclides expected to be found at DOE sites and with little or no apparent internal dose to that organ.

In accordance with *Internal Dose Reconstruction Implementation Guideline* (NIOSH 2002), internal dose is assigned to employees who were monitored but had no detectable activity in their samples and to employees who were not included in a bioassay program because there is some amount of intake and associated dose that is not detectable by an internal dosimetry program. To expedite dose reconstructions, cases that meet the criteria can be evaluated with the method described in this TIB. If the outcome yields a probability of causation greater than 50%, a dose reconstruction using more reasonable assumptions will be performed.

4.0 IMPLAUSIBLE UNDISCOVERED INTAKES

Assumptions

For cases in which it is considered likely that the employee had no significant internal radiation exposure, a method to expedite claims has been developed in accordance with 42 CFR 82.10(k)(2). This method assumes the "largest reasonably possible value" of the source term that consisted of radionuclides that are or were typically the more significant radionuclides (by either preponderance or by internal dose significance) on a site. For this worst-case estimate of internal dose, it is assumed that on the first day of employment the worker had an acute inhalation intake of each of the radionuclides in the source term in the amounts listed below.

Based on historical data, it is believed to be unlikely that such an intake could have occurred without being detected by workplace monitoring at the time. It is also believed that this is an overestimate of internal dose for an unmonitored worker or a worker with no bioassay results exceeding detection thresholds.

Additional assumptions to develop this method are:

- All intakes are inhalations of standard 5-µm activity median aerodynamic diameter, except for ^{131}I, which is assumed to be in vapor form (class SR-1).

- The most soluble form of the radionuclide specified in ICRP (1995) was used to maximize dose to systemic organs, except as noted below; dose to lung is not germane to this exercise.

- Because maximum permissible body burdens (MPBBs) were the derived limits for so many years, the assumed implausible uptake was based on a percentage of the radionuclide-specific MPBB for soluble chemical forms as defined in National Bureau of Standards (NBS) Handbook 69 [also referred to as National Committee on Radiation Protection (NCRP) Publication 22] (NBS 1959). It was assumed that an intake that resulted in 10% of an MPBB would likely not have occurred to an unmonitored worker or would have likely resulted in a readily noticeable bioassay result in a monitored worker, readily noticeable air sample, or other indicator of personnel contamination. In other words, an event that provided the possibility of an intake that would have resulted in a body burden exceeding 10% of the MPBB would not have gone unnoticed and there would be some indication in the worker's records. This

assumption applies to facilities with active radiation protection programs where bioassay or air-monitoring programs were present and able to detect such intakes. The current ICRP methodology is used to calculate doses from these implausible intakes.

- For types F and M materials, the associated derived intakes (i.e., intake resulting in a 10% MPBB) were assumed to be 10 and 20 times 10% of the MPBB, respectively. The factors of 10 and 20 are based on the current ICRP models and approximate the differences between an intake and the activity that is present in the body after the initial clearance of the short-term compartments. These factors are used to relate body burden, the historical quantity of control that was based on ICRP Publication 2 (ICRP 1959) methods, to intake, the present quantity of control that is based on current ICRP methods. These factors were estimated from tables in the November 2002 issue of *Health Physics* that list the intake retention fraction for the whole body (without the extrathoracic (ET) region) as a function of time after acute intake for different elements and inhalation types (Potter 2002). Because initial deposition in the nonsystemic organs was not considered by ICRP (1959) to be part of the body burden, the selected retention fractions allowed some time for the rapid clearance components. Table 4-1 lists examples.

Table 4-1. Fractional retention in whole body after initial clearance from lung.[a,b]

	Inhalation type F		Inhalation type M	
Element	**3 d after intake**	**4 d after intake**	**60 d after intake**	**90 d after intake**
Strontium	0.227	0.199	-	-
Cesium	0.449	0.440	-	-
Cerium	-	-	0.0683	0.0654
Ruthenium	0.251	0.227	0.0392	0.0392
Barium	0.147	0.104	-	-
Lanthanum	0.307	0.291	0.0683	0.0654
Zirconium	0.278	0.252	0.0496	0.0448
Niobium	-	-	0.0476	0.0409
Cobalt	-	-	0.0410	0.0337
Technetium	0.217	0.160	0.0321	0.0238
Europium	-	-	0.0605	0.0568

a. Source: Potter (2002).
b. - = not applicable.

- The assumption of type S for ^{58}Co and ^{60}Co is used because it results in larger doses to the systemic organs because of the high-energy photons. Although the logic in the paragraph above does not directly apply to insoluble (type S) material, the fractional retention in the whole body is similar for type M and type S at 60 and 90 d, so the derived intake is estimated as 20 times the 10% MPBB.

- Zinc-65 is classified as type S in ICRP (1995). As with the ^{58}Co and ^{60}Co type S materials, the logic of determining a body burden-to-intake conversion factor does not directly apply, but use of a factor of 20 does not seem unreasonable.

- Manganese-54 type M has a larger dose conversion factor for most organs and tissues and was generally more favorable to claimants than type F.

- This method applies only to intakes of particulate radioactive material and radioiodines. These intakes are in addition to any intakes of ^{3}H, ^{14}C, or radon/thoron and their progeny, as applicable.

- To be generic to most DOE sites, intakes were assumed to involve the most plausible radionuclides for all the sites, even though it is implausible that one worker had intakes of all the radionuclides. Two groups of radionuclides were considered: those from sites having one or more reactors and those from sites without a reactor. The Nevada Test Site (NTS) was considered a special case for which these two groups of radionuclides might not be appropriate. A review indicated that after 1971 the source term at NTS, except in the tunnels, was consistent with that chosen for reactor sites.

- For sites without a reactor, the actual ratio of radionuclides in mixtures is not relevant because each radionuclide is used at its maximum amount. For sites with reactors, the fission products were chosen for the list based on their relative abundance in fuel or contamination after 180 d of post-irradiation cooling time. This is conservative for any contamination at facilities other than the reactors themselves.

Table 4-2 lists the radionuclides of interest in relation to these assumptions.

A review of the assumed intakes from the method described above and associated possible air concentrations for different periods indicates that the uranium intakes based on soluble uranium might not have been sufficiently conservative for uranium facilities that controlled their programs based on consideration of uranium exposure alone. The derived intakes for ^{234}U and ^{238}U were increased by a factor of 100 to ensure that this scenario bounds doses to those employees who worked at uranium facilities but were not included in a bioassay program or had no detectable occupationally related activity in their samples. Derived intake values for ^{234}U and ^{238}U can be lowered to 50 and 5 nCi, respectively, for employees who worked in areas that were controlled based on the possible presence of other alpha emitters such as ^{238}Pu and ^{239}Pu.

After the intakes of the radionuclides were determined, the intakes from the alpha-emitting radionuclides and the beta/gamma-emitting radionuclides were summed separately to show the total intake of each for the reactor and nonreactor sites. These alpha and beta/gamma intakes were then used to consider what the average air concentrations would have been if the intakes had occurred chronically rather than acutely. A breathing rate of 2.4×10^9 mL/yr, based on Reference Man, was used to calculate the air concentrations for 1, 10, and 30 years that would produce the given intakes. Site air concentration criteria (area controls, respirator usage, etc.) were based on the permissible air concentrations of radionuclides assumed to be present in significant quantities. At many facilities, air concentration controls were specified for alpha emitters, based on $^{238/239/240}$Pu, and beta/gamma emitters based on ^{90}Sr. The typical air concentration controls listed in Table 4-3 are based on the radionuclide air concentration values in NBS (1959), AEC (1968), and 10 CFR 835, which for most radionuclides did not change significantly over time. In later years, the beta/gamma limit might have increased to 2×10^{-9} µCi/mL, but the control criteria also changed and were based on 10% of the limit, which would equate to an air concentration of 2×10^{-10} µCi/mL.

Table 4-3 shows that even chronic intakes at these levels would exceed typical air concentration controls that were being used at most sites since the 1950s to manage access to and work practices in areas that had increased radioactivity in air. Acute intakes are assumed for this worst-case approach because they result in larger assignments of dose.

Table 4-3 also shows that workers who spent significant time in areas where uranium air concentration controls were used to manage access and work practices do not appear to be good candidates for the nonuranium facility approaches. The nonuranium facility approaches can be used for reconstruction of doses for claims that did not involve exposure in uranium process environments for more than a few years. The uranium intakes are included with the alpha intakes, because it is

Table 4-2. Radionuclides of interest, MPBBs, assumed intake absorption types, derived maximum plausible intake quantities, absorption types, and radiation types used for estimating organ doses at DOE sites.

Radionuclide	Soluble (S) MPBB (nCi)[a]	Fractional retention based on type:	Derived intake[b] (nCi)	Absorption type applied for dose determination
Sites without a reactor:				
Sr-90	2,000	F	2,000	F
Tc-99	10,000	F	10,000	F
Cs-137	30,000	F	30,000	F
U-234	50	F	5,000[c]	F
U-238	5	F	500[c]	F
Am-241[d]	50	M	100	M
Cm-244	100	M	200	M
Np-237	60	M	120	M
Pu-238	40	M	80	M
Pu-239	40	M	80	M
Th-230[e]	50	M	100	M
Cf-252	40	M	80	M
Mn-54	20,000	M	40,000	M
Sites with a reactor–all those above plus:				
Co-58	30,000	M	60,000	S
Co-60	10,000	M	20,000	S
Fe-59	20,000	F	20,000	F
Zn-65	60,000	M	120,000	S
Y-91	5,000	M	10,000	M
Nb-95	40,000	M	80,000	M
Zr-95	20,000	F	20,000	F
Ru-103	20,000	F	20,000	F
Ru-106	3,000	F	3,000	F
I-131	700	F	700	F
Ce-141	30,000	M	60,000	M
Ce-144	5,000	M	10,000	M
Pm-147	60,000	M	120,000	M
Eu-154	5,000	M	10,000	M
Eu-155	70,000	M	140,000	M

a. Source: NBS (1959).
b. Derived maximum plausible intake based on 10% of the soluble NBS (1959) MPBB multiplied by factors of 10 and 20 for assumed intake absorption types of F and M, respectively.
c. The uranium values for the general approach are increased to ensure that this is a bounding approach for all facility-types. The lower values of 50 nCi for U-234 and 5 nCi for U-238 can be used to assign worst-case doses to individuals who did not work in areas where there were uranium exposure concerns.
d. Pu-241 is accounted for by the Am-241 intake value.
e. Thorium-230 can be used as a surrogate for Th-232.

unlikely that the measured alpha air concentration would have excluded uranium. Uranium is shown by itself for nonreactor facilities, because the air concentration control in a uranium facility was likely to be larger than the cited gross alpha air concentration control. For facilities with reactor source terms, the uranium air concentration was not listed because it is believed that the control would have been on the gross alpha air concentration and because the uranium concentration would be the same as the comparable nonreactor facility.

Table 4-3. Total intakes and possible average air concentrations.

Facility type	Radiation type	Intake (µCi)	Air concentration based on 1-yr intake (µCi/mL)	Air concentration based on 10-yr intake (µCi/mL)	Air concentration based on 30-yr intake (µCi/mL)	Typical air concentration controls (µCi/mL)
Nonreactor and nonuranium	Alpha	0.815	3.4E-10	3.4E-11	1.1E-11	2 E-12
	Beta/gamma	42	1.8E-08	1.8E-09	5.8E-10	3 E-10
	Uranium	0.055	2.3E-11	2.3E-12	7.6E-13	7 E-11
Reactor and nonuranium	Alpha	0.815	3.4E-10	3.4E-11	1.1E-11	2 E-12
	Beta/gamma	776	3.2E-07	3.2E-08	1.1E-08	3 E-10
Nonreactor and uranium	Alpha	6.26	2.6E-09	2.6E-10	8.7E-11	2 E-12
	Beta/gamma	42	1.8E-08	1.8E-09	5.8E-10	3 E-10
	Uranium	5.5	2.3E-09	2.3E-10	7.6E-11	7 E-11
Reactor and uranium	Alpha	6.26	2.6E-09	2.6E-10	8.7E-11	2 E-12
	Beta/gamma	776	3.2E-07	3.2E-08	1.1E-08	3 E-10

To encompass employees who might have worked in facilities where uranium was the primary radionuclide of concern for internal dose, each assumed uranium intake was increased by a factor of 100. The factor of 100 was chosen to ensure that this approach adequately bounds the level of exposure that could have gone unnoticed at uranium facilities.

This approach can also be used for any cancer site for which the highest nonmetabolic organ is specified for internal dose assessment in ORAUT (2006).

Table 4-4 lists the organs that are appropriate for application of maximum internal dose.

Table 4-4. Organs appropriate for application of the maximum internal dose for certain DOE complex claims.

Adrenals	Heart	Ovaries
Brain	Muscle	Thymus
Breast	Liver	U. Bladder
Colon	Eye	Uterus
Kidneys	Pancreas	Bone surfaces
Red bone marrow	Skin	Testes
Esophagus	Spleen	
G. bladder	Stomach	

5.0 CALCULATION OF INTERNAL DOSE FROM MAXIMUM INTAKES

The calculation of organ dose assumes that the covered employee had maximum intakes of all the radionuclides listed in Table 4-2. While individual exposures to a single radionuclide from the mixtures defined in this method possibly could be underestimated, it is believed that the individual dose determined from this method would be overestimated because, at a minimum, intakes and doses from 12 radionuclides are considered.

6.0 APPLICATIONS AND LIMITATIONS

The following conditions must be met to apply this approach:

- The covered employee's initial hire date was after 1969.

- The covered employee's initial start date was before 1970 (for the DOE Hanford Site, before 1953), provided the dose reconstruction report includes an evaluation or explanation that demonstrates the doses from Table 4-2 intakes overestimate the actual or potential doses received by the worker. The following are some examples of potential information to use in this evaluation.

  1. Employee job title
  2. Bioassay monitoring results
  3. Work location or other job conditions
  4. Recorded external dose
  5. Other site employees with similar jobs

- For Hanford Site employees, the covered employee's hire date was after 1952. See Attachment A for discussion.

- The target organ must be listed in Table 4-4 or must be an organ whose dose is based on the highest nonmetabolic organ dose; the respiratory tract is not included because the intakes are not maximized for insoluble material.

- Employees who would have had no significant exposure to uranium (i.e., no uranium bioassay or did not work with uranium) can be assessed with the smaller uranium source term.

- The employment must have been at a facility with an active radiation protection program.

- Unless it can be demonstrated that the nuclides are appropriate to the site and there was an active radiation protection program that conformed to the standards at the time, dose from Atomic Weapons Employers must be reconstructed by other methods.

- Dose from NTS can be assigned by this approach if the employee worked at the Site after 1971, was not involved in tunnel work, and meets the other conditions herein.

- Dose from tritium is to be considered separately.

- Potential for exposure to radionuclides that are not included in Table 4-2, unless there is a similar radionuclide (i.e., ^{230}Th for ^{232}Th) and supplemental explanation of the substitution.

REFERENCES

AEC (U.S. Atomic Energy Commission), 1968, "Chapter 0524, Standards for Radiation Protection," *AEC Manual*, 0524-01, Washington, D.C., November 8. [SRDB Ref ID: 10668]

Cantril, S. T, 1945, "Tolerance Limits," memorandum to file, HW-4.159, 7-2602, Hanford Works, Hanford, Washington, October 18. [SRDB Ref ID: 13428]

DOE (U.S. Department of Energy), 1988, *Radiation Protection for Occupational Workers*, Order 5480.11, Office of Environment, Safety and Health, Washington D.C., December 21. [SRDB Ref ID: 8073]

HPS (Health Physics Society), 1995, *An American National Standard for Bioassay Programs for Uranium*, ANSI Standard N13.22-1995, McLean, Virginia, October.

ICRP (International Commission on Radiological Protection), 1959, *Report of Committee II on Permissible Dose for Internal Radiation*, Publication 2, Pergamon Press, Oxford, England.

ICRP (International Commission on Radiological Protection), 1995, *Dose Coefficients for Intakes of Radionuclides by Workers*, Publication 68, Pergamon Press, Oxford, England.

NBS (National Bureau of Standards), 1953, *Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water*, Handbook 52, U.S. Department of Commerce, Washington, D.C., March 20. [SRDB Ref ID: 12332]

NBS (National Bureau of Standards), 1959, *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure*, Handbook 69, U.S. Department of Commerce, Washington, D.C., June 5. [SRDB Ref ID: 11110]

NIOSH (National Institute for Occupational Safety and Health), 2002, *Internal Dose Reconstruction Implementation Guideline*, OCAS-IG-002, Rev. 0, Office of Compensation Analysis and Support, Cincinnati, Ohio, August.

ORAUT (Oak Ridge Associated Universities Team), 2004, *Technical Basis Document for the Hanford Site – Occupational Internal Dose*, ORAUT-TKBS-0006-5, Rev. 01, Oak Ridge, Tennessee, November 24.

ORAUT (Oak Ridge Associated Universities Team), 2006, *Internal Dosimetry Organ, External Dosimetry Organ, and IREP Model Selection by ICD-9 Code*, ORAUT-OTIB-0005, Rev. 01 PC-1, Oak Ridge, Tennessee, February 10.

Parker, H. M., 1948. “Health Physics, Instrumentation, and Radiation Protection,” *Advances in Biological and Medical Physics*, Volume I, Academic Press, New York, New York, p. 957.

Parker, H. M., 1955. “Radiation Protection in the Atomic Energy Industry, a Ten-Year Review,” *Radiology*, volume 65, number 6, pp. 903–911.

Patterson, C. M., 1949, “General Operating Tolerances,” letter to L. S. Taylor (National Bureau of Standards), HW-12710, Hanford Works, Richland, Washington, March 11. [SRDB Ref ID: 7756]

Potter, C. A., 2002, "Intake Retention Fractions Developed from Models Used in the Determination of Dose Coefficients Developed for ICRP Publication 68—Particulate Inhalation," *Health Physics*, volume 83, number 5, pp. 594–789. [SRDB Ref ID: 12373]

Wilson, R. H., 1987, *Historical Review of Personnel Dosimetry Development and its Use in Radiation Protection Programs at Hanford, 1944 to the 1980s*, PNL-6125, Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, Washington, February. [SRDB Ref ID: 262]

ATTACHMENT A
USING MAXIMUM INTERNAL DOSE ESTIMATES FROM TECHNICAL INFORMATION BULLETIN 0002 FOR HANFORD SITE CLAIMS FROM 1953 FORWARD

A.1 PURPOSE

The purpose of this attachment is to provide the basis for applying the assumptions, conditions, and results of this TIB to claims for Hanford Site employees before 1970.

A.2 BACKGROUND

This TIB assigns intakes of a number of radionuclides based on the assumption that intakes that resulted in greater than 10% of the MPBB, as defined in ICRP Publication 2 (ICRP 1959) and NBS Handbook 69 (NBS 1959), would not have occurred without being detected by workplace monitoring or bioassay or both. For sites with reactors, which would apply to the Hanford Site, each worker is assigned intakes of 28 radionuclides that are considered representative of potential sources of intake. For situations in which more than one isotope might have been available as a potential source of intake, the more restrictive isotope was assigned (e.g., ^{137}Cs for mixtures of ^{134}Cs and ^{137}Cs, and ^{90}Sr for mixtures of ^{89}Sr and ^{90}Sr). The intakes and resulting doses are considered conservative in that the risk of a worker truly incurring an undetected intake or series of intakes during a career involving all the listed radionuclides at 10% of the MPBB for each is unlikely.

The justification for extending this TIB to Hanford for hire dates earlier than 1970 requires an understanding of the status of the radiation protection program for the earlier years.

A.2.1 Brief Description of the Radiation Protection Program at the Hanford Site

Until 1965, there was one operating contractor at Hanford and, therefore, one radiation protection program. Herbert M. Parker, manager of the Health Instrumentation Division and later manager of Hanford Laboratories, was the guiding force for radiation protection at Hanford in the 1940s and 1950s. Dr. Parker was a leader in the field of health physics who pushed hard for continuously improving the science and the practice of health physics at Hanford and in the United States as a whole. Although managing radiation protection in general, Dr. Parker's expertise was dosimetry, both external and internal. For example, he was a member of the NCRP subcommittee that developed the first set of MPBBs and maximum permissible concentrations (MPCs).

Jack Healy led developments in bioassay and internal dosimetry during this time. Dr. Healy was also one of the foremost experts and leaders in these disciplines. For example, he was a member of the NCRP subcommittee that developed the second set of MPBBs and MPCs.

Because of these men and others, radiation protection was a major concern at Hanford from the start. Considerable research was conducted throughout most of Hanford's history to improve survey instruments, effluent cleanup mechanisms, monitoring instrumentation, and workplace air-sampling practices, and to understand the biokinetics associated with intakes of radionuclides. Some of these developments are described in Dr. Parker's 1948 article in *Advances in Biological and Medical Physics*, "Health-Physics Instrumentation and Radiation Protection" *(*Parker 1948), and his 1955 article in *Radiology*, "Radiation Protection in the Atomic Energy Industry, a Ten-Year Review" (Parker 1955).

ATTACHMENT A
USING MAXIMUM INTERNAL DOSE ESTIMATES FROM TECHNICAL INFORMATION BULLETIN 0002 FOR HANFORD SITE CLAIMS FROM 1953 FORWARD

Nevertheless, the science and practice of monitoring for intakes of plutonium, uranium, and mixed fission and activation products were still in their infancy in the 1940s. Knowledge and skills associated with routine bioassay for plutonium and uranium were rapidly being developed and improved, and the scope of monitored workers was expanding. Limits were based on tolerance doses and tolerance air concentrations, which were forerunners of the MPBB and MPC concepts. However, the tolerance doses were high by today's standards; for instance, the external dose limit at Hanford was 0.1 rep/d and later was revised to 0.3 rep/wk [a rep was a radiation equivalent physical, defined as 83 ergs/g energy deposition in tissue and later redefined as 93 ergs/g]. The internal dose limit for alpha emitters was 0.01 rep/d (Cantril 1945). [Assuming a quality factor of 20, 0.01 rep/d approximately equates to 200 mrem/d.] In addition, the science of calculating intake or air concentration limits based on a limiting dose rate to a "significant organ" was based on very little biokinetic knowledge for radionuclides of concern associated with the Manhattan Project.

Therefore, applying the default intakes from this TIB to the earliest years at Hanford is not recommended.

A.2.2 Air Monitoring

Air concentration limits at Hanford followed national guidance and, because of Drs. Parker and Healy's involvement in setting national guidance, changes would have been implemented promptly, if not actually before the publication of the guidance. For example, in a 1949 letter from C. M. Patterson of the Hanford Health Instrument Division to Lauriston S. Taylor of the National Bureau of Standards, in response to a request from Dr. Taylor, Dr. Patterson replied (examples from the letter), "The permissible tolerances used at Hanford Works are as follows: . . . internal emitter limits – 0.3 rep per week to the significant organ or *whatever the National Committee on Radiation Protection recommends*" (italics not in original letter). The italicized phrase was used in several places. For drinking water, "mixed fission products – 0.1 µc/liter – to be changed when new figure provided by K.Z. Morgan's Subcommittee" (Patterson 1949). Dr. Morgan's subcommittee was the NCRP Subcommittee on Permissible Internal Dose, of which Dr. Parker was a member, and which eventually produced the MPCs published in NBS Handbooks 52 and 69 (NBS 1953, 1959).

Table A-1 compares the MPBBs and MPCs of key radionuclides provided as national guidance in NBS Handbooks 52 and 69 (NBS 1953, 1959). This table is instructive because the MPBBs used in this TIB are directly linked to the MPCs in NBS Handbook 69 and, therefore, to air concentration limits at Hanford since about 1959. However, for before 1959, the table shows what the MPCs were starting in 1953 and how those values compared to 1959 values.

Air monitoring at Hanford was based on gross alpha and gross beta measurements corrected for radon progeny. The beta MPC used at Hanford since or before 1953 was based on the MPC for ^{90}Sr in NBS (1953) applicable at the time. Because, as shown in Table A-1, the MPC for ^{90}Sr actually increased between 1953 and 1959, the use of the MPBBs from the 1959 document is applicable and conservative for the period from 1953 to 1959. Similarly, the alpha MPC at Hanford was 2×10^{-12} µCi/mL, based on ^{239}Pu, which was unchanged from 1953. Areas with air concentrations exceeding either MPC were labeled as airborne contamination areas and required respiratory protection. Therefore, although the MPCs varied somewhat for the other radionuclides between 1953 and 1959, the ^{90}Sr and ^{239}Pu MPCs were always more limiting. Furthermore, these MPC values for

ATTACHMENT A
USING MAXIMUM INTERNAL DOSE ESTIMATES FROM TECHNICAL INFORMATION BULLETIN 0002 FOR HANFORD SITE CLAIMS FROM 1953 FORWARD
Page 3 of 5

Table A-1. Comparison of MPBBs and air MPCs between NBS Handbooks 52 and 69.

Radionuclide	MPBB (nCi)		MPC air (µCi/mL)	
	Handbook 52	Handbook 69	Handbook 52	Handbook 69
Pu-239 soluble	40	40	2E-12	2E-12
Pu-239 insoluble	8	NA	2E-12	4E-11
U-nat soluble	200	5	1.7E-11	7E-11
U-238 soluble		5		7E-11
U-nat insoluble	9		7E-11	6E-11
U-238 insoluble		NA		1E-10
Am-241	56	50	3E-11	6E-12
Sr-90	1,000	2000	2E-10	3E-10
Cs-137	90,000	30,000	2E-7	6E-8
Ce-144	5,000	5,000	7E-9	1E-8
I-131	300	700	3E-9	9E-9
Co-60	3,000	10,000	1E-6	3E-7
Ru-106	4,000	3,000	3E-8	8E-8
Y-91	15,000	5,000	4E-8	4E-8

^{90}Sr and ^{239}Pu (and therefore gross alpha and gross beta measurements on air samples) were continued via AEC (1968) and DOE (1988) into the 1980s.

The point of this discussion is that the MPBB values used for this TIB were directly linked to the air monitoring program at Hanford since 1953, and that the air concentration limits and response to exposures that potentially exceeded the limits were consistent from 1953 to at least 1989.

A.2.3 Bioassay Monitoring

Another key consideration in monitoring for intakes is the bioassay program. The plutonium bioassay program was well established and had years of operating experience at Hanford by 1953 (ORAUT 2004). In fact, the plutonium urinalysis methodology changed little from March 1953 through September 1983, and the minimum detectable activity (MDA) was 0.05 dpm/24-hr sample. For type M plutonium, this MDA translates to a possible missed intake at 365 d after an intake of 5.8 nCi total plutonium alpha compared to the intake of 160 nCi plutonium alpha assumed in this TIB. In addition, the sensitivity of the program improved throughout the period due to increased use of fecal samples in response to potential intake incidents.

Uranium bioassay (elemental analysis) was also well established by 1953 and was stable through about 1969 with an MDA of 4 µg/L. For type M recycled uranium, this MDA corresponds to a possible missed intake at 180 d after intake [sampling was conducted monthly for a while and semiannually part of the time (Wilson 1987)] of 78-nCi total uranium alpha compared to the intakes assumed in this TIB of 55-nCi type F uranium for nonuranium facilities and 5,500 nCi for uranium facilities. For type F recycled uranium, the corresponding possible missed acute intake at 180 d after intake is 163 nCi, but this is equivalent to 179 mg, which greatly exceeds the threshold for permanent renal damage (HPS 1995) and therefore is an unrealistic estimate. In fact, the 55-nCi intake in this TIB is overly conservative for type F uranium from the acute toxicity perspective, but most uranium intakes across the DOE complex were chronic. Uranium sampling was usually biweekly or monthly for workers

exposed to highly soluble forms of uranium, but some sampling was semiannual in the 1960s and it is not known under what conditions the semiannual sampling was allowed (e.g., it might have been just for workers exposed to insoluble forms of uranium).

The largest MDA for the mixed fission product urinalysis method was 70 dpm/24-hr sample. When considered as pure type F ^{90}Sr, this MDA corresponds to a possible missed intake at 365 d after intake of 1,500 nCi compared to the intake of 2,000 nCi assumed in this TIB. When considered as pure type M ^{144}Ce, this MDA corresponds to a possible missed intake at 365 d after intake of 72,000 nCi compared to the intake of 10,000 nCi assumed in this TIB. This implies that an intake of ^{144}Ce at 10% of the MPBB would not have been detectable solely by an annual urinalysis. However, an acute intake of 10,000 nCi of mixed fission products would have been associated with readily detectable contamination on the worker or in the air. For instance, breathing air at the beta concentration limit of 3×10^{-10} µCi/mL for a week would have resulted in an intake of 14 nCi. Allowing for a factor of 100 for possible nonrepresentativeness of the air sample versus the air breathed by the worker still indicates that a 10,000-nCi intake would have been detected and resulted in prompt bioassay.

The mixed fission product urinalysis did not detect intakes of isotopes of cesium or ruthenium or most activation products; however, these radionuclides are factored into the default intakes in this TIB.

A.2.4 Other Considerations

A final consideration is how successful the various monitoring programs were at discovering and documenting intakes. In 1955, Parker reported in *Radiology* on the status of and improvements in radiation protection at Hanford for the preceding 10 years (Parker 1955). Included in this journal article was a table showing the number of internal depositions per year for three equal parts of the 10-year period as follows: "positive cases per year, early period – 0; middle period –1; recent period – 30," the recent period being about 1952 to 1954. This statistic implies that either there were more workers being exposed in the later period or detection capabilities had improved. The truth is probably both, but the point Parker was making was that the ability to detect and confirm intakes had improved considerably from 1944 to 1952. Since sometime before 1965, there was a policy that intakes leading to a body burden that exceeded 5% of the MPBB were recorded in the worker's radiation exposure file. An indication of a possible intake was usually recorded along with the analysis that led to the 5% recording decision. Intakes well below the 5% criterion are listed in the records back to the 1950s. These points – the improved capabilities of detection and the 5% MPBB policy – are not conclusive of themselves, but they lend credence to the strength of the radiation protection programs by the early 1950s and the likelihood that intakes exceeding 10% of the MPBB would not have been missed.

A.3 CONCLUSIONS

- Air concentration limits of 3×10^{-10} µCi/mL total beta activity and 2×10^{-12} µCi/mL total alpha activity were based on the same MPBBs used in this TIB and were in use at least since 1953. These afforded adequate protection from acute intakes.

ATTACHMENT A
USING MAXIMUM INTERNAL DOSE ESTIMATES FROM TECHNICAL INFORMATION BULLETIN 0002 FOR HANFORD SITE CLAIMS FROM 1953 FORWARD
Page 5 of 5

- Routine bioassay from 1953 forward was adequate for either acute or chronic intakes of plutonium or radiostrontium; was marginal for type M uranium, and would not have detected an intake that corresponded to 10% of the MPBB for type M ^{144}Ce if the intake occurred 365 d before the bioassay. However, an intake of 10,000 nCi of ^{144}Ce would have been associated with a large contamination incident and would have resulted in prompt bioassay. The same is true for large intakes of ^{141}Ce from exposure to short-cooled fuel.

- Records show that before about 1952 few intakes were being discovered or at least confirmed, but the radiation protection program showed a large increase in detections in about 1952. The records also show intakes well below 5% of the MPBB starting at about that time.

The Hanford radiation protection program, which consisted of air sampling using ^{90}Sr and ^{239}Pu MPCs for gross beta and gross alpha activities, respectively, workplace contamination monitoring, and routine bioassay, was adequate from 1953 forward to ensure that intakes that corresponded to 10% of the 1959 MPBBs for 28 radionuclides described in this TIB would have been discovered and documented. The assigned dose from these 28 intakes is sufficient to overestimate doses for Hanford employees from 1953 forward who meet all the other conditions described in this TIB.