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Project for NIOSH

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ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
DNA	Defense Nuclear Agency
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
ft	foot
in	inch
km	kilometer
kt	kiloton
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
mi	mile
MDL	Minimium Detection Limit
MPE	Maximum Permissible Exposure
Mt	megaton
NIOSH	National Institute for Occupational Safety and Health
NTS	Nevada Test Site
POC	probability of causation
PPG	Pacific Proving Ground
R	roentgen
SEC	Special Exposure Cohort
SNL	Sandia National Laboratory
TBD	technical basis document
U.S.C.	United States Code
yd	yard
§	section

1.0 INTRODUCTION

Technical basis documents (TBDs) 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 at 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 the 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 or SEC). 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 POC 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.

1.1 PURPOSE

The purpose of this document is to provide guidance for dose reconstruction of non-SEC cancers and those presumptive cancer claims that have less than 250 days of employment for EEOICPA claimants who participated in Pacific Proving Ground (PPG) operations.

An SEC class established for the PPG includes all employees of DOE, DOE contractors, or subcontractors who worked at the PPG from 1946 through 1962 who were monitored or should have been monitored for exposure to ionizing radiation as a result of nuclear weapons testing at the PPG (NIOSH 2005). This SEC applies to workers with covered cancers who were employed for a number of workdays, aggregating at least 250 workdays occurring either solely under this employment or in combination with workdays within the parameters (excluding aggregate workday requirements) established for other classes of employees included in the SEC.

1.2 SCOPE

This site profile consists of six sections: Introduction, Site Description, Occupational Medical Dose, Occupational Environmental Dose, Occupational Internal Dose, and Occupational External Dosimetry.

2.0 SITE DESCRIPTION

Between 1945 and 1962, the U.S. Atomic Energy Commission (AEC; a DOE predecessor agency) conducted 105 atmospheric and underwater nuclear weapon tests at sites at the PPG (DOE 2000). In the Pacific, 29 atolls and 5 islands spread over 770,000 mi^2 with a total land area of about 70 mi^2 comprise the Marshall Islands. Enewetak Atoll, Bikini Atoll, Johnston Island, and Christmas Island in the Marshall Islands are known as the PPG (NIOSH 2005).

Oceanic nuclear testing by the United States consisted mostly of the unconfined detonation of nuclear devices in the atmosphere. An operation includes one or more individual tests, typically designed and conducted for a common purpose. Table 2-1 summarizes the PPG tests, including test name, date, sponsor(s), location, type, purpose, and yield.

Personnel who worked on the PPG tests were based at various DOE sites and traveled to the test location for part or all of an operation. Los Alamos National Laboratory (LANL, previously known as the Los Alamos Scientific Laboratory), Lawrence Livermore National Laboratory (LLNL, previously known as the University of California Research Laboratory), Sandia National Laboratory (SNL, previously known as Sandia Corporation), and the Nevada Test Site (NTS) were the employers for most civilian participants during the various operations. However, other sites in the DOE complex and their contractors (Edgerton, Germeshausen and Grier (EG&G) and Holmes and Narver (H&N) for example) also provided civilian participants.

3.0 OCCUPATIONAL MEDICAL DOSE

Multiple organizations based at various sites in the DOE complex sponsored and took part in the various operations. Based on records provided by DOE, the dose reconstructor must, if possible, determine the facility in the complex with which the employee was associated during participation in an oceanic test or operation.

Table 2-1. PPG tests.[a]

Test	Date[b]	Sponsor	Location	Type	Purpose	Yield
Operation Crossroads – To determine effects on ships						
Able	6/30/46	LANL/DOD	Bikini	Airdrop	Weapons effects	21 kt
Baker	7/24/46	LANL/DOD	Bikini	Underwater	Weapons effects	21 kt
Operation Sandstone - AEC scientific tests to proof-test improved design						
X-ray	4/14/48	LANL	Enewetak	Tower	Weapons related	37 kt
Yoke	4/30/48	LANL	Enewetak	Tower	Weapons related	49 kt
Zebra	5/14/48	LANL	Enewetak	Tower	Weapons related	18 kt
Operation Greenhouse - Thermonuclear weapon development and observation of physical and biological effects of nuclear weapons						
Dog	4/7/51	LANL	Enewetak	Tower	Weapons related	81 kt
Easy	4/20/51	LANL	Enewetak	Tower	Weapons related	47 kt
George	5/8/51	LANL	Enewetak	Tower	Weapons related	225 kt
Item	5/24/51	LANL	Enewetak	Tower	Weapons related	45.5 kt
Operation Ivy - Thermonuclear weapon development						
Mike	10/31/52	LANL	Enewetak	Surface	Weapons related	10.4 Mt
King	11/15/52	LANL	Enewetak	Airdrop	Weapons related	500 kt
Operation Castle - To gage military effects of the explosions (i.e., measure power and efficiency of devices)						
Bravo	2/28/54	LANL	Bikini	Surface	Weapons related	15 Mt
Romeo	3/26/54	LANL	Bikini	Barge	Weapons related	11 Mt
Koon	4/6/54	LLNL	Bikini	Surface	Weapons related	110 kt
Union	4/25/54	LANL	Bikini	Barge	Weapons related	6.9 Mt
Yankee	5/4/54	LANL	Bikini	Barge	Weapons related	13.5 Mt
Nectar	5/13/54	LANL	Enewetak	Barge	Weapons related	1.69 Mt
Operation Wigwam[c] – To determine lethal distances for nuclear effects vs. submerged submarines; one detonation was conducted in 16,000 ft of water						
Wigwam[c]	5/14/55	LANL/DOD	Pacific	Underwater	Weapons effects	30 kt
Operation Redwing – High-yield thermonuclear tests to gage military effects and measure power and efficiency of devices						
Lacrosse	5/4/56	LANL	Enewetak	Surface	Weapons related	40 kt
Cherokee	5/20/56	LANL	Bikini	Airdrop	Weapons related	3.8 Mt
Zuni	5/27/56	LLNL	Bikini	Surface	Weapons related	3.5 Mt
Yuma	5/27/56	LLNL	Enewetak	Tower	Weapons related	190 tons
Erie	5/30/56	LANL	Enewetak	Tower	Weapons related	14.9 kt
Seminole	6/6/56	LANL	Enewetak	Surface	Weapons related	13.7 kt
Flathead	6/11/56	LANL	Bikini	Barge	Weapons related	365 kt
Blackfoot	6/11/56	LANL	Enewetak	Tower	Weapons related	8 kt
Kickapoo	6/13/56	LLNL	Enewetak	Tower	Weapons related	1.49 kt
Osage	6/16/56	LANL	Enewetak	Airdrop	Weapons related	1.7 kt
Inca	6/21/56	LLNL	Enewetak	Tower	Weapons related	15.2 kt
Dakota	6/25/56	LANL	Bikini	Barge	Weapons related	1.1 Mt
Mohawk	7/2/56	LLNL	Enewetak	Tower	Weapons related	360 kt
Apache	7/8/56	LLNL	Enewetak	Barge	Weapons related	1.85 Mt
Navajo	7/10/56	LANL	Bikini	Barge	Weapons related	4.5 Mt
Tewa	7/20/56	LLNL	Bikini	Barge	Weapons related	5 Mt
Huron	7/20/56	LANL	Enewetak	Barge	Weapons related	250 kt
Hardtack I - Three parts to test: (1) continued development of nuclear weapons with detonation of experimental devices from various AEC laboratories, (2) underwater tests to improve understanding of effects on underwater explosions on ships and material, and (3) nuclear weapons in air and ballistic missile defense (first high-yield rocket tests)						

Table 2-1 (Continued). PPG tests.[a]

Test	Date[b]	Sponsor	Location	Type	Purpose	Yield
Yucca (Operation Newsreel)	4/28/58	LANL/DOD	Pacific	Balloon	Weapons effects	1.7 kt
Cactus	5/5/58	LANL	Enewetak	Surface	Weapons effects	18 kt
Fir	5/11/58	LLNL	Bikini	Barge	Weapons related	1.36 Mt
Butternut	5/11/58	LANL	Enewetak	Barge	Weapons related	81 kt
Koa	5/12/58	LANL	Enewetak	Surface	Weapons related	1.37 Mt
Wahoo	5/16/58	LANL/DOD	Enewetak	Underwater	Weapons related	9 kt
Holly	5/20/58	LANL	Enewetak	Barge	Weapons related	5.9 kt
Nutmeg	5/21/58	LLNL	Bikini	Barge	Weapons related	25.1 kt
Yellowwood	5/26/58	LANL	Enewetak	Barge	Weapons related	330 kt
Magnolia	5/26/58	LANL	Enewetak	Barge	Weapons related	57 kt
Tobacco	5/30/58	LANL	Enewetak	Barge	Weapons related	11.6 kt
Sycamore	5/31/58	LLNL	Bikini	Barge	Weapons related	92 kt
Rose	6/2/58	LANL	Enewetak	Barge	Weapons related	15 kt
Umbrella	6/8/58	LANL/DOD	Enewetak	Underwater	Weapons effects	8 kt
Maple	6/10/58	LLNL	Bikini	Barge	Weapons related	213 kt
Aspen	6/14/58	LLNL	Bikini	Barge	Weapons related	319 kt
Walnut	6/14/58	LANL	Enewetak	Barge	Weapons related	1.45 Mt
Linden	6/18/58	LANL	Enewetak	Barge	Weapons related	11 kt
Redwood	6/27/58	LLNL	Bikini	Barge	Weapons related	412 kt
Elder	6/27/58	LANL	Enewetak	Barge	Weapons related	880 kt
Oak	6/28/59	LANL	Enewetak	Barge	Weapons related	8.9 Mt
Hickory	6/29/58	LLNL	Bikini	Barge	Weapons related	14 kt
Sequoia	7/1/58	LANL	Enewetak	Barge	Weapons related	5.2 kt
Cedar	7/2/58	LLNL	Bikini	Barge	Weapons related	220 kt
Dogwood	7/5/58	LLNL	Enewetak	Barge	Weapons related	397 kt
Poplar	7/12/58	LLNL	Bikini	Barge	Weapons related	9.3 Mt
Scaevola	7/14/58	LANL	Enewetak	Barge	Safety experiment	0
Pisonia	7/17/58	LANL	Enewetak	Barge	Weapons related	225 kt
Juniper	7/22/58	LLNL	Bikini	Barge	Weapons related	65 kt
Olive	7/22/58	LLNL	Enewetak	Barge	Weapons related	202 kt
Pine	7/26/58	LLNL	Enewetak	Barge	Weapons related	2 Mt
Teak (Operation Newsreel)	8/1/58	LANL/DOD	Johnston	Rocket	Weapons effects	3.8 Mt
Quince	8/6/58	LLNL/DOD	Enewetak	Surface	Weapons related	0
Orange (Operation Newsreel)	8/12/58	LANL/DOD	Johnston	Rocket	Weapons effects	3.8 Mt
Fig	8/18/58	LLNL/DOD	Enewetak	Surface	Weapons related	20 tons
Argus[c] - Tests in upper regions of atmosphere to test Christofilos theory, which argued that high-altitude nuclear detonations would create radiation belt in upper regions of Earth's atmosphere that would include degradation of radio and radar transmissions, etc.						
Argus I[c]	8/27/58	LANL/DOD	S. Atlantic	Rocket	Weapons effects	1-2 kt
Argus II[c]	8/30/58	LANL/DOD	S. Atlantic	Rocket	Weapons effects	1-2 kt
Argus III[c]	9/6/58	LANL/DOD	S. Atlantic	Rocket	Weapons effects	1-2 kt
Dominic - Primarily high-altitude air bursts with little fallout						
Adobe	4/25/62	LANL	Christmas	Airdrop	Weapons related	190 kt
Aztec	4/27/62	LANL	Christmas	Airdrop	Weapons related	410 kt
Arkansas	5/2/62	LLNL	Christmas	Airdrop	Weapons related	1.09 Mt
Questa	5/4/62	LANL	Christmas	Airdrop	Weapons related	670 kt
Frigate Bird	5/6/62	LLNL/DOD	Pacific	Rocket	Weapons related	200-1,000 kt

Table 2-1 (Continued). PPG tests.[a]

Test	Date[b]	Sponsor	Location	Type	Purpose	Yield
Yukon	5/8/62	LLNL	Christmas	Airdrop	Weapons related	Low
Mesilla	5/9/62	LANL	Christmas	Airdrop	Weapons related	100 kt
Muskegon	5/11/62	LLNL	Christmas	Airdrop	Weapons related	100 kt
Swordfish	5/11/62	LANL/DOD	Pacific	Underwater	Weapons effects	Low
Encino	5/12/62	LANL	Christmas	Airdrop	Weapons related	500 kt
Swanee	5/14/62	LLNL	Christmas	Airdrop	Weapons related	97 kt
Chetco	5/19/62	LLNL	Christmas	Airdrop	Weapons related	73 kt
Tanana	5/25/62	LLNL	Christmas	Airdrop	Weapons related	2.6 kt
Nambe	5/27/62	LANL	Christmas	Airdrop	Weapons related	43 kt
Alma	6/8/62	LANL	Christmas	Airdrop	Weapons related	782 kt
Truckee	6/9/62	LLNL	Christmas	Airdrop	Weapons related	210 kt
Yeso	6/10/62	LANL	Christmas	Airdrop	Weapons related	3 Mt
Harlem	6/12/62	LLNL	Christmas	Airdrop	Weapons related	1.2 Mt
Rinconada	6/15/62	LANL	Christmas	Airdrop	Weapons related	800 kt
Dulce	6/17/62	LANL	Christmas	Airdrop	Weapons related	52 kt
Petit	6/19/62	LLNL	Christmas	Airdrop	Weapons related	2.2 kt
Otowi	6/22/62	LANL	Christmas	Airdrop	Weapons related	81.5 kt
Bighorn	6/27/62	LLNL	Christmas	Airdrop	Weapons related	7.65 Mt
Bluestone	6/30/62	LLNL	Christmas	Airdrop	Weapons related	1.27 Mt
Operations Fishbowl and Dominic (AKA Dominic I)						
Starfish Prime (Operation Fishbowl)	7/9/62	LANL/DOD	Johnston	Rocket	Weapons effects	1.4 Mt
Sunset (Operation Dominic)	7/10/62	LANL	Christmas	Airdrop	Weapons related	1 Mt
Pamlico (Operation Dominic)	7/11/62	LLNL	Christmas	Airdrop	Weapons related	3.88 Mt
Androscoggin (Operation Dominic)	10/2/62	LLNL	Johnston	Airdrop	Weapons related	75 kt
Bumping (Operation Dominic)	10/6/62	LLNL	Johnston	Airdrop	Weapons related	11.3 kt
Chama (Operation Dominic)	10/18/62	LANL	Johnston	Airdrop	Weapons related	1.59 Mt
Checkmate (Operation Fishbowl)	10/20/62	LANL/DOD	Johnston	Rocket	Weapons effects	Low
Bluegill 3 Prime (Operation Fishbowl)	10/26/62	LANL/DOD	Johnston	Rocket	Weapons effects	Sub Mt
Calamity (Operation Dominic)	10/27/62	LLNL	Johnston	Airdrop	Weapons related	800 kt
Housatonic (Operation Dominic)	10/30/62	LLNL	Johnston	Airdrop	Weapons related	8.3 Mt
Kingfish (Operation Fishbowl)	11/1/62	LANL/DOD	Johnston	Rocket	Weapons effects	Sub Mt
Tightrope (Operation Fishbowl)	11/4/62	LANL/DOD	Johnston	Rocket	Weapons effects	Low

a. Prepared from DNA (1981, 1982a,b,c,d,e, 1983a,b,c, 1984); DOE (2000).
b. Greenwich Mean Time
c. This operation and its tests are not considered part of the PPG cohort.

LANL, LLNL, SNL, and NTS provided many of the civilian scientific, research, and support participants during these operations. Additionally, H&N and EG&G provided support personnel (e.g., cafeteria workers, electronics technicians, construction workers, etc.) The assignments were for all or part of an operation and lasted from 2 to 4 months for most civilian participants. Employees of some contractors, for example EG&G and H&N, were associated with more than one DOE facility. The

dose reconstructor should use the occupational medical dose TBD related to the participant's employer and associated DOE site to determine X-ray dose. For most participants, specific guidance for occupational medical dose can be found in the current published revision of:

- ORAUT-TKBS-0008-3, *Technical Basis Document for the Nevada Test Site – Occupational Medical Dose* (ORAUT 2004a)
- ORAUT-TKBS-0010-3, *Technical Basis Document for the Los Alamos National Laboratory – Occupational Medical Dose* (ORAUT 2004b)
- ORAUT-TKBS-0035-3, *Lawrence Livermore National Laboratory – Occupational Medical Dose* (ORAUT 2005a)

While these sites provided many participants, other sites across the complex also provided participants or workers may have been hired from the local population as support personnel. Other employers might have been associated with only one DOE facility or none at all. If an employee's records cannot be associated with a DOE facility for which a TBD is being developed at the time of the dose reconstruction, dose reconstructors should use the guidance in ORAUT-OTIB-0006, *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures* (ORAUT 2005b).

NIOSH concludes it is feasible to determine the maximum potential occupational medical exposures. Because most civilian participants spent the interval of the operation (or part of the operation) at the test location and then returned to the U.S, the use of site-specific information (for example, the documents listed above for NTS, LANL and LLNL), for the participant is reasonable. For other participants that were hired on location, the complex-wide documentation should be applied. The approach for applying occupational medical dose is found in *Occupational X-Ray Dose Reconstruction for DOE Sites* (ORAUT 2004c).

4.0 OCCUPATIONAL ENVIRONMENTAL DOSE

Participants with the potential for radiological exposure received dosimeters during the tests (see Table 2-2). Dose reconstructors may use the guidance in ORAUT-PROC-0060, *External On-Site Ambient Dose Reconstruction for DOE Sites* (ORAUT 2005c), to determine if external ambient dose should be applied if the participant can be clearly identified with a specific DOE complex location that is listed in Attachment A of ORAUT-PROC-0060. Starting with Operation Castle, the LANL film badge dosimetry procedures were adopted (NRC 1989). According to ORAUT-PROC-0060, external on-site ambient dose does not need to be assigned for employees monitored under LANL procedures. For unmonitored participants, coworker doses have been developed using summary data (see Attachment A).

5.0 OCCUPATIONAL INTERNAL DOSE

NIOSH determined in the *SEC Petition Evaluation Report* (NIOSH 2005) that it lacks sufficient personnel monitoring, air monitoring, or source term data to adequately reconstruct the internal exposures at the PPG (NIOSH 2005). As a consequence, NIOSH finds that it is not feasible to estimate with sufficient accuracy the radiation doses resulting from internal exposures during PPG operations.

Table 2-2. External dosimetry 1946 to 1962. [a]

Photon- beta dosimeters								
Year	**Operation**	**Dosimeter**	**Description**	**Issue and exchange**	**Routine Maximum Permissible Exposure (MPE)**	**Bias[f]**	**Uncertainty**	**Minimum Detection Limit (MDL)**
1946	Crossroads (2 events)	Dental Film Packet	Single component Type K double-emulsion dental film packet covered by 0.020-in.-thick lead cross filter. This filter was not totally effective in correcting over-response caused by photons of lower energy. Plastic envelope was used to minimize damage to film from moisture. Exposure range (0 to 2 R).	Issued to RadSafe monitors or a few RadSafe monitors in group (approximately 1 to 2 monitors with dosimeters for 100 participants – cohort badging). Also issued to aircrews. Exchanged daily but record indicates some were worn up to 9 days. Used during decontamination of ships and for unloading ammunition at Kwajalein after August 1946.	Photon exposure with objective of keeping daily exposure below 0.1 R, not to exceed 50-60 R in 2 weeks. Employee withdrawn from operation at 10 R in 1 d or 60 R in 2 weeks.	1.1	1.7	40 mR
1948	Sandstone (3 events)	Eastman Types K and A film	Type K exposure range (0.06 to 2 R). Type A exposure range (1 to 10 R). Covered by 0.020-in. thick lead cross filter. This filter was not totally effective in correcting the over-response caused by photons of lower energy. Plastic envelope was used to minimize damage to film from moisture.	Issued for single-day use to all personnel with exposure potential. (Example on 4/24/48, 9 d after test "X-ray," all participants who were expected to come closer than 530 yd of ground zero were issued dosimeters.)	Exposure to be below 0.1 R per day or 3 R for certain missions	1.1	1.8	60 mR
1951	Greenhouse (4 events)	DuPont 553 Packet	DuPont 553 packet, including Type 502 low-range element (0.05 to 10 R), Type 510 high-range element (1 to 50 R), and Type 606 high-range element (10 to 300 R). No measurable density above background was reported for Type 606 element. Lead filters, 0.020-in. thick. This filter was not totally effective in correcting over-response caused by photons of lower energy.	Cohort, air crews, and ground crews maintaining contaminated air craft. Originally recorded dose likely reflects subtraction for fallout.	3.9 R per 13 weeks; 0.1 R per day not to exceed 0.7 R/week	1.1	1.9	40 mR
1952	Ivy (2 events)	DuPont 558 Packet	DuPont 558 packet, including Type 508 low-range element (0.05 to 10 R) and Type 1290 high-range element (10 to 750 R). Lead filters, 0.020-in thick. This filter was not totally effective in correcting over-response caused by photons of lower energy.	Issued to aircrews, ground crews assigned to working on contaminated aircraft, and reentry parties. Badges were usually issued on mission basis and worn for approximately 1 day.	3.9 R per operation for gamma only	1.1	1.5[b]	40 mR
1954	Castle (6 events)	DuPont 509 Packet	DuPont 509 packet, including Type 502 low-range element (0.02 to 10 R) and Type 606 high-range element (10 to 300 R). Lead filters, 0.028-in. thick, (symmetrical coverage on both sides with open area). This change in thickness from previous filter caused 20% change in response to 120 and 70 keV photons.	Issued to all aircrews in air at H-hr within 185 km of the shot site. Also, all participants likely to receive a significant amount of radiation exposure and a representative 10% of other personnel.	3.9 R per 13 weeks augmented with 0.3 R per week after that	1.0	2.1	40 mR
1955	Wigwam[g] (1 event)	DuPont 559 Packet	DuPont 559 Packet, including Type 502 low-range element (0.02 to 10 R) and Type 606 high-range element (10 to 300 R). Lead filters, 0.028-in thick (symmetrical coverage on both sides with open area).	Issued to almost all participates with extra exchanges for those participants involved in post test sampling and recovery of test instruments. Badge indicated beta to gamma ratios ranged from 1:1 to 3:1.	3.5 R per operation; 20 R per operation hands and feet	1.0	1.4	40 mR

Table 2-2 (Continued). External dosimetry 1946 to 1962. [a]

Photon- beta dosimeters								
Year	**Operation**	**Dosimeter**	**Description**	**Issue and exchange**	**Routine MPE**	**Bias**	**Uncertainty**	**MDL**
1956	Redwing (17 events)	DuPont 559 Packet	DuPont 559 Packet, including Type 502 low - range element (0.02 to 10 R) and Type 606 high-range element (10 to 300 R). Lead filters, 0.028-in thick (symmetrical coverage on both sides with open area).	Permanent badges were issued to all participants. Cellulose acetate holder was found to be defective, so after first 6 weeks film packets were dipped in ceresin wax to keep out moisture. Mission badges (exchanged daily) were issued to personnel entering contaminated areas.	3.9 R per 13 weeks	1.0	1.5	40 mrem
1958	Hardtack and Newsreel (35 events)	DuPont 559 Packet	DuPont 559 Packet, including Type 502 low - range element (0.02 to 10 R) and Type 834 high-range element (5 to 800 R). Lead filters, 0.028-in. thick (symmetrical coverage on both sides with open area). Film was wax covered and housed in rigid polyvinylchloride case. Designed to be worn for several months, no significant failure observed with up to 6 months of use.	Film badges were called in at 60-day intervals. All participants were to wear dosimetry at all times.	3.75 R per 13 weeks; 5 R for operation	1.2	1.4	40 mR
1958	Argus [g] (3 events)	DuPont 559 Packet[d]	Uncertain on which film badge was used. Possibly same as Operation Plumbbob at NTS (i.e., Type 502 low-range element (0.02 to 10 R) and Type 606 high-range element (10 to 300 R)).	4,000 film badges were provided, however due to classified nature of tests only 264 film badges were assigned, all to personnel with knowledge of the tests. No records of the dosimetry are available. Highest exposure recorded by individual's packet was 0.010 R.	3 rem per 13 weeks & 5(N-18)[c] rem per year[e]	1.09[d]	1.4[d]	40 mR
1962	Dominic (AKA Dominic I) and Fishbowl (36 events)	DuPont 556 Packet	DuPont 556 Packet, including Type 508 low - range element (0.02 to 10 R) and Type 834 high-range element (5 to 800 R). Lead filters, 0.028-in. thick (symmetrical coverage on both sides with open area). Film was wax covered and housed in rigid polyvinylchloride case.	Air crews and all participants with exception of certain remote locations.	3 rem per 13 weeks & 5(N-18) rem per year	1.2	1.4	40 mR

a. Prepared from DNA (1981, 1982a,b,c,d,e, 1983a,b,c, 1984); and NRC 1989.
b. Bias is 1.4 for flight personnel.
c. N equals the age of the participant.
d. Information is from Operation Plumbbob conducted at NTS.
e. Routine MPE is from IEER 2006.
f. For the purpose of providing an assignment of dose that is favorable to claimants, the bias will default to 1.
g. This test is not considered part of the PPG cohort. These data should be used to estimate dose only if this oceanic testing location is recognized as a covered DOE facility.

6.0 OCCUPATIONAL EXTERNAL DOSE

A review of the records provided by DOE and application of the operation-specific parameters listed in Table 2-2 will provide a dose estimate for the employee. The assignment of unmonitored dose to participants who did not receive a dosimeter should be evaluated. NIOSH considers the available data and methods adequate for performing external photon dose reconstruction at the PPG. NIOSH determined in the *SEC Petition Evaluation Report* (NIOSH 2005) that it lacks sufficient information to adequately reconstruct neutron doses at the PPG. The following specific guidance is provided for external dose reconstruction:

Energy distribution:	Assume an energy distribution of 100% 30-250 keV for photons. This is very favorable to claimants since it is likely that participants present during the events were exposed to photons >250 keV. Beta dose was not evaluated on the film dosimeters used during these operations. Beta-to-gamma ratios would be consistent with the guidance in the NTS TBD where atmospheric testing also occurred.
Missed dose:	Assign missed dose based on the number of exchanges found in the dosimetry records. During these tests there were operation badges that were worn for the entire test sequence or some other established interval of the operation and there were mission badges that were worn for the duration of a specific task. Since both badges were to be worn at the same time, only one zero should be assigned.
Uncertainty and bias:	Assign uncertainty to the measured photon dose. As an assignment that is favorable to claimants, bias has been defaulted to 1.0 for both the missed and measured doses. According to the information in Film *Badge Dosimetry in Atmospheric Nuclear Tests*, the dose of record was to be divided by the bias, however it is favorable to claimants to assign as discussed above.

7.0 SUMMARY

This site profile provides guidance for dose reconstruction of non-SEC cancers and those presumptive cancer claims that represent less than 250 days of employment for EEOICPA claimants who worked at the PPG. NIOSH finds that the external monitoring records and operational histories available are sufficient to complete photon and beta external dose reconstructions for these employees. Dose reconstructors should use existing NIOSH TBDs and procedures to estimate possible occupational medical exposures. Environmental dose should not be assigned to monitored workers starting with Operation Castle and the institution of LANL procedures regarding the processing of film dosimetry. Exceptions to this guidance are discussed in Section 4. NIOSH lacks access to source term data, bioassay data, or internal monitoring data to estimate internal doses associated with potential inhalation of radionuclides.

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ATTACHMENT A

The following information is available in the DNA radiation reports for the various PPG Operations. Using this summary data provided in the reports, the mid-point of each distribution has been determined and then multiplied by the number of non-DOD participants or badges (for the Crossroads data) that hypothetically received that mid-point dose. The midpoint for the last distribution was calculated using the highest dose as an end point. These were summed across all distributions and then divided by the total. This provides a 50% dose for each operation that can be used as co-worker dose, until such time as co-worker data is available.

50% dose = ? (A_n* B_n) / C

A = midpoint of each distribution
B = total non-DOD participants or badges within the distribution
C = total non-DOD participants or badges

Crossroads – Actual Film Badge Readings (R gamma)

Month	Total Badges	0 (R)	0.001 – 0.1 (R)	0.101 – 1.0 (R)	1.001 – 10 (R)
July totals	3767	2843	689	232	3
% of Badges	100	75	18	6	<0.1
August totals	6664	3947	2139	570	8
% of Badges	100	59	32	9	0.1

Highest dose during Crossroads Operation was to a radiation safety monitor at 3.72 R.

Calculated dose at 50% is 0.118 rem

Sandstone – Film Badge Readings (R gamma) for non-DOD participants (119 participants badged)

April/May	0 (R)	0.001 – 1 (R)	1 – 2 (R)	>2 (R)
Total non-DOD participants	18	83	6	12

Eleven individuals from the Rad Safe group received doses above the imposed standard of 3 R. The highest dose received was 17 R. The average dose for all participants (including DOD) was 0.25 R with 65% receiving a zero recorded exposure.

Calculated dose at 50% is 1.383 rem.

Greenhouse – Film Badge Readings (R gamma) for non-DOD participants (551 participants badged)

April/May	0 (R)	0.001 – 1 (R)	1 – 3 (R)	>3 (R)
Total non-DOD participants	110	325	82	34

The average dose was 0.5 R. The highest dose received was 8.6 R.

Calculated dose at 50% is 0.950 rem.

Ivy – Film Badge Readings (R gamma) for non-DOD participants (367 participants badged)

November	0 (R)	0.001 – 0.999 (R)	1 – 2.999 (R)	>3 (R)
Total non-DOD participants	45	245	74	3

90% of all exposures were less than 1 R for Operation Ivy. The highest dose received was 3.2 R.

Calculated dose at 50% is 0.762 rem.

Castle – Film Badge Readings (R gamma) for non-DOD participants (2175 participants badged)

March/April/May	0 (R)	0.001 – 1 (R)	1.001 – 3 (R)	3.001 – 5 (R)	5.001 – 10 (R)
Total non-DOD participants	86	1221	323	292	81

The average dose was 1.7R for Operation Castle.

Calculated dose at 50% is 1.394 rem.

Wigwam – Film Badge Readings (R gamma) for all participants (146 non-DOD participants badged)
NOTE: This test is not considered part of the PPG cohort. These data should be used to estimate dose only if this oceanic testing location is recognized as a covered DOE facility.

May	0 (R)	0.1 – 0.165 (R)	0.2 - 0.280 (R)	0.315 – 0.385 (R)	0.425 (R)
Total non-DOD participants	6141	329	19	13	1

Average non-zero exposure was 0.129 R for Operation Wigwam. Some badges were not available.

Calculated dose at 50% is 0.055 rem.

Redwing – Film Badge Readings (R gamma) for all participants (3847 non-DOD participants badged)

May - July	0 (R)	0.001 – 0.999 (R)	1 – 2.999 (R)	3 – 4.999 (R)	5 – 9.999 (R)
Total non-DOD participants	426	1237	844	1038	2224

Average non-zero exposure was 1.7 R for Operation Redwing. Some badges were not available. Highest dose to a non-DOD participant was 6.8 R.

Calculated dose at 50% is 2.115 rem.

Hardtack I – Film Badge Readings (R gamma) for all participants (5067 non-DOD participants badged)

April - August	0 (R)	0.001 – 0.999 (R)	1 – 2.999 (R)	3 – 4.999 (R)	5 – 9.999 (R)
Total non-DOD participants	1050	1623	2266	126	2

Average non-zero exposure was 0.87 R for Operation Hardtack. Highest dose to a non-DOD participant was 5.26 R.

Calculated dose at 50% is 1.877 rem.

Dominic I – Film Badge Readings (R gamma) for all participants (4620 non-DOD participants badged)

April - August	0 (R)	0 – 1 (R)	1 – 3 (R)	>3 (R)
Total non-DOD participants	2041	2555	23	1

Over all mean exposure of 0.2 R for Operation Dominic. Highest dose to a non-DOD participant was 7.15 R.

Calculated dose at 50% is 0.288 rem.

The data are found in the fact sheets associated with the various Operations.

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