ORAU Team **Dose Reconstruction Project for NIOSH** Technical Basis Document for the Argonne National Laboratory–West – Site Description	Document Number: ORAUT-TKBS-0026-2 Effective Date: 09/09/2004 Revision No.: 00 Controlled Copy No.: _____ Page 1 of 24
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TABLE OF CONTENTS

Section Page

Record of Issue/Revisions 3

Acronyms and Abbreviations 4

2.1 Introduction ANL-West, February 1951 to present 7

2.2 Experimental Breeder Reactor No. I, April 1951 to December 30, 1963 8

2.3 Boiling Water Reactor Experiment No. 1, Late 1953 to July 22, 1954 10

2.4 Boiling Water Reactor Experiment No. 2, October 19, 1954, to March 1955 11

2.5 Boiling Water Reactor Experiment No. 3, June 9, 1955, to December 1956 11

2.6 Boiling Water Reactor Experiment No. 4, December 3, 1956, to June 1958 11

2.7 Boiling Water Reactor Experiment No. 5, February 9, 1962 to September 1964 12

2.8 Zero Power Reactor No. 3, October 1955 to November 1970 12

2.9 Argonne Fast Source Reactor, October 29, 1959, to Late 1970 13

2.10 Transient Reactor Test Facility, February 23, 1958, to April 1994 13

2.11 Experimental Breeder Reactor No. II, May 1961 to September 30, 1994 14

2.12 Hot Fuel Examination Facility, 1964 to Present 14

2.13 Zero Power Physics (Plutonium) Reactor, April 18, 1969 to April 1992 (standby) 15

2.14 Neutron Radiography Facility, October 1, 1977 to present 15

2.15 Fuel Assembly and Storage Building, 1970 to present 16

2.16 Other ANL-West Support Facilities 16

References 18

Glossary 19

LIST OF TABLES

Table Page

2-1 Radionuclides of concern for all reactors 10

LIST OF FIGURES

Figure Page

2-1 Map of the Idaho National Engineering and Environmental Laboratory 9

RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
Draft	06/21/2004	00-A	New technical basis document for the ANL-W Site Facilities and Processes. Initiated by Norman D. Rohrig.
Draft	08/17/2004	00-B	Incorporates NIOSH review comments. Initiated by Norman D. Rohrig.
09/09/2004	09/09/2004	00	First approved issue. Initiated by Norman D. Rohrig.

ACRONYMS AND ABBREVIATIONS

α	alpha particle
AEC	Atomic Energy Commission
AFSR	Argonne Fast Source Reactor
AL	Analytical Laboratory
ANL	Argonne National Laboratory
ANL-E	Argonne National Laboratory East
ANL-W	Argonne National Laboratory West
ARA	Army Reactor Area (later Auxiliary Reactor Area)
β	beta particle
BORAX	Boiling Water Reactor Experiment
BORAX I	Boiling Water Reactor Experiment No. 1
BORAX II	Boiling Water Reactor Experiment No. 2
BORAX III	Boiling Water Reactor Experiment No. 3
BORAX IV	Boiling Water Reactor Experiment No. 4
BORAX V	Boiling Water Reactor Experiment No. 5
BWR	boiling-water reactor
C	Celsius/centigrade
CAM	continuous air monitor
CFA	Central Facilities Area
c/m	counts per minute
CTF	Core Test Facility
DOE	U.S. Department of Energy
DOE-ID	DOE-Idaho Operations Office
DOELAP	DOE Laboratory Accreditation Program
DU	depleted uranium
EBR-I	Experimental Breeder Reactor No. I
EBR-II	Experimental Breeder Reactor No.II
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
EFS	Experimental Field Station
F	Fahrenheit
FASB	Fuel Assembly and Storage Building
FMF	Fuel Manufacturing Facility
γ	gamma
HFEF	Hot Fuel Examination Facility
ICPP	Idaho Chemical Processing Plant
IWP	Industrial Waste Pond
IET	Initial Engine Test
IFR	Integral Fast Reactor
IMBA	Integrated Modules for Bioassay Analysis
INL	Idaho National Laboratory
INEL	Idaho National Engineering Laboratory

INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Complex
IREP	Interactive RadioEpidemiological Program
IWP	Industrial Waste Pond
kW	kilowatt
MAP	mixed activation products
MFP	mixed fission products
mR	milliroentgen
mrem	millirem
MW	megawatt
NaK	sodium potassium
N_f	neutron flux-fast
NIOSH	National Institute for Occupational Safety and Health
NRAD	Neutron Radiography Facility
NRF	Naval Reactors Facility
NRTS	National Reactor Testing Station
OCAS	(NIOSH) Office of Compensation Analysis and Support
ORAU	Oak Ridge Associated Universities
PIC	Pocket Ionization Chamber (i.e., "pencil" dosimeter)
psig	pounds per square inch gauge
R	Roentgen
rad	radiation absorbed dose
RAM	radiation/remote area monitor
rem	Roentgen equivalent man
RESL	Radiological Environmental Sciences Laboratory
RLWTF	Radioactive Liquid Waste Treatment Facility
RWMC	Radioactive Waste Management Complex
RSWF	Radioactive Scrap and Waste Facility
SPERT	Special-Power Excursion Reactor Test
SPF	Sodium Processing Facility
STP	Sewage Treatment Pond
t	thermal
$T_{½}$	Half-life of a nuclide or isotope
TAN	Test Area North
TBD	Technical Basis Document
TLD	Thermoluminescent dosimeter
TRA	Test Reactor Area
TREAT	Transient Reactor Test
TRIGA	Training Research and Isotope General Atomic
U.S.C.	United States Code
WCA	Waste Characterization Area

WIPP	Waste Isolation Pilot Plant
ZPR-III	Zero Power Reactor No.3
ZPPR	Zero Power Plutonium Reactor (later Zero Power Physics Reactor)

2.1 INTRODUCTION ANL-WEST, FEBRUARY 1951 TO PRESENT

The purpose of this technical basis document (TBD) is to provide an Argonne National Laboratory - West (ANL-W) Site Profile that contains information for use by the Oak Ridge Associated Universities (ORAU) Team, for any dose reconstruction action, to evaluate the total individual occupational dose for claimants under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) of 2000.

TBDs and Site Profile Documents are general working documents that provide guidance concerning 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 National Institute for Occupational Safety and Health (NIOSH) 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 mean an "atomic weapons employer facility" or a "Department of Energy facility" as defined in the EEOICPA (42 U.S.C. 7384l (5) and (12)).

The purpose of this TBD is to assist in the evaluation of worker dose from ANL-W processes using the methodology in *External Dose Reconstruction Implementation Guideline* (NIOSH 2002a) and *Internal Dose Reconstruction implementation Guideline* (NIOSH 2002b). This part describes facilities, processes, and historical information related to worker internal and external exposures for use when actual monitoring data might be unavailable.

This TBD provides supporting technical data to evaluate, with claimant-favorable assumptions, the total ANL-W occupational dose that can be reasonably associated with worker radiation exposure as covered in the EEOICPA legislation. The TBD addresses the evaluation of monitored and unmonitored worker exposure and missed dose. In addition, it presents the technical basis of methods used to prepare ANL-W worker dose records for input to the NIOSH Interactive RadioEpidemiological Program (IREP) and the Integrated Modules for Bioassay Analysis (IMBA) computer codes used to evaluate worker dose. It also presents information on the uncertainty for recorded ANL-W exposure and dose values.

Proving the Principle, *A History of the Idaho National Engineering and Environmental Laboratory, 1949-1999*, by Susan M. Stacy (Stacy 2000) was a resource in the development of facility and process descriptions.

The Idaho National Engineering and Environmental Laboratory (INEEL) or "the Site" is an 890-square-mile reservation encompassing almost 572,000 acres with a maximum distance of about 39 miles from north to south and 36 miles from east to west. It is 30 to 60 miles west of Idaho Falls, Idaho. The Site is on the Snake River Plain of southeastern Idaho at an elevation of about 5,000 ft. INEEL played a major role in early reactor research and development; ANL-W performed much of this work. The Site has operated 52 reactors plus fuel handling and reprocessing and radioactive waste storage and disposal facilities since it began operations in 1949, about 10 of them by ANL-W.

ANL-W was originally known as "the Idaho Division" of ANL. It is an extension of Argonne National Laboratory – East (ANL-E) near Chicago, Illinois. ANL is a U.S. Department of Energy (DOE) research laboratory which has been operated by the University of Chicago throughout its life. The original site is in the southwest portion of INEEL, approximately 18 miles via Highway 20/26 east of Arco, 40 miles via Highway 26 northwest of Blackfoot, or 50 miles west via Highway 20 from Idaho Falls. The original ANL-W location is now a National Historic Landmark and is the site of the now

decommissioned Experimental Breeder Reactor – I (EBR-I), Boiling Water Reactor (BWR) Experiment, Argonne Fast Source Reactor (AFSR), and Zero Power Reactor 3 (ZPR-III) facilities.

The present ANL-W site is in the southeast portion of INEEL, about 35 miles west of Idaho Falls. There are 52 major buildings at this site, including reactor buildings, laboratories, warehouses, technical and administrative support buildings, and craft shops. Figure 2-1 shows the relative location of each facility or technical area discussed in this TBD.

In 1949, the U.S. Atomic Energy Commission (AEC) established the National Reactor Testing Station (NRTS) in Idaho as a Federal reservation to build, test, and operate nuclear reactors. In 1974, the NRTS became the Idaho National Engineering Laboratory (INEL) and, in 1997, the Idaho National Engineering and Environmental Laboratory. In 2004, the Site will become the Idaho National Laboratory (INL).

Dosimetry services at INEEL including ANL-W were unique among DOE facilities in that DOE Idaho Operations Office (DOE-ID) personnel operated and provided internal and external dosimetry services. The DOE-ID dosimetry branch provided and analyzed external dosimetry badges, counted workers in the whole-body counter, and analyzed bioassay samples. Originally, DOE-ID personnel at the Radiological Environmental Sciences Laboratory (RESL) in Building CF-690 in Central Facilities Area (CFA) maintained exposure histories of personnel based on dosimetry records, including bioassay data. With the advent of the DOE Laboratory Accreditation Program (DOELAP), dosimetry responsibility transferred to the prime contractor on January 2, 1989, to eliminate a conflict of interest on the part of DOE-ID.

Personnel working at ANL-W in designated radiological areas were typically required to wear state-of-the-art dosimetry (film badges, thermoluminescent dosimeters [TLDs], personal ion chambers [PICs], etc.) as well as respiratory protection, anticontamination clothing, etc. Facilities and radiological areas were monitored by remote and portable radiation/remote area monitors (RAMs) and continuous air monitors (CAMs). Portable RAMs, CAMs, air samplers, etc., were used for work where fixed units were not available. If airborne radioactivity might be present or if internal exposure was possible, applicable respirators were provided to prevent/reduce internal exposure.

Engineered systems were incorporated as practicable to minimize the potential for radiological airborne radioactivity and direct radiation exposure. Bioassay programs were instituted to monitor and assess potential internal exposures. Environmental monitoring systems were placed around the Site at multiple locations to measure direct radiation, fallout, and effluent discharges or releases to onsite personnel and members of the public. Each facility has had film or TLD badges in specific building areas and around perimeter fences to measure direct environmental radiation accumulation at the location as a check and balance on source terms within Site locations.

The following sections describe the facilities and the associated operations for ANL - W. Table 2-1 lists common radionuclides for reactors.

2.2 EXPERIMENTAL BREEDER REACTOR NO. I, APRIL 1951 TO DECEMBER 30, 1963

EBR-I, the first reactor built at INEEL, was a NaK-cooled, solid-fuel (enriched uranium), unmoderated heterogeneous fast reactor designed for full-power operation at a level of 1 MW. It was built to explore the possibilities of breeding nuclear fuel and for the use of liquid metal cooling. A blanket of ^{238}U around the core provided the fertile material in which nuclear material breeding took place.

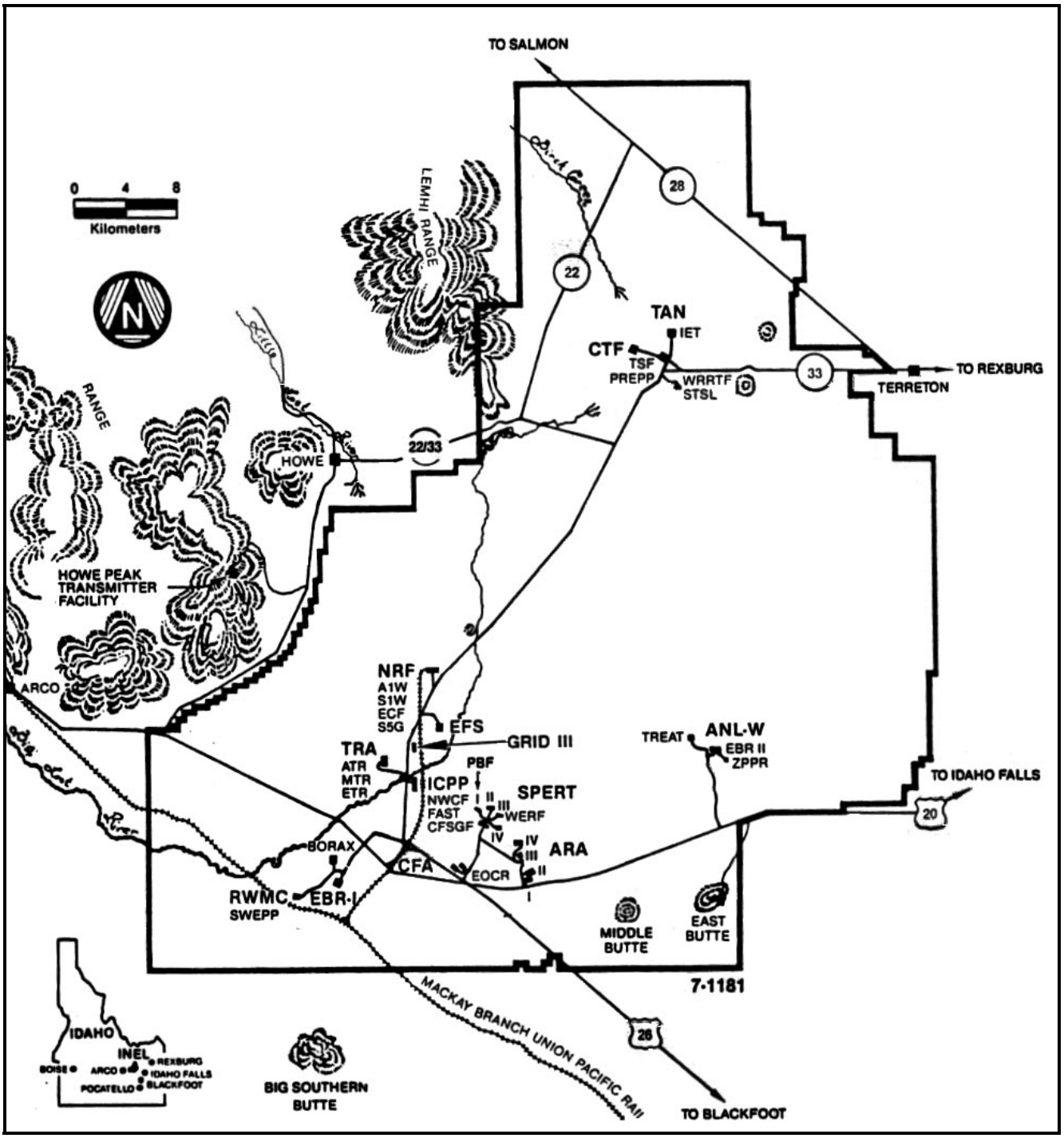

Figure 2-1. Map of the Idaho National Engineering and Environmental Laboratory showing location of ANL-W, including EBR-II, Transient Reactor Test (TREAT) Facility, and Zero Power Plutonium Reactor (ZPPR). ANL-W operated EBR-I and Boiling Water Reactor Experiment (BORAX) areas before their shutdowns. Other INEEL facilities include the Auxiliary Reactor Area (ARA); CFA; Idaho Chemical Processing Plant (ICPP) [now the Idaho Nuclear Technology and Engineering Complex (INTEC)]; Radioactive Waste Management Complex (RWMC); Special Power Excursion Reactor Test (SPERT) area; Grid III, Test Reactor Area (TRA); the Experimental Field Station (EFS); Naval Reactors Facility (NRF); Test Area North (TAN), where the Initial Engine Tests (IETs) occurred; and the Core Test Facility (CTF) at TAN.

Table 2-1. Radionuclides of concern for all reactors.

^{241}Am	^{60}Co	^{131}I	^{103}Ru
^{140}Ba	^{51}Cr	^{133}I	^{106}Ru
^{141}Ce	^{134}Cs	^{140}La	$^{90}Sr/^{90}Y$
^{143}Ce	^{137}Cs	^{54}Mn	^{91}Sr
^{144}Ce	^{152}Eu	^{95}Nb	^{92}Sr
^{242}Cm	^{154}Eu	^{239}Np	^{234}U
^{244}Cm	^{59}Fe	^{238}Pu	^{65}Zn
^{58}Co	^{3}H	^{239}Pu	^{95}Zr

Because the primary coolant was intensely radioactive during and shortly after operation, all primary components were enclosed in concrete-shielded cells. The secondary coolant, which was nonradioactive, required no shielding (Kittel, Novick, and Buchanan 1957). The facility was entirely inside a single building of brick, concrete, and steel. Construction on EBR-I began in May 1949 and was complete in April 1951. Reactor startup occurred on August 24, 1951.

On November 29, 1955, the reactor suffered a 40 to 50% core meltdown. Radiation detection instrumentation measured radioactivity in the building above normal background levels, and all personnel were evacuated. After the partial meltdown, the core assembly was removed from the reactor, using a temporary cave constructed on the reactor top, and shipped to ANL- E (Kittel, Novick, and Buchanan 1957). The core was replaced and the reactor remained operational until December 30, 1963. On August 26, 1966, EBR-I was dedicated as a National Historic Landmark. The principal radiological activity associated with the coolant during operation and shortly after shutdown was ^{24}Na, $\tau_{1/2}$ = 15 hr. The saturation level at full-power operation was approximately 24 µCi/gm. The second most significant activity was about 2 µCi/gm ^{137}Cs, which apparently entered the system during and after the meltdown incident. No other long-lived activity was identified in the primary coolant. Short-lived activity in the form of ^{133}Xe and ^{135}Xe was observed in the cover gas (Haroldson et al. 1963).

Internal exposure potential existed from airborne radioactivity from mixed fission products and activation products.

Personnel received external exposure from mixed fission products and activation products during activities associated with reactor operation and maintenance.

2.3 BOILING WATER REACTOR EXPERIMENT NO. 1, LATE 1953 TO JULY 22, 1954

BORAX-I was an open-top, water-cooled, water-moderated, boiling-water reactor (BWR) used to conduct a series of nondestructive experiments in the latter part of 1953 and early summer of 1954. The reactor was built in an excavated area of earth approximately one-half mile northwest of EBR-I and was housed in a 10-foot-diameter tank open to the atmosphere. The control room was approximately one-half mile away near the EBR-I reactor.

BORAX I was intentionally destroyed in its final experiment on July 22, 1954. The explosion scattered fuel plate fragments and other debris over an area of approximately 200 feet by 350 feet south of the reactor area fence. Instrumentation at the control center showed an instantaneous radiation level higher than 500 mrem/hr, which decreased in about 30 seconds to 25 mrem/hr and within 5 minutes to less than 1 mrem/hr. A detailed discussion of this incident is available (Brodsky and Beard 1960).

Internal exposure might have occurred from airborne radioactivity during operation and other activities associated with a BWR, the core destruction, coolant, and cleanup activities.

External exposure occurred from direct radiation associated with the reactor operation and maintenance activities from mixed fission products and activation products. BWRs typically have a N-16 high energy gamma shine from the primary water loop.

2.4 BOILING WATER REACTOR EXPERIMENT NO. 2, OCTOBER 19, 1954, TO MARCH 1955

BORAX-II replaced BORAX-I as a new reactor that would more closely approximate the characteristics of a practical power reactor operating on the boiling-water principle. BORAX-II, a short distance northeast of the BORAX-I site, was built in 1954 and became operational on October 19, 1954. It was significantly larger than BORAX-I. The vessel was shielded by concrete and housed in a sheet metal building. Tests of new core combinations used varying enrichments of ^{235}U in metal fuel plates. The boiling-water system operated at 300 psi, making it essentially a power experiment. The power level was about 6.4 MW (t) but, because it had no turbine generator, it produced no electricity. The energy produced was released in the form of steam. In 1955, tests of a turbine generator added to BORAX-II demonstrated that turbine contamination would not be a significant problem in BWRs.

Internal exposure was possible from mixed activation products (MAP) associated with work activities from the reactor coolant.

External exposure occurred during routine operations and with loading and unloading the reactor.

2.5 BOILING WATER REACTOR EXPERIMENT NO. 3, JUNE 9, 1955, TO DECEMBER 1956

As a result of the BORAX-I and -II tests, a program began in March of 1955 to modify the BORAX-II reactor to produce electrical energy. The modified reactor became BORAX- III. The previous BORAX reactors were not designed to produce electricity, so a turbine generator was added to the facility to convert thermal energy to electricity. The modified facility was capable of generating 12 MW of thermal energy and 2,300 kW of electrical energy. For 2 hours on July 17, 1955, BORAX-III generated approximately 2,000 kW of electricity; 500 kW were used to power the BORAX-III facility, 1,000 kW were used to power the CFA at the NRTS, and 500 kW were used to light the entire town of Arco, Idaho. BORAX-III became the first nuclear power plant in the world to generate electricity for an entire city. It was operational from June 9, 1955, until sometime before December 3, 1956.

Internal exposure was possible from MAP associated with work activities from the reactor coolant.

External exposure occurred from routine operation and loading and unloading of the reactor.

2.6 BOILING WATER REACTOR EXPERIMENT NO. 4, DECEMBER 3, 1956, TO JUNE 1958

BORAX-IV, the successor to BORAX-III, began operation in December 1956. This reactor, with a design power of 20 MW (t), was used principally to test high-thermal-capacity fuel elements made from ceramics of uranium and thorium. Like the previous BORAX reactors, BORAX-IV was a BWR operating at 300 psig. It was capable of producing 2.5 MW of electricity. It was brought to criticality on December 3, 1956, at atmosphere pressure. It operated with a core of uranium-thorium fuel elements until April 17, 1957. Beginning in May 1957, it operated with a 59-element core at 300 psig and 216°C and continued intermittent operations until December 5, 1957. After the core was revised to increase the maximum power, the reactor was restarted on February 19, 1958, to evaluate the effect of operating with a fuel element defect and to locate defective elements in the core. BORAX-IV

released approximately 4,565 curies of short-lived radionuclides to the atmosphere in March 1958 (Novick 1958). It operated until June 1958. The following measurements were made during reactor operations:

1. Radiation levels of the steam plant equipment
2. Quantitative determination of fission gases ^{138}Xe and ^{88}Kr, which were released to the atmosphere through the air ejector
3. Analysis of reactor water, condensed steam before the turbine, and condensed steam after the turbine (hot-well condensate) for fission products
4. Area contamination downwind from the reactor

Internal exposure might have occurred during work with the defective fuel elements or during planned releases of short-lived fission activity and from airborne MAP/mixed fission products (MFP) associated with the reactor coolant.

External exposure occurred during operation and work with loading and unloading the reactor.

2.7 BOILING WATER REACTOR EXPERIMENT NO. 5, FEBRUARY 9, 1962 TO SEPTEMBER 1964

BORAX-V was a flexible BWR with the same configuration as BORAX-IV, used primarily for testing nuclear superheating concepts. The facility was operational from February 9, 1962, until September 1964.

Internal exposure might have occurred from coolant and airborne activity during routine BWR operation with fuel elements made from ceramics of uranium and thorium, and associated maintenance work.

External exposure occurred from routine activities associated with reactor operation and maintenance.

2.8 ZERO POWER REACTOR NO. 3, OCTOBER 1955 TO NOVEMBER 1970

ZPR III was a low-power, split-table reactor that achieved criticality by bringing two halves of a fuel configuration together. It was used to determine the accuracy of predicted mass geometries and critical measurements for fast reactor core designs.

The building consisted of a reinforced concrete high bay assembly room and a one-story section containing the control room, work room, vault, laboratory rooms, offices, etc. The assembly (reactor) room of reinforced concrete was approximately 45 ft x 42 ft x 29 ft high (Brittan et al. 1961).

The assembly machine was a platform on which two tables or carriages were mounted, one of which was moveable. Half of the reactor was built up on each carriage by inserting drawers containing the reactor material into a matrix structure. Each half of the assembly contained five safety control rods and a 15-curie polonium-beryllium neutron source. Workers could swing a hinged platform into place between the halves on which they could stand while loading or unloading the machine.

The storage vault room was approximately 29 ft long by 26 ft wide with walls and roof of reinforced concrete 9 in. thick. The fuel slugs were stored either on racks or in special "birdcage"-type containers that limited the storage density to 2 kg $^{235}U/ft^3$.

Internal exposure potential existed from possible airborne radioactivity during maintenance operations from MFP/MAP.

External exposure occurred maintenance activities and during loading and unloading of the reactor fuel.

2.9 ARGONNE FAST SOURCE REACTOR, OCTOBER 29, 1959, TO LATE 1970

AFSR was a small fast reactor facility designed to produce neutrons for the development of special equipment for the fast reactor programs of EBR-I, EBR-II, and ZPR-III. The reactor, with a design power of 1 kW, was in a prefabricated Butler-type building with its own heating and air compressor plant built in 1958 near the EBR-I facility. No water was plumbed into the building. Control and safety mechanisms were in a pit below the reactor. The reactor, designed to supply both fast and thermal neutron fluxes for laboratory experiments, was built around a cylindrical core of solid highly enriched uranium with a blanket of solid depleted uranium (DU; Brunson 1959). Reactor startup occurred on October 29, 1959; the reactor was operational until sometime in the late 1970s when it was moved to a new location adjacent to the ZPPR facility at the ANL-W site. The reactor is now shut down and defueled.

Internal exposure might have occurred during routine operations that could create airborne radioactivity.

External exposure occurred from maintenance activities and loading and unloading fuel.

2.10 TRANSIENT REACTOR TEST FACILITY, FEBRUARY 23, 1958, TO APRIL 1994

TREAT was an air-cooled thermal heterogeneous system designed to evaluate reactor fuels and other material under conditions simulating various types of reactor excursions. Construction began in February 1958 and ended in November 1958, and criticality occurred on February 23, 1959. The TREAT complex comprises a reactor building and a control building approximately 1 mile northwest of the EBR-II containment building (Freund et al. 1960).

The reactor building features a high bay section and an adjacent service wing. The high bay section contains the reactor, fuel storage pit, instrument room, and the basement subreactor and equipment rooms. The control building is a single-story concrete block structure approximately one-half mile from the reactor that contains control panels and necessary instrumentation for remote control of the reactor.

Shielding permitted personnel access around and atop the reactor during steady-state operations at 100 kW. Access to the subreactor room was controlled during steady-state operation. Prior to transient operations, the building was evacuated of all personnel. General neutron and gamma radiation levels at a distance of 10 feet from the reactor during operations at 100 kW were (Freund et al. 1960):

- Fast neutron Negligible
- Thermal neutrons 50-1,500 $n/cm^2/sec$
- Gamma 5-8 mrem/hr

Internal exposure might have occurred during routine operations that could create airborne radioactivity; however, it was not expected to occur.

External exposure occurred from routine operations.

2.11 EXPERIMENTAL BREEDER REACTOR NO. II, MAY 1961 TO SEPTEMBER 30, 1994

EBR-II, at the ANL-W site, is a liquid sodium-cooled, unmoderated, heterogeneous fast breeder reactor rated at 62.5 MW thermal, with an intermediate closed loop of secondary sodium and a steam plant capable of producing electrical power through a conventional turbine generator. A fuel processing facility is attached to the reactor. EBR-II was designed to prove the breeding of fuels, the feasibility of a central power station, and onsite fuel processing. It met these objectives in the late 1960s, and its role changed to test reactor. Construction of EBR-II ended in May 1961, and the reactor reached criticality on September 30, 1961. It operated until September 30, 1994, when it was taken to a subcritical configuration and shut down to start a defueling operation. On January 19, 2001, ANL-W verified that the liquid metal sodium coolant had been completely drained from the reactor vessel. At present, the reactor is defueled, the sodium systems have been drained, and the power plant is depressurized.

The reactor was submerged in a primary tank containing approximately 90,000 gallons of liquid sodium. This tank was suspended in an airtight steel-shell containment building of 1-in.-thick steel plate, which would contain an accidental release of fission products, etc., from the primary system. The structure of the primary system is designed to contain the energy release associated with a reactor incident. The reactor building is designed to confine the effects of a maximum sodium-air interaction caused by a major sodium release. The reactor consists of an enriched core surrounded on all sides by a fertile blanket of depleted uranium (McVean et al. 1962; Koch et al. 1957)

The Sodium Plant contains pumping, purification, and storage facilities for the secondary sodium system. It also contains a receiving station for the sodium. The building was not normally occupied. The primary and secondary coolant from EBR-II is converted in the Sodium Processing Facility (SPF) from its elemental, chemically unstable form, to a chemically stable composition suitable for landfill disposal.

The Fuel Manufacturing Facility (FMF) is a secure facility designed for the fabrication of EBR-II fuel. The FMF vault stores special nuclear material in support of the EBR-II shutdown.

An additional building, the Laboratory and Office Building near the EBR-II plant, provided supporting analytical and personnel facilities.

2.12 HOT FUEL EXAMINATION FACILITY, 1964 TO PRESENT

The Hot Fuel Examination Facility (HFEF) complex comprises two hot cell facilities, HFEF/South and HFEF/North. HFEF/South, originally known as the Fuel Cycle Facility and/or the Fuel Conditioning Facility, was used to demonstrate remote processing and refabrication of uranium-fission metal-alloy driver fuel elements in a closed cycle with EBR-II.

Some 35,000 fuel elements were remotely reprocessed and refabricated into EBR-II subassemblies between 1964 and 1968. HFEF/South contains two large heavily shielded hot cells; one with an inert gas (argon) atmosphere, the other with an air atmosphere. The shielding walls of both cells are of high-density concrete. The HFEF/South air cell was decontaminated and refurbished in 1969 and again in 1976.

HFEF/North is a large alpha-gamma hot cell facility that was activated in March 1975. This facility provided the capability for post-irradiation and nondestructive or destructive examination of fuel and material experiments irradiated in EBR-II. HFEF/North contains two hot cells, one with an argon gas atmosphere and the other with an air atmosphere. The air atmosphere cell was known as the decontamination cell. The shielding walls of both cells are of high-density concrete (Baca 1979). HFEF began operation as a fully automated facility for examining highly radioactive experimental reactor fuel elements and other components in 1975. The examinations conducted in HFEF provide data that are essential for determining the performance and condition of fuels and materials irradiated in DOE reactor facilities. HFEF continues in operation, as a vital component of DOE's energy research program.

Remote characterization of material to be shipped to the Waste Isolation Pilot Plant (WIPP) in New Mexico for disposal takes place in the Waste Characterization Area (WCA) of the HFEF high bay.

Internal exposures might have occurred during cell entries when suspended radioactive contamination materials could cause airborne radioactivity from mixed fission products and activation products.

External exposure occurred when entries to the hot cell were made after experiment processes or during equipment maintenance and refurbishment.

2.13 ZERO POWER PHYSICS (PLUTONIUM) REACTOR, APRIL 18, 1969 TO APRIL 1992 (STANDBY)

ZPPR is a split-table critical facility approximately 300 meters from EBR-II in the ANL-W area and about 3 miles north of U.S. Highway 20. The facility is divided into two areas, the mound area and the support wing. The mound area consists of the reactor cell, fuel storage vault, workroom, and equipment rooms as well as access and escape tunnels. The reactor cell is a 50-foot-diameter circular room with floor and walls of reinforced concrete. The roof is composed of layers of washed and dried sand and gravel supported by a catenary cable network.

The basic element of the ZPPR is a bed-and-table system, which holds the matrix assembly. The two tables, one moveable and one stationary, are supported on a cast steel bed. The control and safety rod drives are mounted near the rear of each table. The main floor consists of the reactor control room, offices, an electronics shop, and a core coating room. The core coating room, adjacent to the control room and the entrance to the mound area, is used to clean core stimulants such as ^{235}U and stainless steel. The room contains two hoods for handling suspect materials and a core coating machine that is used primarily to dry and coat depleted uranium with a protective film.

Internal exposure potential was minimal due to the use of hoods and other protective equipment.

External exposure occurred from working with reactor processes, loading and unloading fuel, etc.

2.14 NEUTRON RADIOGRAPHY FACILITY, OCTOBER 1, 1977 TO PRESENT

The Neutron Radiography (NRAD) Facility is a 250-kW, steady-state training research and isotope (built by General Atomics) (TRIGA) reactor in the basement beneath the HFEF/North main cell. The reactor core consists of fuel elements surrounded by graphite assemblies. The core is submerged in a water-filled tank. NRAD began operation on October 12, 1977, with two radiography stations. The East station services the hot cell complex where specimens can be radiographed without removing them from the hot cell environment. The North station is outside the cell in a separate, clean shielded location for the radiography of irradiated or unirradiated items without introducing them into the

contaminated cell. Cask handling and specimen shielding allow for full-size reactor assemblies. The radiography room is easily accessible for development work (Richards and McClellan 1979).

NRAD has limited irradiation capabilities in the core. It has a water-filled port at the center of the core and a dry port at the edge of the core. NRAD operates a MF Physics linear particle accelerator that is used for nondestructive assays of waste and expended nuclear fuel.

Internal exposure potential exists from possible airborne radioactivity primarily from the hot cell environment from mixed fission products and activation products.

External exposure occurred during sample handling and maintenance associated with radioactive samples. Remote handling techniques are used to minimize dose.

2.15 FUEL ASSEMBLY AND STORAGE BUILDING, 1970 TO PRESENT

The Fuel Assembly and Storage Building (FASB) is a multipurpose facility about 100 yards NE of EBR-II that supports development of low-enrichment uranium fuel for research reactors, storage of spent fuel, and examination of the condition of other experimental projects. The East (clean) room houses offices, restrooms etc. The West room contains a vault for the storage of nuclear material. It also contains equipment for performing materials testing and for preparing metallurgical samples, and inert atmosphere glove boxes and hoods. The facility ceased fuel assembly about in 1990 , but other radiological work is ongoing.

Internal exposure might occur from airborne radioactivity associated with the described processes from the uranium fuel and spent fuel examinations.

External exposure occurred from movement of radiological samples and reactor fuel.

2.16 OTHER ANL-WEST SUPPORT FACILITIES

At ANL-W, an Analytical Laboratory (AL) provides the capability for performing chemical and physical measurements of both radioactive and nonradioactive samples. This facility includes six analytical hot cells (the Junior Cave area) and both general and specialized chemistry laboratories. Personnel were subjected to radiation levels in the multi R/hr range on occasion in the Junior Cave Area.

The Radioactive Scrap and Waste Facility (RSWF) provides in-ground retrievable dry storage for nuclear fuels and other highly radioactive scrap and waste, and interim storage for EBR-II spent fuel.

The Radioactive Liquid Waste Treatment Facility (RLWTF) evaporates low-level radioactive liquid waste generated at ANL-W facilities into solidified residue packaged in shielded containers

The Industrial Waste Pond (IWP) is an unlined evaporative seepage pond that is fed by a system of drainage ditches. It has been used since 1964 to receive wastewater from a number of sources. The largest sources of liquid industrial waste going to the IWP are blowdown effluents from the main and auxiliary cooling towers, auxiliary boiler blowdown; water from once-through air conditioning, and cooling water from other sources. There might be inadvertent low-level radioactive contamination in this pond.

The three Sanitary Sewage Treatment Ponds (STPs) north of EBR-II cover an area of about 2 acres. These ponds are not suspected to be radiologically contaminated.

Internal exposure is possible from airborne radioactivity associated with the various types of samples worked in these facilities.

External exposure occurred from working with the variety of radioactive material associated with these facilities (mixed fission products, activation products and transuranics).

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GLOSSARY

activation
The process of inducing radioactivity by irradiation.

annual dose equivalent
The dose equivalent received in a year. The annual dose equivalent is expressed in units of rem (sievert).

Atomic Energy Commission
An agency established by the U.S. Government for oversight of nuclear weapons and power production; a predecessor to the U.S. Department of Energy.

background radiation
The radiation in an ambient environment that includes cosmic rays, radiation from natural sources, and man-made sources.

beta (β) dose
A designation for external dose referring to the dose from beta and less-energetic gamma and X ray radiation; typically a shallow dose or dose to the lens of the eye.

beta radiation
Radiation consisting of electrons or positrons emitted at high velocity from the nuclei of certain radioactive elements. Most direct fission products emit beta radiation.

boiling-water reactor
A nuclear reactor concept in which the coolant water is permitted to boil as it absorbs the heat of the nuclear reaction.

breeder reactor
A nuclear reactor concept in which the operation produces a net increase in fissionable reactor fuel.

containment building
A safety feature of reactors typically engineered to be an airtight building, to prevent the release of radioactive gases or radiological contamination to the atmosphere or area outside the containment.

control rod
A device manipulated within a nuclear reactor constructed of material to absorb neutrons for the purpose of slowing down or increasing the nuclear reaction.

contamination, radioactive
Particulate matter on surfaces or in the air that is radioactive.

control room
The operating center of a nuclear reactor from which the reactor is operated and monitored.

coolant
In a reactor, a gas or fluid (water, liquid metal, etc.) contacting reactor fuel for the purpose of reducing or removing heat generated by the nuclear reaction.

core
That part of the reactor consisting of the fuel and some of the control elements for reactor operation.

curie
A special unit of radioactivity equal to 3.7×10^{10} disintegrations per second (dps).

decontaminate
A process removing radioactive particles from a person, place, or object.

depleted uranium
Uranium material that has undergone a process to remove ^{235}U resulting primarily in ^{238}U.

dose equivalent (H)
The product of the absorbed dose (D), the quality factor (Q), and any other modifying factors. The dose unit is the rem.

dose
Amount of energy from ionizing radiation absorbed per unit of mass.

dosimeter
A device used to measure accumulated radiation exposure.

dosimetry
The science of assessing absorbed dose, dose equivalent, effective dose equivalent, etc., from external or internal sources of radiation.

enriched uranium
Uranium enhanced from its natural state to contain a higher abundance of the isotope ^{235}U.

excursion
Planned or accidental increase in the normal operating power level of nuclear reactions.

exposure
Technically, a measure of X-ray or gamma radiation capability to ionize air (units of Roentgen).

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

fission
A nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy.

fission product
Elements or compounds resulting from fission.

flux
The intensity of particles (e.g., the number of neutrons passing through a unit area in unit time.)

fuel assembly
An arrangement of nuclear fuel and its cladding material into a particular form and shape for use in a nuclear reactor. Fuel may be assembled in plates, rods of various diameters, or other shapes.

fuel reprocessing
A chemical process, usually involving several steps, that recovers ^{235}U and other fissionable products from spent fuel.

gamma rays
Short wave length electromagnetic radiation (photons) originating in atomic nuclei and accompanying many nuclear reactions (e.g., fission, radioactive decay, and neutron capture) in an energy range of 10 keV to 9 MeV.

half-life
The time it takes for one-half of any given number of unstable atoms to decay (disintegrate).

hot cell
A specialized shielded laboratory in which radioactive materials may be handled with the aid of remotely operated manipulators. The walls and windows of the laboratory are made of materials designed to protect workers from radiation.

ionization chamber
A device used to measure exposure or radiation dose.

ionizing radiation
Electromagnetic or particulate radiation capable of producing charged particles through interactions with matter.

irradiate
To expose a substance to radiation.

isotope
Nuclides having the same number of protons in their nuclei (same atomic number), but having a differing number of neutrons (different mass number).

megawatt
A measure of electrical power equal to 1 million watts.

millirem
A unit of radiation equal to one-thousandth of a rem (see rem).

microcurie
A measure of radioactivity equal to one-millionth of a curie.

mixed waste
Waste that is both chemically hazardous and radioactive.

moderator
A material used in a nuclear reactor to reduce the natural speed of neutrons ejected from fissioning atoms (water, graphite etc.).

natural uranium
Uranium occurring in nature that has not been through an enrichment process.

neutron
A basic particle in a nuclear reaction, electrically neutral, with nearly the same mass as a hydrogen atom.

neutron, fast
Neutrons with energy equal or greater than 10 keV.

neutron, thermal
Strictly, neutrons in thermal equilibrium with surroundings. Generally, neutrons with energy less than about 0.5 eV.

nuclear energy
Energy released from a nuclear fission or fusion reaction.

nuclear power plant
An electrical generating facility using nuclear fuel

nuclear waste
A general term used for the byproduct nonuseable material resulting from nuclear reactions, including high-level, intermediate, low-level, mixed and transuranic waste.

nucleus
That part of an atom consisting of the total positive electrical charge and most of the mass.

pocket dosimeters
A type of ionization chamber used by personnel to measure radiation dose. Other names are pencil dosimeter, pocket pencil, pocket ionization chamber (PIC).

photon
A quantum of electromagnetic energy often referred to as X-rays or gamma rays, but also including light and radiant heat.

pressurized-water reactor
A concept in which water used to cool the reactor core is pressurized to prevent boiling. Heat is typically transferred from a primary system to a secondary system.

primary loop
A closed experimental system through which coolant flows as part of the control for a nuclear reaction using the main reactor as the primary source for neutron flux.

proton
An elementary atomic particle with a positive electrical charge equal numerically to the charge of the electron and a mass slightly greater than 1 mass unit.

Quality factor, Q
A modifying factor used to derive dose equivalent from absorbed dose.

rad
The unit of absorbed dose.

radiation
Energy transferred through air or some other media in the form of particles or waves (see ionizing radiation).

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

radioactive waste
Byproducts of nuclear processes that are radioactive and have no useful recyclable purpose (see *nuclear waste*).

radionuclide
A radioactive species of an atom characterized by the constitution of its nucleus specified by the number of protons, neutrons, atomic number, and mass number.

reactor vessel
A container enclosing the fuel elements, control elements, coolant piping, and other structures that support the core of a nuclear reactor.

reflector
Part of the structure of some nuclear reactors designed to reflect neutrons back into the core of the reactor.

rem
A unit of dose equivalent, equal to the product of the rad absorbed and the quality factor.

retention basin
An outdoor basin (of any of several designs) in which liquid solutions are deposited and held pending evaporation or the precipitation of solids.

Roentgen (R)
A unit of exposure to gamma (or X-ray) radiation, defined precisely as the quantity of gamma (or X) rays that will produce a total charge of 2.58×10^{-4} coulomb in 1 kg of dry air STP. An exposure of 1 R is approximately equivalent to an absorbed dose of 1 rad in soft tissue for higher (~>100 keV) energy photons.

secondary loop
The system in a reactor receiving transfer heat from a primary system. The secondary system is not exposed to the reactor core and is free of radioactivity under normal circumstances.

shielding
Any material or obstruction that absorbs (or attenuates) radiation to protect personnel or materials from radiation.

Sievert (Sv)
The SI unit for dose equivalent. (1 Sv = 100 rem.)

spent fuel

Reactor fuel containing fission and activation products that can no longer economically sustain a chain reaction.

spent fuel storage basin

A pool or pit made of reinforced concrete containing water and used to store spent nuclear fuel. The water acts as shielding and as a coolant

thermoluminescence

Property of a material resulting in light emission of stored energy released by heat.

thermoluminescent dosimeter (TLD)

A device containing solid chips of material that when heated release the stored energy as light. The measurement of this light provides a measurement of absorbed dose.

whole-body dose

Commonly defined as the absorbed dose at a tissue depth of 1.0 cm (1000 mg/cm^2); used to refer to the recorded dose.

X-ray

Ionizing electromagnetic radiation of external nuclear origin with energies less than 250 keV or a radiograph.

zero power

Also called low power; operating a reactor to maintain a chain reaction at an extremely low power level producing very little heat. Zero power reactors are used as sensitive laboratory tools to pretest experimental loadings of test reactors and for other analytical purposes.