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Historical and Programmatic Overview of Building 3019

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Chemical Technology Division

HISTORICAL AND PROGRAMMATIC OVERVIEW OF BUILDING 3019

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1. INTRODUCTION

A series of decisions relating to the fate of Building 3019 are currently required. Before these decisions can be prudently made, an understanding of the historical and programmatic background is necessary to establish the extent of the contributions made in support of the government's* missions. Accordingly, this report outlines the scope and objectives of a pilot plant in process development and interim production and relates these functions to both the history and technology development of the reprocessing segment of the nuclear fuel cycle. The specific role of, and contributions made by, the operations within Building 3019 since 1943 are presented and documented.

2. SUMMARY

In early 1943, as part of the Manhattan Project, plans were made to build an air-cooled nuclear experimental pile, a chemical separations pilot plant, and supporting laboratories on an isolated tract known as X-10. These major installations became the prime function of the Clinton Engineer Works, now known as Oak Ridge National Laboratory (ORNL). Since that time, Building 3019 (formerly known as Building 205) has served as a pilot plant in the development of several radiochemical processes that have found plant-scale application in both government and commercial facilities on a worldwide basis. In addition to the process development role, the facility's operations have also produced large quantities of product materials (plutonium, uranium of all isotopes, thorium, and special isotopes) while processing highly irradiated fuel.

Because Building 3019's role was that of a pilot plant during the formative years of reprocessing technology development, an attempt has been made in this report to outline the contributions made in this category. It is also recognized that some degree of historical appreciation is necessary to grasp the significance of the pilot plant in process development; therefore, a brief history of the fuel reprocessing segment of the nuclear fuel cycle is given. Finally, a brief description of the building is given along with a summation of the future plans for the facility.

The major programs conducted within Building 3019 in support of the government's missions during the period from 1943 to 1976 (the period of formidable development) are presented in tabular form. These tables also present the quantities of material recovered as the result of the building's operation. These materials were recycled into other government programs as required. In addition to the efforts expended in the handling of uranium-based spent reactor fuel, a section of the report also addresses a summary of the reprocessing of irradiated thorium in the United States, indicating the quantity of the ^{233}U recovered to date.

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*Government as used in this document refers to the Atomic Energy Commission (AEC), Energy Research and Development Administration (ERDA), or Department of Energy (DOE), depending upon the related time frame discussed.

As is well known, this particular isotope is currently the major one of concern to the operations taking place in the building. It is also recognized that the ^{233}U isotope has unique characteristics relating to criticality, shielding, and contamination control.

In summary, it can be concluded from the information presented in this report that the programs conducted in Building 3019 during its 51-year history have had a major impact on the government's missions. The versatility of the facility has been adequately demonstrated, indicating that the building represents a valuable asset to future government programs.

3. ROLE OF A PILOT PLANT

A pilot plant is one operation step in the orderly plan of chemical process development. The usual function of a pilot plant is to identify and resolve issues arising from the integration of all phases of the process and to obtain adequate quantitative data for the design and operation of an economical production plant. In addition to being a development facility, a pilot plant serves as a small-scale production plant, having many of the characteristics of a full-scale production plant. In general, development programs in a pilot plant should accomplish the following primary objectives:

1. Confirm the feasibility of the proposed process.
2. Obtain quantitative engineering data necessary for the design and operation of a production plant.
3. Provide quantities of the product for large-scale evaluation at other sites.
4. Bring out chemical and engineering problems that were not recognized in smaller scale development work.

4. BRIEF HISTORY OF FUEL REPROCESSING

The first large-scale nuclear reactors were built during World War II. These reactors were designed for the production of plutonium for use in nuclear weapons. The only chemical reprocessing required, therefore, was the extraction of the plutonium, free from fission product contamination, from the spent natural uranium fuel. In 1943, several methods were proposed for separating the relatively small quantity of plutonium from the uranium and fission products. The first method selected, a precipitation process called the Bismuth Phosphate process, was used at ORNL in the 1943–1945 period to produce quantities of plutonium for evaluation and use in weapons programs.

The Bismuth Phosphate process was first operated on a large scale at Hanford, Washington, in the latter part of 1944. It was successful for plutonium separation in the emergency situation existing then, but it had a significant weakness, namely, the inability to recover uranium.

Even before the precipitation process was chosen as the basis for the design of the Hanford plutonium separations plant, research on other methods for treating spent fuel—namely, volatility, adsorption, and solvent extraction—had been initiated. Significant advances in chemical reprocessing methods were made in the immediate postwar period, particularly in methods utilizing solvent extraction. The basic principle upon which this method depends is that the nitrates of uranium and plutonium in the higher oxidation states are readily soluble in certain organic liquids that are immiscible with water. The nitrates of fission products are, in general, essentially insoluble in these liquids.

The first successful solvent extraction process for the recovery of both uranium and plutonium in decontaminated form was developed at Argonne National Laboratory (ANL) soon after World War II. Methyl isobutyl ketone (hexone) was used as the organic solvent, and aluminum nitrate was added to the aqueous phase to improve the separation. Pilot plant testing of this process, the Redox process, was carried out with available equipment at ORNL (Building 3019) from 1945 to 1951, and large-scale operation began at Hanford in October 1952. The Redox process offered advantages over the Bismuth Phosphate process of (1) continuous operation, (2) a large decrease in waste volume, and (3) the ability to recover uranium as well as plutonium.

From 1948 to 1950, while the Redox process was under development, laboratory studies were being made on an improved solvent extraction process. This new method was called the Purex process and employed tributyl phosphate (TBP) as the organic solvent and nitric acid rather than aluminum nitrate in the aqueous phase. The Purex process was developed by ORNL and Knolls Atomic Power Laboratory (KAPL) and was carried through the pilot plant stage at ORNL (Building 3019) from 1949 to 1960. This process offered four significant advantages over the Redox process:

1. a reduction in waste uranium,
2. greater process flexibility,
3. decreased solvent fire hazard, and
4. a decrease in operating costs.

This new process was put into operation at the Savannah River Site (SRS) at Aiken, South Carolina, in November 1954 and at Hanford in January 1956.

Since 1944, reprocessing has been practiced under the auspices of the government at one or more of the defense installations at the SRS near Aiken, South Carolina; at Hanford, Washington; and at Idaho Falls, Idaho. However, the growth of nuclear power generation in the 1960–1970 period prompted the government to encourage the entry of commercial firms into the reprocessing sector of the fuel cycle to recover unburned

uranium and plutonium from fuel assemblies discharged from commercial power reactors. Accordingly, the first commercial reprocessing plant was constructed, and a provisional operational license was granted in 1966 to Nuclear Fuel Services (NFS) for a plant in West Valley, New York. During the period, other firms became active in pursuing commercial reprocessing of irradiated fuel from the nation's reactors. These firms include General Electric (GE) Company, Allied Chemical Corporation, National Lead Company, Atlantic Richfield Company, the Gulf Oil Corporation, and Exxon Corporation. Based on a series of studies, the General Electric Company elected to build a 1-MTHM/d plant in Morris, Illinois, employing the Aquafluor process, which differs considerably from the standard Purex process used in other plants. A third plant of appreciably larger size (5 MTHM/d) was then constructed by Allied General Nuclear Services (AGNS) in Barnwell, South Carolina.

The NFS plant successfully operated for a period of 6 years, during which time a total of 641 tons of irradiated fuel was processed. To become more competitive, the plant was shut down in 1972 to increase its capacity from 1 to 5 MTHM/d. As a result of a series of new and retroactive regulations placed on the reprocessing sector by regulatory groups, mainly in the seismic area, the owners of the plant concluded that the cost of compliance with the new regulations for an expanded plant could not be justified and decided not to reopen the plant. Under terms of its operating permit from the state of New York, plant ownership reverted to the state.

In the case of General Electric's Morris, Illinois, plant, the company decided not to proceed with the operation of the as-built plant following a series of operational difficulties experienced after a lengthy testing period. The difficulties were associated with the operation of a new process employing complicated equipment operating in a remote mode behind heavily shielded walls. No radioactive materials were involved in checkout testing.

The third commercial plant, built during the 1971–1975 period and owned by AGNS, was completed but never operated. Efforts to license and operate this plant were terminated by a commercial reprocessing moratorium in response to proliferation concerns expressed by President Carter.

Exxon was designing a modern reprocessing plant that was scheduled to be built in Oak Ridge, Tennessee; however, because of the moratorium, it was also canceled.

In spite of the dormant conditions of commercial reprocessing in the United States, separations technology has continued to evolve throughout the world, and fuel reprocessing activity has advanced in several nations. Plants currently exist in the United Kingdom, France, Japan, India, Belgium, Germany, China, and the former Soviet Union. In addition to the processing of spent fuels from light-water reactors (LWRs),

development of the technology necessary for the reprocessing of fast reactor fuels is advancing at a rapid pace in these nations. The United States has also been active in the development of this technology by way of research carried out in universities and government-owned laboratories.

5. ROLE OF BUILDING 3019 IN REPROCESSING TECHNOLOGY

It should be noted that the first tens-of-grams quantities of plutonium were precipitated from tons of uranium and grams of fission products in Oak Ridge in 1943, just 4 years after Dr. Seaborg isolated a few micrograms from an accelerator target. Between 1943 and the present, hundreds of thousands of tons of irradiated uranium have been processed, both in defense and commercial reprocessing plants, on a worldwide basis.

Since 1942, ORNL (formally Clinton Engineer Works) has been continuously engaged in process development of the nuclear fuel cycle. The basic process techniques in which ORNL participated, along with their chronology, are listed in Table 1. As can be seen from this table, Building 3019 has played a major role in this development effort. The role of a pilot plant in the major development efforts undertaken in the reprocessing segment of the fuel cycle for the 1943–1976 period (the period of most development) is given in Table 2. The sites of full-scale plants that ultimately resulted from this development effort are also presented in this table. Major segments of reprocessing unit operations were also developed in pilot plants to formulate auxiliary processes for these large plants. Primary among these specific process development programs were the head-end operations necessary to dissolve the irradiated fuel and to remove the iodine and rare gases from the off-gas streams. Table 3 indicates some of the significant processes developed in this category.

For many years, ORNL has been recognized worldwide as a leader in the development of reprocessing technology. In this regard, Building 3019 has played an integral part in each of the spent fuel reprocessing flowsheets used in plant-scale application within the United States (including both defense and proposed commercial facilities). Commercial firms that constructed reprocessing plants that would employ the Purex process, for which Building 3019 was the pilot plant, included the AGNS Plant at Barnwell, South Carolina, and the Midwest Fuel Recovery Plant (MFRP) at Morris, Illinois, operated by General Electric. In the case of the MFRP, the flowsheet selected included both solvent extraction and fluoride volatility methods. Both of these concepts were demonstrated in pilot-scale efforts in Building 3019. Exxon was proposing to build a large reprocessing plant in Oak Ridge that would also employ Purex process concepts. Purex technology has continued to evolve throughout the world and has advanced in several nations. Plants currently exist in the United Kingdom, France, Japan, China, and the former Soviet Union.

Table 1. Chronology of reprocessing experience at ORNL

Period	Process	Building No.
1943–1945	Bismuth Phosphate	3019
1945–1951	Redox	3019
1945–1952	RaLa	3026
1946–1948	Hexone-25	706A
1946–1948	Hexone-23	706A
1948–1949	Uranyl Ammonium Phosphate	706A
1948–1958	Metal Recovery	3505
1948–1953	TBP-25[a]	3505
1949–1960	Purex	3019, 3505
1949–1968	Fluoride Volatility[b]	3019
1949–1976	Fuel Preparation[c]	3019, 4505, 7930
1951–1976	Raw Materials[d]	4500
1952	TBP-Interim-23	3503
1952–Present	Thorex	3019
1953–1959	Feed Materials[e]	4500
1955–1976	Head-End[f]	4500N, 4505, 4507, 7601
1961–1976	TRU[g]	3508, 4507, 7920

[a]Includes Homogeneous Reactor Fuel Processing.
[b]Includes Aircraft Reactor Experiment (ARE) and Molten Salt Reactor Experiment (MSRE) fuel reprocessing.
[c]Includes aqueous sulphate fuels, sol-gel, carbide-graphite-oxide spheres (high-temperature gas-cooled reactor, Experimental Gas-Cooled Reactor Rover), molten salts (MSRE, ARE).
[d]Includes SLURREX, AMEX, DAPEX, MONEX, and other processes.
[e]Includes EXCER, METALLEX, FLOOROX, and DRUHM.
[f]Includes mechanical methods, DAREX, ZIRCEX, ZIRFLEX, Voloxidation, etc.
[g]Includes TRAMEX, CLEANEX, BERKEX, PLURIX, and others.

Table 2. Reprocessing experience at ORNL—separation processes

Development Date	Process	Method	Hot pilot plant	Plant site
1943–1945	Bismuth Phosphate	Precipitation for Pu only, from metal slugs	ORNL	Hanford
1946–1950	Redox	Solvent extraction: hexone for U and Pu from metal slugs	ORNL, Hanford, ANL	Hanford
1946–1950	Radioisotopes	Precipitation, ion exchange, solvent extraction, absorption, distillation	ORNL	ORNL, industry, Hanford
1946–1952	RaLa	Precipitation for lanthanum	ORNL	ORNL, Idaho
1946–1948	Hexone-25	Solvent extraction for fully enriched U-Al alloy	ORNL	Idaho
1947–1950	Hexone-23	Solvent extraction for thorium and ^{233}U from metal slugs	ORNL	ORNL
1948–1949	Metal recovery	Solvent extraction with tributyl phosphate (TBP) for U sludges	ORNL (recovery of WWII uranium)	Hanford
1948–1953[a]	TBP-25	Solvent extraction for fully enriched ^{235}U-Al; homogeneous reactor fuel	ORNL	
1949–1960[a]	Purex	Solvent extraction with TBP for U and Pu	ORNL (2 plants), KAPL, Hanford	Hanford, SRS, NFS, all foreign plants
1946–[a]	Pu ion exchange	Product Pu, ^{235}U	ORNL	
1949–1968	Fluoride	F_2 for ^{235}U recovery. Molten salt fuel, MSRE fuel, plate fuel	ORNL, ANL	None
1952	TBP-interim 23	Solvent extraction for ^{233}U recovery only	ORNL	NFS for Con-Ed Spectral Shift, Hanford, SRS
1955–1956	Zirflex	Ammonium fluoride dissolution of zirconium fuel	ORNL, Idaho	Idaho, UK
1952–1959[a]	Thorex	^{233}U and Th recovery (2 versions)	ORNL	Hanford, Savannah River
1965–1976	Sol-gel	Solvent extraction and precipitation to prepare ^{233}U	ORNL	LWBR ^{233}U fuel demo (Bettis)[b]
1961–1976[a]	TRU processes	Solvent extraction, ion exchange, precipitation for Am, Cm, Bk, Cf, and Es	ORNL, SRS	SRS for ^{252}Cf

[a]Widely used process.
[b]LWBR = light-water breeder reactor.

Table 3. Reprocessing experience at ORNL—head-end and dissolver off-gas processes

Development dates	Process	Method	Hot pilot plant	Plant sire
1943–1976[a]	Chemical dejacketing, batch dissolve	Dissolution in HNO_3	All U.S. plants	All U.S. plants
1949–1952	Xe, Kr absorption	Removal of Kr by charcoal absorption; cryogenic distillation	ORNL	Idaho
1955–1976"	Mechanical dejacketing	Dissolution with Magnox clad fuel	Britain, France	Britain, France
1963[b]	Mechanical dejacketing	Fast reactor fuel: Hallam and SRE,[c] stainless clad metal	ORNL	None
1955–1976[a]	Zirflex HF dissolution	Dissolution of zirconium-clad fuels	ORNL, Idaho	Idaho, Eurochemic
1942–1976[a]	Chap-leach	Power reactor fuels	ORNL (cold)	NFS, AGNS, Britain, La Hague, Japan, India
1965–1976[b]	Crush, burn, leach	HTGR and graphite fuels	ORNL (hot cell); Gulf-GA (cold)	Proposed pilot plant for HTGR
1970–1976	Voloxidation and tritium	UO_2 to U_3O_8 for Kr, I,, tritium	ORNL (hot cell, small scale)	None
1969–1976	Selective absorption of fission gases	Xc, Kr, GO, removal with Freon scrubbing	ORNL, K-25 (full scale coldj	None
1971)–1976	Iodox, Ag zeolite, mercury nitrate, caustic and Ag (NO_3) scrubbers	Increased ^{129}I, ^{131}I retention	ORNL (hot)	Caustic scrub in all plants; others in or planned

[a]Widely used process.
[b]Not for LWR fuel.
[c]SRE = Sodium Reactor Experiment.

Although not stressed in this document, there are many side benefits to the government from the experience gained from the operation of Building 3019. A partial listing of these benefits is presented below:

1. The training of the Du Pont operating staff assigned to operate the Savannah River Plant took place in Building 3019. During the 1952 period, 26 key operations managers were assigned to the facility to train for the production plant operation.

2. Because of the extensive Purex and Volatility experience at Building 3019 with irradiated fuel, key members of the building staff assisted the government in the training and testing of commercial reprocessing plant operators (NFS, GE, AGNS). In essence, *all* of the various operators in these plants that were granted government operating licenses were examined by Building 3019 personnel at the plant site. Each of the written examinations given by examiners for all operating licenses was prepared by the Building 3019 staff.

3. Interim production quantities of plutonium, uranium (all isotopes), thorium, and various special isotopes were provided from the operations in Building 3019 and recycled.

4. A large number of technical papers and reports were prepared and presented as the direct result of the experience gained in Building 3019.

5. Because of the experience gained in the building with the handling of highly radioactive materials, personnel from the building served as consultants to the government in numerous capacities. Included in this category are (1) the recovery of weapons debris from the crash of an aircraft in Thule, Greenland; (2) the safeguards evaluation of the Tokai-Mura plant in Japan; (3) major on-site assistance to the cleanup of Three Mile Island; and (4) other assignments too numerous to mention.

6. EARLY BUILDING 3019 HISTORY AND OPERATING PHILOSOPHY EVALUATION

As is well known, the Oak Ridge site was selected as part of the famous Manhattan Project. Hewlett and Anderson described the construction phase of Building 205 (3019) as follows. "When the Hanford site was finally selected in January 1943, plans were made to build an air-cooled experimental pile, a chemical separations pilot plant (Building 3019 or Building 205), and supporting laboratories on the isolated tract in Bethel Valley, known as X-10. Since the Du Pont Company was charged with both the design and construction of X-10, only a few weeks elapsed between the decision to proceed and the groundbreaking for the first building. Du Pont started the first temporary buildings February 2, 1943, and completed these and utility installations in March 1943. At that time, sufficient data on the separations plant (Building 3019)

were available to permit construction crews to initiate excavation. Two months were required to complete the foundation for the six large underground cells in which the plutonium would be separated from the uranium slugs. With concrete walls several feet thick, the cells would extend one story above ground and would be covered with mammoth concrete slabs which could be removed when replacing equipment. The first cell, linked to the pile building by an underground canal, contained a large tank in which the uranium slugs and their aluminum jackets could be dissolved. The next four cells were designed for the large stainless steel tanks, centrifuges, and piping for the successive oxidation-reduction cycles. The last cell served as a spare for storing contaminated equipment. Stretching alongside the cells was a one-story frame building used for the operating gallery and offices. By June, Du Pont had started the pouring of the cell walls. When the Bismuth Phosphate process was selected, the equipment design function was accelerated. The installation of piping and cell tankage began in September. The testing and extensive modification of process equipment required most of October, but the plant was ready to operate when the first slugs were discharged from the pile (December 1943)."[1] Photographs taken in 1943 of the construction of the building are presented in Figs. 1 to 3. It should be noted that the designation of the building at that time was Building 205.

Since this early beginning, numerous changes have been made to the Building 3019 pilot plant to accommodate the multitude of processes requiring demonstration. Considerable credit should be given to the original designers of the facility to permit this flexibility. Basically, the designers provided a facility and cell structure that could be tested with nonradioactive materials, demonstrate a process with irradiated fuel, collect data, decontaminate equipment to permit its removal, decontaminate the cells, and prepare for the installation of new process equipment. Information contained in Sect. 7 relating to the successful programs accomplished in the building attest to this factor.

As with all maturing technologies, those processes under way in Building 3019 required the facility to undergo numerous changes over the years. Demands made to improve safety, containment, criticality control, process control, safeguards, and data collection are among the requirements that have been responsible for the many physical changes that have taken place over these many years.

7. BUILDING 3019 PROGRAMS

A listing of the major programs conducted in Building 3019 since it was commissioned in 1943 is presented in Table 4. In addition to these programs, other programs involving the development of the ion exchange of plutonium (^{239}Pu, ^{238}Pu) were conducted in the laboratories attached to the main building cells. Analytical procedure development and analysis of the pilot plant samples for process control were accomplished in the analytical cell block on the west side of the building. During the Thorex Program, a remote sample withdrawal system was developed for the process system to decrease radiation exposure

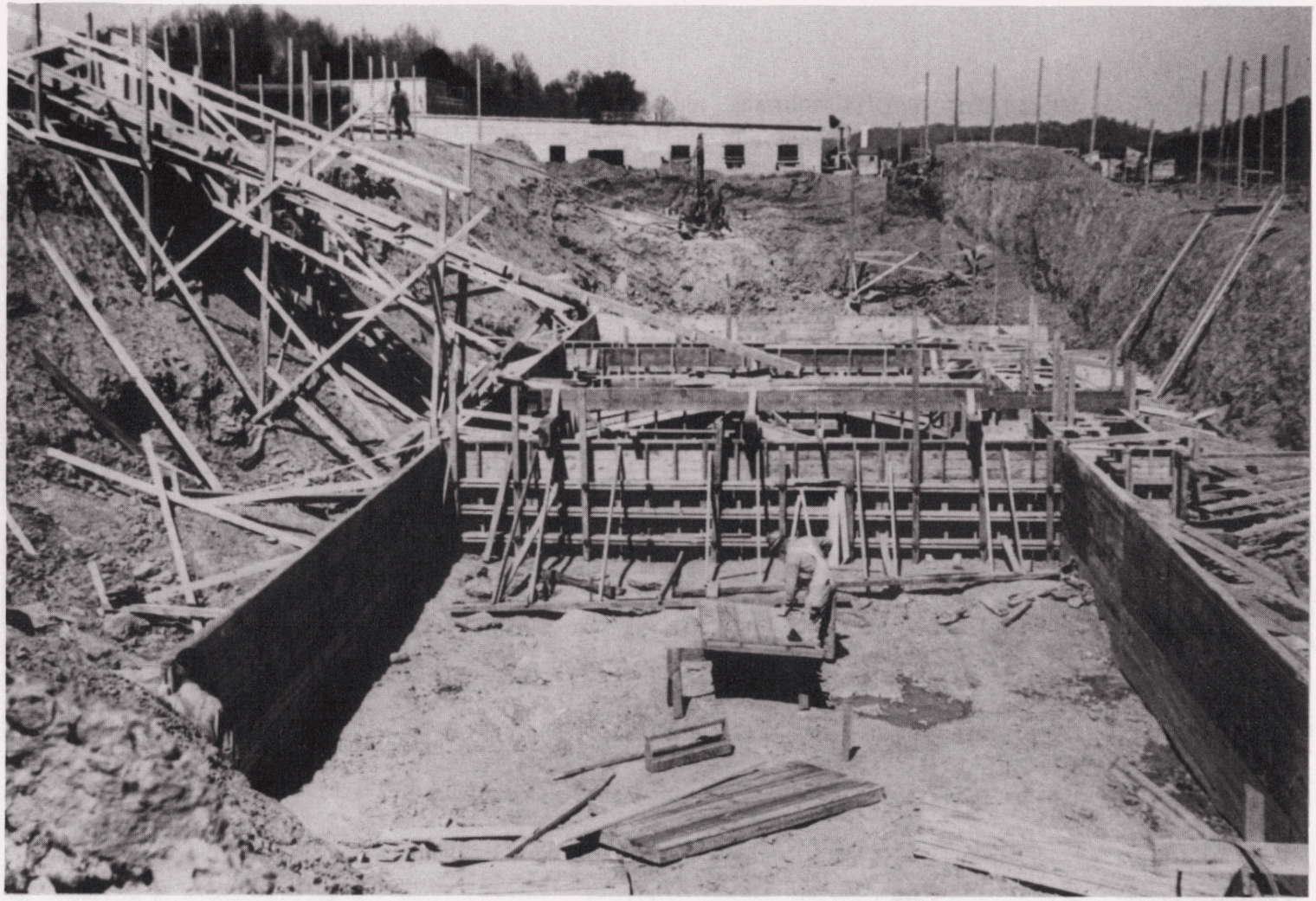

Fig. 1. View (looking east) of excavation and forms of Building 205 of Clinton Engineer Works Project 9733 (date of photograph: May 1, 1943, Roll 20-2).

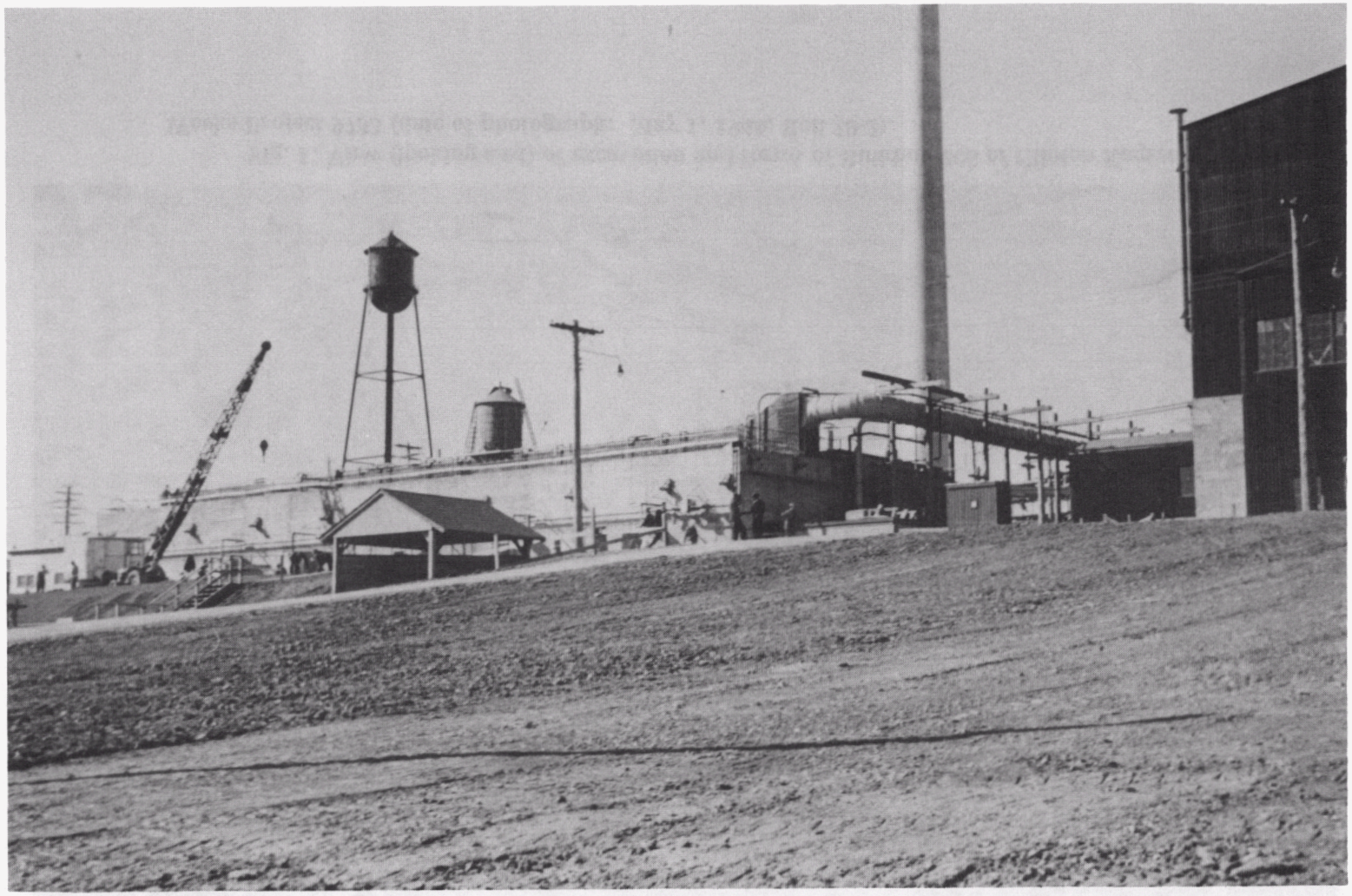

Fig. 2. View (looking northwest) of Building 205, the Separation Building, of Clinton Engineer Works Project 9733 (date of photograph: November 11, 1943, Roll 120-28).

Fig. 3. View (looking northwest) of Building 205, the Separations Building, of Clinton Engineer Works Project 9733 (date of photograph: November 11,1943, Roll 120-29).

Table 4. Building 3019 pilot plant programs

Date	Program	Feed material	Process employed	Material recovered U (kg)	Material recovered Pu (kg)	Irradiation level (Mwd/ton)	Cooling months	Remarks and/or references
1943–1945	Weapons	X-10 uranium slugs	Bismuth Phosphate			Low		Recover Pu; demonstrate separation process; train personnel
1946–1948	Development	Enriched uranium	Redox 25			Low		Separate and recover enriched uranium
1950–1953	Purex	Uranium slugs	Purex	~7,500[a]	~7	~500	2–4	Demonstrate Purex process; recover Pu and U; train personnel; provide engineering data
1954–1958	Thorex	Thorium slugs	Thorex	~60[b]		500–5,000[c]	<1–30	Demonstrate Thorex one-cycle, two-cycle, and three-cycle process at high "g/t" levels and at short decay periods
	High-isotopic-purity ^{233}U	Thorex short-decay waste	Modified Interim-23	0.9[b]			12	Demonstrate recovery process and recover ^{233}U containing <0.5 ppm ^{232}U
1958–1960	SCRUP-2	NRX reactor fuel	Purex	5,386	3.1	~400	24	Recover high-quality Pu
	SRPE	SRP fuel	Purex	1.4[d]	1.5	1,000	~12	Recover enriched U and Pu
	BNL-1,2	BNL reactor fuel	Purex	25,000[a]	18.3	~500	~12	Recover Pu and U; 3019/3505 complex
	SNAP-A	SRP-U slugs	Purex	3,071[e]	3.3	~1,000	~6	Recover Pu high in ^{240}Pu; provide wastes for fission product recovery in 3019/3505 complex
	H-240	SRP-U slugs	Purex	5,800[e]	7.7	~800	3	Recover Pu high in ^{240}Pu in 3019/3505 complex
	S-240	SRP-U slugs	Purex	5,800[e]	13.7	~2,200	3	Recover Pu high in ^{240}Pu in 3019/3505 complex

Table 4. (continued)

Date	Program	Feed material	Process employed	Material recovered U (kg)	Material recovered Pu (kg)	Irradiation level (Mwd/ton)	Cooling months	Remarks and/or references
1958–1960	MTR-I	Pu-Al MTR[f] assemblies	Low TBP		0.5		>6	Recover high ^{240}Pu; 3019/3505 complex
		CP-2 reactor fuel	Purex	4,500		Slightly	>12	
1958–1963	Volatility	ARE molten salt and fuel	Volatility	40.6[a]		Slightly	>12	Recovery enriched U, to demonstrate the volatility process
		Criticality assembly of molten salt	Volatility	72[a]		Slightly	>12	Provide engineering data
		Zr-U fuel	Volatility	23[a]		32% burnup	3–7	Demonstrate the process with Zr-clad assemblies (ref. 1)
1960–1964	Kilorod	$^{233}UO_2(NO_3)_2 \cdot Th(NO_3)_4$	U-solvent extraction; Th-steam demonstration; sol-gel preparation; remote fuel rod fabrication	37[a]		None	NA	To fabricate 1100 SS-clad fuel rods charged with 3% $^{233}UO_2$-97% ThO_2 (ref. 2)
1969–1976	LWBR	^{233}UNH and $^{233}U_3O_8$	Purification (solvent extraction, ion exchange); oxide conversion	1,675[b]		None	NA	To provide ceramic-grade $^{233}UO_2$ of high quality for fabricating LWBR fuel
		$^{233}UO_2$-ThO_2 hard scrap	Thorex dissolution; solvent extraction; ion exchange	711[b]		None	NA	To recover ^{233}U

[a]Enriched U_2, [b]^{233}U, [c]g mass ^{233}U/ton Th, [d]Enriched U, [e]Depleted U, [f]MTR = Materials Testing Reactor

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1. W. H. Carr et al., *Molten Salt Fluoride Volatility Pilot Plant: Recovery of Enriched Uranium from Aluminum-Clad Fuel Elements*, ORNL-4574, Oak Ridge National Laboratory, April 1971.

2. C. C. Haws et al., *Summary of the Kilorod Project—Semiremote 10 kg/day Demonstration of $^{233}UO_2$-ThO_2 Fuel Element Fabrication by the ORNL Sol-Gel Vibratory Compaction Method*, ORNL-3681, Oak Ridge National Laboratory, August 1965.

withdrawal system was developed for the process system to decrease radiation exposure to the pilot plant operators and the analytical chemists. Samples were remotely transferred from the pilot plant to the analytical cells via a shielded conveyor system located on the roof of the building. For some programs where sufficient decontamination could not be attained in Building 3019's solvent extraction cycle, Building 3505 was utilized, which contained three additional cycles along with the isolation system for the plutonium product. An underground pipeline was installed between the buildings to permit the processing of certain fuels under these conditions.

A concern regarding the long-range availability of uranium as a nuclear fuel was demonstrated from 1949 to the early 1950s, and the government turned its development efforts toward thorium. In this regard, Building 3019 has played a major and unique role. As is well known, irradiated thorium contains the isotope ^{233}U, which is also a fissionable isotope. Early pilot plant programs with irradiated thorium took place in the building in the 1954–1958 period, during which time 35 tons of thorium was processed as part of the development of the Thorex and Interim-23 flowsheets. A total of 55 kg of ^{233}U (containing 10–40 ppm ^{232}U) was isolated from this material, which required unique storage requirements. Because of the daughter products of ^{232}U contained in the ^{233}U, this material represents a serious gamma hazard to personnel requiring shielding, especially when aged. As the result of the inventory of irradiated thorium in the reactors at both Hanford and Savannah River, the government wisely selected Building 3019 as the "^{233}U National Repository" in 1962. The Purex plants at both Hanford and Savannah River modified their flowsheets to Thorex and processed a total of 870 tons of irradiated thorium during the 1964–1970 period. The 1400 kg of ^{233}U isolated from these programs was sent to ORNL for storage at Building 3019. Additionally, as instructed by the government, the NFS Plant at West Valley, New York, recovered 1019 kg of uranium from the processing of Consolidated Edison Reactor fuel. This material also found its way to the storage facilities at Building 3019. A summary of the thorium-^{233}U processing in the United States is presented in Table 5.

8. CURRENT BUILDING DESCRIPTION AND PLANNING

Since the time of its construction during the Manhattan Project, the pilot plant, now known as the Radiochemical Development Facility (RDF), has received numerous additions over the years and is currently comprised of various annexes, support buildings, and irregular floor levels (Figs. 4–7). Buildings within the RDF that support operations include

- Building 3100, storage vault for warehousing radioactive substances that are stored in shipping containers.
- Building 3020, the ventilation off-gas stack, for venting the cells, labs, and glove boxes.
- Building 3108 and 3091, off-gas filter houses for filtering cell and hood exhausts.
- The BT and TRUST bulk radioactive liquid storage tank pits.

Table 5. Summary of thorium-^{233}U processing in the United States

Site	Date	Thorium processed (tons)	^{233}U recovered (kg)	^{232}U content (ppm U)	Flowsheet employed	Remarks
			Irradiated fuel reprocessing			
ORNL	1954 and 1958	5	8	10–40	Interim-23	Pilot-scale development
	1955–1958	30	47	10–40	Thorex	Pilot-scale development up to 4,000 Mwd/ton, cooled 30 d
	Total	35	55			
SRP	1964–1965	14	107	225	Interim-23	Th discarded
	1965	9	19	38	Interim-23	Th discarded
	1966, 1968,	193	412	6–9	Thorex	Th recovered, 1.5 *M* HNO_3, 0.25 *M* $Th(NO_3)_4$ AF, 30% TBP
	Total	216	538			
Hanford	1965	4			Interim-23	Th discarded, flowsheet test
	1966	250	270	6–10	Acid thorex	Th recovered, acid-deficient feed
	1970	400	589	6–10	Acid thorex	HNO3 added below HA column feed plate
	Total	654	859			
Nuclear Fuel Services	1969	17	103(1,019)[a]	125	Interim-23	15,800 MWd/ton, Th discarded, 4.3 *M* HNO_3, 112 g/L Th used as salting agent
			Unirradiated processing			
ORNL	1962	2	50	40	2.5% DSBPP	Rod fabrication, Th added to process; recycled
	1973, 1974, 1975	30	1100	10	5.0% DSBPP-IX	Th added to process; discharged
	1957–continuing	9	225	3–250	2.5% DSBPP	Th added to process
	1957–continuing	9	1,000	3–250		
	Total	41				

[a]Mixture of ^{235}U and ^{233}U; Total ^{235}U and ^{233}U is in parentheses.

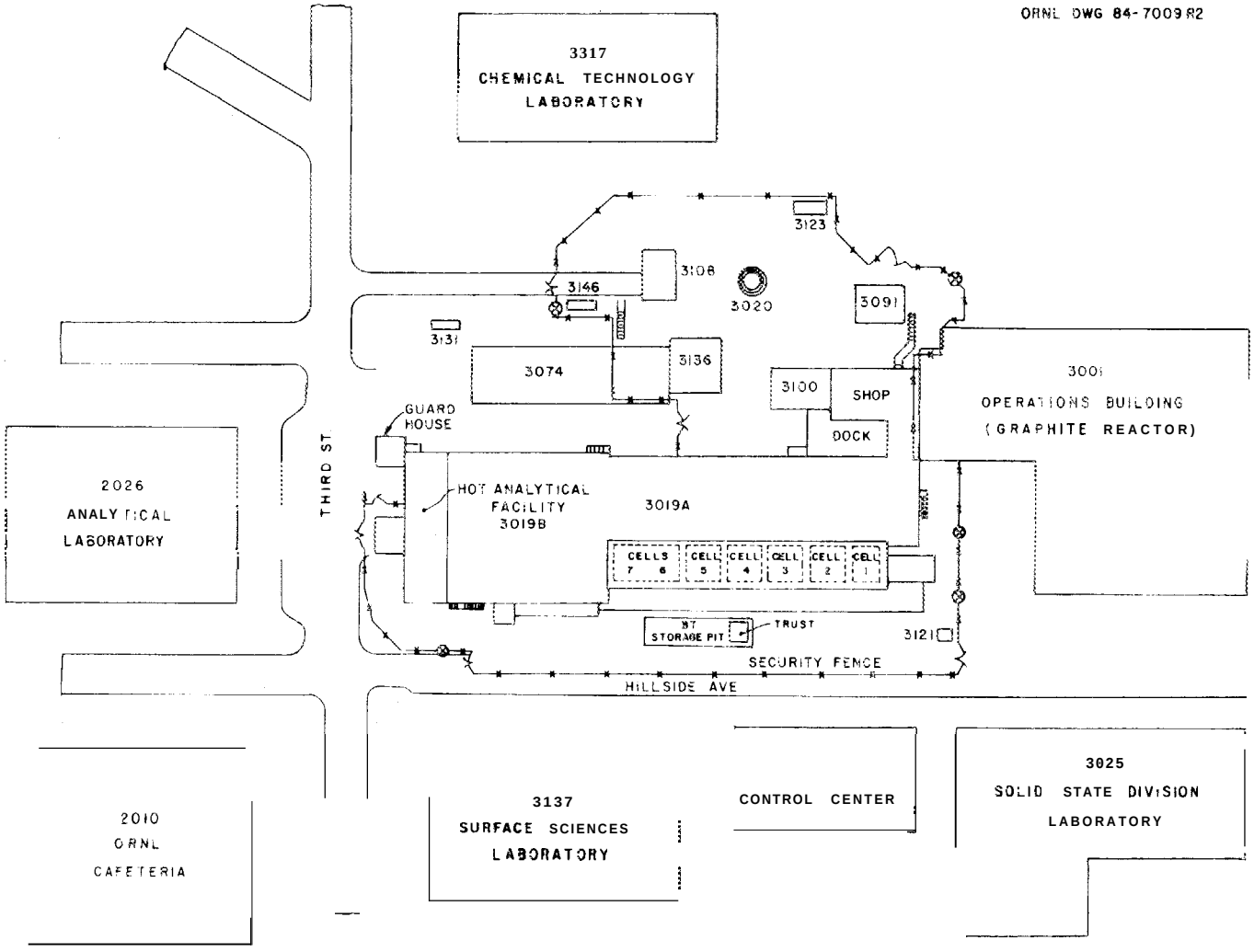

Fig. 4. The Radiochemical Development Facility (RDF) and nearby buildings.

ORNL DWG 84-7010

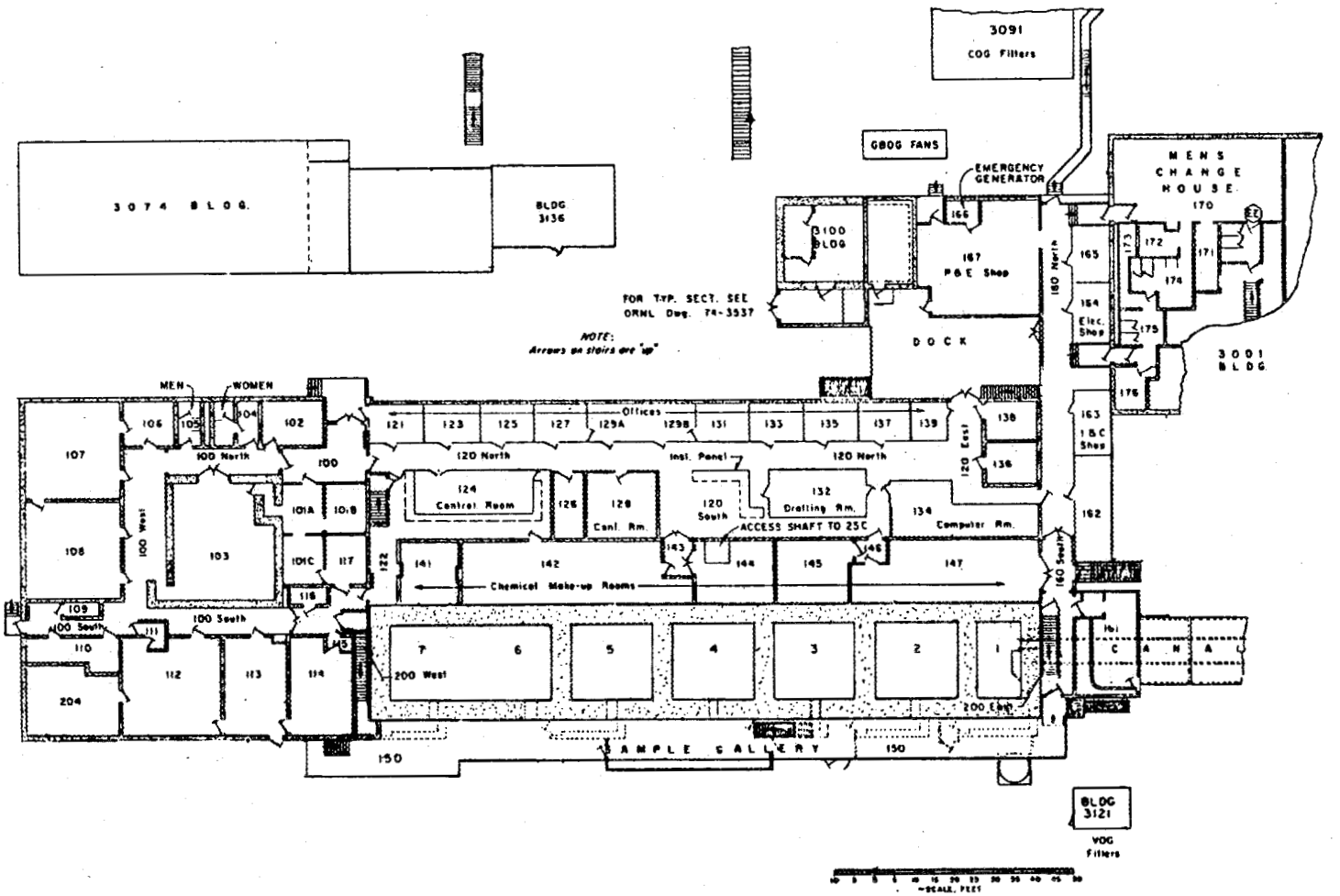

Fig. 5. Layout of main level of RDF.

ORNL DWG 84-7011

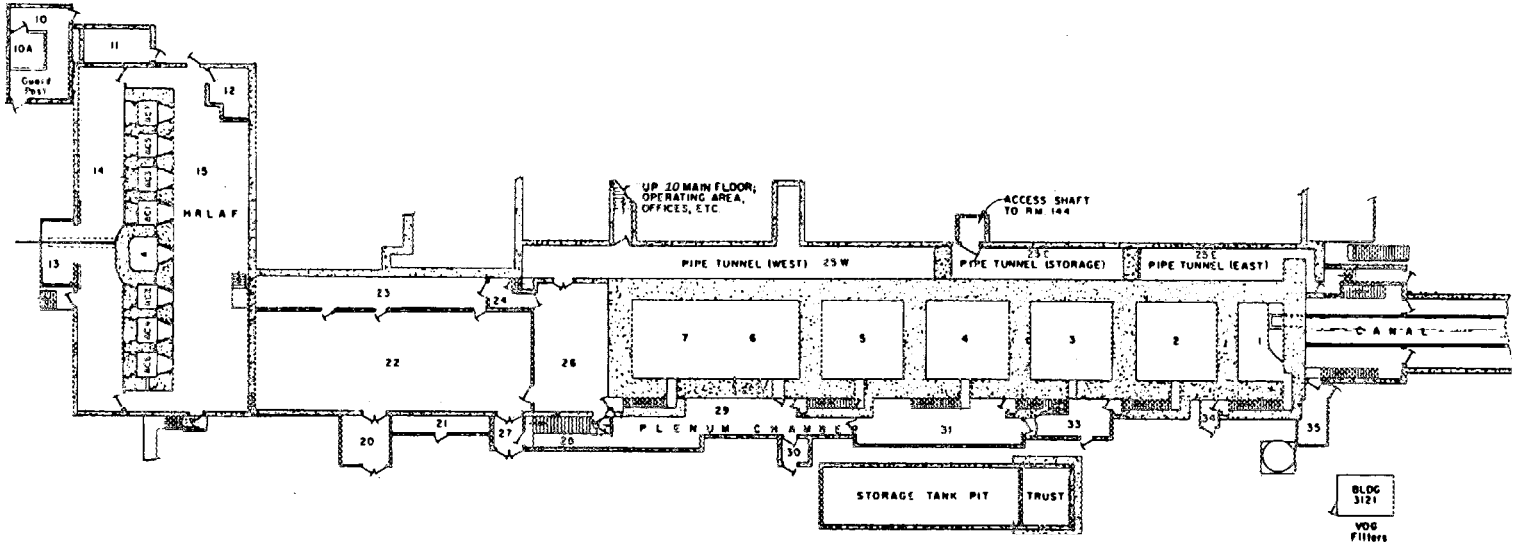

Fig. 6. Layout of lower level of RDF.

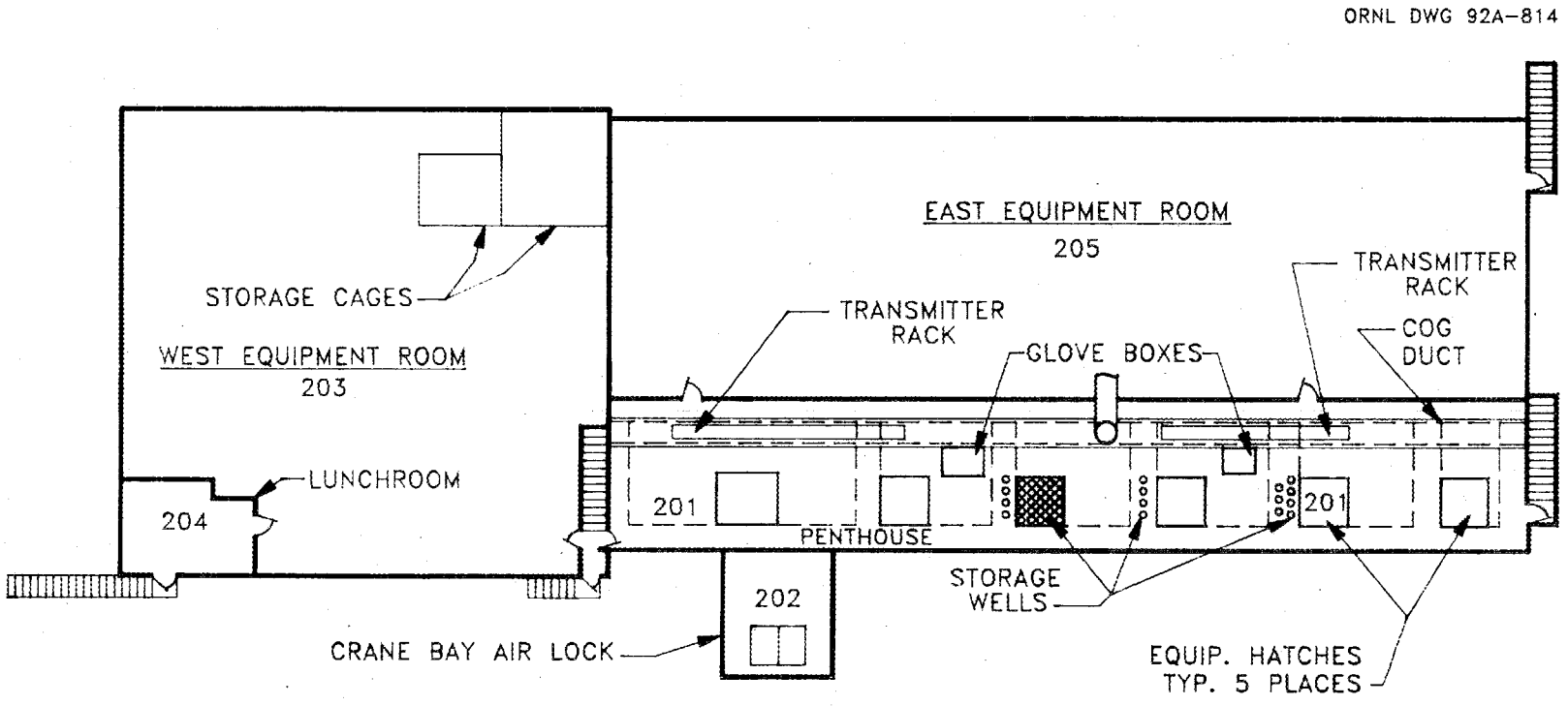

Fig. 7. Layout of upper level of RDF.

- Building 3136, for uncontaminated mockups of process systems.
- Buildings 3123, 3131, and 3146 emergency power generators.

The main building, 3019, includes storage wells for solid fissile materials; hood and glove box laboratories, shielded remote processing cells, and miscellaneous areas for development of radiochemical and decontamination processes; and a bank of eight shielded manipulator-equipped hot cells, the High-Radiation-Level Analytical Facility (HRLAF), formerly used for high-radiation-level radiochemical analyses.

Secure storage wells located behind heavy concrete shielding form the heart of the Solids Storage Facility (SSF) within the RDF. Fissile material is stored in metal containers inside the ventilated vertical storage wells. Access ports to the storage wells are located in the room above the wells (Penthouse). There are two ventilated glove box enclosures in the Penthouse to provide handling facilities for sampling or repackaging operations.

Several laboratories in the RDF are equipped with chemical hoods and glove boxes in which experiments may be conducted on a wide range of radioactive chemicals. Exhaust from these enclosures is HEPA-filtered before discharge up the 3020 stack. Several of the enclosures feature a direct connection to the RDF's low-level waste collection and monitoring system.

Seven shielded, remote processing cells in the main building formed the core of the Manhattan Project structure (shown in the ground floor layout, Fig. 6). Nominal cell floor dimensions are 19 ft long × 20 ft wide × 27 ft high, with Cell 1 being a half-wide cell and Cells 6 and 7 forming a double-width cell separated only by a partial wall and curb at the center. Each of Cells 1–6 has a 9- by 9-ft hatch in the southwestern corner of the cell roof; this hatch is used primarily as an equipment portal. However, in Cell 4, the equipment hatch and the cell space beneath it have been displaced by a group of storage wells in the SSF. With the exception of Cell 4, the cells are not currently in use. Cells 3, 5, 6, and 7 do, however, contain installed equipment from past ^{233}U operations. Cells 1 and 2 are essentially empty.

Plans for the facility include

- continue as the national repository and dispensing facility for ^{233}U,
- provide development services to the Atomic Vapor Laser Isotope Separation Program for demonstration of the product conversion by modified direct denitration,
- provide radiochemical laboratories in which waste treatment studies may be performed,
- provide a test bed for demonstration of novel decontamination techniques, and
- provide secure or bonded storage of other valuable radioactive materials, as appropriate.

9. ACKNOWLEDGMENTS

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