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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
02/22/2006	00	New technical basis document for the Energy Technology Engineering Center – Occupational External Dose. First approved issue. Initiated by Melton H. Chew.
11/16/2006	01	Approved Revision 01 to change the site name to Atomics International throughout the document in keeping with DOE site naming conventions. Updated required language in Section 6.1. Constitutes a total rewrite of document. Incorporates internal formal review comments and corrects typographical errors. Adds a paragraph to section 6.1.2 and clarification to missed dose and magnitude of background dose, Sections 6.2 and 6.8 respectively, as requested by DOL. This revision results in no change to the assigned dose, and no PER is required. Training required: As determined by the Task Manager. Initiated by Melton H. Chew.

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ACRONYMS AND ABBREVIATIONS

AI	Atomics International
D	deuterium
DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
hr	hour
keV	kiloelectron-volt, 1,000 electron-volts
MDL	minimum detectable level
MeV	megaelectron-volt, 1 million electron volts
mR	milliroentgen
mrad	millirad
mrem	millirem
MWt	megawatt (thermal)
NIOSH	National Institute for Occupational Safety and Health
NTA	nuclear track emulsion, type A
NVLAP	National Voluntary Laboratory Accreditation Program
OW	open window
PIC	pocket ionization chamber
POC	probability of causation
QF	quality factor
SNAP	Systems for Nuclear Auxiliary Power
SRE	Sodium Reactor Experiment
T	tritium
TBD	technical basis document
U.S.C.	United States Code
WB	whole body
wk	week
§	section or sections

6.1 INTRODUCTION

Technical basis documents and site profile documents 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 for particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist NIOSH staff in the completion of the individual work required for each dose reconstruction.

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 [EEOICPA; 42 U.S.C. § 7384l(5) and (12)]. EEOICPA defines a DOE facility as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the Department of Energy (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)" [42 U.S.C. § 7384l(12)]. Accordingly, except for the exclusion for the Naval Nuclear Propulsion Program noted above, any facility that performs or performed DOE operations of any nature whatsoever is a DOE facility encompassed by EEOICPA.

For employees of DOE or its contractors with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled "Exposure in the Performance of Duty." That provision [42 U.S.C. § 7384n(b)] says that an individual with cancer "shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the POC [probability of causation[1]] guidelines established under subsection (c) …" [42 U.S.C. § 7384n(b)]. Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation) define "performance of duty" for DOE employees with a covered cancer or restrict the "duty" to nuclear weapons work.

As noted above, the statute includes a definition of a DOE facility that excludes "buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program" [42 U.S.C. § 7384l(12)]. While this definition contains an exclusion with respect to the Naval Nuclear Propulsion Program, the section of EEOICPA that deals with the compensation decision for covered employees with cancer [i.e., 42 U.S.C. § 7384n(b), entitled "Exposure in the Performance of Duty"] does not contain such an exclusion. Therefore, the statute requires NIOSH to include all occupationally derived radiation exposures at covered facilities in its dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external dosimetry monitoring results are considered valid for use in dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction. NIOSH, however, does not consider the following exposures to be occupationally derived:

- Radiation from naturally occurring radon present in conventional structures
- Radiation from diagnostic X-rays received in the treatment of work-related injuries

[1] The U.S. Department of Labor is ultimately responsible under the EEOICPA for determining the POC.

6.1.1 Purpose

The purpose of this TBD is to describe external dosimetry systems and practices at Atomics International (AI). This document discusses historical and current practices at the AI facilities that, unless otherwise noted, used the same dosimeters and external dosimetry programs (Rutherford and Barnes 2006) in relation to the evaluation of external exposure data for monitored and unmonitored workers.

6.1.2 Scope

This TBD contains supporting documentation to assist in the evaluation of occupational external doses from processes that occurred at AI. An objective of this document is to provide supporting technical data to evaluate, with assumptions favorable to claimants, occupational external doses that can reasonably be associated with worker radiation exposures. This document addresses the evaluation of unmonitored and monitored worker exposure, missed dose, and the bias and uncertainty associated with the monitoring of external dose.

The AI facilities, which include four locations, have been identified in various ways over time. This TBD uses AI to refer to all locations unless more specific location information is warranted. In that context, AI includes Area IV of the Santa Susana Field Laboratory (which has also been known as the Nuclear Development Field Laboratory, the Liquid Metal Engineering Center, and the Energy Technology Engineering Center), portions of the Downey facility, the Vanowen Building at the Canoga facility, and the De Soto facility.

North American Aviation (NAA) entered into a contract with AEC to conduct nuclear research operations at Area IV and the Downey, Canoga and De Soto sites. At that time, Atomics International, an internal division of NAA, was the company's designated nuclear research and development division. In addition to the employees of the AI division, other employees of NAA who worked at any of the above sites during the AEC contract period are potentially eligible for EEOICPA benefits." (DOL)

AI had its own dosimeter in the beginning that was very similar to the multielement film dosimeters used at the Y-12 plant (ORAUT 2006a) and the Hanford Site (ORAUT 2004) based on the design developed by Pardue, Goldstein, and Wollan (1944) as well as pocket ionization chambers (PICs or *pencil dosimeters*). Both penetrating and nonpenetrating doses were recorded. AI started using commercial vendors in the early 1960s and continued that practice throughout the rest of its operating life.

6.2 MISSED DOSE

Missed doses at AI facilities generally resulted from dosimeter minimum detectable levels (MDLs) and exchange periods. In reviewing an individual dose record from December 31, 1956, to December 30, 1957, entries were both weekly and biweekly with the former starting in May 1957 (Author unknown 1956). This would suggest that exchange periods varied with time, job, and individual. AI (1960) states, "Normally film badges are to be worn for monthly periods except where the possibility of exceeding 100 mrem/wk of exposure is expected. Then the badges are to be analyzed more frequently." Therefore, missed doses before 1963, if not derived by review of individual records, would be based on weekly exchanges and would be applicable to both *Hp(0.07)* and *Hp(10)*. Starting in 1963, most dosimeters were processed by their vendor (Landauer or its predecessor) (Garcia and Carpenter 1963a). On occasion, workers wore special dosimeters to monitor nonroutine work such as "hot jobs or cell entries" and always without their regular dosimeter. These special dosimeters were always worn in pairs; the results were averaged, and that average result was sent to the vendor for inclusion in the total dose for that period's regular dosimeter result. It has not been determined if the special dosimeter procedure was in effect before 1963. Extremity finger ring film dosimeters were worn on both hands, and individual results were recorded for each hand. It has not been determined when this practice started, but it was in place in the December 31, 1956, dose record (Author unknown 1956) and included what appears to be the same exchange periods.

In cases of lost or destroyed dosimeters, results were derived from past results of similar work, coworker results, or the product of instrument measurements and time spent in the radiation zone. These practices are typical of sites with similar circumstances.

Neutron doses were measured with neutron track analysis, type A (NTA) film beginning with the start of reactor operations and the use of Van de Graaff accelerators. Both fast and thermal neutrons were measured and recorded as whole-body (WB) dose in rem. The NTA film is not effective at energies <0.5 MeV or at exposures of <50 mrem (ORAUT 2006a). It has not been determined what quality factors (QFs) were used. However, because a Po-Be neutron source was used for calibration, a reasonable assumption would be QF = 10 (Garcia 1970).

Missed doses for unmonitored employees could be as much as 500 mrem or 10% of whatever standard was in effect at the time of employment as allowed by AEC and it's successors (AEC Manual Chapter 0524 and DOE Order 5480.11). However, it is very unlikely that anyone could have been exposed to this level since everyone who entered a controlled area was issued a dosimeter (AI, 1960). The unmonitored workers may have been exposed to annual doses, above background, ranging from 10 to 40 mrem (ORAU-TKBD 0038-4, 2006) if they worked in Area IV.

Table 6-1 lists the periods of use, types of dosimeters, exchange periods, MDLs, and estimated annual missed doses.

Table 6-1. Estimated annual missed photon, beta, and neutron dose (rem).

Period[a]	Dosimeter[b]	Exchange period	MDL[c]	Estimated annual missed dose[d]
1954–1962	Pocket dosimeter (PIC) Site-specific two-element film	Daily	0.005	0.625
		Weekly	0.04	1.04
		Biweekly	0.04	0.52
		Monthly	0.04	0.24
1963–1979	Landauer multielement film	Monthly	0.04	0.24
		Quarterly	0.04	0.08
1980[e]–present	Landauer multielement film	Quarterly	0.01[f]	0.02
1954–present	NTA film	Bi-weekly	<0.05	0.650
		Monthly	<0.05	0.300

a. Estimated use periods for first entry. Landauer or its predecessor was the vendor in 1963 and maybe earlier (Garcia and Carpenter 1963a).
b. Neither the actual number of dosimeter elements of the first entry dosimeter nor the period of use of PICs has been determined.
c. Estimated MDLs for each dosimeter in the workplace even though many doses were reported at less than the MDL.
d. Estimated annual missed dose calculated using MDL/2 from NIOSH (2002).
e. Neutron dosimeters continued monthly exchanges (Tuttle 1979).
f. Yoder (2005).

6.3 RADIATION ENERGIES AND PERCENTAGES AT SELECTED FACILITIES

As described in ORAUT (2006b), there were many different types of facilities and processes at AI and other facilities during their periods of operation; these include reactors, critical test facilities, fuel preparation and postirradiation examination facilities, accelerator and calibration facilities, and support facilities. Most reactors were low power (a few kilowatts), with the maximum being 20 MWt, and all had relatively short operating histories. The major accelerator was a Van de Graaff ,Deuterium-Tritium) machine producing neutrons with a maximum energy of 14 MeV. The fuel examination and manufacturing facilities, reactors, and critical facilities handled fissionable fuels with various enrichments, mostly compounds of uranium including carbides. They also handled relatively small quantities of plutonium and thorium with the exception of Buildings 4023, 4029, 4030, and 4363. AI did not perform separations of irradiated fuel and, therefore, there were minimal gross fission product problems. AI did declad some fuels in the hot cells, which resulted in considerable quantities of those fission products with high fission yields (e.g., ^{90}Sr and ^{137}Cs). There was some ^{152}Eu and ^{154}Eu along with some ^{3}H. Tables 6-2 and 6-3 list the facilities and related data.

Table 6-2. Beta and photon energies and percentages at reactors and critical facilities.

Process/ building	Description[a]	Operations Begin	Operations End	Radiation type	Energy (keV)	Percentage
All	Reactors	1956	1980	Beta	>15	100
				Photons	30–250	25
					>250	75
4143	SRE reactor	1957	1964	Beta	>15	100
				Photons	30–250	25
					>250	75
4010	SNAP Experimental Reactor and SNAP 8 Development ReactorS8ER	1959	1965	Beta	>15	100
				Photons	30–250	25
					>250	75
4024	SNAP 2 Development ReactorS2DR	1961	1962	Beta	>15	100
	SNAP 10 Flight Simulation ReactorS10FS3	1965	1966	Photons	30–250	25
	SNAP test facilities	1971	1971		>250	75
4028	Shield Test Reactor and Shield Test and Irradiation ReactorSTIR	1961	1972	Beta	>15	100
				Photons	30–250	25
					>250	75
4059	SNAP 8 Development ReactorS8DR	1968	1969	Beta	>15	100
				Photons	30–250	25
					>250	75
4009	Organic Moderated ReactorOMR, and Sodium Graphite ReactorSGR	1958	1967	Beta	>15	100
				Photons	30–250	25
					>250	75
4100	Advanced Epithermal Thorium ReactorAETR	1960	1974	Beta	>15	100
				Photons (thorium)	30–250	25
					>250	75

a. SNAP = Systems for Nuclear Auxiliary Power; SRE = Sodium Reactor Experiment.

6.4 NEUTRON RADIATIONS AND PERCENTAGES

Table 6-4 lists facilities with neutron radiations. They are reactors, accelerators, and fuel storage facilities. The table includes Buildings 4005 and 4064, the plutonium fuel storage facilities, buildings 4005, which were used for Pu storage, from 1967- to 1987 and 4064 from 1958- to 1993, respectively. However, these facilities are assumed to be a negligible contributor to neutron doses due to the limited quantities of fuel present at any one time. As near as can be determined, NTA film was incorporated in the film dosimeters if there was a potential of exposure >100 mrem in those facilities where neutron exposures were possible. How that was determined has not been found. In the dose record, there are entries in the “n” column. It is assumed that the dose recorded was the result of fast neutron exposure.

A neutron survey report of the SRE Hot Cell containing a 14-MeV neutron generator (Clow 1966) lists dose rates of 75 mrem/hr fast and 11.8 mrem/hr thermal with "the assumption that all fast neutrons are 14 MeV." Clow also states, "As further surveys are taken and the spectrum completely analyzed, the dose rates may be reduced." These surveys were done on the roof of the facility and were higher than those taken at "a window" (62.2 mrem/hr fast and 7.1 mrem/hr thermal) or "at the console" (7.1 mrem/hr fast and 2.2 mrem/hr thermal). The Van de Graaff accelerator with its D-T reaction generates 14-MeV neutrons that are quite monoenergetic in the 0° and 180° directions (Etherington 1958), which might support the assumption that all fast neutrons can be treated as 14 MeV.

Table 6-3. Beta and photon energies and percentages at support facilities.

Building	Description	Operations Begin	Operations End	Radiation	Energy (keV)	Percentages
*SRE-4003, 4163, 4041, 4654, 4689, 4653, 4606, 4773	Support facilities	1954	1964	Beta	>15	100
				Photons	30–250	25
					>250	75
*4020	Hot Laboratory	1957	1988	Beta	>15	100
				Photons	30–250	25
					>250	75
*4064	Fuel Storage	1958	1993	Beta	>15	100
				Photons	30–250	25
					>250	75
4011	Radiation Instrument Calibration Laboratory	1984	1996	Beta	>15	100
				Photons	30–250	25
					>250	75
*4021/4022	Radiation Materials Handling Facility	1959	Present	Beta	>15	100
				Photons	30–250	25
					>250	75
4100	Calibration Laboratory	1985	Present	Beta	>15	100
				Photons	30–250	25
					>250	75
4363	Mechanical Component	1956	1963	Beta	>15	100
				Photons	30–250	50
					>250	50
4029	Radioactive Measurement Laboratory	1959	1974	Beta	>15	100
				Photons	30–250	25
					>250	75
4030	Van de Graaff accelerator	1960	1964	Beta	>15	100
				Photons	30–250	25
					>250	75
4023	Liquid Metal Component Testing	1962	1986	Beta	>15	100
				Photons	30–250	50
					>250	50
*4005	Union Carbide Fuel Pilot Plant	1964	1967	Beta	>15	100
				Photons	30–250	25
					>250	75
*4055	Nuclear Materials Development Facility	1967	1979	Beta	>15	100
				Photons	30–250	25
					>250	75

*For operations involving Th-232, 1964 and 1979.

Table 6-4. Facilities, neutron energies, percentages, and correction factors.

Facility	Source	Neutron energy (MeV)	Default dose % and correction factors
Reactors	Reactors	0.1–2.0, W_{rR}=20	100% Correction factor = 1.91
Pu fuel storage Buildings. 4005 & 4064	Spontaneous fission and alpha- neutron reactions		
4030 Van de Graaff accelerator	D-T reaction	2–14 max, w_R=20	100%, correction factor = 1.32

The distribution of energies and International Commission on Radiological Protection Publication 60 conversion correction factors (ICRP 1991 and ORAUT 2006c) are also listed in Table 6-4. The correction factor for the 2- to 14-MeV energy group was calculated from data in the Y-12 TBD (ORAUT 2006a).

6.5 RECORDED DOSE PRACTICES

Recorded dose quantities at AI are given in Table 6-5 and include those provided by the site, Landauer (the site vendor), and special dosimeters (Hart 1979). The special dosimeters were processed by site personnel using site calibrations, and only the results were sent to the vendor for inclusion in the individual's total dose for that period. This could have resulted in different quantities, on occasion, from those listed in Table 6-5.

Table 6-5. Recorded dose practices.[a]

Period	Dosimeter measured quantities	Compliance dose quantities[b]
1954–1962 + NTA film	Beta = OW, mrem[c] Photon (P), mR Fast Neutron (FN), mrem	Skin = OW + P WB = P + FN
1963–1984 Landauer + NTA film	Beta (B) or nonpenetrating, mR Photon (P), mR Fast Neutron (FN), mrem	Skin = (B) + P WB = B + P + FN WB = 0.15 (B-X-ray) + P + FN[d]
1985–present	Nonpenetrating (Npen) Penetrating (Pen) Fast Neutron (FN)	Skin = Npen + WB[e] WB = Pen + neutrons[e]

a. OW = open window.
b. Before 1985, the Landauer assessment or calibration quantity was the roentgen at the surface of the body. In 1985, Landauer switched to International Commission on Radiation Units and Measurements tissue doses to incorporate American National Standards Institute Standard N 13.11 (HPS 1983) and DOE Laboratory Accreditation PerformanceProgram (DOELAP)(DOE 1986) performance testing dose quantities (Yoder 2005).
c. Garcia and Carpenter (1963 b) discusses the use of eye and gonadal shields that, if used, reduced beta values by a factor of 2.
d. Garcia and Carpenter (1963 b).
e. Garcia (1970).

Garcia and Carpenter (1963a) provided a formula for correcting beta doses measured by the special dosimeters that is different from that in Garcia (1970). The differences are not great and are limited to beta dose corrections. The differences could be the result of a change from DuPont to Kodak film, which could have occurred in the period between the two procedures. Landauer changed to Kodak film in 1968 with the introduction of its Gardray film badge (Yoder 2005).

6.6 INTERPRETATION OF REPORTED DOSES

Table 6-6 summarizes the guidance on the interpretation of reported doses. Personnel doses from Landauer before 1985 were reported in milliroentgen as either penetrating (photon) or nonpenetrating (beta) exposure if beta activity was present. The reported total values included any special dosimeter results sent by AI for that exchange period. Dose reconstructors should obtain organ doses, as needed, from *External Dose Reconstruction Implementation Guideline* (NIOSH 2002).

In general, reported doses have been corrected for background using site-furnished controls. The controls were dosimeters at locations on the site used for storing personnel dosimeters. All personnel dosimeters were stored in storage racks when workers left the site at the end of their shifts. No workers took their dosimeters home at night; all were kept at the site and, as far as could be determined, this practice was in place since startup.

The exception to background correction could occur if individual dosimeters were not exchanged in time to be included with the regular exchange because controls were sent only with each exchange batch. While this could lead to an incorrect result, that result would be favorable to claimants because it would include background and, therefore, err on the high side (Rowles 1988).

Table 6-6. Interpretation of reported dose.

Period	Reported quantity	Description	Interpretation of zeros	Interpretation of blanks (no data)	Rollup of individual and annual data[a]	Monitored/ unmonitored
1954–1960	Skin = rad WB = mR Neutrons = rem	mrad, mR, and mrem used interchangeably	MDL/2 times number of zeros	If no dosimeter for that period, treat as unmonitored.	If special dosimeters were used, include results.	All personnel expected to be exposed to >100 mrem in an exchange period were monitored.
1960–present	Skin = mrem WB = mrem Neutrons = mrem	mrem used for all	MDL/2 times number of zeros	If no dosimeter for that period, treat as unmonitored.	If special dosimeters were used, include results.	Only those >10% of current standard were monitored. Those entering controlled areas were issued a visitor dosimeter.

a. If special dosimeters were used, the results were forwarded to the vendor for inclusion in the totals for that period. It has not been determined if this was always accomplished.

6.7 ADJUSTMENTS TO RECORDED DOSE

Because most but not all penetrating photons are above 30 keV, it is suggested that an adjustment is necessary to account for the contribution to *Hp(10)* from low-energy photons from uranium and thorium. It is estimated that a correction equal to 10% of the <250-keV values should be made. However, corrections can be applied to the total WB dose by using 10% of the <250-keV value, which is 25%, for a total adjustment of 2.5%. Therefore, a correction factor of 1.025 should be applied to the total WB doses. This adjustment also increases the nonpenetrating *Hp(0.07)* dose, regardless of which dosimeter was used, because that dose was always the sum of the OW and WB doses. Table 6-7 lists these corrections.

Table 6-7. Adjustments to recorded dose.

Period	Dosimeter	Facility	Adjustments to reported dose
1954–1963	Site-specific	All facilities	Multiply reported WB dose by 1.025 to estimate *Hp(10)*.
1963–1985	Landauer	All facilities	Multiply reported WB dose by 1.025 to estimate *Hp(10)*.
1985–present	Landauer	All facilities	Same as above even with Landauer becoming certified by the National Voluntary Laboratory Accreditation Program (NVLAP).

6.8 BIAS AND UNCERTAINTY

Bias and uncertainty values were not found in any site data. The values given in Table 6-8 are from the Hanford TBD (ORAUT 2004) and should be similar to those at AI for the multielement dosimeter. These values agree with those of Landauer. In addition, AI used NTA film for its neutron dosimeter as did Y-12, so data from the Y-12 TBD were used to estimate the AI dosimeters bias and uncertainties (ORAUT 2006a). The results are an estimated error of +/- 50% at 100 mrem for the 0.1- to 2-MeV energy range and +/- ±35% for the 2- to 14-MeV range. The latter estimate was obtained using the product of the ratio of the correction factors given in Table 6-4 for the two energy ranges and the +/- 50% error. This is a reasonable assumption because most if not all the neutron energies are above 0.5 MeV.

Table 6-8. Bias and uncertainty.[a]

Site-specific dosimetry system		Bias magnitude and range		Uncertainty factors	
		Overall bias[b]	**Range in bias[c]**	**Systematic[d]**	**Random[e]**
Two element (1954–1963)		1.27	1.13–1.60	1.2	1.8
Multielement (1964–present)[f]		1.02	0.86–1.12	1.1	1.4
NTA film	2 to 14 MeV	1.5	0.50–1.50	1.5	Unknown
	0.1 to 2 MeV	1.35	0.65–1.35	1.35	Unknown

a. Values are repeated here from the Hanford External Dosimetry TBD (ORAUT 2004) because the dosimeters in use at AI are assumed to be similar.
b. Based on the most likely distribution of energy levels and geometry. Divide recorded dose by bias value to determine deep dose.
c. Range of overall bias values.
d. Systematic uncertainty due to lack of knowledge of actual distributions of energies and geometries.
e. Random uncertainty due to variation among workers in energy levels and geometry.
f. These values agree with Landauer since NVLAP certification (Yoder 2005).

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GLOSSARY

accreditation
Recognition that a dosimeter system has passed the performance criteria of the DOE Laboratory Accreditation Program (DOELAP), (DOE 1986), in specified irradiation categories or the National Voluntary Laboratory Accreditation Program (NVLAP).

accuracy
If a series of measurements has small systematic errors, they are said to have high accuracy. The accuracy is represented by the bias.

beta particle
A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Most (if not all) of the direct fission products emit (negative) beta particles. Physically, the beta particle is identical with an electron moving at high velocity.

favorable to claimants
Using a process of estimation based on technical considerations such that the estimated dose is not underestimated.

deep dose equivalent [*Hp(10)*]
The dose equivalent at the respective depth to 10 millimeters in tissue.

dose equivalent (*H*)
The product of the absorbed dose (*D*), the quality factor (*Q*), and any other modifying factors. The special unit is the rem. When *D* is expressed in gray, *H* is in seiverts (1 sievert = 100 rem.)

dosimeter
A device used to measure the quantity of radiation received. A holder with radiation-absorbing elements (filters) and an insert with radiation-sensitive elements packaged to provide a record of absorbed dose or dose equivalent received by an individual.

dosimetry system
A system used to assess dose equivalent from external radiation to the whole body, skin, or extremities. This includes the fabrication, assignment, and processing of the dosimeters as well as interpretation of the results.

exchange period (frequency)
Period (weekly, biweekly, monthly, quarterly, etc.) for routine exchange of dosimeters.

exposure
A measure expressed in roentgens of the ionization produced by gamma (or X) rays in air.

film
Generally means a "film packet" that contains one or more pieces of film in a light-tight wrapping. The film when developed has an image caused by radiation that can be measured using an optical densitometer.

film dosimeter
A small packet of film within a holder that attaches to a worker.

filter
Material used to adjust radiation response of a dosimeter to provide an improved tissue equivalent or dose response.

gamma rays
Electromagnetic radiation (photons) originating in atomic nuclei and accompanying many nuclear reactions (e.g. fission, radioactive decay, and neutron capture). Physically, gamma rays are identical to X-rays of high energy, the only essential difference being that X-rays do not originate in the nucleus.

ionizing radiation
Electromagnetic radiation (consisting of photons or particulate radiation consisting of electrons, neutrons, protons, etc.) capable of producing charged particles through interactions with matter.

neutron
A basic particle that is electrically neutral weighing nearly the same as the hydrogen atom.

nonpenetrating dose [*Hp(0.07)*]
Designation (i.e., NP or NPen) on film dosimeter reports that implies a radiation dose, typically to the skin of the whole body, from beta and lower energy photon radiation.

open window (OW)
Designation on a dosimeter that implies the use of little or no shielding. It commonly is used to label the film response corresponding to the open window area.

penetrating dose [*Hp(10)*]
Designation (i.e. P, Pen, or Neutrons and Gamma) on a dosimeter of the dose recorded at depth of 10 millimeters.

personal dose equivalent [*Hp(d)*]
Radiation quantity recommended for use as the operational quantity to be recorded for radiological protection purposes by the International Commission on Radiological Units and Measurements. The personal dose equivalent is represented by *Hp(d)*, where *d* identifies the depth in millimeters and represents the point of reference for dose in tissue. For weakly penetrating radiation of significance to skin dose, *d* = 0.07 millimeter and is noted as *Hp(0.07)*. For penetrating radiation of significance to whole-body dose, *d* = 10 millimeters and is noted as *Hp(10)*.

photon
A unit of electromagnetic radiation consisting of X- and/or gamma rays.

PM
A procedure detailing specific actions or directions and usually limited to one service or activity.

rad
A unit of absorbed dose equal to the absorption of 100 ergs per gram of absorbing material such as body tissue.

radioactivity
The spontaneous emission of radiation, generally alpha or beta particles, gamma rays, and neutrons from unstable nuclei.

rem
A unit of dose equivalent in human tissue equal to the product of the number of rads and the quality factor and any other modifying factors. The word derives from roentgen equivalent in man.

rep
Historically, used extensively for the specification of permissible doses of ionizing radiations other that X-rays or gamma rays. Several definitions have appeared in the literature but the most widely adopted is a unit of absorbed dose with a magnitude equal to 93 ergs per gram. The word derives from roentgen equivalent physical.

roentgen
A unit of exposure to gamma or X-rays. It is defined precisely as the quantity of gamma (or X) rays that will produce a total charge of 2.58×10^{-4} coulomb in 1 kilogram of dry air. An exposure of 1 roentgen is approximately equivalent to an absorbed dose of 1 rad in soft tissue.

sievert
The International System unit for dose equivalent (1 sievert = 100 rem).

skin dose
Absorbed dose at a tissue depth of 0.07 millimeters (7 milligrams per square centimeter).

tissue equivalent
Term used to imply that the radiation response of the material being irradiated is equivalent to tissue.

whole-body dose
Commonly defined as the absorbed dose at a tissue depth of 10 millimeters (1,000 milligrams per square centimeter); also used to refer to the “dose of record.”

X-ray
Ionizing electromagnetic radiation of extra-nuclear origin.