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TABLE OF CONTENTS

SECTION **TITLE** **PAGE**

Acronyms and Abbreviations 5

2.1 Introduction 7

2.2 Site Description and General Information 8
2.2.1 Santa Susana Field Laboratory 9
2.2.1.1 Development and Testing of Nuclear Reactors 13
2.2.1.1.1 Homogeneous Water Boiler Reactors 13
2.2.1.1.2 Sodium-Cooled Graphite-Moderated Reactors 15
2.2.1.1.3 Systems for Nuclear Auxiliary Power Reactors 17
2.2.1.2 Critical Test Facilities 19
2.2.1.2.1 SNAP Development Test Facilities 19
2.2.1.2.2 Civilian Nuclear Power Test Facilities 20
2.2.1.3 Nuclear Support Operations 21
2.2.1.3.1 Reactor Fuel Manufacturing 22
2.2.1.3.2 Disassembly and Examination of Reactors and Used Reactor Fuel Assemblies 23
2.2.1.3.3 Fabrication, Use, and Storage of Radioactive Sources 24
2.2.1.3.4 Preparation of Radioactive Material for Disposal 24
2.2.1.3.5 Research on Reprocessing Used Reactor Fuel 25
2.2.1.3.6 Operation of Particle Accelerators 26
2.2.1.3.7 Research Using Radioisotopes 26
2.2.1.3.8 Miscellaneous Operations 26
2.2.2 Other Relevant Facilities 27
2.2.2.1 Downey 27
2.2.2.2 Canoga Park 28
2.2.2.3 DeSoto 28

2.3 Isotopes of Concern 30

2.4 Magnitude of Site Activity 30
2.4.1 Operation of Nuclear Reactors 39
2.4.2 Operation of Criticality Test Facilities 40
2.4.3 Manufacture of Reactor Fuel Assemblies 43
2.4.4 Disassembly and Examination of Reactors and Used Reactor Fuel Assemblies 43
2.4.5 Fabrication, Use, and Storage of Radioactive Sources 43
2.4.6 Preparation of Radioactive Material for Disposal 43
2.4.7 Research on Reprocessing Used Reactor Fuel 44
2.4.8 Operation of Particle Accelerators 44
2.4.9 Research Using Radioisotopes 44

2.5 Major Incidents 44

2.6 Radiological Access Controls 44

References 46

Glossary 47

LIST OF TABLES

TABLE	TITLE	PAGE
2-1	Site information of nuclear research operations conducted at Area IV	12
2-2	NMDF operational history	22
2-3	Area information and parameters of nuclear operations	31
2-4	Magnitude of nuclear operations	34
2-5	Reactor operations	41
2-6	Major incidents	45

LIST OF FIGURES

FIGURE	TITLE	PAGE
2-1	Aerial view of Area IV	8
2-2	SSFL and Area IV location map	10
2-3	Summary of primary Area IV programs and operations	11
2-4	Nuclear activities sites at Area IV	14
2-5	SRE plot plan	16
2-6	Radioactivity from reactors	42

ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
AERD	Atomic Energy Research Department
AETR	Advanced Epithermal Thorium Reactor
AI	Atomics International
AMAD	activity median aerodynamic diameter
ATR	Advanced Test Reactor
Ci	curie
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
EBR-I	Experimental Breeder Reactor No. 1
EBR-II	Experimental Breeder Reactor No. 2
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ETEC	Energy Technology Engineering Center
F	fast (solubility type)
ft	foot
g	gram
gal	gallon
HEPA	high-efficiency particulate air
HERF	High Energy Rate Forging
HMRFSR	Heavy Metal Reflected Fast Spectrum Reactor
hr	hour
ISF	Interim Storage Facility
KEWB	Kinetics Experiment Water Boiler
kWt	thermal kilowatt
kWth	thermal kilowatt-hour
lb	pound
LLRW	low-level radioactive waste
LMEC	Liquid Metal Engineering Center
LMFBR	Liquid Metal Fast-Breeder Reactor
LMIC	Liquid Metal Information Center
LMR	liquid metal reactor
M	moderate (solubility type)
mCi	millicurie
MeV	megaelectron-volt, 1 million electron-volts
MPC	maximum permissible concentration
mrem	millirem
MW	megawatt
MWd	megawatt-day
MWthr	thermal megawatt

NAA	North American Aviation
NIOSH	National Institute for Occupational Safety and Health
NMDF	Nuclear Materials Development Facility
NRC	U.S. Nuclear Regulatory Commission
OMR	Organic Moderated Reactor
OMRE	Organic Moderated Reactor Experiment
pCi	picocurie
R&D	research and development
RMDF	Radioactive Material Disposal Facility
RMHF	Radiation Materials Handling Facility
S	slow (solubility type)
S10FS3	SNAP 10 Flight Simulation Reactor
S2DR	SNAP 2 Development Reactor
S2ER	SNAP 2 Experimental Reactor
S8DR	SNAP 8 Development Reactor
S8ER	SNAP 8 Experimental Reactor
SER	SNAP Experimental Reactor
SGR	Sodium Graphite Reactor
SNAP	Systems for Nuclear Auxiliary Power
SNAPTRAN	SNAP Transient
SRE	Sodium Reactor Experiment
SSFL	Santa Susana Field Laboratory
STIR	Shield Test and Irradiation Reactor
STR	Shield Test Reactor
TRU	transuranic
TRUMP-S	Transuranic Management by Pyropartitioning-Separation
U.S.C.	United States Code
W	watt
Wt	thermal watt
WBNS	Water Boiler Neutron Source
yr	year
µm	micrometer
µrem	microrem
§	section

2.1 INTRODUCTION

Technical basis documents 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 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 [probability of causation] 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 radiation exposures 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 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.

This document describes the features and history of the Energy Technology Engineering Center (ETEC), including the site areas or buildings, site processes, periods of operation, radionuclides of concern, and other information pertinent to dose reconstruction. The U.S. Atomic Energy Commission (AEC) established ETEC in 1966. The Center has provided management, engineering, testing, consultation, and project monitoring services for a wide range of energy programs.

ETEC conducted a broad range of energy-related research, testing, and development projects that included component testing for the U.S. liquid metal reactor (LMR) program. Liquid metal test facilities were maintained and operated for evaluating components such as heat exchangers, steam generators, pumps, valves, piping, vessels, and instrumentation. In addition to the reactor component testing program, ETEC provided engineering support, technical management, and monitoring for a number of DOE solar, conservation, geothermal, and fusion energy programs. ETEC facility and capability users other than DOE have included the U.S. Department of Defense, the U.S. Nuclear Regulatory Commission (NRC), and the Electric Power Research Institute.

2.2 SITE DESCRIPTION AND GENERAL INFORMATION

This section describes the Energy Technology Engineering Center (ETEC), including the site areas or buildings, site processes and their magnitude, periods of operation, and other information pertinent to dose reconstruction. Figure 2-1 shows an aerial view of ETEC.

Figure 2-1. Aerial view of Area IV.

The Energy Technology Engineering Center (ETEC), established by the Atomic Energy Commission in 1966, provides management, engineering, testing, consultation, and project monitoring services for a wide range of DOE programs. ETEC is known as Area IV that consists of government-owned buildings within the Santa Susana Field Laboratory (SSFL) currently operated by the Boeing Company. Section 2.2.1 describes the facilities of ETEC in Area IV of the Santa Susana Field Laboratory (SSFL).

In addition to the facilities in SSFL that supported DOE, Rockwell International, under other contracts or grants to DOE or its predecessor agencies, had performed DOE activities at the Downey, Canoga

Park, and DeSoto facilities. These three facilities are all located outside the boundaries of the SSFL site. Since Rockwell International workers could have worked at any or all of these sites as well as at Area IV, Section 2.2.2 of this site description describes them.

2.2.1 Santa Susana Field Laboratory

The Santa Susana Field Laboratory (SSFL), consisting of a total of 2850 acres is located in the Simi Hills of Ventura County, approximately 30 miles northwest of downtown Los Angeles, California. SSFL is divided into four administrative and operational portions based on ownership and operations. DOE operations are conducted in Rockwell International-owned and DOE-owned facilities on a 290-acre westernmost administrative and operational portion designated as Area IV. Figure 2-2 shows its location.

Following World War II, the potential of atomic energy captured the interest of the United States Government and many companies. This created the need for nuclear Research & Development (R&D) facilities. The SSFL was initially established by North American Aviation (NAA) in 1947 to meet the requirements for a field test laboratory to static-fire large rocket engines, but it also met the NAA's need for a nuclear research facility. Area IV was established at the SSFL in 1953 as a nuclear research and development facility. Since then, the SSFL has housed both nuclear development and rocket development groups, although in distinct and separate locations. The rocket development group conducted operations in the SSFL's Area I, II, and III. The Atomic Energy Research Development (AERD) conducted operations in the SSFL's Area IV. In December 1955, these two NAA groups were transformed into separate divisions: Atomic International (AI) and Rocketdyne.

Two distinct groups of AI were housed in Area IV to support DOE. The AI focused on development of civilian nuclear power, and the Liquid Metal Engineering Center (LMEC) was a center for research and testing of non-nuclear components related to liquid metals. Nuclear R&D activities in Area IV increased rapidly from 1953 into the late 1960s, then declined. AI was merged into Rocketdyne in 1984 as a result of this decline.

The LMEC was created in 1966 as a government-owned and contractor-operated organization to provide development and non-nuclear testing of LMR components and to establish the Liquid Metal Information Center (LMIC) for the AEC's Liquid Metal Fast-Breeder Reactor (LMFBR) program. The LMEC was renamed ETEC in 1978 to reflect the DOE's desire to broaden its mission beyond the LMFBR program.

Several corporate mergers and organizational changes occurred over the years. In 1967 NAA merged with Rockwell Standard to become North American Rockwell. In 1973 the corporate name changed to Rockwell International (RI). Rockwell International with AI and Rocketdyne continued to exist as independent divisions until 1984 when AI was absorbed by the Rocketdyne division. The Boeing Company purchased RI in 1996, and Rocketdyne is now a division of Boeing.

ETEC conducted a broad range of energy-related research, testing and development projects that included component testing for the U.S. liquid metal reactor program. Liquid metal test facilities were maintained and operated for evaluating components such as heat exchangers, steam generators, pumps, valves, piping, vessels and instrumentation. In addition to the reactor component testing program, ETEC provided engineering support, technical management and monitoring for a number of DOE solar, conservation, geothermal, and fusion energy programs. ETEC facility and capability users other than DOE include the Department of Defense, Nuclear Regulatory Commission, and Electric Power Research Institute.

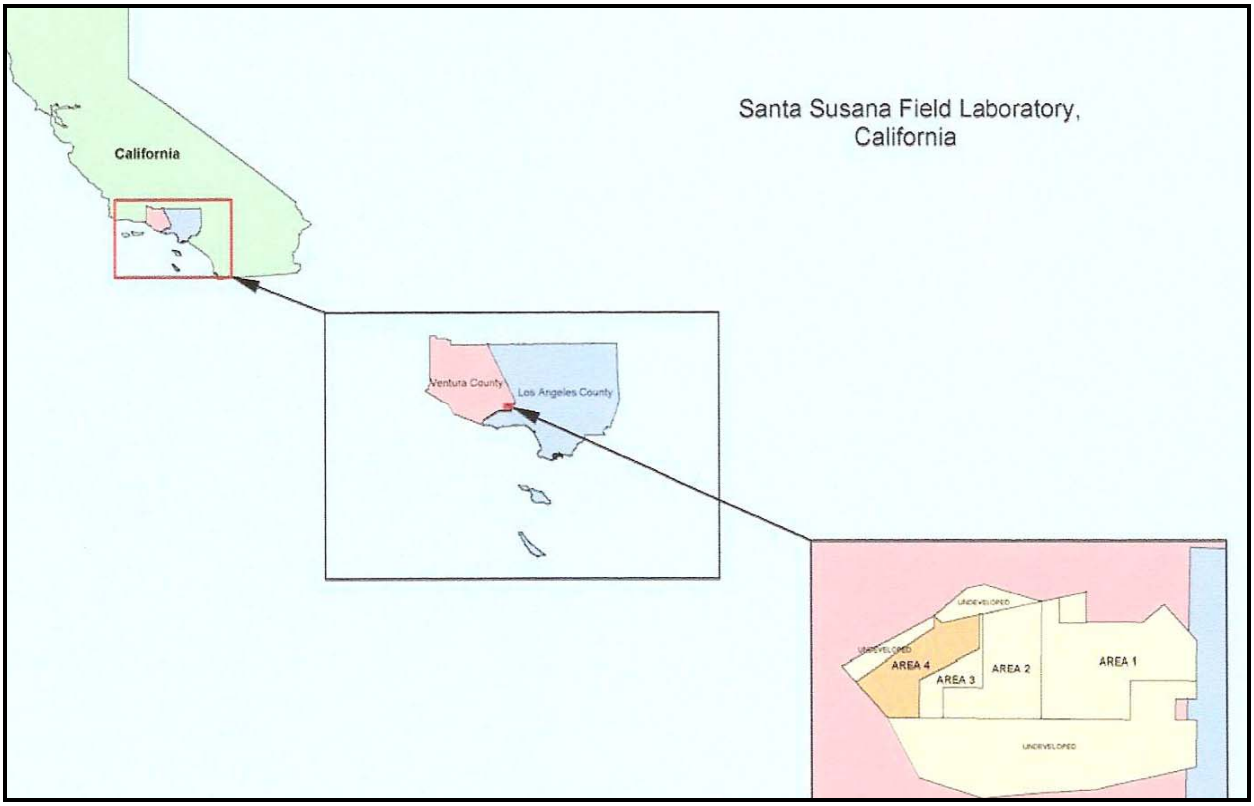

Figure 2-2. SSFL and Area IV location map (Sapere and Boeing 2005).

The phasing out of nuclear operations began during the mid-1960s. By 1988 all nuclear reactor operations in Area IV had ceased. Site cleanup and remediation has been ongoing since then. Nuclear support operations ended in 1996 with the exception of the Radioactive Materials Handling Facility (RMHF), a designated radiological facility that remains operational to provide chemical and radiological waste treatment and packaging for offsite disposal.

Most nuclear research programs and operations ceased in 1988 and all non-nuclear research ended in 1998, although some support operations including the Fuel Storage Facility and the Radiation Instrument Calibration Laboratory did not cease until 1996. Beginning in the 1990s, activities in Area IV have focused on D&D and remediation.

Before the remaining research activities ended in 1998, three primary types of operations were conducted at Area IV: 1) development and testing of nuclear reactors, 2) nuclear support operations, and 3) non-nuclear energy research and development. Figure 2-3 is a chronological representation of the individual programs (including their duration and corporate history) that supported the three primary types of nuclear research operations conducted in Area IV since its inception in 1953. Table 2-1 lists the specific nuclear operations conducted in Area IV, the site(s) or building(s) where the operation took place, and the time period of operations. Figure 2-4 shows the location of the sites where nuclear research activities were carried out at the SSFL and indicates the decontamination status of these sites as of 1991.

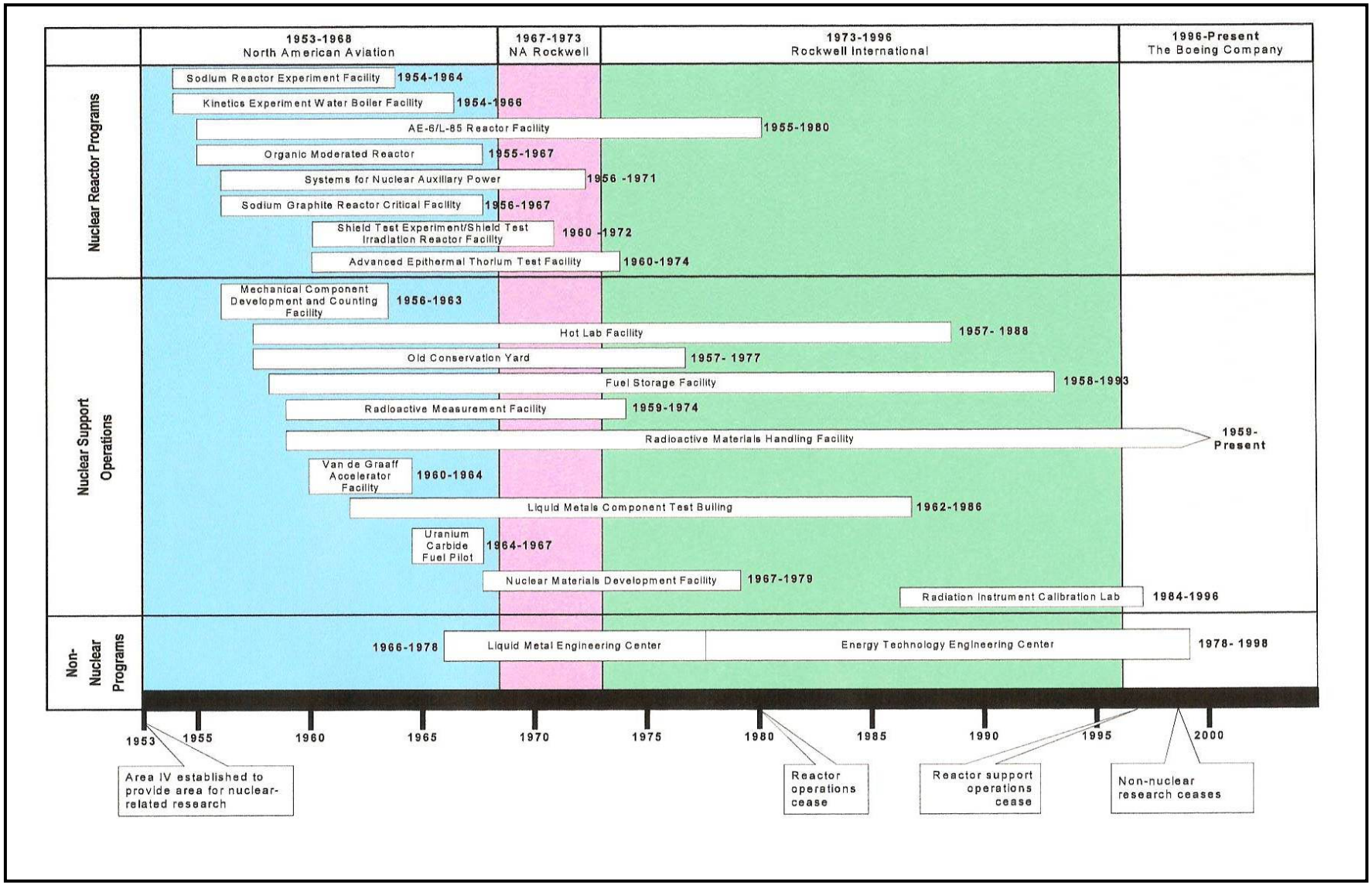

Figure 2-3. Summary of primary Area IV programs and operations (Sapere and Boeing 2005).

Table 2-1. Site information of nuclear research operations conducted at Area IV[a]

Section	Name	Description	Period of operations[b]	Facility
Reactor operations				
2.2.2.1	WBNS Reactor	Water Boiler Neutron Source Reactor 4 Wthr	1952-1955	Downey Plant
2.2.2.2	L-47, L-77	Aqueous uranyl sulfate homogeneous reactors 10 Wthr	1954-1960	Canoga Park Plant Vanowen Building
2.2.2.3	L-77	Aqueous uranyl sulfate homogeneous reactor 10 Wthr	1960-1976	DeSoto Plant Building 104
2.2.1.1.1 (1)	KEWB Reactor	Kinetics Experiment Water Boiler Reactor 1 kWthr	1956-1966	Building 4073
2.2.1.1.1 (2)	WBNS or L-85 Reactor	Water Boiler Neutron Source Reactor 3 kWthr	1956-1980	Building 4093
2.2.1.1.2 (1)	SRE Reactor	Sodium Reactor Experiment Reactor 20 MWthr	1957-1964	Building 4143
2.2.1.1.3 (1)	SER	SNAP Experimental Reactor 50 kWthr	1959-1960	Building 4010
2.2.1.1.3 (2)	S8ER	SNAP 8 Experimental Reactor 600 kWthr	1963-1965	
2.2.1.1.3 (3)	S2DR	SNAP 2 Development Reactor 50 kWthr	1961-1962	Building 4024
2.2.1.1.3 (4)	S10FS	SNAP 10 Flight Simulation Reactor 7 kWthr	1965-1966	
2.2.1.2.1 (4)	SNAP Transient Test Facility	SNAP Transient Test Facility	1971	
2.2.1.1.3 (5)	STR	Shield Test Reactor 50 kWthr	1961-1964	Building 4028
2.2.1.1.3 (6)	STIR	Shield Test and Irradiation Reactor 1 MWthr	1964-1972	
2.2.1.1.3 (7)	S8DR	SNAP 8 Development Reactor 600 kWthr - 1 MWthr	1968-1969	Building 4059
2.2.1.2.1 (2)	SNAP Critical Test Facility	Second SNAP Critical Test Facility	1962-1968	Building 4012
	HMRFSR		1970-1972	
2.2.1.2.1 (1)	SNAP Critical Test Facility	First SNAP Critical Test Facility	1957-1963	Building 4373
2.2.1.2.1 (3)	SNAP Flight System Critical Facility	SNAP Flight System Critical Facility	1964-1965	Building 4019
2.2.1.2.2 (2)	OMR Critical Facility	Organic Moderated Reactor Low power critical experiment	1958-1967	Building 4009
2.2.1.2.2 (3)	SGR Critical Facility	Sodium Graphite Reactor Low power critical experiment	1958-1967	
2.2.1.2.2 (4)	AETR Test Facility	Advanced Epithermal Thorium Reactor	1960-1974	Building 4100
2.2.1.2.2 (5)	Fast Critical Experiment Laboratory	Fast Critical Experiment Laboratory used to study different reactor core configurations	1961-1980	
Nuclear Support Operations				
2.2.2.3	Powder Room	Advanced Test Reactor (ATR) fuel fabrication and supporting activities	1959-1983	DeSoto Plant Building 101
2.2.2.3	Radiochemistry Laboratories	Hot radiochemistry Laboratories	1959-1989	DeSoto Plant Building 104
2.2.1.3.1 (1)	Engineering Test Building	Reactor fuel manufacturing facility to support Sodium Reactor Experiment	1954-1964	Building 4003
2.2.1.3.5 (1)	Hot Cave	Hot cell for reprocessing used reactor fuel	1954-1964	
2.2.1.3.4 (2)	ISF	Interim Storage Facility for SRE fuels	1958-1964	Building 4654
2.2.1.3.1 (3)	Uranium Carbide Fuel Pilot Plant	Uranium Carbide Fuel Manufacturing Pilot Plant	1964-1967	Building 4005
2.2.1.3.6 (1)	Van de Graaff Accelerator	Particle accelerator	1960-1964	Building 4030
2.2.1.3.2 (1)	Hot Lab	Hot Laboratory for disassembly and examination of used reactor fuel	1957-1988	Building 4020

Table 2-1 (Continued). Site information of nuclear research operations conducted at Area IV[a]

Section	Name	Description	Period of operations[a]	Facility
Nuclear Support Operations (continued)				
2.2.1.3.7 (2)	Corrosion Testing Laboratory	Liquid Metals Component Testing Facility	1962-1986	Building 4023
2.2.1.3.3 (1)	Radioactive Measurement Facility	This facility for storage and use of radioactive sources for calibration of radiation instruments	1959-1974	Building 4029
2.2.1.3.1 (2)	NMDF	Nuclear Materials Development Facility for development work involving plutonium fuel manufacturing	1967-1979	Building 4055
2.2.1.3.1 (4) 2.2.1.3.7 (1)	Fuel Storage Facility	Fuel Storage Facility is a vault built to provide storage for fissionable fuel material (EU & Pu)	1958-1993	Building 4064
2.2.1.3.4 (1)	RMDF	Radioactive Materials Disposal Facility was built for fuel storage and processing solid and liquid waste for disposal in conjunction with the SRE operation	1959-present	Buildings 4021/4022

a. This table includes the nuclear research facilities in the off-site Downey, Canoga Park and DeSoto Plants for completeness.
b. For reactors, refers to operation of the reactor rather than program duration dates provided in Figure 2-3.

The specific operations and its associated facilities are summarized in the following sections:

2.2.1.1 Development and Testing of Nuclear Reactors

Between 1954 and 1980, several nuclear reactors were built, tested, and operated in Area IV. These included both nuclear reactors and critical test assemblies. Nuclear reactor programs focused on the development and operation of homogeneous water boiler-type reactors, sodium-cooled graphite-moderated reactors, and uranium-zirconium hydride reactors.

2.2.1.1.1 Homogeneous Water Boiler Reactors

The water boiler reactors were operated in Buildings 4073 and 4093. The water boiler reactors used a 93% enriched uranyl sulfate solution held in a critical configuration in a spherical vessel. Rather than actually boil, the neutron and gamma flux caused radiolytic decomposition of water into hydrogen and oxygen in the form of tiny bubbles, which gave the impression of boiling. Area IV contained two water boiler reactors.

(1) Kinetics Experiment Water Boiler (KEWB), Building 4073. This reactor was located in Building 4073 and operated from 1956 until 1966. This was the first nuclear reactor to be operated at the SSFL. It was a small research reactor using a water solution of uranyl sulfate as fuel. The reactor started up with a spherical tank core in July 1956, and later operated with the cylindrical tank core. The cores were enclosed in a cube of graphite approximately 5 ft on a side. The graphite cube, contained in an aluminum box, was installed in a specially designed concrete vault (Building 073) built underground. The reactor was used to study the dynamic behavior and inherent safety of homogeneous water boiler reactors. Most operations were at very low power (1 kWt or less), but the reactor was operated briefly at 50 kWt. The final use was as a neutron pulse test facility, for many different tests. It was shut down for the last time in November 1966. In 1975 the reactor was removed and disposed of, and the facility was decommissioned, decontaminated, released for unrestricted use, and demolished in 1975.

Incidents: There were no incidents of any consequence with the KEWB.

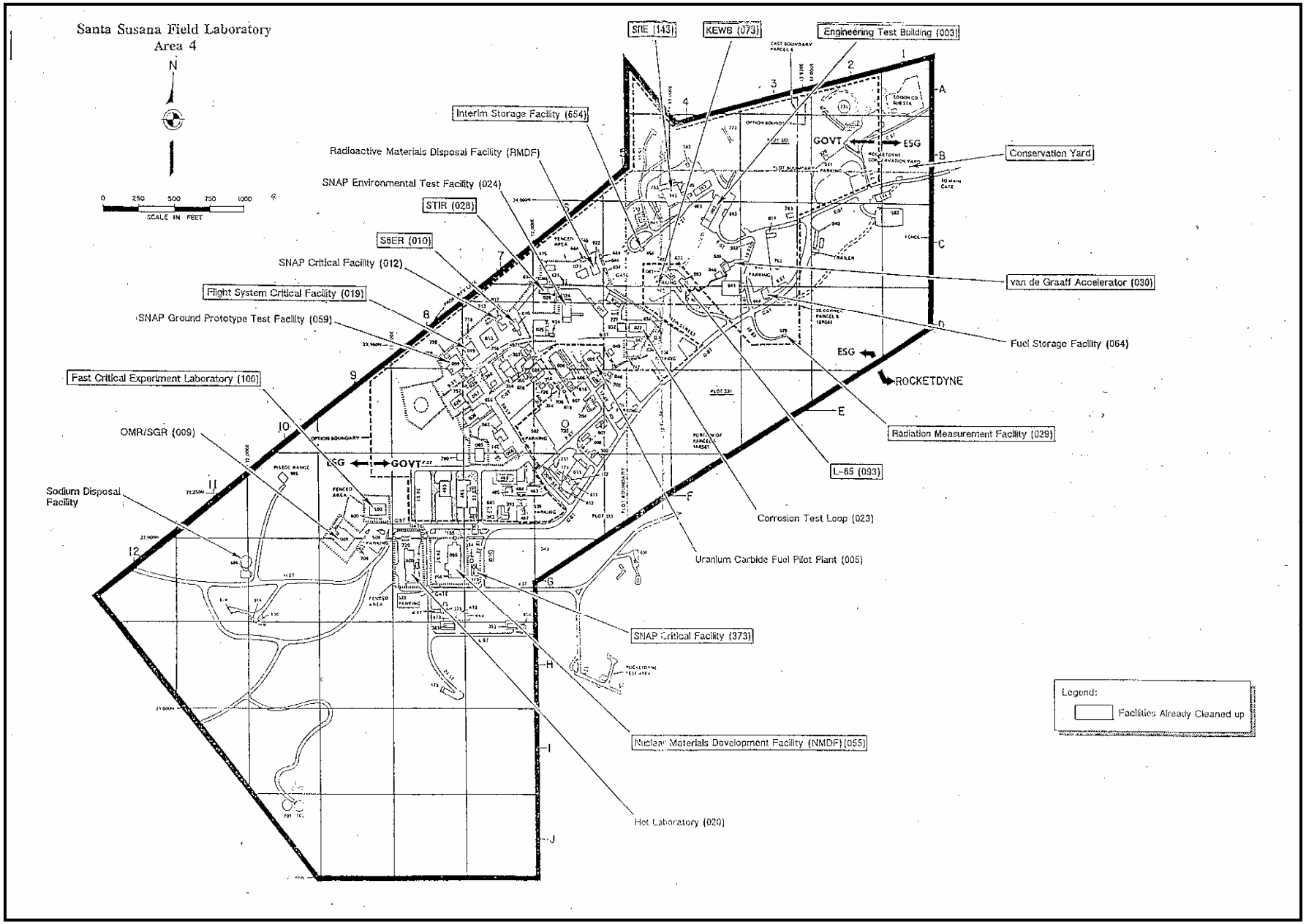

Figure 2-4. Nuclear activities sites at Area IV (Oldenkamp and Mills 1991).

(2) Water Boiler Neutron Source (WBNS), Building 4093. This was a small low-power research reactor, initially named AE-6. In 1972 the reactor name was changed to L-85. The core was a solution of uranyl sulfate in a spherical tank surrounded by a graphite reflector. This reactor had a homogeneous solution core as did the KEWB, but it could operate at up to 2 kWt. It was used as a neutron source for many different tests and for reactor operator training. The reactor operated off and on for 24 years from November 1956 to February 1980. It was then shut down, removed, and disposed of, and the facility was decommissioned and decontaminated. The reactor facility was released for unrestricted use on April 8, 1987.

Incidents: On March 25, 1959, one of the instruments that controlled the power of the AE-6 malfunctioned and allowed the reactor to exceed the normal power level of 3 kWt and to approach 4 kWt. As soon as the power level was recognized, the reactor was shut down by the operator.

2.2.1.1.2 Sodium-Cooled Graphite-Moderated Reactors

Figure 2-5 is a plan view of the Sodium Reactor Experiment (SRE) facility during its operating period. There were 12 structures on the site including the reactor building, office buildings, and support structures. Eight structures were directly involved in operations with radioactive materials:

1. Reactor Building (Building 4143)
2. Component Storage Building (Building 4041)
3. Temporary Hot Waste Storage Building (Building 4686)
4. Site Service Building (Building 4163)
5. Cold Trap Vault (Building 4695)
6. Liquid Radioactive Waste Vault (Building 4653)
7. Interim Radioactive Waste Storage Area (Area 4654)
8. Intermediate Contaminated Storage Area (Area 4689)

(1) Sodium Reactor Experiment (SRE), Building 4143. The SRE started in Area IV in 1954 as part of an AEC program to develop a graphite-moderated sodium-cooled reactor for power application and to demonstrate the feasibility of such reactors as an energy source for power stations.

The SRE reactor in Building 4143 was a 20-MW thermal reactor using slightly enriched uranium metal fuel in the initial core loading. The fuel was stainless-steel-clad rods with sodium bonding in the annulus between the fuel and cladding. The active core length was 6 ft. Heat generated in the reactor was transported by a primary sodium cooling system to a heat exchanger, and then by a secondary sodium system to a steam generator, which powered a steam turbine and generator provided by Southern California Edison Company. The SRE was the first civilian nuclear reactor in the United States to produce power for supply to a commercial power grid; it provided electricity to the City of Moorpark as part of the demonstration. Construction of the SRE reactor was completed in February 1957, and the ambient temperature subcritical experiment, without sodium in the core, was started on March 23, 1957. On April 25, 1957, the SRE was brought to criticality with 350°F sodium in the core. The reactor was brought to full power in early May 1958 and operated until February 1964. During this time, it generated 37,000 MWhr of electrical power in more than 27,000 operating hours.

In 1959, the SRE reactor experienced a coolant failure described below. The reactor was shut down for repair on July 27, 1959, and restarted on September 5, 1960. The reactor then operated without further incident until 1964 when the DOE terminated the program. It was shut down for the last time on February 15, 1964, and maintained in a safe shutdown condition until September 1967. At that time, the sodium coolant was drained and the core was removed. These items were sent off the site for disposal, and the facility was then maintained in place until 1974.

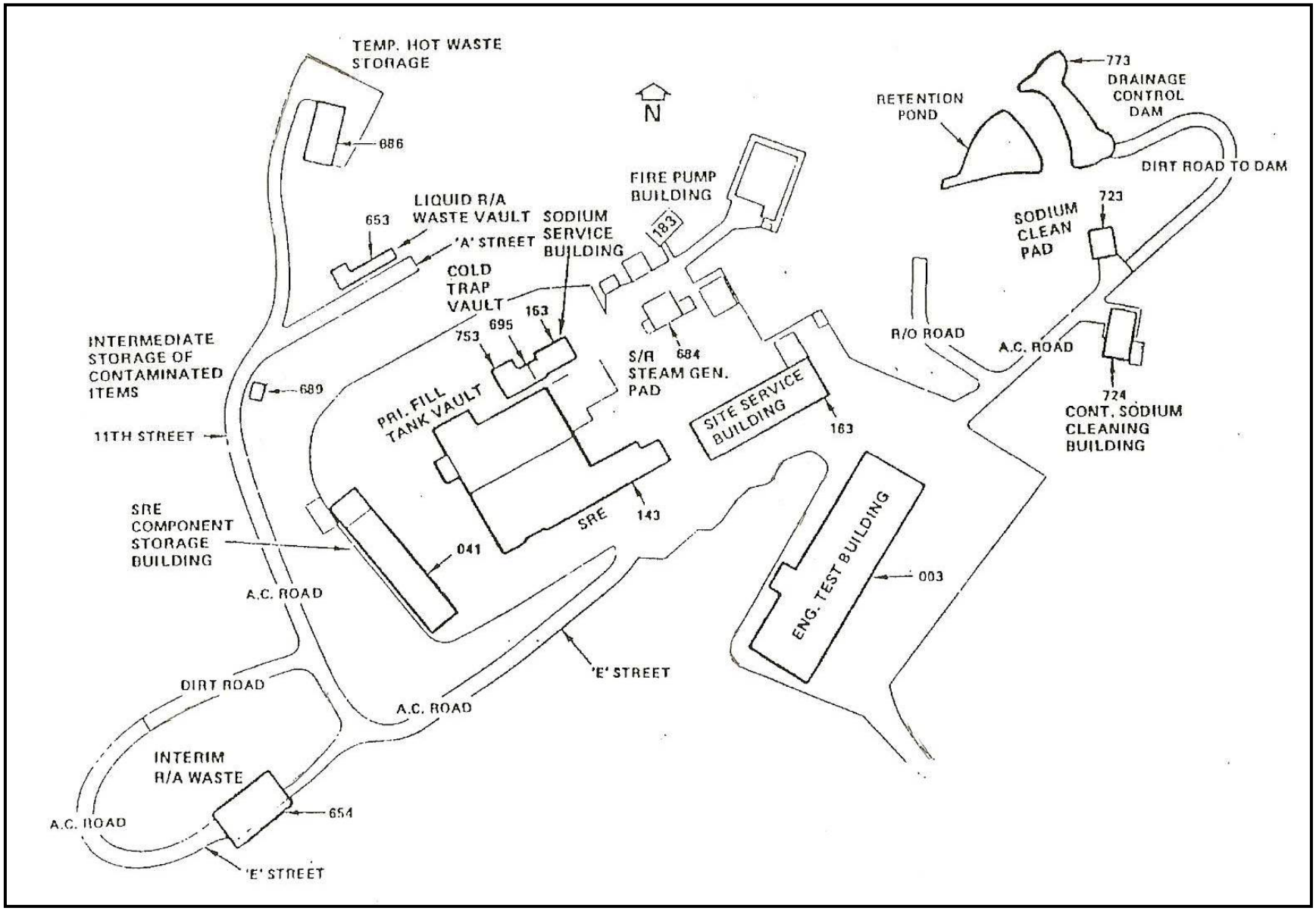

Figure 2-5. SRE plot plan (Oldenkamp and Mills 1991).

D&D of the SRE began in 1974 and was complete in 1983. The work involved the removal of over 136,000 ft^3 of radioactive waste and of nearly 90% of the entire reactor-generated radioactivity from the SSFL. The final radiation survey was verified independently by a group from Argonne National Laboratory, and the site was released for unrestricted use in 1983. The building was used as a storage facility from 1983 until its demolition in 1999.

Incidents: The reactor underwent an accidental partial blockage of sodium coolant in some reactor coolant channels in July 1959. This resulted in the partial melting of 13 of the reactor fuel assemblies and the release of some fission products that contaminated the reactor cooling system. All of the reactor safety systems functioned properly, and the reactor was safely shut down. The reactor fuel assemblies were removed, inspected, and stored at the Radioactive Materials Disposal Facility (RMDF). (They were later declad in the Hot Lab, and the fuel and cladding were shipped off the site.) A second fuel loading was inserted, and the test operations were continued.

2.2.1.1.3 Systems for Nuclear Auxiliary Power Reactors

The Systems for Nuclear Auxiliary Power (SNAP) program operated from 1956 to 1971 to support the development and testing of small reactors designed to provide power for research missions in space. The SNAP reactors were uranium-zirconium hydride reactors that used fully enriched (93%) uranium dispersed in fuel rods containing zirconium hydride. Seven SNAP reactors were tested and operated in Buildings 4010, 4024, 4028, and 4059.

(1) <u>SNAP Experimental Reactor (SER), Building 4010</u>. Building 4010 was built in 1959 as a test facility for the SER, a uranium-zirconium hydride reactor in which fully enriched uranium was dispersed in fuel rods containing hydrogen at about the density of water. Also known as the SNAP 2 Experimental Reactor (S2ER), the SER was a prototype for the basic SNAP reactor. Operated in Building 4010 at a power level of 50 kWthr, the reactor was used for power demonstration and endurance tests. The reactor was controlled by movable segments in a beryllium reflector sleeve and was shielded by lithium hydride.

The SER operated from September 1959 to December 1960 when the reactor and the associated test equipment were removed, examined, and sent off the site for disposal. The facility was then modified to test the larger SNAP 8 Experimental Reactor (S8ER) described next.

Incidents: There were no incidents of any consequence with the SER.

(2) <u>SNAP 8 Experimental Reactor (S8ER), Building 4010</u>. This was a prototype SNAP 8 reactor, the first in a series of reactor tests to be performed to develop a flight-qualified SNAP 8 reactor. The SNAP 8 Experimental Reactor was a compact, 600-kWt reactor installed in Building 4010 after the removal of the SNAP SER in 1960. It was cooled by flowing NaK, a liquid alloy of sodium and potassium metals. The S8ER operated from May 1963 to April 1965 at its designed power level of 600 kWthr.

Following completion of the S8ER operations, the core and associated equipment were then removed, examined at the Hot Lab, and sent offsite for disposal. D&D of Building 4010 was completed in 1978. The building was demolished and removed. A total of 7,150 ft^3 of radioactive waste was removed.

Incidents: During operation of the S8ER some cracks developed in the cladding, which served to separate the zirconium-uranium alloy fuel from the NaK coolant. The cracks were the result of swelling in the fuel that stretched the cladding beyond its ductility limit. Some fission products diffused

out of the fuel and found their way into the flowing NaK through the cracks in the cladding. There was no melting of the fuel or cladding. The fission products were completely contained within the reactor system.

(3) SNAP 2 Development Reactor (S2DR), Building 4024. This was a prototype of the SNAP 2 reactor; it was tested at a nominal power level of 65 kWt without any power conversion system equipment. The reactor was tested in Vault 1 of the SNAP Environmental Test Facility. [Building 4024 also contained the SNAP 10 Flight System 3 (S10FS3) reactor in a different vault, and the SNAP Transient (SNAPTRAN) Reactor criticality tests occurred in this building.] The S2DR operated from April 1961 to December 1962.

Incidents: There were no incidents of any consequence with the S2DR.

(4) SNAP 10 Flight Simulation Reactor (S10FS3), Building 4024. This was a SNAP 10A reactor used to test the reliability and performance of the reactors in space. Between January 1965 and March 1966, the reactor operated continuously for 10,000 hr at 37 kWthr. It was collocated with S2DR in Building 4024, in the west cell of the building.

Following completion of the S10FS3 operations, the reactor was removed from the building and sent off the site for disposal. The D&D activities for Building 4024 were completed in 1978. About 2000 ft^3 of material was removed. Some activated concrete shielding remains in the vaults. At that time the nonvault portions of the building were declared suitable for release for unrestricted use. The test vaults remain restricted and have been in surveillance and maintenance mode since 1978. Additional decontamination and demolition is scheduled to occur in 2005.

Incidents: There were no incidents of any consequence with the S10FS3 reactor.

(5) Shield Test Reactor (STR), Building 4028. This reactor was used primarily to generate radiation fields for shielding tests of SNAP reactors. It operated from 1961 to 1964 with a power rating of 50 kWt. The 50-kWt core was fueled with SNAP reactor fuel elements. It first went critical in December 1962. In addition to shielding tests, tests were also done to study radiation damage to electronic systems, and to qualify reactor hardware for SNAP reactors. The reactor was installed in a tank of water in Building 4028.

In 1964, the reactor was modified to raise the power rating to 1,000 kWt and renamed the Shield Test and Irradiation Reactor (STIR) described next.

Incidents: There were no incidents of any consequence with the STR.

(6) Shield Test and Irradiation Reactor (STIR), Building 4028. This was a rebuild of the STR to increase its power level for testing purposes. A new core fueled with fuel from the Materials Test Reactor in Idaho was installed. This increased the maximum rated power level to 1 MWt. The STIR operated from 1964 to 1972 when the fuel was removed and disposed of. The water from the reactor pool was drained in June 1973, and the facility was secured until September 1975 when D&D work began. D&D was completed in March 1976 and involved the removal of 1,500 ft^3 of radioactive waste.

After D&D, the facility was used for arc melting of depleted uranium. This work has been completed, and the arc-melting furnace has been removed. Additional D&D occurred and was complete in 1998. The above-grade portion of the facility was removed. The below-grade part of the building is again suitable for release for unrestricted use.

Incidents: There were no incidents of any consequence with the STIR.

(7) SNAP 8 Development Reactor (S8DR), Building 4059. Building 4059 was built in 1962 to 1963 for development testing of SNAP reactors. It had two reactor test cells in its basement. Testing of the S8DR, a second prototype SNAP 8 reactor, began in the north cell in June 1968 with the reactor operating under vacuum to simulate space flight conditions. A vacuum system and vacuum chamber were installed in a vault in the basement of Building 4059 for this test program. The S8DR operated from June 1968 to December 1969 at a power level between 600 kWthr and 1 MWthr.

At the end of the test operations, the reactor core and control system were removed, sent to the Hot Lab for inspection, and then shipped off the site for disposal. At this time, sufficient D&D occurred to make a portion of the facility available for other use. The reactor cell was sealed, and the vacuum system prepared for storage. Further D&D of the facility (except for the reactor cell and vacuum system) occurred between June and September of 1978.

The activated below-grade part of the facility was kept sealed and periodically inspected. An inspection in 1983 disclosed that groundwater was leaking into the reactor vault and becoming contaminated. Action was immediately taken to remove the contaminated water, process it, and dispose of it, and to begin a pumping program to ensure that radioactive water did not leak back out of the cell. The leak was found and sealed, and the situation was stabilized. However, another inspection in 1987 showed the potential for structural deterioration, so a D&D program was begun to remove the remaining radioactivity.

D&D of the below-grade part of the facility has been underway since 1987. The work is being done in two phases. In Phase 1, completed in June of 1989, the vacuum system suction pipe and its sand shielding were removed. This required removal of 4,600 ft^3 of radioactive waste. Phase 2 involves removing the vacuum chamber and the concrete test cell walls, which contain activation products. This work generated an additional 7,000 ft^3 of radioactive waste containing about 58 Ci of radioactivity. Phase 2 was completed in 1992. At that time, the entire facility was released for unrestricted use.

Incidents: Just as with the S8ER, cladding cracks due to fuel swelling and low cladding ductility occurred during the operation of the S8DR. As with the S8ER, there was no melting of the fuel or the cladding and all fission products were contained in the reactor system.

2.2.1.2 Critical Test Facilities

Several programs used critical test facilities (i.e., low-power reactors) in Area IV. Use of these low-power reactors began in 1954 and continued until 1974.

2.2.1.2.1 SNAP Development Test Facilities

Test facilities in Area IV for the SNAP program included Buildings 4373, 4012, 4019, and 4024.

(1) First SNAP Critical Facility, Building 4373. This was a critical test facility constructed in a building originally built to make high-energy rocket engine fuels. It was used for tests of five SNAP reactor critical assemblies (SCA-1, S2ERC, SCA-2, SCA¬3, and SCA-4C) between 1957 and 1963. It was later replaced by Building 4012, which was built specifically as a critical test facility. At the end of these tests, radiation surveys were performed and the facility was released for unrestricted use. The facility was resurveyed in 1987 and verified to be uncontaminated.

The D&D activities in Building 4373 were completed in 1995. Demolition of the building was completed in 2003.

(2) Second SNAP Critical Facility, Building 4012. This facility was built to continue criticality testing of SNAP reactors. Three SNAP reactor critical assemblies (SCA-4A, SCA-4B, and SCA-5) were tested here for the AEC between 1961 and 1967, and additional criticality tests of space reactor configurations occurred for NASA through 1971. The critical assemblies and associated equipment were removed and disposed of, but some contamination remains in the test vault, which was used as a packaging area for a short time. From 1970 to 1972, Building 4012 housed a critical assembly for the Heavy Metal Reflected Fast Spectrum Reactor (HMRFSR).

Initial demolition efforts in Building 4012 were completed in 1986 to accommodate construction of a non-nuclear building. Final D&D in the remaining portion of the building was performed in 1995. Demolition of the building was completed in 2003.

(3) SNAP Flight System Critical Facility, Building 4019. This was built to test-qualify SNAP reactor power systems before delivery to the AEC for launch as space power systems. It was used for the criticality tests of the S10FS3 reactor before that was moved to SNAP Environmental Test Facility in Building 4024 for power tests. It was also used for testing of the SNAP 10A reactor and its backup launched in April 1965. Three reactors (FS-1, FS-4, and FS-5) were assembled and tested from 1964 to 1965. This facility is not contaminated.

The D&D activities for the SNAP Flight System Critical Facility were completed in 1965. Following additional decontamination in 1998, the building was released. The building remains standing and is inactive.

(4) SNAP Transient Test Facility, Building 4024. Only operated in 1971, this was a criticality test facility set up in the same building as the SNAP Environmental Test Facility, where the S2DR and S10FS3 reactors were tested. It was used for low-power tests of the response of a SNAP reactor to rapid changes in control drum position. This was the SNAPTRAN test; the reactor criticality responses were studied at the SSFL, and then the reactor was moved to Idaho for power testing.

After completion of SNAP operations the assemblies were removed from the building and sent off the site for disposal. D&D activities in Building 4024 were completed in 1978. At that time the nonvault portions of the building were declared suitable for release for unrestricted use. The test vaults remain restricted and have been in surveillance and maintenance mode since 1978. Additional D&D is scheduled to occur in 2005.

2.2.1.2.2 Civilian Nuclear Power Test Facilities

Critical test facilities supporting the development of civilian nuclear power included Buildings 4009 and 4100.

(1) Organic Moderated Reactor (OMR) and Sodium Graphite Reactor (SGR), Building 4009. These two critical test facilities were operated in adjacent high-bays in Building 4009. During their operation, there were no incidents of contamination. When the programs ended, all associated equipment was removed. Later some additional test work occurred in a laboratory in this building that resulted in some radioactive contamination in the liquid waste holding tank system. It has been removed from SSFL. The east (SGR) high bay is now used for storage of Rockwell's in-service inspection equipment, which sometimes becomes slightly contaminated when used for inspecting reactors operating off the site. The west (OMR) high bay was used for tests of high energy rate forging

(HERF), which uses a variety of materials including depleted uranium. HERF can under certain circumstances increase materials strength. The developmental program conducted at SSFL yielded laboratory-sized samples to permit further study and understanding of the technique. There was about 800 lb of depleted uranium stored in Building 4009 as part of the HERF program. It has been removed.

(2) Organic Moderated Reactor (OMR), Building 4009. This was a low-power critical experiment facility used for testing reactors moderated and cooled by organic liquids from 1958 to 1967. The critical assembly core used slightly enriched uranium fuel in a heterogeneous organic-moderated lattice. Various types and configurations of fuel elements and core geometries were tested. The OMR supported the development and construction of the Piqua Nuclear Power Facility.

The D&D activities for the OMR were completed in 1967. Building 4009 is currently being used for non-nuclear R&D.

(3) Sodium Graphite Reactor (SGR), Building 4009, Also a low-power critical experiment facility, the SGR was operated from 1958 to 1967 to determine the operating characteristics of reactors with cores cooled by sodium and moderated with graphite. The basic critical assembly was a cylindrical array of hexagonal graphite cylinders into which various amounts and configurations of fuel and sodium (in cans or simulated by aluminum) could be inserted. It supported the development and construction of the Hallam Nuclear Power Facility.

The D&D activities for the SGR Critical Facility were completed in 1967. Building 4009 is currently being used for non-nuclear R&D.

(4) Advanced Epithermal Thorium Reactor (AETR), Building 4100. The AETR was built to study and test reactor core configurations for thorium and uranium-fueled reactors. It supported the development of reactors for the Southwest Atomic Power Association. The reactor operated from 1960 to 1974.

The D&D activities for the AETR were completed after the program was terminated in 1974. Building 4100 currently houses the radiation safety group's counting and instrument calibration laboratory and a computer-aided tomography system.

(5) Fast Critical Experiment Laboratory, Building 4100. This was a licensed facility built for the Southwest Atomic Power Association of private utility companies for epithermal and fast neutron criticality tests between 1961 and 1974. Twenty different reactor core configurations were studied. The early tests were of thorium- or uranium-fueled reactors that operated on neutrons of intermediate energies (epithermal flux spectra); later tests were of reactors with high-energy (fast) neutrons. It was decontaminated, decommissioned, and released for unrestricted use in 1980; the facility license was terminated October 1, 1980. It is now being used for office space and for storage and use of sealed radioactive sources for instrumentation calibration. The vault contains a computerized tomography device for nondestructive inspection of rocket engine components.

2.2.1.3 Nuclear Support Operations

Starting in 1956 several operations were conducted in Area IV to support nuclear programs. These included the manufacture, management, and disassembly of fuel for reactor operations as well as the operation of nuclear waste management facilities for offsite disposal. With the exception of the RMHF, Fuel Storage Facility, and the Radiation Instrument Calibration Laboratory, operations were terminated by 1988. Operations were terminated at the Fuel Storage Facility and Radiation

Instrument Calibration Laboratory in 1993 and 1996, respectively. Radiation instrument calibration is currently performed in Building 4100. The RMHF continues to operate in support of the DOE's cleanup effort and will be terminated as the facility goes into closure.

2.2.1.3.1 Reactor Fuel Manufacturing

As part of the nuclear reactor development work performed for the government, three different reactor fuel manufacturing operations occurred at the SSFL in Buildings 4003, 4055, and 4064. The first operation was the assembly of fuel elements for the SRE, the second was a plutonium fuel manufacturing facility, and the third was a uranium carbide fuel pilot plant. There was also a Fuel Storage Facility, used to store the Special Nuclear Materials (enriched uranium and plutonium) used to make the fuels.

(1) Engineering Test Building (Building 4003). Building 4003 was built to support the SRE for assembly of SRE fuel elements and was used for many different types of developmental tests of reactor components. The assembly of SRE fuel elements involved loading of uranium and thorium metal slugs into metal tubes, filling the interstices with sodium metal, and sealing the tubes. Fuel elements for three cores were prepared, but only two were used. The third core was eventually shipped off the site.

Research on reprocessing used reactor fuel occurred in the Hot Cave in Building 4003. D&D of this facility, including the Hot Cave, was completed in 1975. It required removal of 4,200 ft^3 of waste. Some traces of radioactivity were later found in the drain line, which was removed. The facility has been released for unrestricted use.

(2) Nuclear Materials Development Facility (NMDF), Building 4055. The NMDF was built specifically for development work involving plutonium fuel manufacturing and incorporated all of the safety systems and safeguards required for such work. It was completed in 1967 and operated with no unpermitted releases until 1979. Table 2-2 summarizes the NMDF's operational history.

Table 2-2. NMDF operational history.

Operating period	Operations
1967–1968	Development of analysis technologies for uranium-plutonium oxide fuels
4/68–6/69	Recycle of scrap uranium-plutonium fuel
7/68–6/70	Development of technologies to mix tungsten into uranium-plutonium carbide fuel
4/70–9/70	Preparation of samples for uranium-plutonium oxide irradiation studies
9/70–3/74	Idle
1974–1975	Bench scale tests, recovery of plutonium from simulated waste
1975–5/77	Mixed uranium-plutonium carbide fuel fabrication
5/77–11/78	Partial decontamination and cleanup
11/78–11/79	Fabrication of depleted uranium carbide fuel
11/79–10/82	Idle
10/82–10/86	D&D
7/87	Released for unrestricted use

D&D of Building 4055 is completed, and the building is released for unrestricted use. This required the removal of 692 ft^3 of transuranic waste and 16,527 ft^3 of other radioactive waste. The facility was removed from the Rockwell Special Nuclear Material License on October 7, 1987.

(3) Uranium Carbide Fuel Manufacturing Pilot Plant, Building 4005. This was a small-scale production facility built to study the operations associated with manufacturing reactor fuel assemblies

from uranium carbide. In the pilot plant, uranium oxide was reacted with graphite to convert it to uranium carbide. The uranium carbide was cast into pellets, machined to the proper dimensions, and placed in cladding tubes to make fuel assemblies. The initial operations were with depleted uranium to check out the equipment, then enriched uranium was used to make fuel assemblies for a critical assembly to be built at another AEC facility. Operations were completed in about 9 months in 1967.

Building 4005 was contaminated with enriched uranium. The building has been decontaminated except for some ventilation system ducts and filters, and some underground piping, which remain to be cleaned up.

(4) Fuel Storage Facility, Building 4064. This was a vault built to provide secure storage for fissionable fuel material (enriched uranium and plutonium). The building was constructed above ground of concrete and concrete blocks to meet the AEC criteria for vaults for storage of fissionable materials. Closed containers of radioactive waste were stored outside on a concrete pad within the locked and fenced facility perimeter equipped with intrusion alarms.

Some residual radioactive contamination was confirmed in the side yard outside the vault in a 1988 radiation survey. Approximately 9 mCi of old mixed fission products was removed during cleanup of this yard. In removing this soil, approximately 9 mCi of natural radioactivity was also removed. D&D was completed in August 1989; 3,000 ft^3 of contaminated material was removed. The exhaust system still contains some radioactive contamination, and there is some contaminated equipment inside the building.

Following removal of all fissionable material in the mid-1980s, miscellaneous equipment and containers of radioactive waste (principally soil) were stored in the building. The building was emptied of all contents by 1993. D&D activities for Building 4064 were completed in 1997.

2.2.1.3.2 Disassembly and Examination of Reactors and Used Reactor Fuel Assemblies

(1) Hot Lab, Building 4020. During reactor test operations, it was often necessary to examine reactor fuel assemblies and other test specimens to determine how they were performing. This involved handling and examining highly radioactive items, for which the Hot Lab operated in Building 4020 from 1959 to 1990. The Hot Lab was a 16,000-ft^2 facility with four large hot cells with remote manipulators and cranes, a mock-up area, an operating area, and decontamination areas. Construction was completed in 1959, and the facility was used until 1990.

When a reactor operation was complete and the reactor was no longer needed, it was removed from its operating location, disassembled, the fuel removed, and the radioactive structure cut up into pieces small enough to be shipped for disposal. The disassembly, fuel removal, and size reduction operations usually involved working with highly radioactive materials, so many of these operations occurred in the Hot Lab. In addition, the Hot Lab was used for work on radioactive material generated outside the SSFL, which consisted in large part of used reactor fuel from other nuclear reactors. The fuel elements were shipped to the Hot Lab and disassembled or separated from their cladding material, and the separated materials were then shipped away. The Hot Lab was used to manufacture sealed sources (see Section 3.3.5), for leak checks on sources, and for cutting and machining operations involving ^{60}Co.

The Hot Lab was used to examine fuel and/or components from the SRE, SER, S2DR, S8ER, S8DR, and S10FS3 reactors at the SSFL, the OMR and SGR criticality test facilities, and the Piqua, Ohio, reactor. It was also used to declad fuel from the SRE, EBR-I, EBR-II, Hallam, Fermi, and Southwest Experimental Fast Oxide Reactor reactors.

As a result of the work in the Hot Lab, the interior of the Hot Cells and the equipment they contain have been contaminated by small amounts of uranium, plutonium, thorium, and fission and activation products. Some exterior surfaces have become slightly contaminated as well. The extent of this contamination is approximately 2.2 Ci in the drain system, ventilation exhaust system, and inside the shielded cells plus traces of contamination on the building walls and surroundings. This radioactivity will be removed when the Hot Lab is decontaminated and decommissioned. During the period when the facility underwent D&D operations, the Hot Lab was being used for temporary storage of some radioactive materials. The license for this facility was changed in 1990 to limit operations to D&D work. D&D in Building 4020 were completed in 1999.

Incidents: On May 19, 1971, a fire occurred in the process of disposal of about 100 gal of NaK (a sodium-potassium eutectic that is liquid at room temperature). The NaK contained about 100 Ci of mixed fission products. The fire was started upon loss of containment of the NaK when a hole was drilled in the tank fill line. Approximately 25 gal of NaK were released into the decontamination cell and burned. The normal facility high-volume ventilation system that draws all building air through high-efficiency particulate air (HEPA) filters confined essentially all combustion products to the Hot Lab.

Airborne radioactivity and surface contamination monitored during and after the fire showed concentrations inside the building of between 2% and 20% of the occupational maximum permissible concentration (MPC). The average concentration of the release from the exhaust stack of the laboratory during the week of the fire was about 5% of the permitted concentration in an unrestricted area. No measurable external or internal exposures of radiation were received by personnel involved in the activities before or during the fire.

2.2.1.3.3 Fabrication, Use, and Storage of Radioactive Sources

Operations at SSFL required many instruments for detecting and measuring radioactivity, and these instruments must be calibrated periodically using known quantities and types of radioactivity called *sources*, which are sealed containers that contain small measured quantities of radioisotopes. Sources are also used for some forms of radiography, irradiation testing, and other applications. Sources were manufactured in the Hot Lab at SSFL and used in various facilities at SSFL and elsewhere. Approximately 140,000 Ci of radioactive material (primarily ^{147}Pm) were fabricated into sources at the Hot Lab. They were stored in secured locations and used under carefully controlled conditions. There are currently less than 100 Ci in sources stored at SSFL.

(1) <u>Radiation Measurements Facility, Building 4029.</u> This building housed storage and use of radioactive sources to calibrate radiation detection instruments for the SRE and other reactor tests. In March 1964 a radium source was dropped in a storage thimble. The plastic secondary encapsulation cracked and a small amount of radium contaminated the thimble. All of the sources were removed by April 1974, and the facility has since been used for temporary storage of nonradioactive materials. The contaminated thimble was removed and disposed of in October 1989. Radiation survey data shows that the facility now meets the requirements for release for unrestricted use.

2.2.1.3.4 Preparation of Radioactive Material for Disposal

The operation of nuclear reactors generates radioactive waste and other radioactive material that must be disposed of off the site. Other operations at the SSFL (fuel fabrication, reactor and fuel examination, etc.) also generated radioactive waste. Radioactive waste was prepared for disposal at the RMDF with support at the Interim Storage Facility (ISF) in Building 4654.

(1) Radioactive Materials Disposal Facility (RMDF). The RMDF was built in 1958 for fuel storage and processing solid and liquid waste for disposal in conjunction with the operation of the SRE. It has subsequently been used to support all of the SSFL nuclear operations. The facility consists of the following structures or areas:

Building 4022	Radioactive material storage vault
Building 4021	Decontamination and packaging facility
Building 4075	Low Specific Activity waste storage
Building 4621	Source storage
Buildings 4034 & 4044	Offices
Building 4665	Non-radioactive material storage
Leach Field	Sanitary sewer septic tank

There was an incinerator and a flocculation tower at the facility, but they were removed. The incinerator was a test installation built to determine if some of the waste (paper, plastics, and fabrics) could be disposed of by burning. It was tested with nonradioactive waste and failed to function well, so it was dismantled. It was never tested with radioactive waste. The flocculation tower was built to pretreat radioactively contaminated water to make it easier to filter. It was made unnecessary by better filters and has since been removed.

The RMDF is still in use, and parts of it are contaminated. The flocculation tower and the rest of the system used to treat radioactively contaminated water have been removed. The septic tank leach field was contaminated by a dilute solution of fission products (primarily cesium and strontium) in 1962 by the inadvertent opening of a valve in a liquid waste system. The valve was removed, and the leach field has been cleaned up and released for unrestricted use. There was a small amount of radioactive contamination on the north slope of the hill below the facility that was cleaned up. Other buildings at the facility are still slightly contaminated. Because this facility is useful in supporting the cleanup of the other SSFL facilities, the facility itself will be cleaned up last.

Incidents: Two noteworthy spills of dilute radioactive liquids occurred at the RMDF. The first was an accidental diversion of radioactive liquid into a sanitary system septic tank leach field. The valve that connected the radioactive system to the sanitary system was removed and the area was cleaned up and released for unrestricted use. The second incident was the loss of some liquid from the flocculation tower that overflowed and spilled down the north slope of the RMDF perimeter. As mentioned, the flocculation tower was removed and almost the entire spill was cleaned up.

(2) Interim Storage Facility (ISF), Building 4654. The ISF was built in 1958 to store SRE fuel elements in 10 thimbles installed in holes drilled in bedrock. It was subsequently used for storage of fuel shipping casks for other reactors (OMRE and SNAP). It was taken out of service in 1964, the thimbles removed and the area decontaminated and released for unrestricted use.

2.2.1.3.5 Research on Reprocessing Used Reactor Fuel

(1) Hot Cave, Building 4003. The Hot Cave in the Engineering Test Building supported testing of nuclear fuel reprocessing. The used fuel assemblies from nuclear reactors contain unused fissionable material, fissionable transuranic products (mainly plutonium), and fission products. Rockwell developed a process to make a partial separation of used fuel, removing part of the fission products so that the material could be used again as reactor fuel. The experiments used up to kilogram quantities of unirradiated uranium and thorium, and up to 100-g quantities of highly irradiated materials.

2.2.1.3.6 Operation of Particle Accelerators

(1) Particle Accelerator, Building 4030. There are other ways to generate artificial radioactivity besides nuclear fission. One way is to bombard a target material with atomic particles accelerated to high speeds by means of a particle accelerator. A common form of particle accelerator is a Van de Graaff generator, which uses a high-voltage electrostatic field to accelerate atomic particles to high speeds (high energy levels). Collisions of these particles with a target material (such as aluminum or tritium) can generate small amounts of radioactivity. Rockwell operated a Van de Graaff generator in Building 4030, bombarding tritium targets with deuterons to produce neutrons.

A second Van de Graaff generator was operated for neutron activation analyses of materials. It was removed before the SRE facility was decontaminated and decommissioned.

These accelerators were removed in 1962 and a radiation survey made of the facility showed it to be clean. A resurvey made in 1988 confirmed that there was no activation in the building.

2.2.1.3.7 Research Using Radioisotopes

Some of the research at the SSFL required the use of special radioisotopes. For these tests, small quantities of specially prepared radioisotopes were brought to the SSFL, used in laboratories under carefully controlled conditions, and then either shipped back out or stored safely when reuse was required.

The Transuranic Management by Propartitioning-Separation (TRUMP-S) program used research amounts of radioisotopes to develop fundamental thermodynamic and electrochemical data on various transuranic materials so that processes could be developed to separate long-lived radioactive isotopes from spent nuclear fuel. These long-lived radioactive isotopes could then be destroyed by fissioning them in a nuclear reactor or accelerator, thereby eliminating the long-term hazard associated with the disposal of spent nuclear fuel. The program used small quantities of transuranic materials (plutonium, neptunium, and americium).

(1) Fuel Storage Facility, Building 4064. The Fuel Storage Facility contains the materials for the TRUMP-S tests, which were planned to be in the Hot Lab but were transferred to the University of Missouri. The material included 75 g of depleted uranium, 5 g of plutonium, 4 g of neptunium, and 4 g of americium, which was shipped to Missouri. Building 4064 no longer stores any Special Nuclear Material and is scheduled for D&D.

(2) Corrosion Testing Laboratory, Building 4023. Another radioisotope research program was a corrosion test in the Corrosion Testing Laboratory. A pumped sodium corrosion test loop was built for study of the deposition behavior of activation products (^{54}Mn and ^{60}Co) in flowing sodium to develop more effective traps for these isotopes. An activated piece of fuel cladding containing these isotopes was used in these tests. The test specimens and the test loop were removed from the building. Some slight contamination of the ventilation exhaust system and drains remains.

2.2.1.3.8 Miscellaneous Operations

Neither the Conservation Yard nor the Sodium Disposal Facility was intended for use with radioactive materials, but both were inadvertently contaminated.

(1) Conservation Yard. This outdoor area was used for storage and salvage of used equipment. A 20-by-20-ft area of the surface of the Conservation Yard was found to be slightly contaminated (total

activity on the order of 0.001 Ci) by radioactivity in 1988. A total of 132 ft^3 of contaminated soil and asphalt was removed and shipped off the site for disposal. The site was released for unrestricted use in 1995.

(2) Sodium Disposal Facility. Also called the sodium burn pit, this facility was built to clean nonradioactive metallic sodium and NaK from various scrap test components (pumps, valves, etc.) before they were disposed of. In addition, it was used to treat nonradioactive waste sodium and NaK, and to burn nonradioactive combustible liquid waste (oils, etc.). The facility consisted of a large, rectangular, concrete-lined pit filled with water, surrounded by a concrete slab with two water-filled basins, a small building (Building 4886), and steam lance cleaning equipment.

Components were placed on the slab, opened to expose the sodium or NaK, and washed with water. The water reacted with the sodium to generate hydrogen, which often burned in the air. Sometimes the sodium and NaK also burned. The washed items were then often placed into the pit where the reaction with water continued, then placed into one of the basins where they were allowed to remain until any residual sodium or NaK was reacted. They were then retrieved and disposed of off site as solid waste.

One hazardous feature of sodium and NaK disposal was when an imperfectly sealed container (left slightly open to the atmosphere) was handled. A chemically unstable layer of sodium hydroxide and water and/or potassium superoxide could form on the surface of the sodium or NaK. If this layer was disrupted, a violent reaction could occur. Therefore, containers suspected of having this unstable characteristic were very carefully taken to the disposal field where they would be opened to the atmosphere from a safe distance by Security personnel using a high-powered rifle. After this procedure was completed and the violent reactions were allowed to occur, the material would be allowed to react with the atmosphere for a while.

The sodium-water and NaK-water reactions generated sodium hydroxide and potassium hydroxide, which subsequently reacted with carbon dioxide in the air to form sodium carbonate and potassium carbonate, both nonhazardous materials. Combustible nonradioactive liquids such as oils or biphenyls (an organic material used as a heat transfer fluid) were burned near the concrete-lined pit. The concrete-lined pit was cleaned out and resurfaced, and the basins are now dry. Several areas of the contaminated basin were dug out, and several small parts of scrap test components containing radioactivity were found and removed. Most of the buried nonradioactive waste has been excavated and removed. The site was remediated, revegetated, and released for unrestricted use in 1998.

In the 1960s tests were conducted at Area IV to determine how deeply a falling radioisotope heat source would penetrate the soil. During one of these tests a 1-kg slug of depleted uranium was lost after being dropped from a helicopter. No documentation was found to suggest the slug was ever recovered. The area where the slug was dropped has been surveyed several times and contamination has not been detected. Further reconnaissance is planned to recover the missing slug.

2.2.2 Other Relevant Facilities

2.2.2.1 Downey

The Downey facility is on Lakewood Boulevard in Downey, California. AEC-funded activities were performed by Rockwell's Atomics International Division in a small portion of this large building between 1948 and 1955. AEC activities included mainly paper studies, research and development, and engineering studies. However, these activities also involved the use of a 2-MeV Van de Graaff

generator, a small-scale radiochemical laboratory, a neutron counting room, and a construction area with a small 0.5-W teaching reactor. In addition, the AEC funded a 4-W WBNS at the Downey facility.

Startup for the reactor was in April of 1952. The reactor fuel was uranyl sulfate with a sealed polonium and beryllium neutron source; only very small quantities of radioactive material were ever present at the facility. There were 3 Ci of radioactive material present when the reactor was at full power. The WBNS operated at Downey until December 1955. In 1956 it was dismantled and moved to Area IV. Personnel and operations from Downey moved to the Canoga Avenue facility in late 1955.

The major quantity of radioactive material at Downey was canned normal and depleted uranium metal used in the exponential pile. The exponential pile was a system designed to model different fuel/moderator lattice configurations. The behavior of neutron flux in these lattices was measured. The 4-W WBNS was used as a neutron source for the exponential pile. The radioactive material was obtained from a variety of AEC and government contractors. After use it was returned to the source or transferred to the SSFL. The loading dock was the only place where the fuel was stored. All isotopes used at Downey by Rockwell were used for industrial radiography at Building 004, on Clark Avenue. All isotopes were disposed of in the early 1990s.

Effective remediation of the Downey facility was accomplished in 1956. In 2000, Boeing performed a survey verifying that the previous remediation met current NRC and California requirements. Ownership of the Downey facility was then transferred to the City of Downey.

2.2.2.2 Canoga Park

AEC-funded activities at Rockwell's Canoga Park, California, occurred in the Vanowen Building from approximately 1954 to 1960. This work had been performed at North American Aviation's Downey Facility, but was moved to Canoga Avenue at the end of 1955. Principal work in the Vanowen Building included design, development, and operation of small aqueous fuel reactors, fuel development, and radiochemistry, and beryllium machining is believed to have occurred. The reactors activities involved the construction of small 10-W aqueous uranyl sulfate homogeneous reactors named L-47 and L-77 for use in training institutions. Reactor fueling occurred only after the reactors were installed at the training institutions. A few fuel elements for the organic moderated reactor were fabricated at this facility.

Facilities where AEC-funded work took place within the Vanowen Building included the machine shop (where some beryllium machining took place), a radiochemical laboratory, and office space. The wastewater from all facilities except the laboratory discharged into a common treatment plant. The wastewater from the radiochemical laboratory went to a clarifier, where it was tested for radioactivity before being released to the sanitary sewer if it was below established standards. The sludge from the clarifier was disposed of in a government repository or an AEC site for low-level waste.

Once the AEC work was completed, the clarifier was surveyed for radioactivity, determined to be within acceptable standards, and backfilled. The transfer lines from the clarifier to the sewer main could still be present, but they are not in use.

2.2.2.3 DeSoto

Radiological operations occurred at the DeSoto Facility from 1959 to the mid-1990s. AI used nuclear fuel material and other radioactive materials in Buildings 101 and 104 from 1959 to 1983. A much-reduced level of work was continued by Rocketdyne in Building 104 into the mid-1990s. Before 1984, Buildings 101 and 104 were designated as 001 and 004. Much of the historical documentation refers

to these building numbers. The following paragraphs briefly summarize the nuclear operations in these buildings.

L-77 Reactor (NRC Licensed). The L-77 small research reactor operated in Room 416-61 of Building 104 from 1960 to 1976. The L-77 was a low-power (10 W) reactor using enriched uranyl sulfate solution. The L-77 was a prototype teaching reactor sold to many universities and around the world. The laboratory housing L-77 was decommissioned and decontaminated in the late 1970s. The NRC released the facility for unrestricted use and terminated the reactor's license in February 1982.

Advanced Test Reactor (ATR) Fuel Fabrication and Supporting Activities. NRC-licensed fuel fabrication operations were conducted in the northern section of the first floor of Building 101, with radiochemistry support operations conducted on the first and second floors of Building 104. These support activities included hot chemistry laboratories (east section of second floor), an emission spectroscopy laboratory (Room 411-72, first floor), and an X-ray diffraction laboratory (Room 411-58, first floor). The fuel fabrication facility produced a variety of different fuel elements for test reactors. Many fuel manufacturing programs began in 1959 using 2% to 93% enriched uranium metal and composites. Some of the work involved developing uranium-aluminum alloys and, because of the uranium, occurred in sealed gloveboxes. One of the larger programs was fuel manufacture for the ATR using uranium-aluminum (UAl_X) powder with an enrichment of 93%. Fuel manufacturing ended in 1983. In addition, AEC-sponsored work involving the manufacture of beryllium-containing parts took place at this site.

D&D of Buildings 101 and 104 included removal of all fuel and radioactive materials and waste; removal of contaminated equipment, drain lines, tanks, and ventilation ducts; and cleaning of all surfaces including floors, walls, and ceilings.

Gamma Irradiation Facility (GIF). This state-licensed aboveground vault in Building 104 used sealed ^{137}Cs and ^{60}Co sources for radiation hardening tests of electronic components and for food irradiation research. The Gamma Irradiation Facility consisted of Rooms 41M-11 and 41M-11A on the northeast corner of Building 104. Activity ceased in the late 1980s, and the sources were shipped off the site for recycling in the early 1990s. Bi-annual leak checks of these sources detected no leaks. In 1995, a Rocketdyne survey of the GIF verified that it was not contaminated.

Mass Spectroscopy Laboratory (Helium Laboratory). Up until 1995, Rocketdyne used the state-licensed Mass Spectroscopy Laboratory to analyze miniature radioactive specimens of neutron-irradiated nonfissile metals from DOE and international reactors for helium content. The Mass Spectroscopy Laboratory consisted of Rooms 414-69, 416-72, 414-75, 416-76, 416-76A, 414-77, 416-80, 416-80A, and 414-81 in the northeast section of the 1st floor of Building 104. Operations of the DeSoto Mass Spectrometer Laboratory generated very small quantities of radioactive, hazardous, and mixed waste, including radioactive solvents, solvent wipes, and acids shipped from other U.S. and international research organizations. In 1995, the equipment was shipped to Pacific Northwest National Laboratory in Richland, Washington, where it continues to be used.

Fuel fabrication was terminated in 1984, but small-scale laboratory research work on gamma irradiation and analysis of radioactive samples continued until 1995. Remedial activities occurred at various times in the 1980s followed by NRC license termination. In mid-1998, all remaining equipment, interior walls, and drain lines were removed, and the facility was decontaminated. Residual contamination was low level and confined to the laboratory. No elevated radiation levels or contamination outside the laboratory were detected before or during D&D.

Former sewage lines connecting sinks and showers at Building 101 were plumbed into a network that discharged into a pair of 1,500-gal steel holding tanks. The tanks allowed sufficient time for sampling and analysis of the sanitary water before discharge to the main municipal sewer line. If the concentration of radionuclides was below the MPC, the water was released to the municipal sewer. Overly contaminated water would have been transported to the RMDF for evaporation, but no water in the holding tanks was ever above the MPC. During decommissioning of the facility in the 1980s, radioactive contamination of the small areas of soils adjacent to some of the drain lines was slightly above acceptable limits. Approximately 10 of 140 soil samples had activities in the range of 50 to 80 pCi/g in comparison to the NRC limit of 48 pCi/g. D&D included the removal of the holding tanks and excavation of contaminated soil. The outflow lines from the holding tanks to the main sewer between Buildings 101 and 104 remain in place.

2.3 ISOTOPES OF CONCERN

Table 2-3 identifies the potential radiological contaminants associated with the specific nuclear operations at SSFL in terms of isotopes of concern. The guidance for the preparation of Site Profiles (ORAU 2005) requires for this table to include dose reconstruction parameters such as the solubility type and assumed particle size of the contaminants, although the same information is also required in Section 5, *Internal Dosimetry*. Since this *Site Description* section, Section 2, is for informational use only, the data given in Section 5 should be used for dose reconstruction, regardless.

In the absence of any measurements or studies, NIOSH guidance requires the use of default solubility classes and particle size values from the International Commission on Radiological Protection (NIOSH 2002, pp. 15, 16). With one exception, facility-specific solubility and particle size data for ETEC has not been found.

2.4 MAGNITUDE OF SITE ACTIVITY

Table 2-4 intends to provide a perspective of the magnitude of the nuclear operations at SSFL. The Site Profile preparation guide (ORAU 2005) requires the magnitude of the operations be expressed in radioactivity (Ci) of the isotope of concerns. Again, the same information is also required in Section 5, *Internal Dosimetry*. Hence, radioactivity values in Section 5 should be used for dose reconstruction. In cases where available information allows the estimation of the radioactivity at the time of the operations, the number of curies of each isotope is listed. In cases where numeric data is not available, the table locates the descriptive text that gives the magnitude of the nuclear operations.

Activity fractions were not available with the exception of those for limited fuel fabrication operations. For highly enriched research reactors, values from Shleien, Slayback, and Birky (1998) have been listed as an approximation. For other areas, default assumptions from Barnes (1999, Table D-3) have been used. By coupling the activity fractions with the data in Table 2-5, the radioactivity for each of the isotope of concern can be derived.

Table 2-3. Area information and parameters of nuclear operations.

Section	Name	Period of operations[a]	Facility	Radioactivity		
				Radio-isotopes	Solubility type	Part'le size (µm AMAD)
Reactor operations						
2.2.2.1	WBNS Reactor/ 0.5 Wthr	1952-1955	Downey Plant	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241	F F M M M S S S S M	5 5 5 5 5 5 5 5 5 5
2.2.2.2	L-47, L-77 10 Wthr	1954-1960	Vanowen facility			
2.2.2.3	L-77 10 Wthr	1960-1976	DeSoto Facility Bldg. 104			
2.2.1.1.1 (1)	KEWB Reactor 1 kWthr	1956-1966	Building 4073			
(2)	L-85 Reactor 3 kWthr	1956-1980	Building 4093			
2.2.1.1.2 (1)	SRE Reactor 20 MWthr	1957-1964	Building 4143	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 Th-232 H-3	F F M M M S S S S M M M M M	5 5 5 5 5 5 5 5 5 5 5 5 5 5
2.2.1.1.3 (1)	SER 50 kWthr	1959-1960	Building 4010	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	F F M M M S S S S M M M M	5 5 5 5 5 5 5 5 5 5 5 5 5
(2)	S8ER 600 kWthr	1963-1965				
(3)	S2DR 50 kWthr	1961-1962	Building 4024			
(4)	S10FS 7 kWthr	1965-1966				
2.2.1.2.1 (4)	SNAP Transient Test Facility	1971				
(5)	STR 50 kWthr	1961-1964	Building 4028			
(6)	STIR 1 MWthr	1964-1972				
(7)	S8DR 600 kWthr - 1 MWthr	1968-1969	Building 4059			
2.2.1.2.1 (2)	SNAP Critical Test Facility	1962-1968	Building 4012	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241	F F M M M S S S S M	5 5 5 5 5 5 5 5 5 5
	HMRFSR	1970-1972				
2.2.1.2.1 (1)	SNAP Critical Test Facility	1957-1963	Building 4373			
(3)	SNAP Flight System Critical Facility	1964-1965	Building 4019			

Table 2-3 (Continued). Area information and parameters of nuclear operations.

Section	Name	Period of operations[a]	Facility	Radioactivity		
				Radio-isotopes	Solubility type	Part'le size (µm AMAD)
Reactor operations (continued)						
2.2.1.2.2 (2)	OMR Critical Facility	1958-1967	Building 4009	Sr-90 Cs-137	F F	 5
(3)	SGR Critical Facility	1958-1967		U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154	M M M S S S S M M M M	5 5 5 5 5 5 5 5 5 5 5
(4)	AETR Test Facility	1960-1974	Building 4100	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Th-232	F F M M M S S S S M M	5 5 5 5 5 5 5 5 5 5 5
Nuclear Support Operations						
	DeSoto Facility	1966-1968	Building 101 (powder room)	U-234 U-235 U-236 U-238	S S S S	1 1 1 1
2.2.1.3.1 (1) 2.2.1.3.5 (1)	SRE Support Complex	1954-1964	Buildings 4003, 4163, 4041, 4654, 4689, 4653, 4606,4773	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 Th-232	F F M M M S S S S M M M M M	5 5 5 5 5 5 5 5 5 5 5 5 5 5
2.2.1.3.1 (3)	Uranium Carbide Fuel Pilot Plant	1964-1967	Building 4005	U-234 U-235 U-238	M M M	5 5 5
	Radiation Instrument Calibration Laboratory	1984-1996	Building 4011	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 Th-232	F F M M M S S S S M M M M M	5 5 5 5 5 5 5 5 5 5 5 5 5 5

Table 2-3 (Continued). Area information and parameters of nuclear operations.

Section	Name	Period of operations[a]	Facility	Radioactivity		
				Radio-isotopes	Solubility type	Part'le size (µm AMAD)
Nuclear Support Operations (continued)						
2.2.1.3.6 (1)	Van de Graaff Accelerator	1960-1964	Building 4030	H-3		
2.2.1.3.2 (1)	Hot Laboratory	1957-1988	Building 4020	Sr-90	F	5
				Cs-137	F	5
				U-234	M	5
				U-235	M	5
				U-238	M	5
				Pu-238	S	5
				Pu-239	S	5
				Pu-240	S	5
				Pu-241	S	5
				Am-241	M	5
				Co-60	M	5
				Eu-152	M	5
				Eu-154	M	5
				Pm-147	M	5
2.2.1.3.7 (2)	Liquid Metals Component Test Building	1962-1986	Building 4023	Sr-90	F	5
				Cs-137	F	5
				Co-60	M	5
				Eu-152	M	5
				Eu-154	M	5
2.2.1.3.3 (1)	Radioactive Measurement Facility	1959-1974	Building 4029	Ra-226	M	5
2.2.1.3.1 (2)	NMDF	1967-1979	Building 4055	U-234	M	5
				U-235	M	5
				U-238	M	5
				Pu-238	S	5
				Pu-239	S	5
				Pu-240	S	5
				Pu-241	S	5
2.2.1.3.1 (4) 2.2.1.3.7 (1)	Fuel Storage Facility	1958-1993	Building 4064	Cs-137	F	5
				U-234	M	5
				U-235	M	5
				U-238	M	5
				Pu-238	S	5
				Pu-239	S	5
				Pu-240	S	5
				Pu-241	S	5
				Am-241	M	5
				Co-60	M	5
				Eu-152	M	5
				Eu-154	M	5
2.2.1.3.4 (1)	RMDF	1959-present	Buildings 4021/4022	Sr-90	F	5
				Cs-137	F	5
				U-234	M	5
				U-235	M	5
				U-238	M	5
				Pu-238	S	5
				Pu-239	S	5
				Pu-240	S	5
				Pu-241	S	5
				Am-241	M	5
				Co-60	M	5
				Eu-152	M	5
				Eu-154	M	5
				H-3	M	5
	Mechanical Component Development and Counting Building	1956-1963	Building 4363	Sr-90	F	5
				Cs-137	F	5

Table 2-3 (Continued). Area information and parameters of nuclear operations.

Section	Name	Period of operations[a]	Facility	Radioactivitiy		
				Radio-isotopes	Solubility type	Part'le size (µm AMAD)
Nuclear Support Operations (continued)						
2.2.1.2.2 (4) (5)	Radiation Instrument Calibration and Radiological Sample Counting Laboratory	1985-present	Building 4100	Sr-90	F	5
				Cs-137	F	5
				U-234	M	5
				U-235	M	5
				U-238	M	5
				Pu-238	S	5
				Pu-239	S	5
				Pu-240	S	5
				Pu-241	S	5
				Am-241	M	5
				Co-60	M	5
				Eu-152	M	5
				Eu-154	M	5
				H-3	M	5

a. For reactors, refers to operation of the reactor rather than program duration dates provided in Figure 2-2.

Table 2-4. Magnitude of nuclear operations.

Section	Name, Rating, Period[a]	Facility	Radio-isotopes	Magnitude	
				Ci	Text description
Reactor operations					
2.2.2.1	WBNS Reactor/ 0.5 Wthr 1952-1955	Downey Plant	Sr-90	1.47E+00	2.2.2.1
			Cs-137	1.53E+00	
			U-234	1.61E-07	
			U-235	3.72E-06	
			U-238	5.79E-08	
			Pu-238	1.99E-03	
			Pu-239	3.66E-05	
			Pu-240	1.72E-05	
			Pu-241	9.99E-04	
			Am-241	3.48E-06	
2.2.2.2	L-47, L-77/ 10 Wthr 1954-1960	Vanowen facility	--	--	2.2.2.2
2.2.2.3	L-77/ 10 Wthr 1960-1976	DeSoto Facility Bldg. 104	--	--	2.2.2.3
2.2.1.1.1 (1)	KEWB Reactor 1 kWthr 1956-1966	Building 4073	Sr-90	2.93E+03	2.4.1
			Cs-137	3.06E+03	
			U-234	3.22E-04	
			U-235	7.44E-03	
			U-238	1.16E-04	
			Pu-238	3.97E+00	
			Pu-239	7.32E-02	
			Pu-240	3.44E-02	
			Pu-241	2.00E+00	
			Am-241	6.96E-03	
(2)	L-85 Reactor 3 kWthr 1956-1980	Building 4093	Sr-90	8.80E+03	2.4.1
			Cs-137	9.18E+03	
			U-234	9.65E-04	
			U-235	2.23E-02	
			U-238	3.47E-04	
			Pu-238	1.19E+01	
			Pu-239	2.20E-01	
			Pu-240	1.03E-01	
			Pu-241	5.99E+00	
			Am-241	2.09E-02	

Table 2-4 (Continued). Magnitude of nuclear operations.

Section	Name, Rating, Period[a]	Facility	Radio-isotopes	Magnitude	
				Ci	Text description
Reactor operations (continued)					
2.2.1.1.2 (1)	SRE Reactor 20 MWthr 1957-1964	Building 4143	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 Th-232 H-3	-- -- -- -- Total activity 1.20E+08 -- -- -- --	2.4.1
2.2.1.1.3 (1)	SER 50 kWthr 1959-1960	Building 4010	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	1.47E+05 1.53E+05 1.61E-02 3.72E-01 5.79E-03 1.99E+02 3.66E+00 1.72E+00 9.99E+01 3.48E-01 -- -- 1.94E+03 6.18E+02	2.4.1
(2)	S8ER 600 kWthr 1963-1965	Building 4010	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	1.76E+06 1.84E+06 1.93E-01 4.46E+00 6.95E-02 2.38E+03 4.39E+01 2.06E+01 1.20E+03 4.18E+00 -- -- 2.32E+04 7.42E+03	2.4.1
(3)	S2DR 50 kWthr 1961-1962	Building 4024	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	1.91E+05 1.99E+05 2.09E-02 4.84E-01 7.53E-03 2.58E+02 4.76E+00 2.23E+00 1.30E+02 4.52E-01 -- -- 2.52E+03 8.03E+02	2.4.1

Table 2-4 (Continued). Magnitude of nuclear operations.

Section	Name, Rating, Period[a]	Facility	Radio-isotopes	Magnitude	
				Ci	Text description
Reactor operations (continued)					
(4)	S10FS 37 kWthr 1965-1966	Building 4024	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	2.93E+06 3.06E+06 3.22E-01 7.44E+00 1.16E-01 3.97E+03 7.32E+01 3.44E+01 2.00E+03 6.96E+00 -- -- 3.87E+04 1.24E+04	2.4.1
2.2.1.2.1 (4)	SNAP Transient Test Facility 1971	Building 4024	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	-- -- -- -- -- -- -- -- -- -- -- -- -- --	2.4.1
(5)	STR 50 kWthr 1961-1964	Building 4028	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	1.47E+05 1.53E+05 1.61E-02 3.72E-01 5.79E-03 1.99E+02 3.66E+00 1.72E+00 9.99E+01 3.48E-01 -- -- 1.94E+03 6.18E+02	2.4.1
(6)	STIR 1 MWthr 1964-1972	Building 4028	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	1.82E+06 1.89E+06 1.99E-01 4.61E+00 7.17E-02 2.46E+03 4.53E+01 2.13E+01 1.24E+03 4.31E+00 -- -- 2.40E+04 7.65E+03	2.4.1

Table 2-4 (Continued). Magnitude of nuclear operations.

Section	Name, Rating, Period[a]	Facility	Radio-isotopes	Magnitude	
				Ci	Text description
Reactor operations (continued)					
(7)	S8DR 600 kWthr - 1 MWthr 1968-1969	Building 4059	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	1.08E+05 1.12E+05 1.18E-02 2.73E-01 4.25E-03 1.46E+02 2.68E+00 1.26E+00 7.33E+01 2.55E-01 -- -- 1.42E+03 4.53E+02	2.4.1
2.2.1.2.1 (2)	SNAP Critical Test Facility 1962-1968	Building 4012	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241	-- -- -- -- -- -- -- -- -- --	2.4.2
	HMRFSR 1970-1972				
2.2.1.2.1 (1)	SNAP Critical Test Facility 1957-1963	Building 4373			
(3)	SNAP Flight System Critical Facility 1964-1965	Building 4019			
2.2.1.2.2 (2)	OMR Critical Facility. 1958-1967	Building 4009	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154	-- -- -- -- -- -- -- -- -- -- -- -- --	2.4.2
(3)	SGR Critical Facility. 1958-1967				
(4)	AETR Test Facility. 1960-1974	Building 4100	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Th-232	-- -- -- -- -- -- -- -- -- -- --	2.4.2
Nuclear Support Operations					
2.2.2.3	DeSoto Facility 1966-1968	Building 101 (powder room)	U-234 U-235 U-236 U-238	-- -- -- --	2.2.2.3

Table 2-4 (Continued). Magnitude of nuclear operations.

Section	Name, Rating, Period[a]	Facility	Radio-isotopes	Magnitude	
				Ci	Text description
Nuclear Support Operations (continued)					
2.2.1.3.1 (1) 2.2.1.3.5 (1)	SRE Support Complex 1954-1964	Buildings 4003, 4163, 4041, 4654, 4689, 4653, 4606,4773	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 Th-232	-- -- -- -- Total Activity 1.20E+08 -- -- -- -- -- --	2.4.3 2.4.7
2.2.1.3.1 (3)	Uranium Carbide Fuel Pilot Plant 1964-1967	Building 4005	U-234 U-235 U-238	-- -- -- --	2.2.1.3.1 (3)
	Radiation Instrument Calibration Laboratory 1984-1996	Building 4011	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 Th-232	-- -- -- -- -- -- -- -- -- -- -- -- -- --	
2.2.1.3.6 (1)	Van de Graaff Accelerator 1960-1964	Building 4030	H-3	--	2.2.1.3.6 (1) 2.4.8
2.2.1.3.2 (1)	Hot Laboratory 1957-1988	Building 4020	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 Pm-147	2.93E+06[a] 3.06E+06 3.22E-01 7.44E+00 1.16E-01 3.97E+03 7.32E+01 3.44E+01 2.00E+03 6.96E+00 -- -- 3.87E+04 1.40E+05	2.4.4 2.4.5
2.2.1.3.7 (2)	Liquid Metals Component Test Building 1962-1986	Building 4023	Sr-90 Cs-137 Co-60 Eu-152 Eu-154	-- -- -- -- --	2.2.1.3.7 (2) 2.4.9
2.2.1.3.3 (1)	Radioactive Measurement Facility 1959-1974	Building 4029	Ra-226	--	2.2.1.3.3 (1)

Table 2-4 (Continued). Magnitude of nuclear operations.

Section	Name, Rating, Period[a]	Facility	Radio-isotopes	Magnitude	
				Ci	Text description
Nuclear Support Operations (continued)					
2.2.1.3.1 (2)	NMDF 1967-1979	Building 4055	U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241	-- -- -- -- -- -- -- --	2.4.6
2.2.1.3.1 (4) 2.2.1.3.7 (1)	Fuel Storage Facility 1958-1993	Building 4064	Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154	-- -- -- -- -- -- -- -- -- -- -- --	2.2.1.3.7 (1) 2.4.3 2.4.9
2.2.1.3.4 (1)	RMDF 1959-present	Buildings 4021/ 4022	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	-- -- -- -- -- -- -- -- -- -- -- -- -- 	2.4.6
	Mechanical Component Development and Counting Building 1956-1963	Building 4363	Sr-90 Cs-137	-- --	
2.2.1.2.2 (4) (5)	Radiation Instrument Calibration and Radiological Sample Counting Laboratory 1985-present	Building 4100	Sr-90 Cs-137 U-234 U-235 U-238 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Co-60 Eu-152 Eu-154 H-3	-- -- -- -- -- -- -- -- -- -- -- -- -- --	2.2.1.2.2 (4) (5)

a. The radioactivity of S10FS3 is listed. It represents the highest radioactivity in low-power reactors at the site.

2.4.1 Operation of Nuclear Reactors

Operation of a nuclear reactor creates three sources of radioactivity: Fission, transuranic, and activation products. When part of the fissionable material in the fuel element is used up, or when a reactor is decommissioned, the fuel elements are removed. These spent fuel elements contain the

fission products and transuranic materials generated by operation of the reactor, and the activation products in the cladding. The amount of radioactivity generated by a nuclear reactor depends in part on the amount of heat it generates. The heat generated is measured in thermal watts. The reactors at SSFL all operated at low power levels. Six had power levels of less than 100 kWt, three had power levels of 600 to 1,000 kWt, and one was a 20-MWt test reactor.

The amount of radioactivity generated by a nuclear reactor is not measured while the reactor is operating, but it can be calculated from the power level and other parameters of the reactor. The radioactivity generated per watt of power is a function of operating time. However, an equilibrium is reached after about 1 year of operation, wherein the amount of new radioactivity being generated is balanced by the decay of short-lived fission products. This equilibrium radioactivity is approximately 6 Ci/Wt for a reactor that has operated between 1 and 10 years. This value agrees with the results of a nuclear reactor design computer code (RSIC 1987) and with measured data (5.6 Ci/W from Glasstone and Sesonske 1981). Therefore, the curies of radioactivity in a reactor can be estimated (conservatively) by multiplying its thermal power level in watts by 6.

Small amounts of tritium can be formed when neutrons from reactors are absorbed by the lithium naturally present in minute quantities in the granite aggregate used in the concrete shielding. When a ^{6}Li atom absorbs a neutron, it transmutes into an alpha particle (helium nucleus) and tritium.

There have been 10 different nuclear reactors at the SSFL in seven different facilities over the last 30 years. Table 2-5 lists the reactor name, building number, facility name, nominal power level, operating period, total power generated, and calculated level of radioactivity for each reactor.

A total of 135 million Ci of radioactivity was generated in the fuel from about 7,200 MWd of total reactor operation; a much smaller amount (perhaps several thousand curies) was generated as activation products in the reactor vessels, shields, and facilities. Figure 2-6 is a graph of the amount of radioactivity at Area IV as a function of time. As the graph shows, the vast majority of the radioactivity has been removed, but about 60 Ci remains among a few reactor sites and other facilities. Almost 90% of the total SSFL radioactivity was generated by the 20-MWt SRE.

The total amount of artificial radioactivity in the form of activation products and contamination still present at SSFL is about 60 Ci; over 99% of this is contained in a controlled manner in activated or contaminated structures that are locked, fenced, and within a guarded perimeter. There is calculated to be less than 0.1 Ci that is unconfined. The unconfined radioactivity is present in very low concentration levels in three areas. Access to these areas is controlled and restricted in accordance with applicable regulations. Routine surveys show that this radioactivity is not mobile.

The distinct steps in Figure 2-6 represent the discontinuation of SRE operations in 1964, the SNAP reactors in 1972, and the L-85 experimental reactor in 1980. The current residual contamination and activation level of 60 Ci is predominantly (58 Ci) attributed to the SNAP Ground Prototype Test Facility (Building 4059) where final decontamination was completed in 1992.

2.4.2 Operation of Criticality Test Facilities

A controlled nuclear chain reaction can only be sustained when the neutrons generated by fission of the reactor fuel balance the neutrons used up and lost. When the reactor is adjusted so that this balance is achieved, it is said to be *critical*. Criticality can be achieved in several ways such as by bringing parts of a core of fissionable material together (to reduce the number of neutrons that escape) or by removing control rods (to reduce the number of neutrons captured in the control rods).

Table 2-5. Reactor operations (Oldenkamp and Mills 1991).

Reactor Name	Bldg No.	Facility Name	Map Loc.	Power Level (kWt)	Operating Period	Power Generated (MWd)	Radioactivity at End of Operation (10^3 Ci)
KEWB	073	Kinetics Experiment Water Boiler	5C	1	7/56 to 11/66	1	6
L-85/AE-6	093	L-85 Nuclear Experimentation Reactor	4C	3	11/56 to 2/80	2	18
SRE	143	Sodium Reactor Experiment	4B	20,000	4/57 to 2/64	6700	120,000
SER	010	SNAP Experimental Reactor Facility	7D	50	9/59 to 12/60	13	300
S2DR	024	SNAP Environmental Test Facility	6D	65	4/61 to 12/62	13	390
STR	028	Shield Test Facility	6D	50	12/61 to 7/64	1	300
S8ER	010	S8ER Test Facility	7D	600	5/63 to 4/65	215	3,600
STIR	028	Shield Test Irradiation Facility	6D	1,000	8/64 to /74	28	3,714
S10FS3	024	SNAP Environmental Test Facility	6D	37	1/65 to 3/66	16	6,000
S8DR	059	SNAP Development Reactor Facility	8D	619	5/68 to 12/69	182	220
		Totals		22,400		7171	135,000

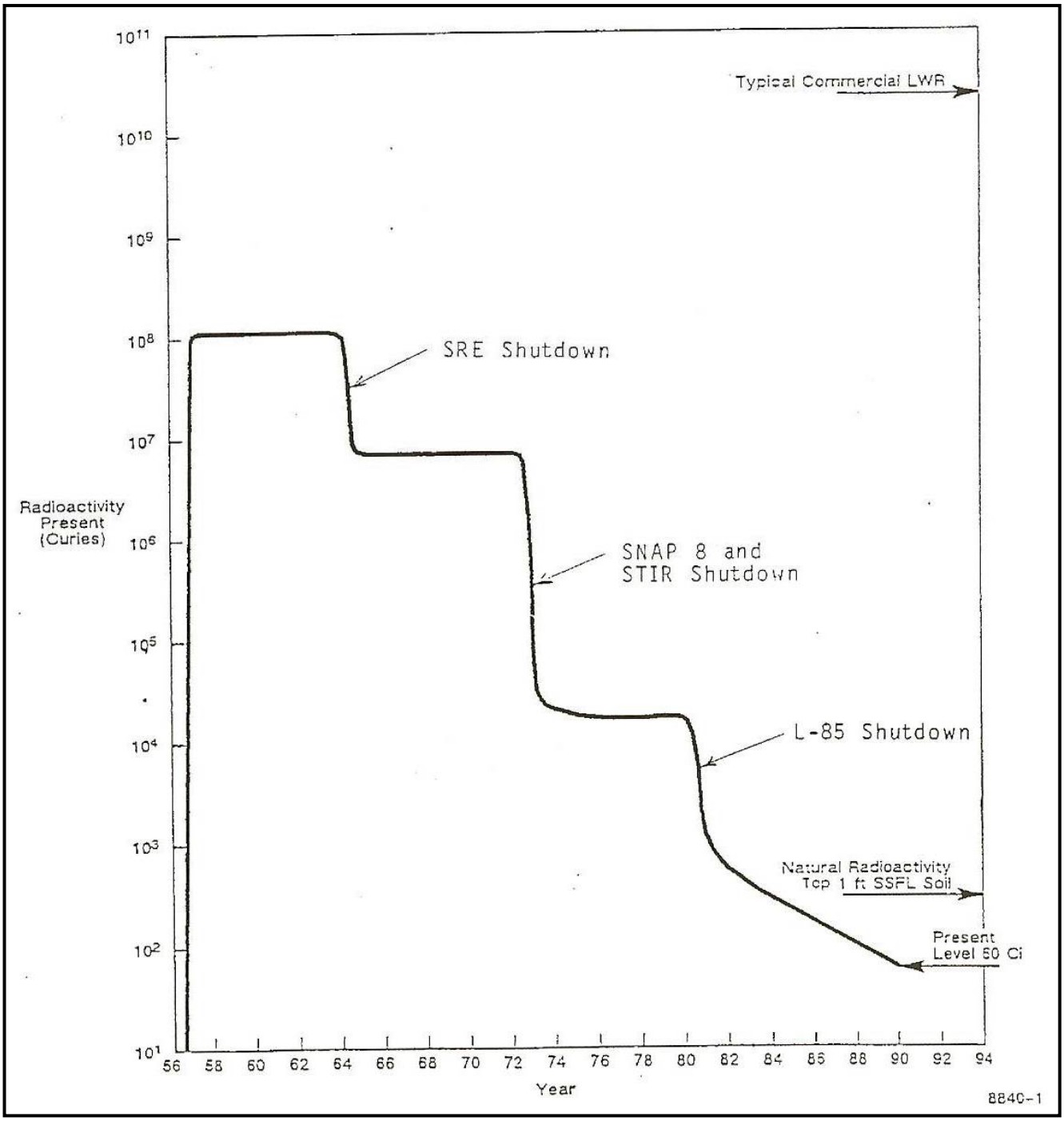

Figure 2-6. Radioactivity from reactors (Oldenkamp and Mills 1991).

Performance of a criticality test generates the same types of radioactivity as operation of a reactor, but in extremely small amounts. A criticality test operates at a very low power level (up to a few hundred watts), and neutron levels are correspondingly very low. Therefore, a large number of criticality tests can occur in the same test facility without generating much activation product radioactivity. Almost the entire amount of generated radioactivity is contained within the fuel elements of the criticality test. When these are removed, the radioactivity is removed. There have been dozens of criticality tests at Area IV in seven different facilities (i.e., SNAP Critical Facilities (2), SNAP Transient Test Facility, OMR, SGR, AETR, and the Fast Critical Experiment Laboratory).

2.4.3 Manufacture of Reactor Fuel Assemblies

The SRE fuel elements were assembled in the Engineering Test Building (Building 4003) from uranium and thorium metal slugs made off the site. The slugs were loaded into metal tubes, the interstices were filled with sodium metal, and the tubes were sealed. Fuel elements for three cores were prepared, but only two were used. The third core was eventually shipped off the site.

The NMDF (Building 4055) was built specifically for development work involving plutonium. It was operated with releases below the effluent limits until 1979.

The uranium carbide fuel manufacturing pilot plant was a small-scale production facility built in Building 4005 to study the operations associated with manufacturing reactor fuel assemblies from uranium carbide. Operations were completed in about 9 months in 1967, and production was small.

The Fuel Storage Facility (Building 4064) was a vault built to provide secure storage for fissionable fuel material (enriched uranium and plutonium) used to make reactor fuel.

2.4.4 Disassembly and Examination of Reactors and Used Reactor Fuel Assemblies

Disassembly and examination of reactor fuel assemblies and other test specimens occurred remotely in the heavily shielded Hot Lab (Building 4020) built at the SSFL for that purpose. The disassembly, fuel removal, and size reduction operations usually involved working with highly radioactive materials. The Hot Lab was also used to disassemble or separate the radioactive material from its cladding, and the separated materials then shipped away. In addition, the Hot Lab was used to manufacture sealed sources, for leak checks on sources, and for cutting and machining operations on ^{60}Co.

During normal operation, workers on the cold side of the hot cells primarily received external radiation from the radioactive materials inside the hot cell shielded by the shield walls and windows. In general, the design basis for the shield wall and window was to attenuate the direct radiation to a dose rate of 0.5 mrem/hr at the surface of the shield walls or windows.

2.4.5 Fabrication, Use, and Storage of Radioactive Sources

Radiation sources were used to calibrate nuclear instruments and for some forms of radiography, irradiation testing, and other applications. Sources were manufactured in the Hot Lab and used in various facilities at the SSFL and elsewhere. Approximately 140,000 Ci of radioactive material (primarily ^{147}Pm) were fabricated into sources at the Hot Lab. They were stored in secured locations and used under carefully controlled conditions. There are currently less than 100 Ci of sources stored at the SSFL.

2.4.6 Preparation of Radioactive Material for Disposal

Radioactive waste was prepared for disposal primarily at the RMDF with support operations at the ISF. The RMDF was built and used for fuel storage and processing solid and liquid waste for disposal in conjunction with the operation of the SRE. It has since been used to support all of the SSFL nuclear operations. The ISF was built to store SRE fuel elements in 10 thimbles installed in holes drilled in bedrock, and it was used for storage of fuel shipping casks for other reactors (OMRE and SNAP).

2.4.7 Research on Reprocessing Used Reactor Fuel

Tests occurred at the SSFL for the development of a reactor fuel reprocessing process in the well-shielded Hot Cave in Building 4003, the Engineering Test Building. These experiments used up to kilogram quantities of unirradiated uranium and thorium, and up to 100-g quantities of highly irradiated materials. In general, the design basis for the shield wall and window was to attenuate the direct radiation to a dose rate of 0.5 mrem/hr at the surface of the shield walls or windows.

2.4.8 Operation of Particle Accelerators

Rockwell operated a Van de Graaff generator in Building 4030 to bombard tritium targets with deuterons to produce neutrons. A second Van de Graaff generator operated at the SRE facility to generate neutrons for neutron activation analyses of materials.

2.4.9 Research Using Radioisotopes

The TRUMP-S program required the use of radioisotopes as described in Section 2.2.1.3.7. The program used small quantities of transuranic materials: 75 g of depleted uranium, 5 g of plutonium, 4 g of neptunium, and 4 g of americium were ordered for the TRUMP-S program. All of these materials were received and initially stored in Building 4064, but the material was shipped to the University of Missouri when the program transferred there.

Another radioisotope research program was a corrosion test program in the Corrosion Testing Laboratory (Building 4023). The laboratory was used to study the deposition behavior of activation products (^{54}Mn and ^{60}Co) in flowing sodium to develop more effective traps for these isotopes. An activated piece of fuel cladding containing these isotopes was used in these tests.

2.5 MAJOR INCIDENTS

Table 2-6 describes major site incidents that might have significant potential for internal or external exposure to personnel.

2.6 RADIOLOGICAL ACCESS CONTROLS

Each specific facility or building in which nuclear operations were conducted at the SSFL site was designated as Radiological Control Area. Entry to those areas was controlled.

Table 2-6. Major incidents.

Location/facility	Description
Water Boiler Neutron Source (WBNS) Building 4093	On March 25, 1959, one of the instruments that controlled the power of the AE-6 malfunctioned and allowed the reactor to exceed the normal power level of 3 kWt and to approach 4 kWt. As soon as the power level was recognized, the reactor was shut down by the operator. The operation at the higher power level lasted only 1 minute. A small amount of fission gas was released when an operational error occurred during the transfer of gases (oxygen and hydrogen from the radiolytic decomposition of the water in the fuel) from the reactor vessel to a holding tank. It is estimated that the maximum release was less than 10 mCi, principally Xe-135. The building volume was sufficient to dilute the activity to a concentration essentially equal to that permitted by regulation for continuous 40-hr/week exposures. The contamination was cleaned up quickly and effectively, and there were no measurable radiation exposures to any of the personnel involved. Corrective action was taken, and there were no further incidents of any consequence.
Sodium Reactor Experiment (SRE) Building 4143	The reactor underwent an accidental partial blockage of sodium coolant in some reactor coolant channels in July 1959. This resulted in the partial melting of several of the reactor fuel assemblies and the release of some fission products that contaminated the reactor cooling system. All of the reactor safety systems functioned properly, and the reactor was safely shut down. The reactor fuel assemblies were then removed, inspected, and stored at the RMDF. (They were later declad in the Hot Lab, and the fuel and cladding was shipped off the site.) A second fuel loading was inserted, and the test operations were continued. Two of the fission products released from the damaged fuel elements were Xe-135 and Kr-85. These inert gases contaminated the protective reactor cover gas system. The cover gas was transferred to a holding tank and held long enough for the Xe-135 to decay away (9.2-hr half-life) and then released to the atmosphere through the stack in a controlled manner in concentrations which met AEC requirements. Based on measurements of the cover gas concentration and volume, less than 5 Ci of Kr-85 (10.8-yr half-life) were released in this way. The dispersion of the Kr-85 in the atmosphere diluted it so much that it would have resulted in a maximum theoretical calculated dose of 0.06 µrem to someone living in Susana Knolls, the nearest residential area at that time. The other fission products were retained in the primary sodium coolant and were removed during cleanup operations. About 54,950 lb of bulk primary sodium were drained into 158 55-gal drums that were shipped to Hanford, Washington, for storage and possible use in the Fast Flux Test Facility. Residual sodium was reacted with alcohol and the solution mixed with diatomaceous earth in 55-gal drums that were shipped to Beatty, Nevada, for permitted burial.
SNAP 8 Experimental Reactor (S8SR) Building 4010	During operation of the S8ER some cracks developed in the cladding that separated the zirconium-uranium alloy fuel from the NaK coolant. The cracks were the result of fuel swelling that stretched the cladding beyond its ductility limit. Some fission products diffused out of the fuel and found their way into the flowing NaK through the cracks in the cladding. There was no melting of the fuel or cladding. All of the fission products were completely contained within the reactor system.
SNAP 8 Development Reactor (S8DR) Building 4059	As with the S8ER, cladding cracks due to fuel swelling and low cladding ductility occurred during the operation of the S8DR. There was no melting of the fuel or the cladding, and all fission products were contained in the reactor system. The activated below-grade part of the facility was kept sealed and periodically inspected. An inspection in 1983 disclosed that groundwater was leaking into the reactor vault and becoming contaminated. Action was taken immediately to remove the contaminated water, process it, and dispose of it, and to begin a pumping program to ensure that radioactive water did not leak out of the cell. The leak was found and sealed, and the situation was stabilized.
Hot Lab Building 4020	On May 19, 1971, a fire occurred in the process of attempting to dispose of about 100 gal of NaK. The NaK contained about 100 Ci of mixed fission products. The fire was started upon loss of containment of the NaK when a hole was drilled in the tank fill line. Approximately 25 gal of NaK were released into the decontamination cell and burned. The normal facility high-volume ventilation system that draws all building air through HEPA filters confined essentially all combustion products to the Hot Lab. A radioactive source containing 1.57 mCi of Sr-90 was missing from the Hot Lab in January 1986. An investigation concluded that it was inadvertently included in radioactive waste during a cleanup and shipped off the site and disposed of as radioactive waste.
Radioactive Materials Disposal Facility (RMDF)	The septic tank leach field was accidentally contaminated by a dilute solution of fission products (primarily cesium and strontium) in 1962 due to the inadvertent opening of a valve in a liquid waste system. The valve was removed, and the leach field was cleaned up and released for unrestricted use. There was also a small amount of radioactive contamination on the north slope of the hill below the facility that was cleaned up.

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GLOSSARY

criticality

A state at which the nuclear chain reaction is sustained due to neutrons generated by fission of the fissile material balance the neutrons used up and lost. (k_{eff}=1)

criticality test facility

Criticality in reactors can be achieved in several ways such as by bringing parts of a core of fissionable material together (to reduce the number of neutrons that escape) or by removing control rods (to reduce the number of neutrons captured in the control rods). Criticality test facility is used to evaluate and develop parameters for reactor to achieve criticality for a variety of reactor core materials, moderators and reflectors.

curie (Ci)

Traditional unit of radioactivity equal to 37 billion (3.7×10^{10}) becquerels, which is approximately equal to the activity of 1 gram of pure ^{226}Ra.

rem

Traditional unit of radiation dose equivalent that indicates the biological damage caused by radiation equivalent to that caused by 1 rad of high-penetration X-rays multiplied by a quality factor. The average American receives 360 millirem a year from background radiation. The sievert is the International System unit; 1 rem equals 0.01 sievert. The word derives from roentgen equivalent in man; rem is also the plural.