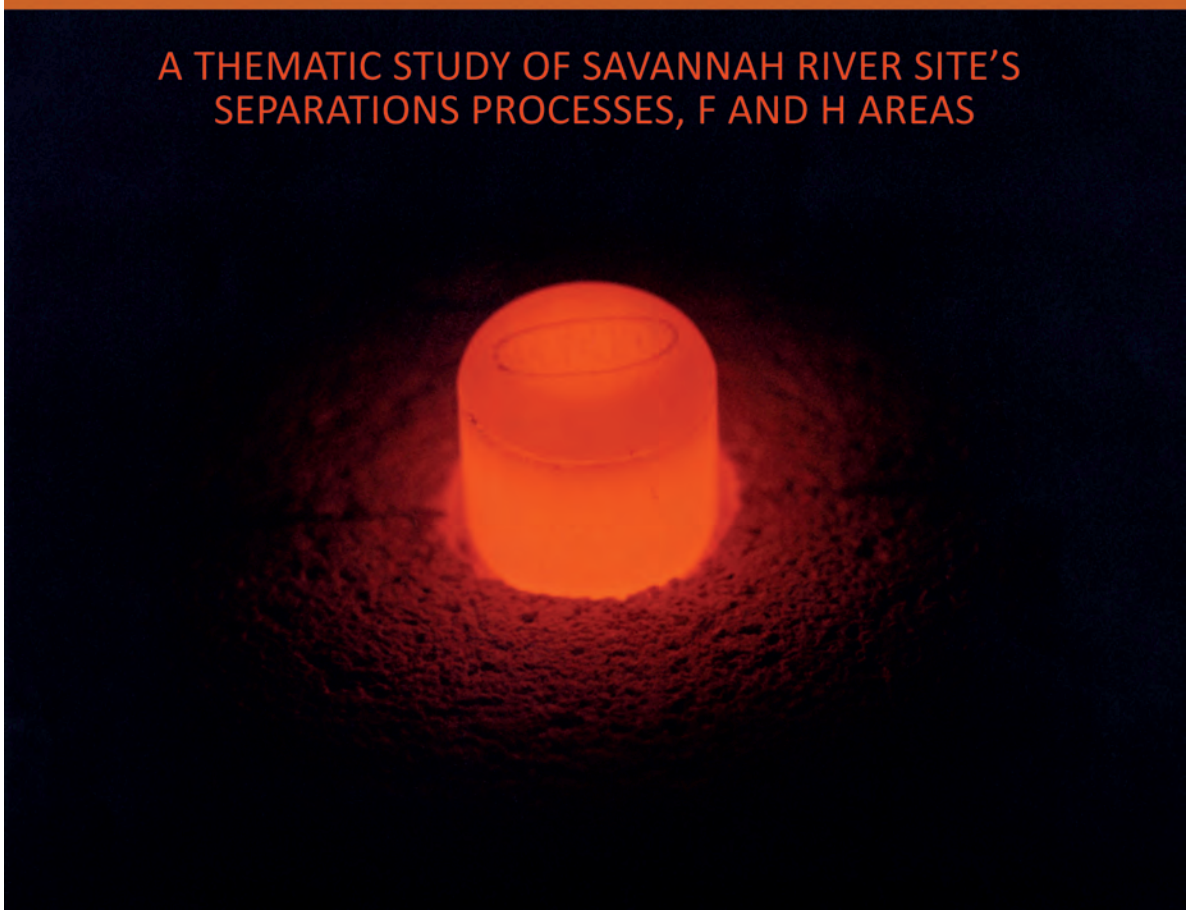
SAVANNAH RIVER SITE COLD WAR
HISTORIC PROPERTY DOCUMENTATION

Volume 1

NARRATIVE AND PHOTOGRAPHY

BRINGING IT TO FORM

A THEMATIC STUDY OF SAVANNAH RIVER SITE'S SEPARATIONS PROCESSES, F AND H AREAS



Aiken and Barnwell Counties , South Carolina

NEW SOUTH ASSOCIATES
PROVIDING PERSPECTIVES ON THE PAST

SAVANNAH RIVER SITE

COLD WAR HISTORIC PROPERTY DOCUMENTATION

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A THEMATIC STUDY OF SAVANNAH RIVER SITES'S SEPARATIONS PROCESSES, F AND H AREAS

Aiken and Barnwell Counties, South Carolina

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July 29, 2013 • FINAL

New South Associates Technical Report No. 2202

ABSTRACT

This documentation was prepared in accordance with the SRS Cold War Historic Property Cultural Resources Management Plan (2004) in response to the proposed deactivation and decommissioning (D&D) of historic properties identified in the Site's F and H areas. Both areas were historically associated with the Site's separation processes. The plan outlined a thematic approach to capturing the history of each historic process at the site through the creation of a historic narrative, collection of oral histories, and photographic documentation. This guidance was used in producing this two-volume study of the Separations processes used at SRS during the Cold War. New South Associates completed the research, prepared the narrative, and compiled the documentation, while Savannah River Nuclear Solutions (SRNS) completed the photographic documentation.

ACKNOWLEDGEMENTS

The authors would like to thank the many individuals who made a contribution to this effort. Paul Sauerborn, our technical contact at the Site, has helped coordinate the project and has been unstinting in his knowledge of the Site's history. Denny Vanover of Document Control provided access to the engineering drawings and maps pertinent to the project. The SRS Archives were made available by Carmen Hall and Maxine White, who helped identify needed historic files.

Many thanks to SRS Separations employees Paul Carroll, Bill Dallis, Ken Fuller, Kevin Gallahue, Mike Holland, Mike Lewczyk, and Dennis McCaskill for conducting tours of F and H Areas, providing access to research materials, as well as their invaluable knowledge about the separations process. SRS Photography personnel, Tom Kotti, Steve Ashe, and Bruce Boulineau, are always a privilege to work with, exuding professionalism and providing great photographic support. Caroline Bradford, Cold War curator at SRS, was also a great help, arranging tours, identifying historic views and artifacts associated with separations. Terri Gillett worked hard compiling the document and designing it.

The following individuals were interviewed to help us better learn what occurred in F and H areas: Edward Albenesius, Charles Goergen, Perry Holcomb, John Porter, Albert Kishbaugh, Mal McKibben, Vince Minardi, Don Orth, William Poe, William Prout, Bob Romine, Major Thompson.

Each of these individuals enriched the document, telling a story about the one process at SRS that seems the most mysterious, completed in remote cells and involving equipment and specially designed facilities that were to a great extent remotely controlled.

Many interviewees noted that reactors have always held the limelight at Savannah River with separations getting short shrift despite its importance in delivering nuclear materials to the complex. Mal McKibben, now retired, delivered this assessment: "the reactor people were just hot-feed prep to us [in Separations]!" Dr. Don Orth described it succinctly: "the reactors and the reactor people make a big bunch of radioactive materials that can't be used. *We bring it to form*…the product comes out of Separations."

We thank Dr. Orth for his words which became the title of this document and all interviewees who provided their histories so we can better understand the role separations played in nuclear materials production and how their contribution to our nation's defense during the Cold War.

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ACRONYM LIST

ACHP	ADVISORY COUNCIL ON HISTORIC PRESERVATION
AMCP	ASSISTANT MANAGER FOR CLOSURE PROJECTS
AM&F	AMERICAN MACHINE AND FOUNDRY
AEC	ATOMIC ENERGY COMMISSION
AEC SROO	ATOMIC ENERGY COMMISSION SAVANNAH RIVER OPERATIONS OFFICE
AED	ATOMIC ENERGY DIVISION – DU PONT COMPANY
AOE	ASSESSMENT OF EFFECT
CAB	SAVANNAH RIVER SITE CITIZEN'S ADVISORY BOARD
CERCLA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT
CFR	CODE OF FEDERAL REGULATIONS
CNTA	CITIZENS FOR NUCLEAR TECHNOLOGY AWARENESS
COE	U. S. ARMY CORPS OF ENGINEERS
CRM	CULTURAL RESOURCE MANAGEMENT
CRMP	CULTURAL RESOURCE MANAGEMENT PLAN
CSRA	CENTRAL SAVANNAH RIVER AREA
DECP	DECOMMISSIONING PROJECT (DOE-SR)
D&D	DEACTIVATION AND DECOMMISSIONING
DOD	DEPARTMENT OF DEFENSE
DOE	U. S. DEPARTMENT OF ENERGY
DOE	DETERMINATION OF ELIGIBILITY
DOE FPO	U. S. DEPARTMENT OF ENERGY FEDERAL PRESERVATION OFFICER
DOE-SR	U. S. DEPARTMENT OF ENERGY SAVANNAH RIVER
DWPF	DEFENSE WASTE PROCESSING FACILITY
ECS	EMERGENCY COOLING SYSTEMS
EM	ENVIRONMENTAL MANAGEMENT
EOC	EMERGENCY OPERATIONS CENTER – SRS
EPA	U. S. ENVIRONMENTAL PROTECTION AGENCY
ERDA	ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
FFA	FEDERAL FACILITIES AGREEMENT
FRA	FEDERAL RECORDS ACT
GS	GIRDLER SYSTEM, GIRDLER SULFIDE
HABS	HISTORIC AMERICAN BUILDINGS SURVEY
HAER	HISTORIC AMERICAN ENGINEERING RECORD
HWCTR	HEAVY WATER COMPONENTS TEST REACTOR
INL	IDAHO NATIONAL LABORATORY
IRM	INFORMATION RESOURCE MANAGEMENT DEPARTMENT - SRS
JCAE	JOINT COMMITTEE ON ATOMIC ENERGY
LANL	LOS ALAMOS NATIONAL LABORATORY
LTBT	LIMITED TEST BAN TREATY
LTR	LATTICE TEST REACTOR
MED	MANHATTAN ENGINEERING DISTRICT
MOA	MEMORANDUM OF AGREEMENT
MPPF	MULTI-PURPOSE PROCESSING FACILITY

NARA	NATIONAL ARCHIVES RECORDS ADMINISTRATION
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NEPA	NATIONAL ENVIRONMENTAL POLICY ACT
NHL	NATIONAL HISTORIC LANDMARK
NHPA	NATIONAL HISTORIC PRESERVATION ACT
NNSA	U. S. DEPARTMENT OF ENERGY NATIONAL NUCLEAR SECURITY ADMINISTRATION
NPS	NATIONAL PARK SERVICE
NPT	NON-PROLIFERATION TREATY
NRC	NUCLEAR REGULATORY COMMISSION
NRHP	NATIONAL REGISTER OF HISTORIC PLACES
NTG	NEUTRON TEST GAGE
NURE	NATIONAL URANIUM RESOURCES EVALUATION
NYX	NEW YORK SHIPBUILDING COMPANY
ORA	OPERATIONS RECREATION ASSOCIATION
ORNL	OAK RIDGE NATIONAL LABORATORY
PA	PROGRAMMATIC AGREEMENT
PDP	PROCESS DEVELOPMENT PILE
PSE	PRESSURIZED SUB-CRITICAL EXPERIMENT
RBOF	RECEIVING BASIN FOR OFFSITE FUEL
RTR	RESONANCE TEST REACTOR
SALT	STRATEGIC ARMS LIMITATION TREATY
SCDAH	SOUTH CAROLINA DEPARTMENT OF ARCHIVES AND HISTORY
SCDHEC	SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
SCIAA	SOUTH CAROLINA INSTITUTE OF ARCHAEOLOGY AND ANTHROPOLOGY
SDI	STRATEGIC DEFENSE INITIATIVE
SE	SUB-CRITICAL EXPERIMENT (EXPONENTIAL TANK)
SHPO	STATE HISTORIC PRESERVATION OFFICE/OFFICER
SHRINE	SAVANNAH RIVER INFORMATION NETWORK ENVIRONMENT
SP	STANDARD PILE
SRARP	SAVANNAH RIVER ARCHAEOLOGICAL RESEARCH PROGRAM
SRI	SAVANNAH RIVER NATURAL RESOURCE MANAGEMENT AND RESEARCH INSTITUTE
SRL	SAVANNAH RIVER LABORATORY
SREL	SAVANNAH RIVER ECOLOGY LABORATORY
SRNL	SAVANNAH RIVER NATIONAL LABORATORY
SROO	SAVANNAH RIVER OPERATIONS OFFICE
SRP	SAVANNAH RIVER PLANT
SRS	SAVANNAH RIVER SITE
SRSO	U. S. DEPARTMENT OF ENERGY-SAVANNAH RIVER SITE OFFICE
SRSOC	SAVANNAH RIVER SITE OPERATIONS CENTER
SRTC	SAVANNAH RIVER TECHNOLOGY CENTER
STI	SCIENTIFIC AND TECHNOLOGICAL INFORMATION
TC	TEMPORARY CONSTRUCTION
TCAP	THERMAL CYCLING ABSORPTION PROCESS
TRAC	TRACKING ATMOSPHERIC RADIOACTIVE CONTAMINANTS
TTBT	THRESHOLD TEST BAN TREATY
UCNI	UNCLASSIFIED CONTROLLED NUCLEAR INFORMATION
UGA	UNIVERSITY OF GEORGIA
USC	UNIVERSITY OF SOUTH CAROLINA
USFS	U. S. FOREST SERVICE
USH	UNIVERSAL SLEEVE HOUSING
VWF&S	VOORHEES, WALKER, FOLEY AND SMITH
WIND	WEATHER INFORMATION AND DISPLAY SYSTEM

I. INTRODUCTION

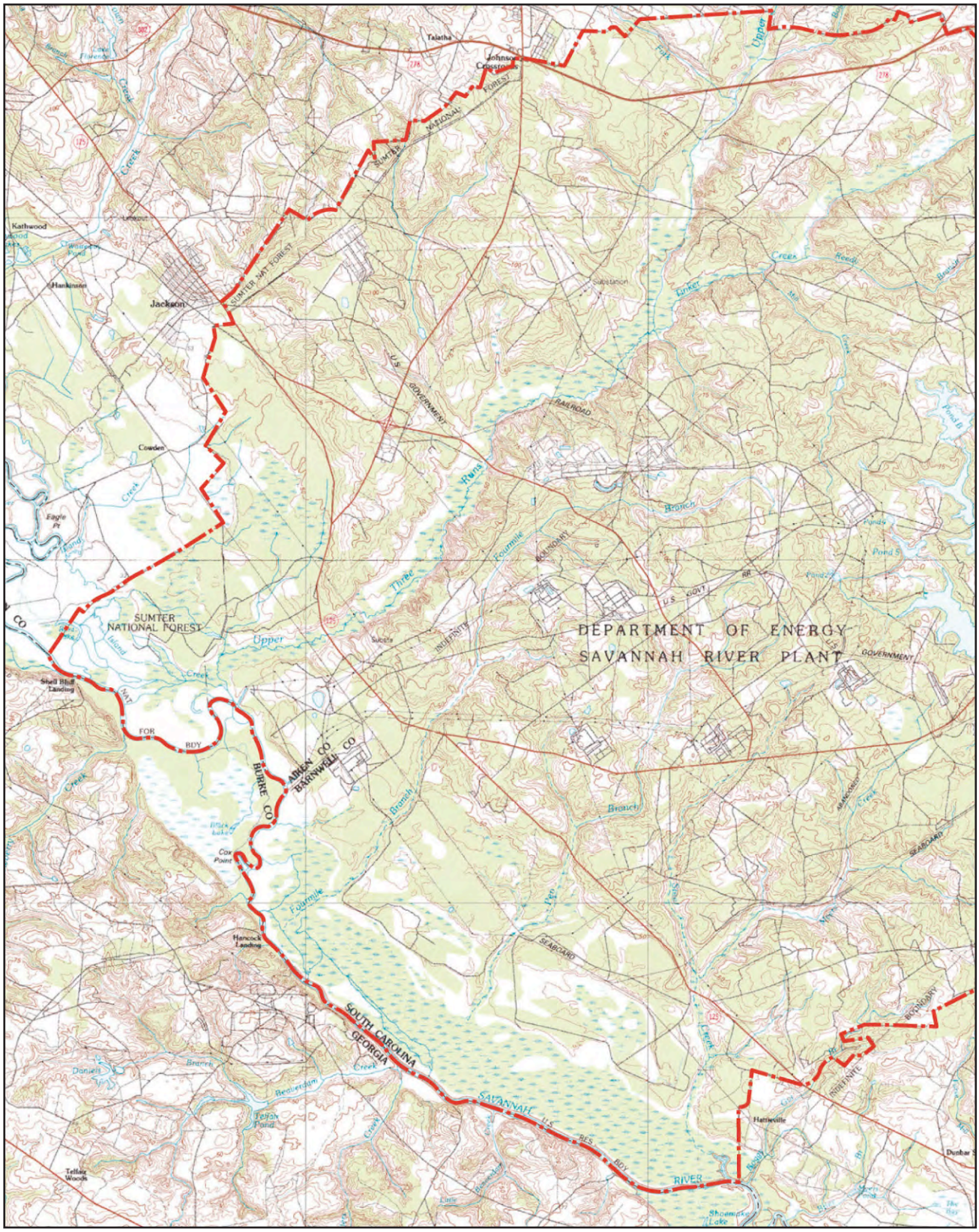
This document is a thematic study focusing on the separations process and nuclear waste handling and their associated structures at Savannah River Site (SRS), formerly known as the Savannah River Plant (SRP). SRS is located on 198,344 acres in Aiken, Barnwell, and Allendale counties of South Carolina. The Savannah River is its western border. The rural site comprises roughly one percent of the state of South Carolina and contains approximately 310 square miles within the upper coastal plain of the state. Historically, the area that became the Site was mostly agricultural and its current physical setting remains fairly rural. The county seat of Aiken County, the city of Aiken, lies 12 miles to the north, and the Augusta, Georgia, metropolitan area lies 15 miles to the northwest. The cities of Jackson and New Ellenton are located on the edge of the Site's northern perimeter. It is considered to be part of the 18-county Central Savannah River Area (CSRA) adjoining the Savannah River in both South Carolina and Georgia, located south of Aiken, South Carolina, within Aiken, Barnwell, and Allendale counties.

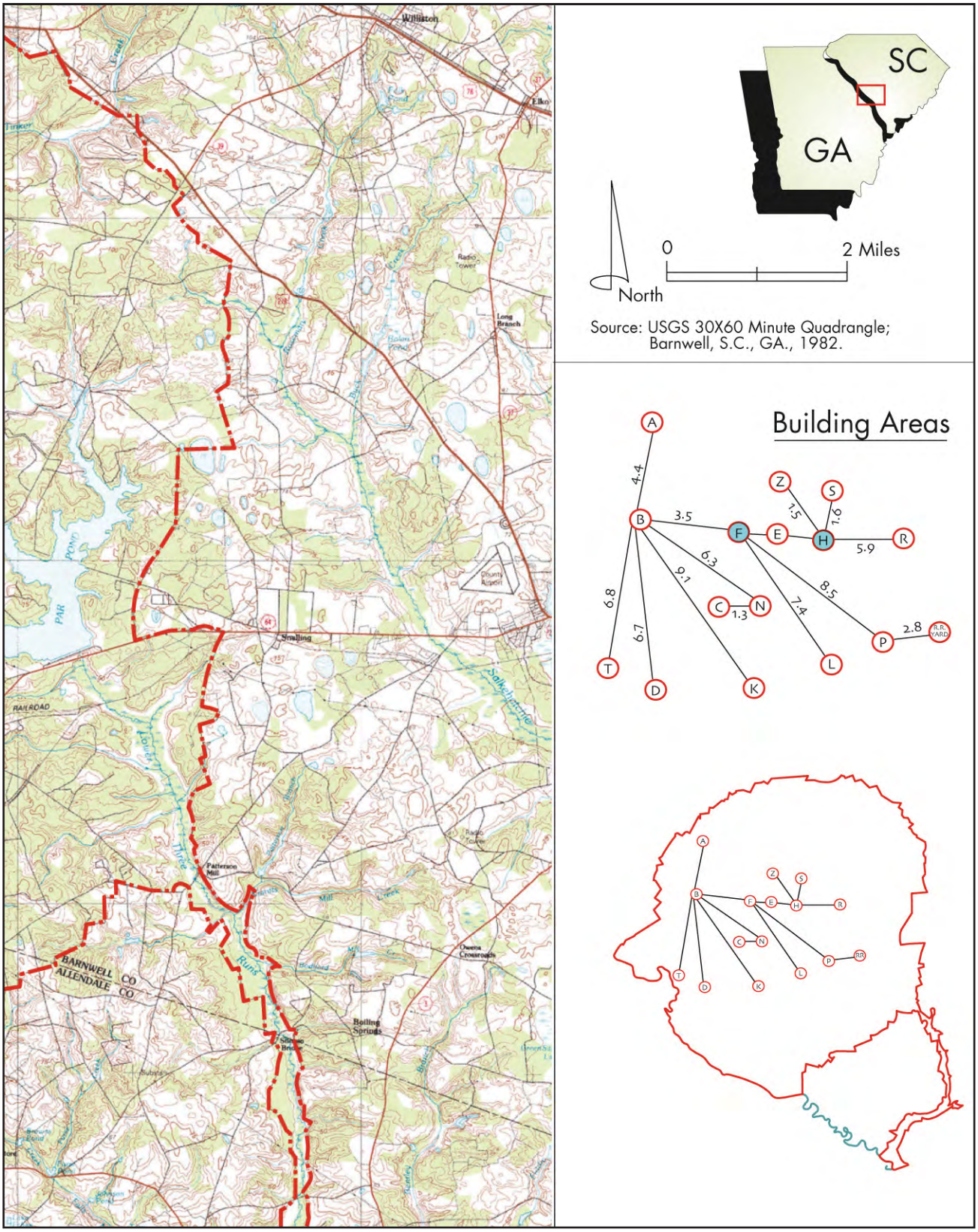
SRS's role within the Department of Energy (DOE) weapons complex was primarily the manufacture of plutonium and tritium, raw materials needed for the production of nuclear and thermonuclear weapons during the Cold War. Nine industrial plants - five heavy water moderated reactors, two chemical separations plants, a heavy-water production area, and a fuel and target fabrication area – were built to accomplish the production mission as well as administration and support areas.

In 2004, the Department of Energy Savannah River (DOE-SR) entered into a Programmatic Agreement with the South Carolina State Historic Preservation Office (SHPO), the Advisory Council on Historic Preservation (the Council or ACHP), the SRS Citizens Advisory Board (SRSCAB), the Citizens for Nuclear Technology Awareness (CNTA), and the cities of Aiken, Augusta, and New Ellenton, for the preservation, management, and treatment of the NRHP-eligible historic properties within the SRS Cold War Historic District. As a result of that agreement, a Cultural Resource Management Plan (CRMP) was developed, which outlined how historically significant buildings that were considered eligible for nomination to the National Register of Historic Places (NRHP) would be treated prior to Deactivation and Decommissioning (D&D). Because SRS is such a large site with so many historically significant structures, the documentation plan called for a series of thematic studies to be developed, in which the buildings would be grouped logically by function and/or geography. To date, six thematic studies have already been completed:

- *Savannah River Site Cold War Historic Property Documentation: 300/M Area Fuel and Target Fabrication, Aiken County, South Carolina (2006).*
- *Savannah River Site Cold War Historic Property Documentation: CMX and TNX Savannah River's Pilot Plants, Aiken County, South Carolina (2006).*
- *Savannah River Site Cold War Historic Property Documentation: 700/A Area Site Administration, Safety, Security, and Support, Aiken County, South Carolina (2007).*

SRS Location Map




Williston
Elko
Smalling
Patterson Mill
Owens Crossroads
Boiling Springs
BARNWELL CO
ALLENDALE CO
SC
GA
0
2 Miles
North
Source: USGS 30X60 Minute Quadrangle; Barnwell, S.C., GA., 1982.
Building Areas
A
B
C
D
E
F
H
K
L
N
P
R
S
T
Z
4.4
3.5
1.5
1.6
5.9
6.3
9.1
8.5
7.4
1.3
2.8
6.8
6.7

- *Savannah River Site Cold War Historic Property Documentation: 400/D Area Heavy Water Production, Aiken County (2008).*
- *Savannah River Site Cold War Historic Property Documentation: REACTOR ON, Thematic Study of SRS' Five Reactor Areas (2009).*
- *Savannah River Site Cold War Historic Property Documentation: You Can't Run a Reactor If You Can't Get To It, Thematic Study of SRS' Infrastructure (2010).*

As defined in the CRMP, a thematic study involves the development of 1) an illustrated narrative history based on extensive primary and secondary research; and 2) photographic documentation.

The goal of this thematic study is to describe the separations process detailing how nuclear materials were treated in the canyon facilities, as well as what happened to the waste after the useful elements were retrieved. In addition, both separations areas, 200-F and 200-H, their buildings and process equipment will be described. The narrative was based to the fullest extent possible on primary sources. Records kept by both Du Pont and the DOE and its predecessor agencies were researched. Engineering drawings or "as builts" for each of the building types were gathered for the study and extensive research through the Site's Photographic Archives was completed. Many of these historic views were selected for illustration.

An essential part of the primary research was the gathering of oral history from knowledgeable SRS retirees and current employees that were part of separations or waste operations. Their recollections contributed greatly to the narrative. Thirteen oral history interviews were completed. Excerpts are given in Chapter 12 and full transcriptions are included in Appendix B.

Photographic documentation is a critical mitigation tool and an essential component of this study but specific challenges posed by the type and condition of the historic facilities to be documented had to be addressed. Both F and H areas are centered around a long, low concrete structure that is commonly known as a "canyon." The canyons contain contaminated areas that are not personnel accessible, including the main process areas, which are the most significant portions of the building. Traditionally, this resource type, given its importance to the process as a whole, would be extensively documented with large format photography. However, the current conditions in the canyon buildings prevented sufficient photographic documentation of many historically significant areas.

Given the above, a photographic documentation work plan was developed that moved away from documentation solely through mitigation photography of the building's end state. Instead, historic photography, complemented by end state photography where needed, was selected and compiled into a photographic portfolio. SRS maintains a photographic archive that contains an extensive collection of historic views that range in content from pre-construction, to construction, through the operation era. SRS has always employed onsite professional photographers and large format photography was consistently used to record the site's buildings and activities through the 1970s. The portfolio of large format historic views was supplemented by end state photography when the historical record had an omission or when a historic property had an intact and significant interior that needed to be documented. Current photography was completed with a digital camera capable of high-resolution images that will be developed to meet archival standards.

SRS COLD WAR HISTORIC DISTRICT AND ITS SIGNIFICANCE

The separations canyons and their associated buildings and structures are considered to be highly significant resources in a Cold War Historic District that meets the criteria for nomination to the National Register of Historic Places (NRHP). DOE-SR under Section 110 of the National Historic Preservation Act inventoried its Cold War associated cultural resources in 2004 and identified 220 historic properties that met the NRHP criteria. A discussion of the district and its significance follows.

The Savannah River Site is an exceptionally important historic resource containing information about our nation's twentieth-century Cold War history. It contains a well-preserved group of buildings and structures placed within a carefully defined site plan that are historically linked, sharing a common designer and aesthetic. The site layout, predicated on environmental safety best practice in 1950 and a functional industrial approach, is intact. The site, its buildings, structures and its layout, constitute a unique cultural landscape that possesses historical significance on a national, state and local level in the areas of engineering, military, industry, and social history. The Site is directly associated with the Cold War, a defining national historical event of the twentieth century that lasted over four decades. This association satisfies National Register Criteria A or the association of a property with events that have made a significant contribution to the broad patterns of our history. The Site's process and research facilities were also used to further research in pursuit of peaceful uses of atomic energy. The Transplutonium Programs, the discovery of the free neutrino, the production of plutonium-238 for heat sources, and the production of heavy water for research were all notable achievements. The Cold War and the development of atomic energy for weapons and for peaceful purposes have received considerable scholarly attention as definitive forces within twentieth-century American history.

The proposed Cold War district also satisfies National Register Criteria C as it embodies best practice principles of nuclear design and safety when constructed. It represents the work of a master in that Du Pont was the designer of the unique and unprecedented complex that required the simultaneous construction of five nuclear production reactors, two separation plants, an industrial size heavy water plant, and a fuel and target manufacturing plant. Du Pont was considered the single American firm with the capability to handle the enormous job entailed in the Site's construction and operation. While this facet of Criteria C is usually applied to an architect or architectural firm, it is appropriate here. Du Pont brought its unique corporate culture, management skills, adherence to flexible design, and its deep atomic energy experience to the job. A letter from President Truman to Du Pont requesting they take on the project underscores the fact that Du Pont was considered uniquely qualified to build and operate the Savannah River Site.

The historic district is also considered eligible under Criteria C for the methods of construction used that involved flexible design, an innovative approach that was characteristic of Du Pont and its management style and that directly contributed to the Site's success. The proposed district's buildings and structures reflect unique architectural and engineering attributes that were consonant with their mission. These include unique construction materials, functional design, and special design criteria for radiological shielding, personnel safety, and the ability to sustain a military attack. The engineering required to bring the nine Savannah River plants online was innovative and was successfully completed under rigorous schedules unparalleled in our nation's twentieth-century history. For all the above reasons, the proposed Cold War District amply satisfies National Register Criteria C.

Table 1. National Register for Historic Places Eligible Separations Buildings

Building #	Building Name	Completion Date	Survey #
211-H	Canyon Auxiliaries (Tank Farm)	1955	R/03/2509
211-2F*	Control and Check House	1954	R/03/2582
211-3F*	Truck Unloading Building	1954	R/03/2583
211-4H**	Sampling House	1952	R/03/2506
217-F*	Storage Building	1953	R/03/2586
221-F	Canyon Building	1953	R/03/2597
221-H	Canyon Building	1953	R/03/2512
221-1F	A-Line	1954	R/03/2589
222-F	Cold Feed Preparation Area	1960	R/03/2598
235-F	Metallurgical Building	1954	R/03/2602
240-F**	Compressor House	1967	R/03/2603
241-F	Waste Tanks	1954	R/03/2625
241-H	Waste Tanks	1956	R/03/2626
241-1F	Control Room	1971	R/03/2610
241-11F	Gang Valve House	1969	R/03/2604
241-18F	Control House	1976	R/03/2608
241-20F	Cooling Towers/Pumphouse	1974	R/03/2611
241-28F	Change House	1976	R/03/2612
241-28H	Evaporator Control Building	1978	R/11/0402
241-31H	DB No. 7 and Gang Valve House	1977	R/11/0403
241-34H	IX/RO/Evaporator OH Tank Containment	1977	R/11/0404
242-F	Evaporator		R/03/2627
242-H	Evaporator		R/11/0432
242-16F	Evaporator House	1982	R/03/2626
242-1H**	Evaporator/Containment Building	1952	
244-1H	RBOF Storage Building	1980	R/03/2541
244-H**	Receiving Basin for Off-Site Fuel	1962	R/03/2542
251-F	Primary Substation (High Voltage 115KV)	1954	R/03/2638
251-H	Primary Substation	1952	R/03/2545
260-1F	Monitor Building	1955	R/03/2640
260-4H	Monitor and Change Building for 241-H	1958	R/03/2547
280-1F	Chemical Feed Building	1954	R/03/2641
280-1H	Chemical Feed Building	1952	R/03/2548
281-1F	Return Water Delaying Basin	1952	R/03/2644
281-1H	Return Water Delaying Basin	1955	R/03/0433
281-2H	Return Water Pumping Basin	1952	R/03/2560
281-4F**	Monitor Building	1953	R/03/2646

Table 1. National Register for Historic Places Eligible Separations Buildings

Building #	Building Name	Completion Date	Survey #
281-5F	Segregated Water Delaying Basin	1953	R/03/2647
281-5H	Segregated Water Delaying Basin	1952	R/03/2562
281-6F**	Monitoring House	1954	R/03/2646
281-6H	Monitoring House	1953	R/03/2563
281-8H	Lined Storage Basin, 4 Million Gallon	1970	R/03/2564
282-F	Reservoir/Pump House	1952	R/03/2651
282-H	Reservoir and Pump House	1952	R/11/0424
284-F*	Powerhouse	1954	R/03/2654
284-H	Powerhouse	1952	R/11/0425
285-F*	Cooling Tower	1954	R/03/2655
285-H*	Cooling Tower	1952	R/03/2567
288-H*	Ash Disposal Basin	1952	R/11/0427
291-F	Canyon Stack	1954	R/03/2656
292-1F**	Vessel Vent Fan House	1954	R/03/2657
292-2F	Sand Filter Fan House	?	R/03/2396
292-F	Fan House	1952	R/03/2658
292-H	Canyon Exhaust Fan House	1953	R/03/2568
293-F**	Metallurgical Building Stack	1982	R/03/2659
294-1F	Additional Canyon Sand Filter	1969	R/03/2660
294-1H	Additional Canyon Sand Filter	1969	R/03/2569
294-F	Sand Filter	1952	R/03/2662
294-H	Sand Filter	1952	R/03/2560
614-F	Monitoring House	1955	R/03/2667
701-1F	Gate House/Patrol House	1955	R/03/2673
701-1H	Gate House/Patrol House	1952	R/03/2571
701-20H	Gate House	1955	R/03/2398
701-2F	Gate House	1953	R/03/2675
701-4H	Gate House	1952	R/03/2573
701-5F*	Guard House to 217 Storage Magazine		
704-F	Area Administration and First Aid Building	1953	R/03/2680
704-H	Area Administration and First Aid Building	1952	R/03/2575
706-H	Project Office Building	1952	R/03/2577
709-F	Fire Station	1953	R/03/2687
717-F	Mock-up Building/Area Shop Building	1954	R/03/2690
723-F*	Laundry Building	1952	R/03/2693
724-H	Office, Shop, and Storage Building	1955	R/11/0429
772-F	Control Laboratory	1953	R/03/2699

* Demolished ** Pending D & D

Separations Area Buildings
(Categorized by Function)

- Covered in this Study
- Covered Under Separate Thematic Study
- Demolished

Canyon Facilities

Canyon Ventilation Facilities

Waste Facilities

Covered in this Study
Covered Under Separate Thematic Study
Demolished


260-4H


281-1F & 281-1H


281-2H

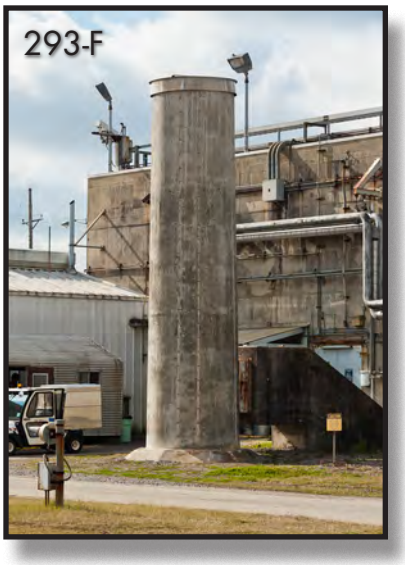

281-4F


281-5F


281-5H


281-6F


281-6H
281-6H



Separations Area Support Facilities

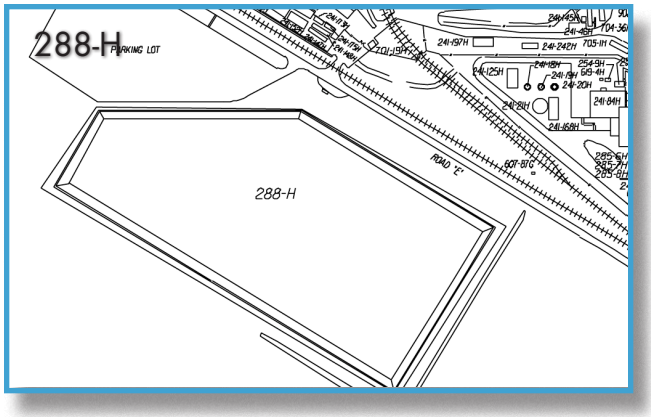
Covered in this Study
Covered Under Separate Thematic Study
Demolished


282-F & 282-H


280-1F & 280-1H


285-F & 285-H


284F & 284–H


288-H
PARKING LOT
288-H
ROAD "E"


614-F


701-1F


701-1H

Covered in this Study
Covered Under Separate Thematic Study
Demolished

Savannah River Site's historic district may also fulfill National Register Criteria D, the potential to yield information in history. While this criteria is usually reserved for archaeological resources, it is applicable here. Much of the historical data that elucidates Savannah River's full Cold War history is held as classified information. When these records are declassified and open to the American public, new information disclosed might yield important information about the Site's Cold War past that is unknown or imprudent to publicly release at this time.

While its national importance to the Cold War is evident, SRS also gains National Register standing for its impact on South Carolina as a whole and on the Central Savannah River Area (CSRA) as a region. The selection of the site along the Savannah River for the construction of what would be known as the Savannah River Plant had a profound impact on the state, although one less readily quantified. It shifted the image of South Carolina from that of a rural agrarian state to one that was more progressive and industrialized. The training and inclusion of locals within the SRS' workforce demonstrated the ability of southerners to work in modern industrial highly technical facilities. Du Pont's management of this labor force, and the harmonious relations between races at the Site, further diminished northern concerns about establishing factories in the South. SRS' existence, and the efforts of local politicians, would result in additional nuclear facilities coming to the region. Interstate and regional pacts on nuclear topics were developed that would become models for interstate cooperation. The presence of SRS would begin to shift state university curriculums from solely an agricultural focus to a new emphasis on engineering, raised the hopes and self esteem of its citizens, and placed the state at the forefront of the march to a New Age. No other single construction, site or event would so affect South Carolina's history in the Cold War era, and the SRS derives National Register standing at the state level from this influence as well.

No other construction would so dramatically alter a region. By its very construction, the SRS rewrote the history of the CSRA. Communities, like Ellenton and Dunbarton, vanished in its wake, as did the rural areas that surrounded them. Other communities, like Aiken, changed almost overnight. As the first "open" nuclear site, the SRS brought an immigration of scientists and engineers that few regions in the nation experienced; it changed the housing stock and appearance of the towns these atomic immigrants moved to; changed the composition of their schools, political parties, and other social organizations; and rewrote local history. It is difficult to imagine anyone within the CSRA, if asked about the history of their region, not mentioning SRS. The SRS has extreme regional significance, in addition to that it holds at the state and national level.

DOCUMENT ORGANIZATION

After this introduction, a context for the Site and its Cold War mission is presented to anchor the separations discussions and to provide the reader with some general background on the Site's history. Chapter 3 provides a physical description of the site, the separations areas, and the buildings involved in the separations process. Chapter 4 discusses the development of the separations process. Chapte 5 describes Purex, which is the chemical process by which the useful isotopes and elements are separated from fission products. Chapter 6 details the different sections of the canyon, as well as its support buildings and their individual functions. Chapters 7 and 8 focus on changes and improvements to the process from start up through 1980. Chapter 9 deals with the other programs that SRS and separations specifically were involved in, aside from the main mission. Chapter 10 delves into the issues surrounding the disposal of radioactive waste and Chapter 11 focuses on site clean up.

The document closes with excerpts from oral history interviews with individuals associated with separations during the history of SRS. After the endnotes, Appendix A contains photographic documentation of the buildings and processes associated with separations. Appendix B includes architectural drawings of many of the separations buildings. Appendix C contains the full transcripts of the oral histories conducted for this study.

II. SAVANNAH RIVER SITE COLD WAR CONTEXT

Savannah River Site (SRS), built by E. I. Du Pont de Nemours and Company for the U.S. Atomic Energy Commission, had its origins in the early years of the Cold War as a facility for the production of plutonium and tritium, materials essential to the nation's nuclear arsenal. From the beginning, its mission was military. It was designed primarily to produce tritium, and secondarily to produce plutonium and other special materials as directed by the Department of Energy (DOE) and its precursor organizations, the Atomic Energy Commission (AEC) and the Energy Research and Development Administration (ERDA). Because of this mission, SRS has been an integral part of the nuclear weapons production complex. The production goal of the complex was to transform natural elements into explosive fissile materials, and to bring together fissile and non-fissile components in ways that would best meet the goal of Cold War deterrence. SRS provided most of the tritium and a large percentage of the plutonium needed for the production of fissile components from 1953 through 1988.

In addition to the Cold War defense mission, there was another, almost parallel, story of research and development using Site technologies and products for peaceful uses of atomic energy. Such government-sponsored research was strongly supported by the AEC, which was a civilian organization independent of military control. Although many of the non-defense programs conducted at SRS did not develop with the promise hoped for in the 1950s and 1960s, this was not for want of effort on the part of the AEC, Du Pont, or the scientists who helped operate SRS.

The two basic missions at SRS, nuclear materials production for defense, and production for non-defense programs, are explored in greater detail below. Both were considerable achievements. The defense mission produced much of the material required for the nuclear bombs and warheads constructed during the height of the Cold War. The non-defense programs generated new materials and increased the general knowledge of our nuclear science.

COLD WAR DEFENSE MISSION

The defense mission of the Savannah River Plant (SRP), as it was known prior to 1988, was an integral part of the AEC program to create weapons-grade plutonium and tritium for incorporation into fission and fusion bombs, known respectively as atomic and hydrogen bombs. The defense mission of SRP, and for that matter, the AEC, had its origins in the Manhattan Project, the World War II program that manufactured the world's first fission bombs, using both uranium and plutonium. It was the use of these devices against Japan in August 1945 that ended World War II, and ushered in the Atomic Age. The Manhattan Project, a vast and secret enterprise, set the tone for its successor, the AEC, even though the two were organized in different ways.

The Manhattan Project

The Manhattan Project, formally known as the Manhattan Engineer District (MED), was established in August of 1942, more than half a year after Pearl Harbor.[1] Its mission was to beat the Germans in what was widely assumed to be a race for the atom bomb.[2] Unlike other Army Corps of Engineers districts, the MED had no specific

geographical boundaries and virtually no budget limitations. General Leslie Groves was put in charge of the operation, and he was allowed enormous leeway. As Groves himself would state after the war, he had the role of an impresario in "a two billion dollar grand opera with thousands of temperamental stars in all walks of life."[3] In organizing the MED, Groves established a precedent that would carry over to the AEC: scientific personnel and resources would be culled from the major universities, but production techniques would be obtained from corporations familiar with the assembly line.[4] The Manhattan Project could not have succeeded without a willing army of brilliant physicists (many of whom were refugees from Hitler's Europe), the nation's huge industrial base of capital and personnel skills, and the leadership and construction skills provided by the Army Corps of Engineers.[5]

The last half of 1942 saw the groundwork laid for the development of the Manhattan Project. Groves and others selected the methods and sites to be used to produce the bomb. For both speed and economy, Groves wanted to concentrate on one single method for bomb production, but science would not oblige.[6] In the fall of 1942, there were a number of equally valid and equally untried methods for obtaining the fission material for an atomic bomb. There was even a choice of materials: uranium-235 and plutonium.

Commemorative Manhattan Project Button "A" Bomb Button. Courtesy of Oak Ridge National Laboratory.

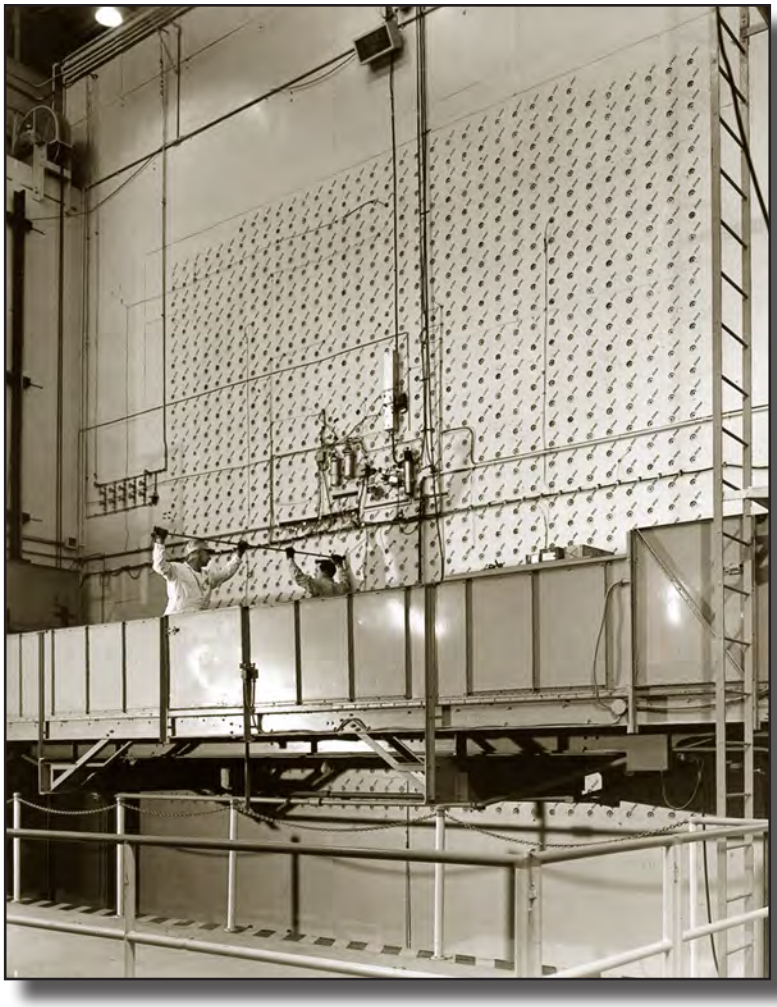
The methods best known to the scientific community at the start of the Manhattan Project dealt with the collection of isotope uranium-235, which comprises only a very small percentage of natural uranium. There were at least four possible methods for removing uranium-235 from the matrix of natural uranium: the centrifuge method; thermal diffusion; gaseous diffusion; and electromagnetic separation.

General Leslie Groves (left), Manhattan Engineer District Leader and Robert Oppenheimer (right), Scientist, Los Alamos.

To complicate matters, there was also a new method based on the production of a man-made element, plutonium, discovered and named by Glenn Seaborg and others in 1941. Plutonium could be produced by irradiating natural uranium in a pile, or reactor, after which it could be separated from uranium chemically, something not possible with isotopes like uranium-235.[7]

By the end of 1942, the field was narrowed to three main methods in the race to produce nuclear materials: gaseous diffusion, electromagnetic separation, and plutonium production. In December 1942, when President Roosevelt gave his final approval for the all-out push, it was decided to proceed with all three.[8] The last of these methods certainly got a boost on December 2, 1942, when Italian refugee Enrico Fermi, working at the University of Chicago, created the world's first self-sustaining chain reaction in a graphite reactor.[9]

By this time, three huge test and production sites had been selected for MED's work. The first was Oak Ridge in Tennessee, then known as "Clinton Engineer Works," selected as the site for a full-scale electromagnetic plant (Y-12), a gaseous diffusion plant (K-25), and a plutonium pile semi-works (X-10).[10] Constructed in 1943, X-10 became the world's first production reactor when it went critical on November 4, 1943.[11] Hanford, in Washington



X-10 Pile Constructed by E. I. Du Pont de Nemours & Co. at Oak Ridge, Tennessee, now Designated as a National Historic Landmark. Courtesy of Oak Ridge National Laboratory.

State, was selected as the main plutonium production site, while Los Alamos in New Mexico, under the direction of Robert Oppenheimer, was chosen to be the nerve center of the project and the bomb assembly site.[12]

While Los Alamos may have been the center of the MED, Hanford was the key to the plutonium bomb, which required the new element in quantities unimaginable before the war. For the construction of the X-10 at Oak Ridge and the full-scale reactors to be built and operated at Hanford, Groves picked Du Pont. This was done not only because of Du Pont's history of explosives manufacture and its association with the U.S. military, but also because it was a large chemical firm that had the personnel, organization, and design capabilities required to do the job.[13] Most importantly, it had a tradition of translating scientific ideas and laboratory techniques into assembly line production.[14]

Because Du Pont was not an expert in the field of nuclear technology, they would depend heavily upon the Metallurgical Laboratory of the University of Chicago for their nuclear physics and radiochemistry experience. Du Pont's key technical employees were sent to Chicago and to Clinton to learn from the research scientists about problems that would bear on the design and operation of the semi-works and the full-scale production plants. This dialogue between the industrial engineers and the academic scientists would be the basis for the selection of processes, and the design of the equipment needed to carry them out, at both the semi-works and at Hanford.[15]

Hanford's three reactors (B, D, and F) and two separations buildings were constructed in 1943-1944. The reactors, water-cooled and graphite-moderated, went on line between September 1944 and February 1945.[16] One of the first crises in the plutonium program occurred shortly after the Hanford B reactor went critical in September 1944. The reactor would go critical and then shut down in a totally unexpected series of oscillations that threatened to ruin the production schedule. After frantic research, it was determined that the reaction had been killed by a periodic build-up of xenon that proved to be a huge neutron absorber with a nine-hour half-life.[17] An engineering feature added by Du Pont was instrumental in solving the problem of xenon poisoning.

When scientists at the University of Chicago's Metallurgy Laboratory insisted that only 1500 tube openings were needed in the reactor face, Du Pont added an additional 500 openings as a precaution. This spare capacity, built into every Hanford reactor, made it possible to load the extra openings and simply overpower the effect of the xenon.[18]

By early 1945, Hanford was shipping plutonium to Los Alamos for bomb assembly work.[19] With a detonation device based on implosion, which was more complicated than that required for the uranium bomb, the plutonium bomb had to be tested near Alamogordo, New Mexico, in July 1945. One month later, a similar device was dropped on Nagasaki, only three days after the uranium bomb was dropped on Hiroshima.

The Manhattan Project had been a purely military undertaking, conceived and successfully concluded as a top-secret operation of the Second World War. In the year that followed the war, the project began to unravel as top scientists and others left the project to return to civilian life, and the government considered different proposals for dealing with the awesome power that had ended the war.

Onset of the Cold War

Relations between the United States and the Soviet Union, guarded during WWII, began to chill in the aftermath. The Cold War had its "official" beginnings in February and March of 1946, with three critical events. The first was Stalin's speech (February 9) to Communist Party stalwarts, reaffirming the Party's control over the Soviet Union, and promising more five-year plans and an arms race to overtake the capitalist powers. This was followed on February 22 by George Kennan's famous telegram describing the expansionist worldview of the Soviet leadership, and suggesting "containment" as the best solution. Last but certainly not least, on March 5, was Churchill's "Iron Curtain" speech at Fulton, Missouri.[20]

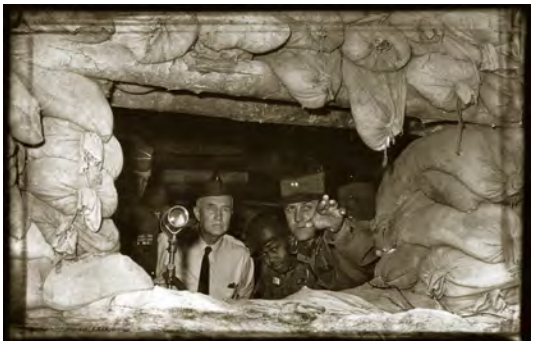
The beginnings of the Cold War in early 1946 quickly derailed initial talk of international control of atomic energy. By the time the AEC was created by Congress in the summer of 1946, atomic energy had become the cornerstone of the nation's defense against the Soviet Union's preponderance in conventional land forces. For this reason, President Truman was shocked to discover that when the AEC took over Los Alamos in early 1947, the United States did not possess a single assembled working bomb.[21]

Between 1947 and 1950, during the chairmanship of David Lilienthal, the main mission of the AEC was the re-establishment of the nation's nuclear arsenal. The AEC was created as an umbrella agency to control all of the nation's nuclear research and materials production. In this capacity, by early 1950 the AEC oversaw a virtual nuclear empire that not only included old MED facilities at Oak Ridge, Hanford, and Los Alamos, but also encompassed offices in Washington, D.C. and facilities at Argonne National Laboratory (Chicago); Schenectady, New York; Brookhaven National Laboratory, New York; and the University of California Radiation Laboratory at Berkeley, in addition to other small facilities around the country.[22]

During this same period, international events conspired to make the AEC's defense mission even more critical, as international relations slid further into the deep freeze. Concerned that a devastated postwar Europe might drift into the Communist camp, the U.S. government introduced the "European Recovery Program," first espoused by

George Marshall in June of 1947. The "Marshall Plan," as it was commonly known, was worked out between the U.S. and various European nations months before it passed Congress in April of 1948. Although offered to all European nations, Stalin saw to it that his side refused to participate. When middle-of-the-road Czechoslovakia expressed interest in the plan, the local Communists, aided by the Red Army, staged a coup in February 1948. This move also gave the Soviets direct access to the rich Joachimstahl uranium mines, desperately needed by Stalin's nuclear program.[23]

Unwilling to cooperate with the Western allies in the postwar reorganization of Germany, Stalin initiated the Berlin Blockade, which began in the summer of 1948 and lasted almost a year. It was the first direct confrontation between the United States and the Soviet Union, and it led to the creation of the North Atlantic Treaty Organization (NATO) in 1949.[24] Other crises soon followed. In May of 1949, the Chinese Nationalists, still devastated from the Japanese invasion during World War II, collapsed before Mao's Communist insurgents. Even more ominous, on August 29, 1949, the Soviet Union detonated its first atomic bomb (a plutonium device), an achievement that Truman and most of the U.S. nuclear establishment thought would elude the Soviets for years to come.[25] At the end of 1949 and beginning of 1950, in the wake of the Soviet bomb, Truman and the AEC made plans for the development of the hydrogen bomb, the so-called "Super."[26] Almost simultaneously, Klaus Fuchs, a German émigré who had served in the British Mission to the Manhattan Project at the highest levels of plutonium bomb research, confessed to spying for the Soviets. This revelation in February 1950 sent shock waves through the nuclear community in both Britain and the United States, and seemed to reinforce the decision for both the Super and tighter security. Senator Joseph McCarthy began his accusations just days after news of Fuchs' confession, and four months later, on June 25, 1950, North Korea invaded South Korea.



Senator and Brigadier General in the U.S. Army Reserve Strom Thurmond, Representative Leroy Anderson and Captain Harry Peters, 1957. "Along the Iron Curtain, Looking into Communist East Germany from 11th Armored Cavalry Regiment Observation Post." Courtesy of the Special Collections, Clemson University Libraries, Clemson, South Carolina.

During the Korean War (1950-1953), the AEC's defense mission was paramount, as witnessed by the explosion of the first H-Bomb in November 1952, and the growth of the nation's nuclear arsenal from 300 to 1000 bombs. The military mission remained strong long after the war, with the official U.S. policy of "massive retaliation" announced by Secretary of State John Foster Dulles in January 1954.[27] The centerpiece of the nation's nuclear arsenal was the H-Bomb, a thermonuclear device that relied on a complex combination of fission and fusion, with fission required to heat and fuse atoms of hydrogen isotopes like tritium to release the high-energy neutrons required for the blast. During the 1950s, a number of thermonuclear devices were detonated, first by the United States and quickly followed by the Soviet Union. These new bombs required increased supplies of plutonium as well as tritium, which had a half-life of 12 to 13 years. The push for the hydrogen bomb led to the expansion or establishment of new AEC facilities, beginning in 1950. Foremost among these new or improved facilities were the Los Alamos Scientific Laboratory, the Lawrence Livermore Laboratory in California, and the SRP in South Carolina.[28] The SRP was first conceived to produce tritium, but was designed to be versatile in its production capacity, accommodating the production of both tritium and plutonium, in addition to other nuclear materials.

The first U.S. thermonuclear device, Mike I, was detonated in November 1952, before the completion of SRP. However, for at least a decade after the first SRP reactor went critical in December 1953, the main, if not overwhelming, mission of the Plant was the production of plutonium and tritium, in the percentages required by annual AEC quotas. SRP played a crucial role in the production of nuclear materials for both fission and fusion bombs, first for Air Force bombers, and finally for the long-range missiles that became prevalent in the late 1950s and early 1960s. During the period when the Cold War was at its peak, between the Korean War (1950-1953) and the Cuban Missile Crisis (1962), SRP was a main contributor to the AEC's defense mission.

Savannah River Plant as Part of the Big Picture

Cold War nuclear weapons production in the United States can be divided into four phases: (1) a research phase, (2) a growth and production phase, (3) a stabilization phase, and (4) a second growth and production phase. The first research phase lasted from the end of World War II until 1955. The second phase witnessed a period

Mike 1 Detonation. Courtesy of the Los Alamos National Laboratory.

of growth and production that lasted from about 1955 through approximately 1967. It was in preparation for this production that the Savannah River Plant was constructed, and this period approximates the more productive era of reactor operations at the site. The primary mission of the Savannah River Plant has been first to produce tritium, and second to produce plutonium and other special materials as directed by the Department of Energy and its precursor organizations.

Complex-wide, plutonium production reached its peak in the early 1960s. The third period was one of stability, during which the concentration of effort was on the improvement of performance and operations of the nuclear arsenal; this phase lasted from about 1967 until 1980. During this period, eight of the nine Hanford reactors

were closed down, and the ninth reactor that remained in operation was used to produce fuel-grade plutonium. This left Savannah River as the primary source of weapons-grade plutonium during the period. The fourth phase was a second period of growth, which began in 1980 and saw the restart of L reactor at SRP and the return of Hanford's N reactor to weapons-grade plutonium production. In addition, SRP's C, K, and P reactors were used to produce super-grade plutonium that could be blended with excess fuel-grade plutonium that had been produced in the Hanford N reactor. This phase ended in 1988, when all plutonium production was halted.[29]

The following context, which is specific to Savannah River Site, is based generally on this chronological framework. The plant's construction (1950-1956) is treated as a separate phase in the Site's history, followed by a stable period of production and performance improvement that lasts through 1979. Between 1980 and 1989, SRS experienced dramatic change. The decade began with expansion but this was soon sharply curtailed by shifts in the public's perception of nuclear technology and the abbreviation of the Site's defense mission with the fall of the Iron Curtain.

SAVANNAH RIVER PROJECT, 1950-1955

The Soviet Union detonated its first atomic bomb on August 29, 1949. Labeled "Little Joe" by American journalists, the bomb's unpublicized detonation was confirmed through the AEC's program of sampling rainwater. As a consequence, production needs were increased by the Joint Chiefs of Staff who established new minimum requirements for the atomic stockpile. Programs that had been stalled were now begun with vigor. To accommodate the perceived production needs, new "production piles" were required and the Joint Committee on Atomic Energy (JCAE) decided to build new reactors rather than upgrade those at Hanford.

Enlarging the nation's nuclear weapons stockpile was the first response to the Soviet bomb. The second was the decision to produce a hydrogen bomb, a weapon many times more powerful than the uranium and plutonium devices dropped on Japan at the end of World War II. On January 31, 1950, Truman signed a presidential directive that directed the AEC to continue work on all forms of nuclear activity, including the development of the thermonuclear bomb, stating, "We have no other course."[30] A program jointly recommended by the AEC and the Department of Defense to produce materials for thermonuclear weapons in large quantities received presidential approval in June. The AEC had already estimated the construction costs for a new production center at approximately $250,000,000 and Sumner T. Pike, Acting Head of the AEC, immediately began negotiations with Crawford H. Greenewalt, president of E. I. Du Pont de Nemours & Co.[31] Truman requested funds from Congress for the construction of two heavy water reactors for the production of thermonuclear weapons on July 7 and shortly after the AEC drafted a letter contract framed in anticipation of Du Pont's acceptance of the project.[32]

Du Pont Signs On

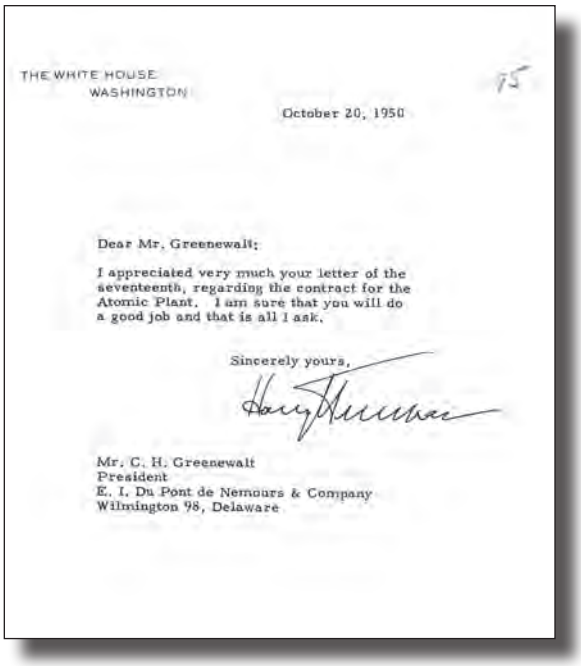
With the passage of the appropriations bill in early 1950, the AEC opened negotiations with Du Pont to build and operate the new plant. Du Pont had built the X-10 reactor and semi-works for the separation of plutonium from irradiated fuel slug facility at Oak Ridge and had built and operated Hanford during World War II through 1946. Both ventures left an indelible print on the corporation headquartered in Wilmington, Delaware, and the success

of both Du Pont efforts had left an equally indelible print in the minds of the MED's Leslie Groves and the AEC. In the field of atomic energy industry, they were seasoned players with a pennant under their belts. Crawford Greenewalt and his staff had participated in a period of intense creativity in which the labors of atomic scientists in their laboratories were duplicated on the production line under wartime conditions. Between 1942 and 1946, Du Pont's engineers and scientists had become experts within the atomic energy field. No other American firm could match Du Pont's expertise in the design and construction of production reactors and chemical processing facilities.[33]

AEC representatives visited Greenewalt formally in May of 1950 to apprise him of the proposed project and on June 8th the Wilmington firm was asked to complete the following: finish the site survey; design, construct, and operate a new reactor installation; and act in a review capacity for the technical aspects of the reactors and the processes for the production of heavy water.[34] The Commission also asked Du Pont to find a location that would not warrant the construction and management of a "company" town, a significant departure from previous military atomic energy plants established by the government.

Du Pont replied that it would consider the project if it had full responsibility for reactor design, construction, and initial operation. The "flexible" reactor design specified by the Commission called for a heavy water moderated and cooled reactor and Du Pont wanted to delay commitment to the project until they were able to review initial plans, particularly for heavy water production, and get a sense of proposed schedule. Greenewalt added a final proviso - that Truman himself request Du Pont's involvement in the project because of its urgency and its importance to the nation's security - which was done in a letter dated July 25, 1950.[35] Greenewalt's request was aimed at squelching any associations with the "merchants of death" label that lawyer Alger Hiss had leveled at the corporation in the 1934 U.S. Senate investigation of the munitions industry. Truman's letter, briefly written and to the point, would become an industrial icon for Du Pont. On July 26, Du Pont's Executive Committee adopted a resolution to undertake the project. The internal resolution also established the Atomic Energy Division (AED) within Du Pont's Explosives Department. The AED would be responsible for the new project.[36]

A letter contract, backdated to August 1, 1950, was signed between Du Pont and the AEC.[37] The letter, which would be superceded by a formal contract three years later, specified that there would be no "facility village" associated with the project and that Du Pont would not be held liable for any lawsuits that might result.[38] On October 18, Greenewalt wrote the company's stockholders that Du Pont would assume responsibility for the construction and operation of the new facility. As at Hanford, the government would pay all costs and receive any patents that might develop out of the work; Du Pont would get an annual fee of just one dollar.[39] Some of the contractual clauses that were first written into the Hanford contract and were duplicated in the SRP contract would become standard in operating contracts undertaken in the modern nuclear industry.[40]


THE WHITE HOUSE
WASHINGTON

75

October 20, 1950

Dear Mr. Greenewalt:

I appreciated very much your letter of the seventeenth, regarding the contract for the Atomic Plant. I am sure that you will do a good job and that is all I ask.

Sincerely yours,

Harry Truman

Mr. C. H. Greenewalt
President
E. I. Du Pont de Nemours & Company
Wilmington 98, Delaware

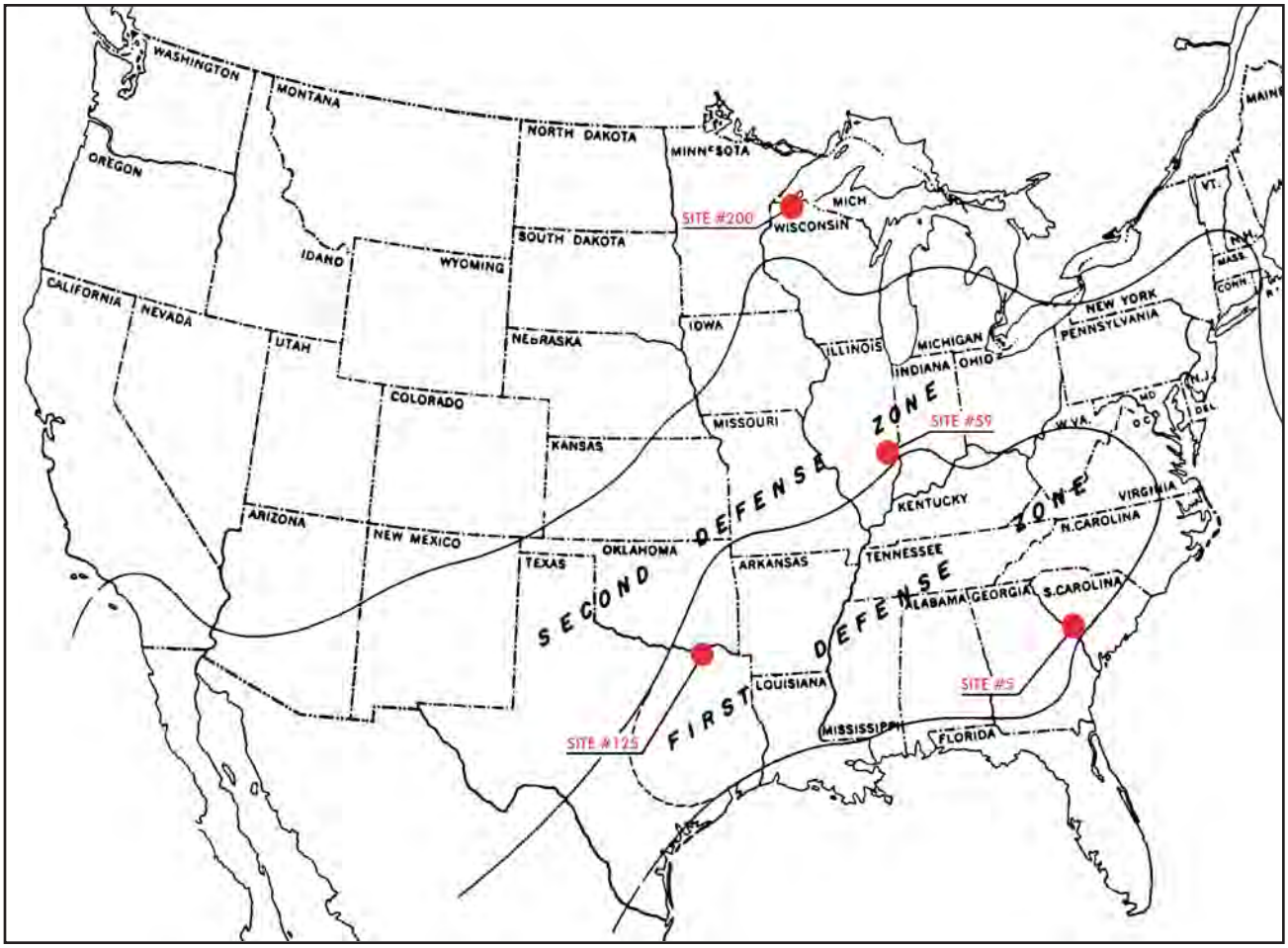
At the time of the letter agreement, the AEC wanted Du Pont to build a tritium plant with two reactors, each to operate at an energy level of around 300 megawatts (MW). The AEC had selected the reactor type advanced by Argonne National Laboratory that was cooled and moderated with heavy water and Du Pont after review accepted the design. By 1950, heavy water reactors were considered more versatile than the graphite reactors Du Pont had built at Hanford and had better neutron economy.[41] As early as August of 1950, Du Pont's Atomic Energy Division had made preliminary improvements to the basic heavy water design proposed by Argonne and was on a pathway to construction.[42]

Site Selection

The proposed site, referred to as "Plant 124," was selected after a six-month investigation launched by Du Pont's Engineering Department and aided by the U.S. Army Corps of Engineers (COE). Truman had advised AEC's Gordon Dean not to brook any political pressure in the decision-making process and the selection process began on June 19, 1950.[43]

The AEC had first contacted the COE and asked them to prepare a list of sites including government-owned lands that might be suitable. This preliminary data was reviewed in the Cincinnati Corps Office of the Great Lakes Division but was found lacking in definition. The following methodology was agreed upon: all rivers with a recorded minimum flow of 200 cubic feet per second (c.f.s.) were marked on sectional maps prepared by the Corps and locations within 20 miles to a river were considered. Bands were drawn along selected rivers and potential sites were located within these bands. The preferred site would also be located in the "The First Defense Zone" for strategic reasons imposed by the Department of Defense. This zone encompassed area that stretched from Texas to Virginia and north to Illinois. Embracing the central portion of the Southeast, it included 84 candidate sites. A second band of area that stretched from Arizona to New Hampshire was considered the "Second Defense Zone." The latter had six candidate sites. C. H. Topping, Principal Architect and Civil Engineer within Du Pont's Design Division, further described the selection process that was guided by "basic site requirements" that were jointly arrived at by Du Pont and the AEC. The requirements were: a one-square mile manufacturing area; a 5.6-mile buffer zone enclosing the manufacturing area; a 10-mile distance to neighboring communities of 500 individuals and a 20-mile distance from communities with 10,000 individuals; presence of supporting populations to absorb the incoming workforce; ample water and power supplies; accessibility by rail and highways; favorable meteorology and geology; and positive conditions for construction and operating costs.[44]

Sixty-five sites were eliminated when progress in reactor design studies established that the minimum acceptable water supply was 400 c.f.s. By August 2, the list was pared down to seven sites. Members of the AEC, Army Corps of Engineers staff, and the Du Pont team, between August 6 and 17, chose these as candidates for a field inspection. Three local sites made it to this shortlist: two in South Carolina and one in Georgia. The site in Georgia was eliminated when it was learned that the Clark Hill reservoir would put a portion of the desired site under water and a site in northwestern South Carolina was considered too isolated. Site #5 in Aiken and Barnwell counties stayed in the running.



Site Selection Map Showing Military Defense Zones and the Location of Candidate Sites. Site No. 5 is the future Savannah River Plant.

Changing water requirements also led to searches in colder climate areas both within and outside of the Second Defense Zone. These sites were put into the selection mix and similarly eliminated as the selection criteria were applied. In mid August, the requirement for the minimum water supply was increased to 600 c.f.s.[45] The Special Committee of the National Security Council on Atomic Energy had called for the construction of three additional reactors.[46]

A final evaluation of sites using the original and expanded criteria focused on four locations. These were Site #125, which was located along the Texas and Oklahoma border on the Red River; Site #59 which was located on the border of Illinois and Indiana on the Wabash River; Site #205 which was located on the shores of Lake Superior in Wisconsin; and Site #5 located in Aiken, Barnwell and Allendale counties on the Savannah River in South Carolina. Essentially, three factors were compared. The first was the availability of large quantities of reasonably pure water for process capability, the second was the presence of towns of sufficient population that could absorb the proposed labor force but were at a sufficient distance to minimize any impacts, and third, the presence of sufficient land that was suitable to the construction of production areas. During the week of August 24th, these sites were field checked by the AEC's Site Review Committee composed of five experts drawn from American engineering firms such as Black and Veatch, Sverdrup, etc., that were authorities on site selection.

Site #5, a rural site along the Savannah River in South Carolina, was recommended to the Site Review Committee on November 13, 1950 as the final selection. In the words of Du Pont Engineer, C. H. Topping, it "more nearly meets the requirements than do the others."[47] The Site Review Committee concurred with the recommendation and Site #5 was selected. The AEC formally confirmed the decision on November 28 and the public was notified by an AEC press release on the same day. AEC's Curtis A. Nelson was named as the plant first local manager in August. Nelson, a Nebraska born civil engineer and colonel in the Manhattan Project, was familiar with heavy water technology through his work as a liaison with Canada's Chalk River Plant. He also brought strong construction experience to the new project from his years in the Civilian Conservation Corps and as engineer in the Corps of Engineers where he had supervised the construction of the Joliet Illinois Ordnance Plants.[48] He was charged, along with Bob Mason, Du Pont's Field Manager for Construction, with moving the project off the Du Pont Company's and their subcontractor's drawing boards and placing nine industrial plants into the rural South Carolina landscape. Mason, a Hanford veteran, was assigned to the project on September 25.

Announcement

The swiftness and military execution of the site selection announcement attests to the months of planning involved in its preparation. At 11 o'clock on Tuesday morning, November 28, 1950, the announcement was made simultaneously at press conferences held in Atlanta and Augusta in Georgia; at Columbia, Charleston, and Barnwell, in South Carolina; and to mayors, presidents of chambers of commerce, state, city, and county officials. During the day, teams representing both AEC and Du Pont called on city, county, and state officials in Atlanta, Columbia, Augusta, Aiken, Barnwell, Ellenton, Jackson, Dunbarton, Snelling, Williston, White Pond, Windsor, and Blackville. Later in the day further details were released concerning the project by the AEC in Washington, D.C. Teams gathered that evening in the office of the Du Pont Field Project Manager at the Richmond Hotel to compare notes.[49]

AEC Field Manager Curtis Nelson and Du Pont's Chief Engineer formally delivered the news to Governor Strom Thurmond and Governor-elect James F. Byrnes in Charleston, South Carolina, where they were attending the Southern Governors Conference. Governor Thurmond invited Georgia's Governor Herman Talmadge to join in the press conference prepared for the journalists covering the conference. The timing of the announcement for what could only be forecasted as a regional economic success story was excellent for both Thurmond and Talmadge. Byrnes was well versed in atomic energy development for military purposes. He had acted as Franklin Roosevelt's "Assistant President," running the country while FDR fought the war and he was Truman's Secretary of State.[50] All three men were major figures in national and Southern politics and it is unlikely they watched the site selection process unfold without knowledge or interest.

The public announcement of the project signaled a new era in which the American public's right to know was at least partially fulfilled. Previous military atomic energy undertakings had been done in total secrecy as part of a wartime defensive effort. The Savannah River Project was complex and atypical as it was to be constructed during peacetime, its mission still required secrecy, and a government town was not to be constructed. The

latter meant that the surrounding communities, which were fairly settled, were to absorb the new workforce estimated in the thousands and to create the infrastructure and services needed for this population increase. Public disclosure was warranted and unavoidable. A straightforward approach was chosen in which public outreach and partnership initiatives were advocated. Public meetings, lectures, project managers working with community development and business leaders, and the airing of a movie called *The Du Pont Story* in Augusta for business leaders and new employees were just some parts of the AEC and Du Pont's well-orchestrated strategy for strong and positive public relations.

The Augusta Chronicle

$260,000,000 H-bomb material facilities will be constructed in S. C. near Augusta

Allies facing 'new war'

Aiken-Barnwell site is selected for plant

Grim note is voiced by Gen. MacArthur

Shocked officials seek urgent steps

Plant means big boom for Augusta

Ellenton's residents stunned, but accept news patriotically

Front page of The Augusta Chronicle, *November 29, 1950, reported on the announcement from several angles reflecting the many meanings the new plant would have for the country, the CRSA, and for those displaced by the proposed land acquisition.*

Meeting at Ellenton Auditorium, December 6, 1950. The U.S. Corps of Engineers real estate officers responsible for the land acquisition called a public meeting in Ellenton. A representative from each family was asked to attend the question and answer session. Reportedly, over 500 individuals attended what appears to have been a segregated meeting with attendees, both black and white, spilling out of the main hall into the building entries and lobby. Courtesy of SRS Archives, negative 1221-1.

Site Description

With the site survey behind them, Du Pont moved forward with site definition and acquisition strategies. When acquired, the site would contain about 200,646 acres or 310 square miles within Aiken, Barnwell, and Allendale counties situated within two sub-divisions of the Atlantic Coastal plain: the Aiken Plateau and the Alluvial terraces that lie along the river. Eighty percent of the site was situated within the Aiken Plateau, where elevations ranged between 300 and 385 feet. The terraces are composed of three tiers of varying widths banding the river. From north to south, six streams dissected the tract: Upper Three Runs Creek, Four Mile Creek, Pen Creek, Steel Creek, Hattie Creek, and Lower Three Runs Creek. Five streams empty into the river in a southwesterly direction, the sixth, Lower Three Runs, flows to the southeast and drains the eastern portion of the proposed site. Although irregular in shape, the site measured roughly 22 miles in width and 22 miles in length.

The proposed site was rural but not isolated. The nearest large urban centers in Georgia were Augusta (20 miles northwest), Atlanta (155 miles west and north), Savannah (85 miles to the southeast) and in South Carolina, Columbia (65 miles northeast). In addition, data was gathered on towns with populations of over 1,000 individuals within a 50-mile radius to the site. The project area contained seven communities: Ellenton and Hawthorne in Aiken County, and Dunbarton, Meyers Mill, Robbins, Leigh, and Hattieville in Barnwell County. Ellenton, a post-Civil War railroad community and local trading center, was the largest with a population of 600. Dunbarton, also a railroad town, had a population of 231 individuals. The remaining communities were smaller. Meyers Mill possessed some stores and a cotton gin while Leigh was synonymous with a box and crate manufactory, the Leigh Banana Case Company, that operated at that site between 1904 and 1954, employing about 300 people in 1950.[51]

Camp Gordon, Oliver General Hospital and its annex, Daniel Field, and the Augusta Arsenal were military installations less than 26 miles from the proposed site and six airports, five municipal fields on which there was a recapture clause in case of war and one USAF inactive airfield, that were within 40 miles.[52] The existing road system was composed of state highways that intersected with U.S. highways and in addition, there was a well-defined network of unpaved "farm to market" dirt roads. Rail service was already in place. The Charleston and Western Carolina (CWC) Railroad paralleled the river, providing service from Savannah to Augusta and the Atlantic Coast Line Railroad ran from Barnwell to Robbins where it joined the CWC line. The CWC ran through Ellenton and Dunbarton and the smaller communities were railroad stops on the line.

Three companies provided power to area residents and businesses: the South Carolina Electric and Gas Company, the Aiken Electric Cooperative, and the Salkahatchie Electric Cooperative. Two phone companies, Southern Bell and Cassels Telephone Company, were communications providers as were telegraph offices in Ellenton and Dunbarton. U.S. post offices were located in Meyers Mill, Ellenton, and Dunbarton.[53]

The acquisition process was handled over an 18-month period by the South Atlantic Real Estate Division of the U.S. Army Corps of Engineers on behalf of the AEC. The process formally began the day after the announcement so that the government would have the necessary lands either by declaration of taking or through actual purchase by June 30, 1952. The acquisition process was staged to accommodate construction requirements. Priority

zones were established, rights of entry obtained, and property transfers swiftly occurred. Ultimately, 123,100 acres situated in Barnwell County, 73,462 acres in Aiken County, and 4,084 acres in Allendale County were acquired. Boundary realignments occurred as the acquisition process progressed, eliminating two of the four communities (Jackson and Snelling) that were originally within the project area and adding on a 4,453 acre corridor of land on both sides of Lower Three Runs Creek in Barnwell and Allendale counties.

Six thousand individuals were evacuated from their homes and homesteads. Some displaced owners moved their homes, joined neighboring communities, and worked at the plant. Business owners relocated and new businesses were spawned by the influx of plant employees, particularly during construction. Others sold their properties and left the area viewing the change as an opportunity. While a sense of patriotism motivated most of the project area residents, it was difficult for all involved as government appraisals were guaranteed to fall short when values were attached to land that had generations of farming and family life invested in its soil.

Site Layout

SRP was originally organized into nine manufacturing areas, a central administration area, and two "service" building areas known as the Temporary Construction Area (TC Area) and Central Shops. Between building areas, buffer areas were forested, masking the earlier landscape and providing a sense of distance and isolation. The areas were linked by a well-designed transportation system that included 210 miles of surfaced highways, the first cloverleaf constructed in the state, and 58 miles of railroad track. Previous road names were erased and letter designations, such as Road A, Road B, etc., were assigned.

Some residents preferred to move their homes to locations outside the new federal site. Du Pont designated a House Moving Coordinator to handle the moves. All land was acquired by June 30, 1952. Courtesy, SRS Archives.

Each area was given a number and a unique letter designation (Table 2). Function was reflected in the area numbers; letters identified site geography. This code-like system, used first at Hanford for the identification of building areas and their associated facilities, and the road lettering system heightened the anonymous and utilitarian character that evolved at the site.

Each 100 area, 100-R, 100-P, 100-L, 100-K, and 100-C, was situated in the central part of the site, aligned in an arc. The reactor areas were purposely dispersed at 2.5-mile intervals from each other and 6 miles from the site boundary to minimize the impact of an "atomic blast." Early maps show the site layout process and the

1956 Basic Information Map - General Areas.

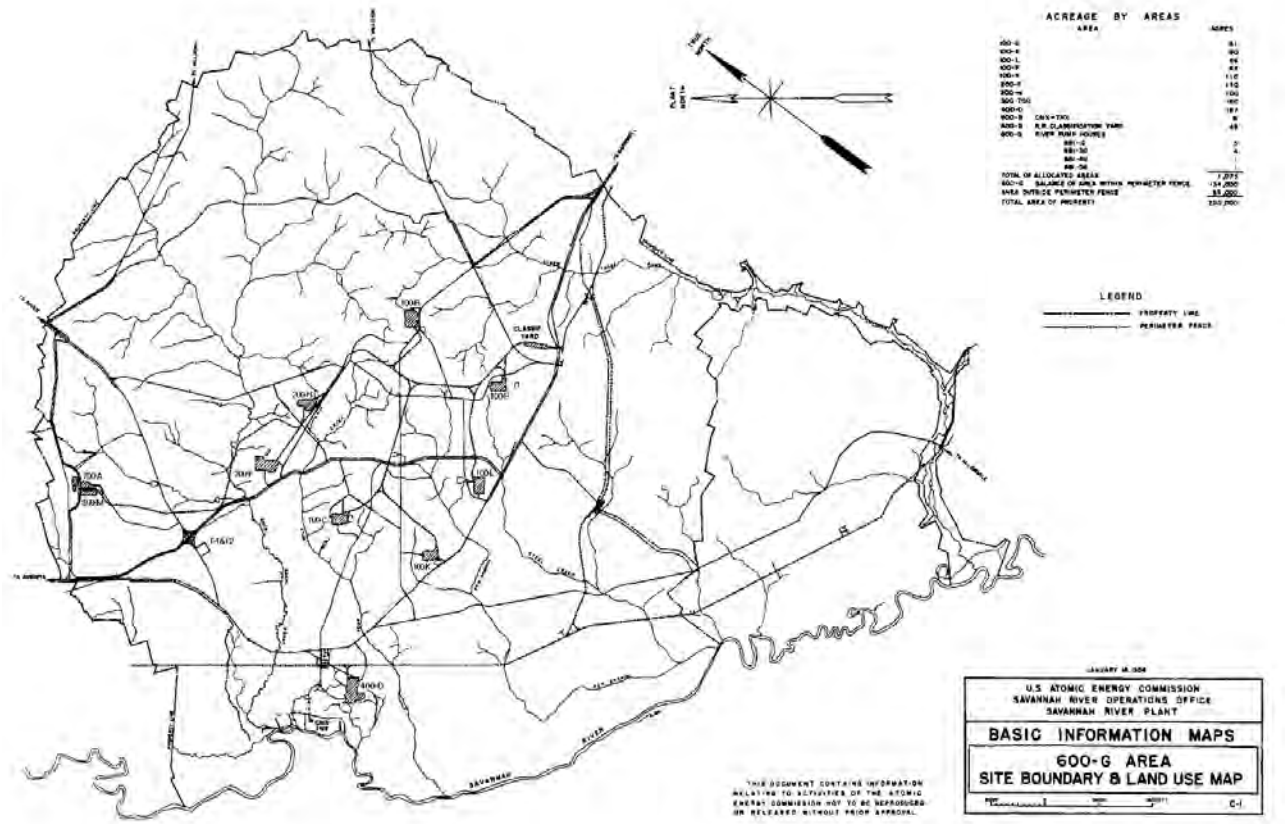


Table 2. Area Nomenclature

100 - Reactor Area	100-R, P, L, K, and C
200 - Separations Areas	200-F, H
300 - Fuel and Target Fabrication Area	300-M
400 - Heavy Water Production Area	400-D
500 - General (lighting, transmission lines, substations, etc)	500-G
600 - General	600-G
700 - Administration Area	700-A
900 - General	900-G

reservation of space or alternative sites for future expansion. The *Engineering and Design History* notes that much discussion occurred between Du Pont and AEC consultants on where the process buildings should be located, however it was the U.S. Air Force that had the final word on their dispersal, suggesting that the pattern chosen had military ramifications.[54] Two river water pump houses, one at the mouth of Upper Three Runs Creek and a second two miles upstream from the first, supplied water to the 100 areas, primarily for cooling the heavy water coolant.

The 200 Areas, 200-F and 200-H, were also centrally located within the site's core area, approximately 2.5 miles from the closest reactor area and about 6 miles from the project area perimeter. The canyon buildings, massive concrete buildings, would dominate each separations area. F area contained four process buildings originally and was built to be self-sufficient. H Area did not contain the same process buildings but space was allotted for future expansion. Water to both 200 areas was supplied from deep wells.

The 400-D Area, located near the site's southwest perimeter approximately one mile from the river, housed heavy water production units and support buildings. Resembling an oil refinery, the 400 Area was characterized by three steel tall tower units, a flaretower, a finishing facility and other support buildings including a powerhouse. After SRP was closed to the public, this area was viewable from outside the site boundaries and the GS towers and flare tower was the visual image most area residents connected with SRP. A third river pump house supplied water to 400 Area.

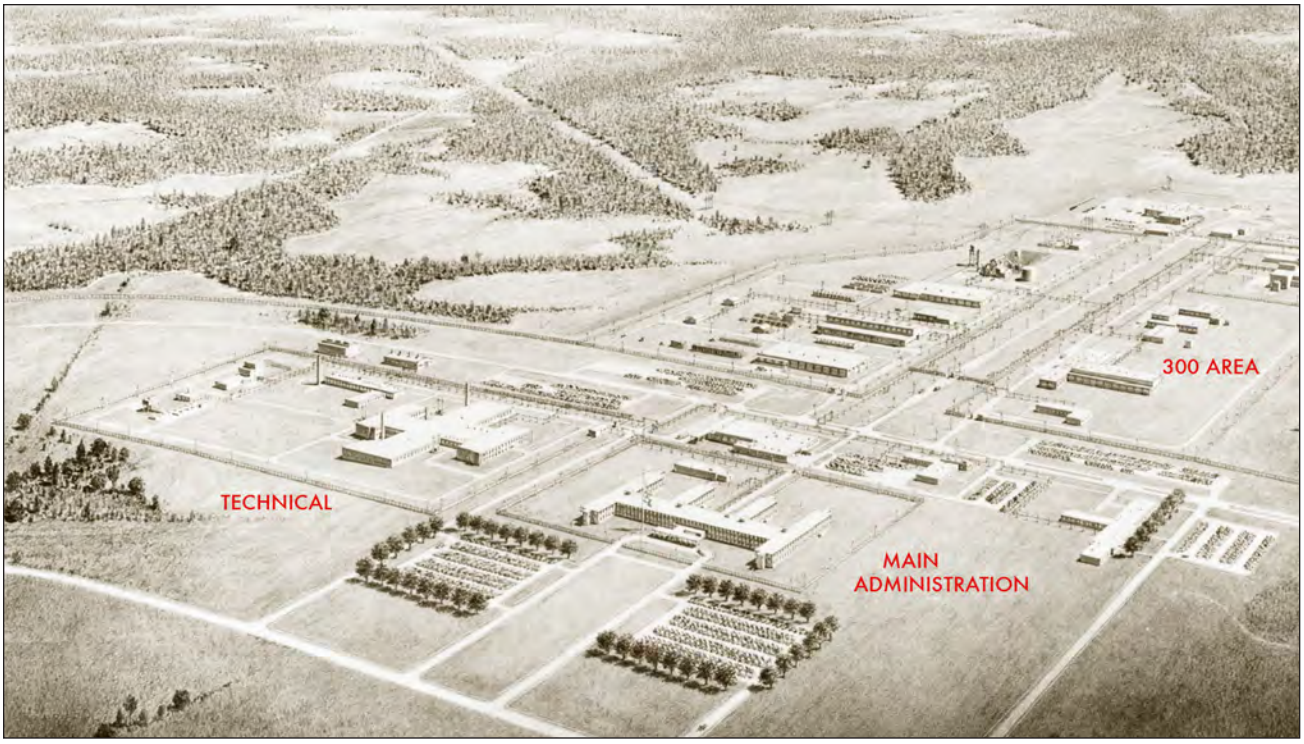
The 300-M Area was situated near the northwest perimeter of the project area where it was laid out in a rectangle that adjoins the 700 Area. It contained testing and fabrication facilities for reactor fuel and targets. Two buildings, 305-M (now 305-A) and 777-M (now 777-10A), contained test reactors that were used to test the components manufactured in the 300 Area and to aid development and testing for SRP reactor design.

The 700-A Area was SRP's administrative and "service" center. It contained the main administration building noted in the excerpt above, the medical facility, communications facilities, patrol headquarters as well as a variety of maintenance and storage buildings. A Area also contained the Main Technical Laboratory, now Savannah River National Laboratory, in which plant processes were researched, designed, and tested, and other research facilities.

Finally, two pilot plant facilities, CMX and TNX, were located near the 400 Area. The former was designed to run corrosion tests on heat exchanger equipment installed in the reactors and to investigate what types of water treatment processes were needed for plant operations. A small pump house accompanied it. The latter was a pilot plant for processes completed in the 200 area canyons.

Nine coal-burning powerhouses located in the building areas supplied steam to the process areas and the overall site. The large pipes that carried the steam are above ground, arching over roadways where necessary and paralleling the road system. Outside the manufacturing and service building areas, general facilities needed for either process support or general site support included three-river water pump houses, a pilot plant, railroad classification yard, and burial ground for solid wastes.

The first generation of buildings at SRP was simply designed using a functional ethic. The AEC's specification that the project's buildings be spartan in their design was a done deal given the climate of American post-war industrial architecture. The choice of building materials, reinforced concrete and transite paneling, were mandated by the building code. Articulated in reinforced concrete or steel frame with transite panels, the majority were beige or



Architectural Rendering of the Main Administrative Area (700-A) and the Fuel and Target Fabrication Area by Architects Voorhees, Walker, Foley & Smith, ca. 1951.

gray boxes built for maximum flexibility and for government service. Their uniformity in color, their number and size, and their geometric forms create a harmonious grouping of buildings within an ordered industrial landscape where form reverberates function. This functional perspective is further emphasized by the placing of the Site utilities above ground so that massive pipes parallel roads or arch over them. Economically motivated, this design feature has strong visual impact.

Subcontractors

It was recognized from the start that Du Pont Engineering Department would need supporting organizations to complete the project given its size and schedule. Temporary use was made of the Bush House located on Highway 19 as the Field Construction Office and a tenant farmer's dwelling was adapted for use as the Field Cost Office. The need for immediate construction buildings while Du Pont was organizing called for the hiring of a local architectural and engineering firm, Patchen and Zimmerman of Columbia, SC, to get things off the ground.[55] This firm's design work at the TC Area with its two massive cartwheel buildings and the adjacent cloverleaf created one of the most visually distinctive layouts on site.

Engineering and design assistance to Du Pont was provided by the following subcontractors: American Machine and Foundry Company, Blaw-Knox, the Lummus Company, Gibbs & Hill, Inc, and Voorhees, Walker, Foley & Smith. Each of these firms had demonstrated experience in their respective areas and each made significant contributions to the equipment and SRP building stock.

Table 3. Subcontractors for Du Pont Project 8980

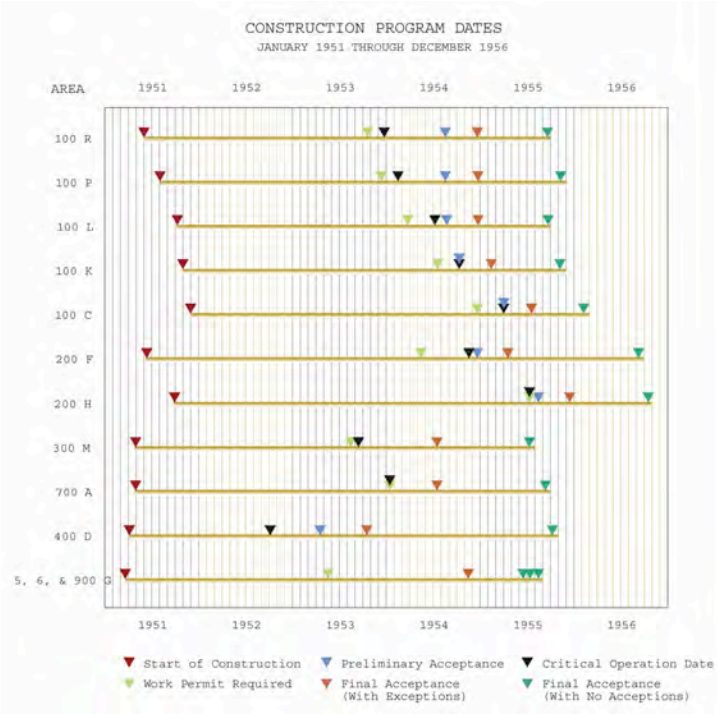
American Machine and Foundry (AM&F) - This firm was charged with the design and fabrication of special mechanical equipment for use in the 100, 200, 300, and 400 area process facilities. AM&F described their firm as manufacturers of machines for industry. In 1950 they were considered the world's largest manufacturer of cigarette and cigar making equipment.[56]
The Lummus Company - This firm was requested to design and partially procure six "GS" units (towers 116' in height) including the DW and finishing plants for the 400 area heavy water production facilities. The firm brought strong petroleum, petrochemical, and chemical experience to the project. Self described as a network of men, minds, and machines that were dedicated to transforming ideas and capital into profit earning processes and equipment, the Lummus Company, international in scope and headquartered in New York, were expert in the design of distillation processes.[57] The 400-area design benefited from an agreement between the Girdler Corporation, which had designed the Dana Plant, and the Lummus Company for the exchange of technological information gained from the Dana Plant that could be applied at SRP.[58]
Blaw-Knox Company - Design of process buildings and equipment required in 200 area facilities, general area facilities (600 area) related to 200 area processes.
Gibbs & Hill, Inc. - Design of steam, water, and electrical facilities for process areas and overall plant. This engineering firm based in New York was subsumed by Dravo Corp of Pittsburgh in 1965 then later sold to Hill International, a New Jersey based firm.
Voorhees, Walker, Foley & Smith - This New York architectural/engineering firm was responsible for the design for all "service" buildings including laboratories and general facilities including roads, walks, fences, and parking areas; the manufacturing buildings in the 300 area; laboratories; some design work for 200 areas and overall site clearance at SRP. It was also responsible for Du Pont's Experimental Station in Wilmington, the MED laboratories at Columbia University and Argonne National Laboratory.[59]
New York Shipbuilding - This firm was responsible for fabricating the five reactor vessels that were transported by barge to the South Carolina site. Known as the NYX Program, this effort produced the cover plate of the reactor vessels known as the "plenum" (a laminated steel plate 19 feet in diameter, four feet thick, weighing about 100 tons, and drilled with 500-4-inch tubes), the reactor vessels, and the primary piping.[60] Organized in 1899, New York Shipbuilding was located on the banks of the Delaware River in South Camden, New Jersey. The firm brought its experience in the fabrication of heavy industrial equipment and machinery to the task. A company history notes that the firm had taken on projects as "a public service where the facilities of the Yard provided the only available means for constructing unusual items. Its location on tidal waters, with weight handling equipment up to 300 tons, makes it possible to load assemblies which may be beyond the size or weight limitations for shipment by rail."[61] These qualities were probably well known to Du Pont who also had a plant in the Camden area.

Unfolding Scope of Work and Flexible Design

By Hanford standards, the 38 months from start of construction to operation for C reactor at Savannah River was quite slow. However, by later standards, such a pace would appear incredibly rapid. The placing of R reactor in operation in December 1953, when the conceptual design had only been sketched out in December 1950, seemed to later nuclear specialists a remarkable achievement in engineering and management.[62]

The scale, shape, and funding of the Savannah River Project and the mix of plutonium, tritium, and other radioisotopes to be produced in its reactors was determined by the AEC. The schedule was set by world events. Du Pont's design team, in association with their primary subcontractors, was responsible for translating the larger conceptual design outline by the AEC into reality within an atmosphere of "urgency and commitment."[63] Du Pont designers accomplished their goals using a "flexible design" approach. This approach operated at two levels: the first entailed postponing design decisions until the best design could be determined by research or through consultation, and the second was to build in the potential for future design options should AEC policy change.

In the first scenario, Du Pont designers based some design decisions on their experience from previous atomic energy plant construction projects and from scientific research completed at the AEC's national laboratories. This allowed them to move forward with production in some areas while alternative design choices were researched for others. In the second scenario, postponement of design was necessary as part of the current and future client-contractor relationship. AEC directives, based on Department of Defense guidance on what product or product mix was needed for its weapons program, directly translated into design decisions. Du Pont recognized this as an integral feature of their contract and responded with aplomb to an evolving scope of work. Their ability to do so was characteristic of the firm's management that had an internal set of departmental checks and balances and well-honed procurement strategies.[64]



Bar Graph Showing the Construction Schedule and the Milestones Reached. Source: Engineering Department, E. I. Du Pont de Nemours & Co., Savannah River Plant Construction History, Volume I, DPES 1403, 1957.

SRP Operations, 1955 - 1989

As an integral part of the nuclear weapons production complex, SRP's primary mission has been first to produce tritium, and second to produce plutonium and other special materials as directed by DOE and its precursor organizations.[65] Its role was not one that can be described as one step along a linear process, but rather as one of the hubs of material movement through the complex. Table

3 shows how the site was integrated into the overall nuclear weapons complex and the direction of material flow that established the relationship.

Table 4. Direction of Flow of Materials into and from the Savannah River Site to other Sites within the National Nuclear Weapons Production Complex

Other Sites Within Complex	Direction of material flow	SRP Area	Type of Material
FMPC and Weldon	To	300 Area	**Raw Materials:** natural and low enriched uranium for fuel and target manufacture
Oak Ridge Site Y-12 Plant	To	300 Area	**Isotope enrichment:** highly enriched uranium for fuel and target manufacture
Oak Ridge Site Y-12 Plant	To	300 Area	**Isotope enrichment:** Lithium for target manufacture
Oak Ridge Site Y-12 Plant	From	400 Area	**Isotope enrichment:** Heavy Water for deuterium production and deuterium gas
Dana Plant	To	100 Area	**Isotope enrichment:** Heavy Water for moderator and coolant
FMPC and Reactive Metals, Inc.	From	300 Area	**Fuel and Target Fabrication:** depleted uranium for fuel
Weldon Spring Plant, FMPC, Oak Ridge Site K-25 Plant, and Paducah Gaseous Diffusion Plant	From	200 Areas	**Separations** (for raw materials recycle): low enriched uranium for recycle
Oak Ridge Site Y-12 Plant	From	200 Areas	**Separations** (for raw materials recycle): highly enriched uranium for recycle
Rocky Flats	From	200 Areas	**Separations:** plutonium metal buttons for pit production
Mound Plant	To	200 H Area	**Separations/component manufacture:** recovered tritium for purification and reuse
Pantex Plant and Iowa Army Ammunition Plant	From	200 H Area	**Separations/component manufacture:** filled tritium reservoirs ready for assembly

Source: USDOE Office of Environmental Management, *Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to their Environmental Consequences* (Washington, DC: USDOE Office of Strategic Planning and Analysis, 1997), 18-19, 154-155.

Heavy Water Production and Rework

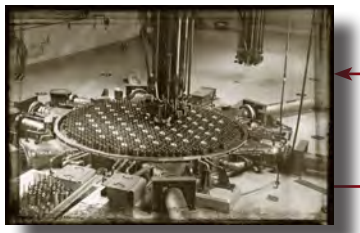
The Heavy Water plant at SRP (D Area) used the Girdler Sulfide (GS) process of hydrogen sulfide-water exchange. This portion of the plant, completed in 1952, included 144 process towers ranging from 6.5 to 12 feet in diameter, each 120 feet tall.[66] Between 1952 and 1957, the D Area plant and the heavy water plant at Dana,

We don't dig Uranium out of the ground, and we don't make bombs, but we do nearly everything in between.

Plant Processes

Fuel and Target Fabrication

Heavy Water Extraction



Reactor Irradiation

Waste Management

Separations

Products

Plutonium-238

Produced by neutron irradiation of neptunium-237, a byproduct of uranium irradiation. Valuable for its heat generating capacity.

Curium-244

Properties and applications similar to plutonium-238.

Plutonium-239

Used as a nuclear explosive, a breeder reactor fuel, or as the starting target material for production of heavier radioisotopes.

Tritium *(Hydrogen-3)*

A radioactive isotope of hydrogen, component of thermonuclear explosives, and a potential fuel for thermonuclear fusion power generation.

Cobalt-60

Known radiation source and has long been used for radiotherapy.

Californium-252

One of the rarest man-made isotopes, has great potential value in medicine, industry, research, and education.

Heavy Water *(D_2O)*

Important nonradioactive product of the Savannah River Plant. It occurs at a concentration of 0.015% in natural water and must be concentrated to 99+% to be useful in reactors as a neutron moderator.

And Other Radioactive Isotopes

Depiction of Plant Processes and Products Compiled from Savannah River Laboratory's Nucleonics of Tomorrow in the Making Here Today (Aiken, South Carolina: E. I. Du Pont de Nemours and Company, not dated).

Indiana, supplied most of the heavy water for the nuclear weapons production complex. A sufficient stockpile of heavy water had been accumulated by 1957 to allow the closure of Dana and of two-thirds of the Savannah River units. The remaining units continued to operate until 1982, primarily to reconcentrate heavy water that became diluted during reactor operations. During its 30 years of operation, D Area produced over 6,000 tons of heavy water.[67]

In the spring of 1953 a small plant was constructed in D Area to produce deuterium gas from heavy water by electrolysis. Some of this deuterium was used at Savannah River in the Tritium facility (tritium reservoirs were actually filled with a mixture of tritium and deuterium), and some was sent to the Oak Ridge Site to be converted to the lithium deuteride used in the secondary assemblies of thermonuclear weapons. A second, larger deuterium plant was constructed in D Area in 1954.[68]

Fuel and Target Fabrication

The manufacture of early reactor fuel elements, or slugs, was fairly straightforward. Although there had been problems in the early fabrication process at Hanford, the lessons learned there allowed SRP production in the M Area to proceed with relatively few problems. The slugs were solid natural uranium rods about one inch in diameter and eight inches long, clad in aluminum. The uranium rods were fabricated by Femald (FMPC) and shipped to Savannah River. The metallurgical structure of the uranium rods was adjusted (first at Savannah River, later at FMPC prior to shipment); the slugs were then sealed in aluminum.

Lithium target slugs were also needed for the production of tritium, and for use as control rods in the reactors. Lithium was sent from the Oak Ridge Site to Savannah River Building 320-M, where it was alloyed with aluminum, cast into billets, extruded to the proper diameter, cut to the required length, and canned in aluminum. The lithium-aluminum slugs were also encased in aluminum sheaths, called raincoats. At Savannah River, tritium was initially produced as a reactor byproduct in the lithium-aluminum control rods. As AEC requirements for tritium increased, reactor elements specifically designed for tritium production were needed. Driver, or fuel, elements of highly enriched uranium were used to provide the neutrons for irradiating the lithium-aluminum target elements. Enriched uranium drivers were extruded in 320-M until 1957, after which they were produced in the newly constructed 321-M, built specifically for this process.[69]

The M Area at Savannah River continued to produce most of its own fuel and target assemblies until the end of the Cold War. Revisions and upgrades were made to the facilities, as needed, one of the most important being the change from solid slugs to tubular elements. The production of solid slugs ended late in 1957. Production in the M Area increased and decreased with the needs of the reactors. The last large increase was in 1983, when the operations in 321-M went to 24 hours a day. Operations fell off as the reactors closed, and for the most part have ceased altogether since 1989, when the last reactor was taken off line.[70]

Reactor Operations

There were five production reactors operating at the Savannah River Plant during the Cold War, identified as C, K, L, P, and R reactors. The first SRP reactor to go online was the R reactor, which was tested for integrity and operability during the fall of 1953 and went critical in December of that year. The first few months of operation were problematic because instruments triggered frequent automatic power reductions and "scrams," or unscheduled emergency shutdowns. Improvements to the instrumentation and signal systems mitigated these problems, and the number of scrams, one a day in February 1954, fell to an average of one in three days by May. P reactor was the second to go critical, the event occurring on February 20, 1954. The first irradiated fuel was discharged from R reactor the following June, and all five reactors were operating by the end of March 1955.[71]

Changes were quickly made to both the reactors and reactor operations. Although Savannah River was originally intended as a tritium production site, the lithium-aluminum slugs from which tritium was produced were at first used only as control rods. As a result the first tritium was produced essentially as a by-product of plutonium production. However, AEC requirements for tritium production had increased by 1955, and that year the reactors were loaded in configurations specifically meant to produce tritium. As operators found they could increase the power levels at which the reactors operated, they began adding extra heat exchangers to eliminate the increased heat. C reactor had 12 heat exchangers, but the other four reactors only had six, a necessary shortcoming due to limited supplies of heavy water and vender production capabilities during the construction period. The number of heat exchangers was increased to 12 on all reactors in 1956, and the original power output of 378 megawatts was increased to 2,250 megawatts.[72] A megawatt, as used in reference to production reactors, is not a measure of electrical generation but of thermal output, a convenient measure of the operation of a reactor.

To further increase the capabilities of the cooling system, a large retention lake was created. Heavy water was used to remove heat from the reactors, and light water from the Savannah River was used to remove heat from the heavy water. The increase in the amount of heat being removed via the heavy water meant a concurrent increase needed to be made in the amount of heat being removed by the light water. Unlike the heavy water, the light water was returned to the river, so a means of dissipating its heat before returning the light water to the environment was necessary. The 2,600-acre P and R (Par) Pond was constructed for this purpose, and was integrated into the cooling system in 1958. All the cooling water from R reactor then was routed to Par Pond, and a portion of P reactor water was sent out via Par Pond. The new reservoir not only served as a means of cooling water, it also created an additional source of cooling water for P and R reactors, which produced savings in pumping costs. Since they would then be drawing less water from the Savannah River, more would be available for the other three reactors. This and further improvements in the light water circulating system allowed C reactor to be brought to a power level of 2,575 megawatts in 1960, and to eventually reach its all-time peak of 2,915 in 1967.[73]

Another major change in reactor operations came with the use of computers. Computers were first used to monitor the 3,600 reactor process sensors on an experimental basis in K reactor beginning in 1964. The experiment was successful, and the system was added to the three other then-operating reactors (R reactor had been placed on

standby in 1964) by the end of 1966. In 1970, a closed loop control system began trial operation at K reactor. Computers were used to assess information from the sensors, and to make adjustments to groups of control rods based on that information. Using computers to do this was another means of optimizing reactor performance. In the late 1970s, new computer systems were installed to provide safety functions and to monitor and add additional control over reactor operations.[74]

By 1970, the heyday of reactor operations had passed. R reactor was shut down in 1964 due to a lack of demand for reactor-produced products, and L reactor was placed on standby status in 1968 for the same reason. C, K, and P reactors continued to produce tritium, plutonium, and other isotopic elements as directed by the AEC in pursuit of both military and non-military programs.

Separations

The specific purpose of this thematic study is to explain, as fully and in as much detail as possible, the separations processes carried out at SRS; however, a brief overview for this context follows. Operations at the Savannah River Plant included two main types of separations: combined plutonium/uranium extraction, and tritium extraction. The former was conducted primarily in the canyons in F and H areas. The F Canyon went into operation in November 1954, and the H Canyon was online the following July. In these two buildings, the fuel elements that came from the reactors were dissolved in acid to separate the uranium and plutonium from waste fission products by chemical extraction in solution.

Tritium separations took place in two much smaller areas. Slugs irradiated to produce tritium were initially sent to Building 232-F, which started operating in October 1955; there, the slugs were melted rather than dissolved, to release the gaseous tritium.[75] After melting, the tritium was purified by a process known as thermal diffusion. A 232 building was also constructed in the H Area, and began production in 1956. By the end of the year two lines were operating. Tritium was originally shipped elsewhere for placement in the reservoirs, but in August 1958, tritium began being recycled in 232-H as well. Tritium processing capacity in the H Area facilities was doubled that year, and the F area 232 facility was closed that autumn. A new facility, the Replacement Tritium Facility, went into operation in 1993, and it continues to perform the tritium mission today.[76]

The two canyons were originally designed to operate using the Purex process by remote operation and maintenance—which meant that the process areas were not designed to be entered by personnel on a routine basis. During the first year of operation, the F Canyon attained its designed throughput level of three metric tons of uranium per day. Lessons learned from early operations in F Canyon allowed H Area operations to achieve a throughput of seven tons per day.[77]

In early 1957, the F Area canyon was closed down so that substantially larger equipment could be installed to increase throughput, and so that a new facility to convert the plutonium to metal could be built on the canyon roof. This would more than double the capacity of the canyon. The modifications took two years to complete, and the F Canyon went back into operations in March 1959, with a capacity to process 14 tons of uranium each day.[78] As soon as F Area was back in operation, H Area was shut down for conversion to a modified Purex process designed to safely recover enriched uranium from target elements then beginning to be used in the SRP

reactors, a change that took only three months. H Canyon was back in operation by June.[79] Many more minor modifications of the canyons followed over the years to allow products other than uranium and plutonium to be recovered, but the fundamental processes for extracting plutonium and uranium remained essentially the same throughout the Cold War.

Waste Management

In general, the waste facilities at Savannah River were modeled on those at Hanford, though modified since the radioactivity of the high-level wastes at SRP would be greater than those at Hanford. The original tanks each had a capacity of 750,000 gallons, were supported by internal columns, set on top of a steel pan to catch any leaks, and encased in concrete. Separate tanks were provided for high- and low-level wastes, and the high-level units were provided with cooling coils to remove heat generated during the decay of the wastes (cooling coils were added to all these tanks in 1955). Waste evaporation facilities were also provided as a means of reducing waste volume.[80]

Eight such tanks were originally built in F Area, and four in H Area (with space for four additional tanks set aside), each buried under at least 9 feet of soil. Four more tanks were approved for H Area in 1954, due to expected increases in the throughput of H Canyon. These four tanks were larger, each having a capacity of 1.07 million gallons, but other details of design were essentially the same as that of the original 12 tanks. They were constructed in 1955 and 1956. By June 1955, the first high-level waste tank was already full, prompting efforts to reduce the volume of waste sent to storage.[81]

Four single-wall tanks for low-heat high-level wastes were constructed in F Area in 1958, and four in the H Area in 1962. These tanks have caused numerous problems due to leakage through fine cracks caused by the reactions of the solutions stored there. However, only one of the original 12 tanks has leaked substantially. Four others have deposits on the outside of the tank walls that may indicate leakage, but no leaks have been found. An additional 27 tanks, each with a capacity of 1.3 million gallons, have been constructed since 1962. These are all similar in design to the initial tanks, except the catch pans extend the full height of the tanks, rather than only five feet, as with the initial design.[82]

Two burial grounds serve as the disposal site for solid wastes. The original burial ground occupied about 76 acres and was used from 1953 until 1972. The second, larger burial ground has been used since 1972; it covers approximately 119 acres. Solid low-level waste from all plant areas were buried there, with special areas set aside for items with higher levels of radiation or with plutonium fission products. The trans uranium (TRU) solid wastes were buried in designated sections of the burial ground but, by the early 1980s, they were being stored on concrete pads in containers that allowed for later retrieval.[83]

Research, Development, and Testing

The scientists and researchers at the Savannah River Laboratory (SRL) were responsible for research and improvements in process design in support of SRP's operations. From the beginning, it was noted that neither heavy-water moderated reactors, nor the Purex process, had ever been operated on an industrial scale.[84] Also,

the versatility of the reactors called for the development of new fuel and target elements. The need to explore the safety and process issues involved called for the installation of laboratory facilities that were fully equipped to allow research and experimentation on a laboratory or micro scale of the processes that were writ large in the process buildings. Consequently, the general laboratory area that was established in A Area was fitted out with sand filter systems and waste treatment facilities. The main research facilities were: the main laboratory; 777-M (later 777-10A), an experimental physics laboratory; process pilot plant facilities CMX and TNX (also referred to as semiworks); 735-A, the Health Physics Laboratory; and 723-A, the Equipment Engineering laboratory.

SRL, the main laboratory, was the focus of separations technology studies, metallurgical research and development, heat transfer studies, and radiation monitoring. Its "High Level Caves" allowed chemical and metallurgical equipment studies on highly radioactive materials behind heavy shielding windows and the Isotopes Process Development Laboratory allowed radionuclides to be encapsulated for use as targets.[85] After 1983, the testing of new fuel and target elements was moved from CMX to SRL. The TNX Semiworks Facility, a pilot plant, was equipped with instrumentation and stainless steel equipment for "cold" processing for chemical engineering studies on a larger scale afforded by the main laboratory facilities.

777-M, later designated 777-10A, the Physics Laboratory, contained three test reactors: the Process Development Pile, the Standard Pile, and the Subcritical Experiment. These test reactors allowed scientists to provide experimental measurements needed to test reactor charge design. While computers would eliminate the need for these test reactors in the 1980s, they were integral to the safe and successful operation of SRP's five reactors, as reactor charges were first tried out in the laboratory environment prior to their use in reactor operation. The reactor designers who used the test reactors in 777-10A used slide rules, mathematical tables, and desk top calculators to make the calculations that would later be generated by computers.

In addition to the central mission of supporting plant operations, a second laboratory system was established at SRP devoted to environmental studies. Savannah River Ecology Laboratory (SREL) was first housed in the Forest Service area but was given a new building in 1977 in A Area where it is surrounded by a complement of environmental laboratory facilities that range from duck pens to greenhouses. SREL and a consortium of other research programs conducted by the Savannah River Forest Station (SRFS), Savannah River Archaeological Research Program (SRARP) and Du Pont feature research on disparate ecological topics that range from reptile studies, aquatic insects, restoration of degraded habitats, reintroduction of endangered species, and investigations into the Site's cultural history. SRS was designated as the first National Environmental Research Park (NERP) in 1972 as a result of the National Environmental Policy Act (NEPA), the Energy Reorganization Act and the Non-Nuclear Energy Research and Development Act. Under these acts, the Site area became an outdoor laboratory set aside for national environmental goals in ecological research, research into the effects of nuclear energy on the environment, and finally, the disposition of this area is reportable to the public.

DEVELOPMENT OF PEACEFUL USE OF ATOMIC ENERGY, AND ITS IMPACT ON SRP

The tug-of-war between military and non-military applications of atomic energy was present at the inception of the AEC. Senator Brien McMahon of Connecticut championed civilian control over atomic power, and his bill, which became the Atomic Energy Act of 1946, barely beat out others that championed direct Army control.[86] Congress passed the McMahon Bill in July, and Truman signed it into law the following month. According to this act, the AEC was to become effective December 31, 1946/January 1, 1947.

After advice or directives had filtered through the Commission, the Office of the General Manager carried out the directives, with work divided into various divisions, such as Production, Raw Materials, Military Application, Research, Engineering, Biology and Medicine, and Administrative Operations.[87] Even though the AEC's main mission was defense-related (peaceful use of the atom was not even a formal part of the Atomic Energy Act of 1946), civilian control meant that there was always a push at the AEC to justify atomic energy use for non-military purposes.

The early leadership of the AEC certainly demonstrated this interest in the non-defense mission. David Lilienthal, appointed as the first chairman of the AEC by Truman in October 1946, was himself a strong proponent of the peaceful use of atomic energy, taking his case to the public in a number of articles that tried to correct the popular perception that nuclear energy was just for bombs.[88] Among the peaceful uses of the atom listed by Lilienthal were the control of disease, new knowledge of plants and the workings of the natural world, and even incredibly cheap electricity provided by nuclear power plants.[89]

During the Korean War, 1950-1953, little was heard about the peaceful use of the atom. With the close of that conflict, however, President Eisenhower reopened this potential with his "Atoms for Peace" address at the United Nations on December 8, 1953.[90] In direct response to this initiative, Congress passed a new Atomic Energy Act in 1954 that essentially amended the original act to allow for international cooperation in the development of atomic energy and in the civilian use of atomic energy. This allowed domestic utility companies to build and operate nuclear power plants.[91] The 1954 Atomic Energy Act not only broadened the scope of the AEC, but also allowed nuclear energy to be used outside of its purview. While peaceful uses of the atom had always been an interest of the AEC, it was now an official part of its charter.[92]

Purely scientific studies, like the neutrino research conducted at SRP in 1955-1956, were just the beginning of the non-defense mission conducted at AEC facilities. In addition to the Oak Ridge School of Reactor Technology, established in 1950, the AEC sponsored a five-year reactor development program in the mid-1950s, designed to test five experimental reactors for potential use.[93] Out of this work came two broad agendas: the breeder reactor program, which was largely for the Navy, which was keenly interested in nuclear power for ships and submarines; and power reactor research for civilian use.

The use of nuclear power for the production of electricity was first done in December 1951 at the National Reactor Testing Station (later, the Idaho National Engineering Laboratory). In 1955, this capability was expanded to Arco, Idaho, the first U.S. town to be powered by nuclear energy.[94] The development of commercial power

reactors soon spread to selected spots throughout the country, using reactor types that varied from the heavy-water cooled and moderated variety found at SRP and favored by the AEC, to the light-water reactors favored by the Navy. Other reactors, like Hanford's N-Reactor, were dual purpose, capable of both nuclear materials production and power.

The AEC favored the development of heavy-water power reactors, and the SRP was closely involved in the AEC plans to provide this technology to commercial utilities throughout the country. By the late 1950s, heavy-water power reactor studies were commonly produced at the Savannah River Laboratory, and these studies culminated in the design and construction of the Heavy Water Components Test Reactor (HWCTR), built and operated at SRP in the early 1960s.[95] During this same period, and drawing on technical data obtained from HWCTR, the Carolinas-Virginia Tube Reactor, near Columbia, South Carolina, became the first heavy-water moderated power reactor in the U.S.[96]

Despite AEC efforts to push heavy-water power reactors, the example of HWCTR and the Carolinas-Virginia Tube Reactor was not generally emulated in the United States (HWCTR itself was closed down in 1964).[97] As early as 1962, U.S. utility companies showed a clear preference for light-water reactors.[98] These reactors, using pressurized light water, were based on research that came out of the U.S. Navy's reactors program, especially the Navy's light-water reactor at Shippingport. Ironically, the AEC "Atoms for Peace" program, which provided partially enriched uranium to commercial reactors, worked against the AEC heavy-water reactor program: heavy-water reactors might have been more popular if utility companies had been forced to use natural uranium.[99]

Speaking in 1963, Lilienthal described Eisenhower's "Atoms for Peace" initiative as "still alive, but in a wheelchair."[100] While almost surely in reference to the international aspect of that initiative, Lilienthal's comment could be said to apply to the AEC's program to spread heavy-water power reactor technology to U.S. utility companies. Despite considerable research and achievements, the program simply did not progress in the direction intended.

With the reduction of the AEC's military mission in 1964, the stage was set for another series of programs to further develop the peaceful use of the atom. These new initiatives were two-fold: provide isotopic heat sources for the U.S. space program, then becoming a major national concern; and contribute to the transplutonium programs that were pushed by Glenn Seaborg, one of the discoverers of plutonium and chairman of the AEC from 1961 to 1971.

Among the isotopic heat sources produced for the space program was cobalt-60, desirable because it did not produce a decay gas.[101] Another isotopic heat source requested of the AEC was curium, and the production of this material dovetailed with the transplutonium program.[102]

The heavy-water reactors at SRP were pivotal to the transplutonium campaigns, which began with the production of curium during the Curium I program (May-December 1964). The successful attempts to produce curium and other heavier nuclides led to a succession of programs conducted at SRP and coordinated throughout AEC facilities nationwide. These programs included the High Neutron Flux program, both at SRP and at Oak Ridge,

where the High Flux Isotope Reactor (HFIR) began operation in 1965.[103] Curium II (1965-1967) completed the required production of curium, and provided a start for the most ambitious of the transplutonium campaigns: the production of californium. The Californium I program (1969-1970) was designed to produce enough californium to make the isotope available to industry and private sector interests.

The production of californium went hand-in-hand with the Californium Loan Program, sponsored by the AEC to help create a potential industrial and medical market for this powerful neutron source.[104] Despite the best of intentions, however, most of this work was in vain. Even though samples of californium were distributed to willing participants throughout the country and elsewhere in the 1970s, no viable market developed for what was still an expensive isotope with a relatively limited application.

The problems inherent in the Californium Loan Program were ones that plagued other potential applications of atomic energy for non-military use: the expense was simply more than the limited market would bear. The transplutonium programs, while wildly successful as scientific endeavors, failed to take up the slack left by the reduction in the defense mission. In the case of SRP, the production reactors were just too expensive to maintain and operate for the production of non-defense nuclear materials.

When the defense mission went into eclipse in the late 1980s, the non-defense mission, especially that for production reactors, went into decline as well. The close of the Cold War in 1989 solidified the forecast for Savannah River and the other production sites. The rise of environmentalism in the 1970s had already made inroads into nuclear progress, changing American attitudes about the safety of nuclear production plants and nuclear power plants. The promise of nuclear energy was increasingly called into question and new regulators and environmental regulations were placed into effect. While the ramp up of military might under Reagan characterized the start of the decade, by its close, world affairs and changing public opinion created new missions related to environmental clean-up and restoration rather than nuclear materials production.

ENVIRONMENTALISM, EXPANSION, AND CHANGE AT SAVANNAH RIVER

At the end of the Carter Administration and throughout the Reagan years (1980-1988), there was a resurgence in the production of nuclear weapons materials. This reaffirmation of the nuclear weapons complex was opposed by the environmental movement and then halted by the end of the Cold War. All of this led to conflicting changes at Savannah River Plant, especially in the 1980s. The decade opened with new requirements set by the Department of Defense for plutonium and tritium that directly translated into physical change for the plant. New construction occurred in the process and administration areas to house new programs and personnel, worn facilities were repaired, and technical upgrades were made to operating systems and equipment. Updated security provisions and other physical changes were made with the installation of Wackenhut Services Inc. as the on-site security force.

While SRP expansion was gaining momentum, the environmental movement was also becoming a force that ultimately changed the nature of how the expansion would take place. The accident at Three Mile Island in 1979 drew national attention to the nuclear power industry and reactor safety. The environmental movement hastened change but it was the end of the Cold War in 1989 that shaped new missions for the Savannah River Site.

Rise of Environmentalism

In December of 1974, the Environmental Protection Agency issued the first sanitary NPDES permit for the Savannah River.[105] While this was largely pro forma, it was a harbinger of things to come. In subsequent years, there would be an increase in environmental regulation on federal lands, and Savannah River was not exempt from this trend. In 1976, the Resource Conservation and Recovery Act (RCRA) gave the EPA authority to enforce environmental laws on all Department of Energy weapons-production sites. As a result, regulatory agencies began to weigh in on the previously "closed" controversy over the relative merits of confinement and containment at nuclear reactors, as well as the need for towers to cool reactor effluent water, a feature that was already standard for commercial power reactors.

Despite a promising collaboration in the early 1970s, environmental regulation and the nuclear community did not have the same agenda, and this became clear during the mid- to late-1970s. Environmental regulators soon moved beyond a balanced concern for the environment and the search for new energy sources, and began to micromanage commercial and DOE facilities solely for the benefit of the environment. The nuclear community, long sustained by public awe of atomic power, now began to find itself under attack by a public that increasingly feared the atom and its residual effects. By the late 1970s, the average environmentalist was antinuclear and environmental regulators were responsive to that shift.

Carter, an "environmental president," was the first to promote alternative sources of energy, such as solar and wind power. The exploration of such avenues was in fact one of the main reasons for the establishment of the Department of Energy in 1977. This exploration did not extend to the nuclear industry. In addition to banning the reprocessing of spent nuclear fuels for commercial reactors, Carter put a stop to the breeder-reactor demonstration program started by Nixon.

In the early 1980s, President Reagan would attempt to revive both the commercial reprocessing of spent fuels and the breeder reactor program, but by this time interest had flagged both in Congress and within the U.S. commercial nuclear industry. The demonstrated abundance of natural uranium certainly played a role in this shift of opinion, but the biggest change would be the accident at Three Mile Island. Even though it was the worst accident to befall the U.S. nuclear industry, its most disastrous impact was in public relations.[106]

The impact within the industry was great. Many of the energy concerns and conservation programs conceived in the early 1970s were simply abandoned by the late 1970s and early 1980s. Due to environmental regulations and a lessening demand for nuclear energy that was apparent even in 1979, there was less concern about the uranium supply or the discovery of new uranium sources. This spelled the end of projects like NURE, and effectively put an end to any real demand for the reprocessing of spent nuclear fuels for commercial reactors.

Three Mile Island also had an impact on the nation's production reactors. Up to that point, reactor safety had concentrated on the prevention of major accidents, with an acceptance of certain low-level risks as a requirement of the job. In the wake of Three Mile Island, however, more thought was given to low-probability accidents, and to ways of reducing reactor power levels as well as levels of radioactivity. With this new emphasis, "Loss of

Coolant Accidents" (LOCA) became a major concern of the 1980s.[107] With LOCA raised to greater significance, there was a corresponding rise in the importance of Emergency Cooling Systems or ECS. The idea behind the Emergency Cooling System was that even after shutdown, the ECS could still supply cooling water to a reactor in the event of an emergency. Throughout the nuclear industry, and certainly at Savannah River, Emergency Cooling Systems were added to reactors or were augmented in the years after 1979.[108]

At the other end of the nuclear process, Three Mile Island also focused attention on the problem of radioactive waste, a dilemma that had never been permanently resolved. There were two types of radioactive waste, low-level and high-level, and both had their unique problems and potential solutions. The Low-Level Radioactive Waste Policy Act of 1980 made every state responsible for the low-level waste produced within its borders. Even though the solution to most low-level waste involved burial, progress in implementing this law was so slow that Congress was forced to amend the act to give several states more time to comply.[109]

The problems associated with high-level waste, especially those of the defense industry, were greater and more intractable. Here, simple burial was not adequate, even though the idea of "geological disposal" of high-level waste had been proposed in underground salt deposits and at Yucca Mountain, Nevada, since at least 1957. Storage in high-level radioactive waste tanks was the preferred method of disposal, but this was recognized to be a temporary solution, and never more so than when the first serious leaks began to compromise the tanks in the early 1970s.[110] By the end of the decade, it was acknowledged that there would have to be some sort of "Defense Waste Processing Facility" to provide a more permanent solution to the problems of storage.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, also known as the "Superfund" legislation, helped provide the resources to clean up radioactive waste sites around the country. The money came with strings attached. The EPA and the states under authority delegated by the EPA, were given more authority to regulate DOE weapons production sites. The Nuclear Waste Policy Act of 1982, which President Reagan signed into law in January 1983, followed this law two years later. Robert Morgan, manager of Savannah River Operations Office (SROO) between 1980 and 1988, played a significant role in carrying out this act, which required the Department of Energy to establish a long-term site for the permanent disposal of the waste generated by nuclear power plants.

Reactor Upgrades, L-Restart, 700 Area Expansion, and Close of Heavy Water Facilities

Only four of the nation's production reactors were in operation in 1980: SRP's P, K, and C and Hanford's N reactor. Plutonium irradiated in N reactor had a high concentration of plutonium-240 that was unsuitable for weapons grade material. This shortcoming could be corrected by blending it with plutonium that had a lower concentration of plutonium-240 and SRP was directed to produce the proper plutonium for blending. A program to recover scrap plutonium at Rocky Flats in particular also had ramifications for SRP Operations. In order to comply with the change in product needs, SRP was compelled to upgrade and modernize its three operating reactors to allow them to attain higher power levels within shorter cycles. In 1980, one assessment cited the following problems: one-quarter of the reactor heat exchangers were irreparable due to wear and aging; plant facilities had obsolete and worn out instruments and controls, not only in the reactors but in other plant areas as well; that the needed parts could seldom be replaced in kind; and finally there were too few engineers available to design modern equivalents.

To begin to refurbish the Site's facilities, a five-year Restoration Program was established and funded at $350 million dollars, which was to be dovetailed with a $300 million dollar Productivity Retention Program by Du Pont. The Restoration Program did not include capital funds needed for new construction such as the Defense Waste Processing Facility (DWPF) discussed below but was the source of funding for L-restart and other upgrades.

By 1983, SRP's engineers were successful in this endeavor as the reactors reached the needed power levels, exceeding expectations. In addition, Du Pont was directed in 1981 to reactivate L reactor, a project that, when completed in 1984, brought L reactor to a safety and dependability level comparable to that of the three reactors that had remained in operation and had been continually upgraded. Employees in the 300 Area worked a seven-day workweek to keep up with the pace the higher power level in the reactors warranted and in anticipation of L reactor startup.[111] This was a major initiative budgeted at $214 million, employing a peak workforce of 800 for the renovation efforts, and projected to employ an operating workforce of 400 to run the reactor. It was also the first time that a reactor on standby had ever been refurbished and restarted after being out of service for more than a decade. The reactor was refurbished with new heat exchangers, replacement piping, removal of aluminum-nitrate from the reactor tank and nozzles, and the addition of safety upgrades. The challenges for the Restart Program stemmed from environmental rather than technological challenges.

The L Reactor Startup Team was the first management group to be placed under Du Pont's "program management" organizational philosophy. The program management structure was applied plant-wide in 1982. Courtesy of SRS Archives, negative 34872-3.

DOE had completed an internal study of all associated environmental issues involved with the restart program, but chose not to follow the Environmental Impact Statement (EIS) procedure that provides for public hearings. This choice, characteristic of an agency committed to the "need to know" ethic, led to great controversy as local and national environmental groups called for action. Senator Strom Thurmond held local hearings in response as part of the Armed Service Committee's responsibilities that demonstrated the controversy production reactors could evoke by the 1980s.[112] By the close of 1983, it was recognized a lake would have to be constructed, not to impound cooling water, but to cool effluent water leaving the reactor before it would enter the Savannah River Swamp. L Reactor was finally re-started in 1985. It operated less than three years before it was shut down again. During its period of operation, its output was often constrained by the environmental requirement to limit the temperature in L Lake to 90 degrees F in the summer months.

The process areas were not the only focus of upgrades and new construction in the 1980s. The main Administration area was expanded under a long-range building program that aimed at replacing trailers with administrative facilities.[113] Between 1980 and 1989, nine buildings were added to the Upper 700 Area to ameliorate working conditions. Others were also added to F and H areas. The design and building materials used in this construction was based on obtaining the most space for the available money. The buildings were considered "Local Practice Commercial Standard Office Buildings" and were let to bid as "Design-Build" projects.

Another change in the 1980s was the closure of the last of the Heavy Water production units in 1982. The area was in operation for slightly over 29 years, and had produced a sufficient amount for the needs of the Site's three operating reactors. Heavy water produced at SRP was sold to foreign countries and domestic consumers for a variety of uses and it, along with timber, was a revenue producer for SRP. For example, the AEC negotiated the sale of 450 tons of heavy water valued at $42 million dollars in 1969.[114] Over 6,000 tons were produced during D Area's years of operation.[115]

Defense Waste Processing Facility (DWPF) and Naval Fuels Program

Two additional programs were also started in the 1980s concurrent with the restoration program further exacerbating financial and manpower deficiencies. The DWPF got underway as did the Naval Fuels Program.

The long term problem of defense wastes was tackled in the early 1970s when scientists began to research for a solid waste form and a process by which defense wastes could be converted and stored in that form. Glass was selected after much research. The converted waste once vitrified would be encased in stainless steel canisters for permanent storage. Radioactive materials in the waste tanks were separated from nonradioactive materials through chemical separation processes that allowed the remaining sludge of radioactive materials to be sent to the DWPF Building, a monumental reinforced concrete building about 360 feet in length, 115 feet in width and 90 feet in height, for vitrification. Modeled after the canyons, most of the process work that occurs in this facility is conducted remotely behind heavy shielding. The salt that remains after the separation process is dissolved in water, cesium-137 and strontium-90 are precipitated and filtered then sent over to DWPF as a slurry for vitrification. The remainder, a salt solution, is hardened into a cement-like substance by mixing it with fly ash, furnace slag, and Portland cement. The final product called "saltstone" is placed in long concrete enclosures in Z Area. Construction began in 1984 but would be hampered by a lack of funding. The facility was complete in 1989 and actual vitrification began in 1996.[116]

Aerial View of DWPF Building 1977. Courtesy of SRS Archives, Negative 97-1527-1.

The Naval Fuels program was aimed at converting uranium feedstock into usable fuel in support of the Navy's nuclear propulsion program. Facility 247-F housed the processes involved in this conversion; it was constructed and operated for a short while before it was deactivated.

The scale of the needed repairs and the new construction engendered by the Naval Fuels and the DWPF facilities was prodigious. Moreover, the timing was awkward. In historian Bebbington's words, all of these programs were coincident with the first generation of SRP employees reaching retirement age, compelling Du Pont to hire and train a new workforce that was in size and in scope comparable to that of 1950. The major departure in the 1980s from the 1950s was the hiring of outside contractors to fill the needed gaps in the Du Pont team.

A second large change in staffing came about in 1984 when DOE requested that a specialized security force be designated for plant protection that would be able to respond to the changing world order. Prior to 1984, Du Pont handled site security. The Du Pont security force was disbanded and security of the plant was transferred to Wackenhut Services, Inc. in 1984. At this time, physical barriers protecting restricted areas were enhanced and security measures were updated.[117]

Reactor Shutdowns and Du Pont's Departure

In 1986, a coolant system assessment indicated a situation could arise in which insufficient amounts of cooling water would be available to the reactors in an emergency situation. The power levels of the reactors were decreased by 25 percent in November of that year. Then, in early 1987, a special panel of the National Academy of Science set maximum reactor power levels to about 50 percent of normal full-power operations.

By this time, Du Pont was clearly interested in pulling out of the atomic energy business. In October 1987, Du Pont formally announced that it would not seek to renew its contract with the Department of Energy, scheduled to expire in early 1989. The rationale for their departure was first that the government no longer appeared willing to guarantee the work and that Du Pont was no longer uniquely qualified to do it. Following almost immediately, there were safety hearings before a House subcommittee.[118] Since the mid 1980s, DOE and its contractors had been under examination in Congress for allegations of poor safety practices at federal nuclear facilities. In hearings before the Subcommittee on Oversight and Investigations of the House Committee on Energy and Commerce, Savannah River was noted for its poor fire prevention procedures. Congress wanted sprinkler systems installed in the reactor buildings, and this was a government expenditure that SROO and Du Pont management had resisted for the simple reason that the all-concrete reactor buildings could not burn.

The concern over fire prevention was eclipsed by a news story reported on the front page of *The New York Times* in 1988. A report, "SRP Reactor Incidents of Greatest Significance" compiled three years before, which detailed and categorized 30 significant incidents in the history of the five Savannah River reactors, was released to the public. Most of the incidents in the 1985 report had been summarized in an earlier ERDA document. An internal memorandum initially, the report's purpose was to show that the serious reactor incidents at the Savannah River Plant were largely confined to the early years of operation, and that the safety precautions of later decades had greatly reduced the incidence of error. The 1988 report was released in an effort to show that nuclear work

was in fact becoming safer. This was not how the information was received, and the national media immediately interpreted 30 "incidents" as "accidents." The outcry over the disclosure led to further congressional hearings over perceived problems at Savannah River. Media attention reached a peak in late 1988.

Responding to ever-tougher safety regulations and a relatively large stockpile of nuclear materials, the Department of Energy shutdown the three remaining reactors, P, K, and L in 1988. The fact that the Savannah River reactors had all been shut down was almost lost in the public debate. Although this shut down was initially intended to be temporary, it soon became permanent. In March 1987, administrative limits were placed on the power levels at K, L, and P reactors due to lingering uncertainties over the Emergency Cooling System (ECS). The following year, all three were shut down due to continuing concerns over the ECS, as well as the possibility of a "loss of pumping accident" or a "loss of coolant accident." K reactor was the first to go, in April 1988, followed in rapid succession by L in June and P in August. The ripple effect of these shutdowns passed through other areas of Savannah River as well. The production of fuel tubes ceased in Building 321-M that same year.

When Westinghouse assumed Du Pont's mantle in April 1989, all the reactors were shut down, and the U.S. had ceased the production of weapons-grade fissionable material altogether. The Site was officially included on the National Priority List and became regulated by the Environmental Protection Agency. In the same year, the Department of Energy formally announced that its primary mission had changed from weapons production to a comprehensive program of environmental compliance and cleanup. In a signal that it was making a break with the past, the facility's name was changed from the Savannah River Plant to the Savannah River Site.

Later attempts to use the reactors for further production were half-hearted. Even though L Reactor was selected as a backup for tritium production (1990), and K Reactor was restarted for power ascension tests (1992), the Department of Energy ordered both reactors shutdown with no capacity for restart in 1993.[119] While the work of nuclear processing continues in the Separations Areas and other places on-site, the SRS reactors themselves are now used to warehouse discarded radioactive materials.

End of Cold War

The controversy over "Star Wars," not to mention conflicts in Afghanistan and Nicaragua, kept the Cold War fairly warm in the early 1980s. There was also a confrontation over missile deployment in Europe. It was in this context that the L Reactor Restart program was initiated and completed. By the mid-1980s, however, Soviet society was beginning what would turn out to be a permanent thaw. Yury Andropov, Brezhnev's successor, died in 1984 after only a couple of years in power, and was eventually succeeded by Mikhail Gorbachev in 1985. Within a year, Gorbachev became the first Soviet leader to openly admit the weakness of his country's planned economy. More remarkably, he was the first Soviet leader to admit that elements of the old Communist doctrine were wrong or, at the best, outdated.[120] By the late 1980s, Gorbachev was well into the programs now associated with his name: *glasnost* (openness) and *perestroika* (economic and political restructuring of the old Soviet system).

The nuclear accident at Chernobyl played a role in this development. After first denying the accident, Soviet authorities soon made a complete turn-around, with relatively open disclosure of the problem and solicitations for foreign assistance. The approach to Chernobyl paved the way for new approaches to other problems. In December of 1987, the U.S. and Soviet authorities signed an agreement to eliminate all land-based intermediate range nuclear missiles from Europe. More was to follow in almost dizzying succession. In the fall of 1989, the Berlin Wall, symbol of the Cold War in Europe, was dismantled, permitting a rapid reunification of Germany. Communist regimes collapsed throughout Eastern Europe. Within two years, in 1991, the Soviet Union itself would collapse, leaving the former giant split into its various constituent republics. Gorbachev, now jobless, was forced to bow out to Boris Yeltsin, the president of Russia.

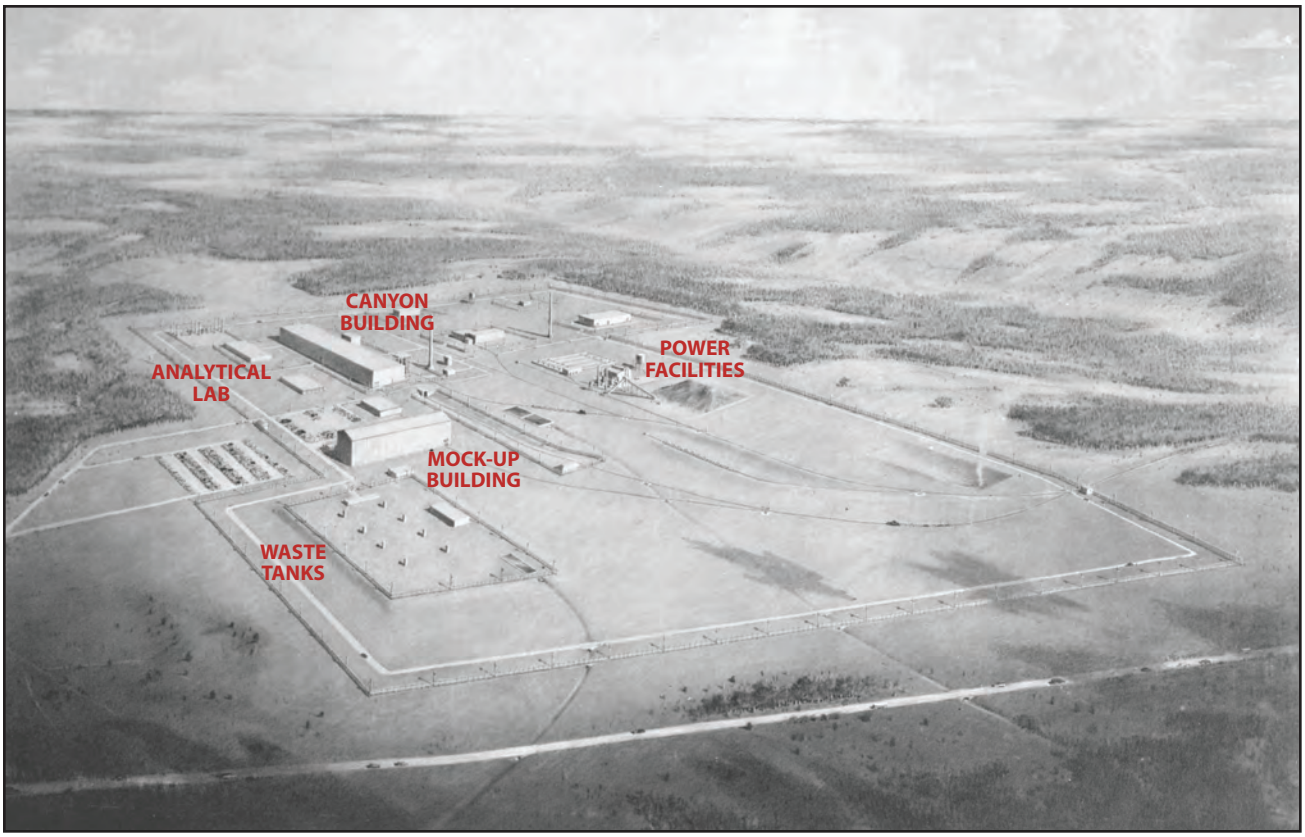
In the decade that followed, there would be additional problems with Russia as its economy continued downward, but there would no longer be the threat of an ideologically fueled nuclear war between the two great superpowers of the Second World War. Now it was the time to take stock of the vast nuclear arsenals in both countries, and initiate a general clean up of forty years of nuclear production. Savannah River Site, under the aegis of the Westinghouse Savannah River Company, was already poised to head in that direction.

This chapter has provided a context for Savannah River's Cold War history from a national and complex-wide perspective to provide background for the narrative that follows. The next chapters deal specifically with the history of Savannah River's separations facilities and their operation.

III. CONSTRUCTION

Du Pont initially thought that Savannah River would have just one separations area. By the end of 1950, just before construction, it was decided to build two, F and H Areas. Both were made part of the inner circle of radioactive areas. Du Pont always believed in contingency plans, and a third separations area was also "laid out" in reserve. Called "200-X," it was located 2.5 miles northeast of H Area.[1] It was never developed because F and H canyons were large enough and versatile enough to handle any increased workload.

A great deal of thought was put into the placement of the reactor and separations facilities at the Savannah River Plant. Reactor effluent water had to flow in open streams and might contain contamination, so it was critical to place the reactors so that their effluent drained back into the Savannah River downstream from the massive river water intakes that supplied the reactors with cooling water. Since the river water intakes had to be situated on the site's only patch of high ground along the Savannah River, and this patch was located immediately below the mouth of Upper Three Runs Creek, none of the five reactors could be allowed to drain into the Upper Three Runs Creek. This put the reactors on the south side of the inner circle. As a result, the two separations areas by default were placed at the north, close to Upper Three Runs Creek, in order to close the inner circle of nuclear facilities. They were situated on the ridge between two drainages: Upper Three Runs Creek to the north, and Four Mile Branch to the south.



Architectural Rendering of the 200-F Separations Area by Architects Voorhees, Walker, Foley & Smith, circa 1951.

With this general situation in mind, it was important to position the separations waste tanks in such a way that any leak there would trend toward Four Mile Creek and not Upper Three Runs. For this reason, the canyon buildings themselves were always on the north side, at the top of the ridge, with the waste tanks to the south, within the Four Mile Creek drainage.[2]

Another important consideration was that the waste stream from the canyons should go to the waste tanks by way of gravity flow. In later years, this rule was not always followed, as pumps became more commonly used to move waste to the tanks and from tank to tank, but in the beginning this rule was paramount. In the original design, the waste streams from both the F and H canyon buildings would go to waste tanks in F Area, designated 241-F. Soon it was decided to have a waste tank farm in H Area as well, with the waste stream from each canyon building diverted to its own waste tank farm. Later it was decided to have the canyon buildings and the waste tank farms separated from each other by a thousand feet. All other buildings and facilities would be placed in the vicinity of the canyon buildings as required by the process.[3]

This sort of flow consideration was critical for the processes that occurred in the canyons, where operations were done in liquid form. Materials from the reactors had to be dissolved, separated as liquids, and waste streams diverted as liquids, before the final product was turned back into solid, even metal forms. These were the "wet" processes. The tritium facilities represented the "gaseous" processes, and their placement was almost completely independent of elevation and gravity flow concerns.

SRS CONSTRUCTION PARAMETERS

At an early date the Atomic Energy Commission informed the Du Pont Company of its preference for spartan simplicity in building design. This policy required Du Pont and its subcontractors to design facilities with maximum economy consistent with functional requirements and to standardize designs and specifications for buildings and associated facilities to achieve uniformity.[4]

Functional Design

SRP encapsulated a multi-purpose factory system that produced more than one product. Despite its unique mission and the safety, security, and environmental issues it imposed, the layout of individual building areas and their architecture had their roots in American industrial architecture and factory design. Industrial architects in the first half of the twentieth century adhered to the tenet that form should follow function, espoused by modernist Le Corbusier. Reinforced concrete became the preferred building material for factories and industrial architects such as Albert Kahn championed the need for the integration of specialists such as process engineers in the development of well-designed factories. Buildings constructed within this functional vocabulary were enclosed by smooth planes, featured industrial materials, and eschewed decoration.[5]

By World War II, a factory type had emerged that was a mechanical unit for the production of goods. It typically had a steel superstructure, a flat roof, and panel walls. Its interior was an open bay characterized by uninterrupted floor space with support and personnel related use areas on a mezzanine level, penthouses, or in wings. Single

story in height, windowless, and boxlike, the factory building typically had suspended walkways that connected to mezzanines where restrooms were located. The walkways allowed non-manufacturing employees and visitors entry without disturbing the work process. Conveyors, winches, and other handling mechanisms were also suspended to keep the floor clear.[6]

Successful industrial architecture provided for the efficient movement of materials through a production process and enabled employees to perform their work efficiently: "from parking space, to changing room, to machine station to cafeteria and back."[7] This called for analyses of the flow of materials to determine equipment layout and its consequences for the building envelope. Design would begin with the process line, move to the support and storage facilities, and end at the parking lot. Should a shift system of work be employed, the number of parking spaces needed for efficient flow of personnel was doubled. Materials handling and personnel flow were charted as architects and engineers grappled with the best "flexible" design to allow for changes in process that may cause change in necessary manufacturing equipment and/or its arrangement and for future factory expansion. "Flexibility" was the key design guideline.

The use of "functional design" was second nature to VWFS, a leader in industrial design for laboratories. VWFS had an impressive number of projects such as the Murray Hill Bell Telephone Building that included a cyclotron building at Columbia University and Argonne National Laboratory in the atomic energy field. Its credits in 1954 included laboratories and factory facilities for NY Telephone, Ford, GE, IBM, R.H. Macy, Proctor & Gamble, General Foods and others.

The New York firm was also responsible for the site plan and design of Du Pont's Experimental Station in Wilmington, Delaware, described as a "campus of six modern laboratory establishments" and an additional campus for Du Pont's rural headquarters at Milford Crossroads near Newark, Delaware. The laboratory complex was designed using the flexible-modular concept: "VWFS studied the particular requirements of each of the six participating (Du Pont) departments, then ëadded up the modules' in every instance and juggled them around and around - rather like children's blocks– until they all slipped into the one best possible combination for each case." [8]

For Du Pont's rural headquarters project, VWFS, under the guidance of senior partner, Perry Coke Smith, designed immense H-shaped buildings that pivoted on a "space unit" design. This design hinged on a unit of space – a floor of a wing – that could be subdivided in whatever manner the client needed. Given this experience with specialized building types and a functional modular approach and their corporate experience with Du Pont, VWFS was an easy choice as subcontractor for architectural and engineering.

The first generation of buildings at SRP were simply designed using the functional ethic described above. The AEC's specification that the project's buildings be austere in their design was a done deal given the climate of American post-war industrial architecture.

The choice of building materials, reinforced concrete and Transite™ paneling, were mandated by the building code. Articulated in reinforced concrete or steel frame with Transite™ panels, the majority are beige or gray boxes built for maximum flexibility and for government service. Their uniformity in color, their number and size, and their geometric forms create a harmonious grouping of buildings within an ordered industrial landscape where form reverberates function. This functional perspective is further emphasized by the placing of the Site

utilities above-ground so that massive pipes parallel roads or arch over them. Economically motivated, this design feature has strong visual impact.

As-built drawings show that the architects developed "typical modules" for each building's elevations when possible. Using structural columns, reinforced concrete, and Transite™ panels in which windows could be placed as their main vocabulary, the architects repeated the typical exterior module as many times as necessary to create an envelope for the space required. This approach plus the use of neutral colors produced the desired effect - a rhythmic feel to the buildings and symmetry that contributed to their anonymous and functional character.

Blast Proof Construction

Meetings between Du Pont, the AEC and other sub-consultants were ongoing in November and December of 1950. A meeting at Drexel Institute of Technology in Philadelphia between Professor H. L. Bowman and Du Pont engineers tackled the building criteria needed to protect the proposed facilities from atomic blast and to allow it either wholly or in part to operate in the face of such an attack. Three types of construction were developed and this classification system was codified and placed into a supplement to the Uniform Building Code published in January 1, 1946 that was adopted for plant construction use.

Class I buildings were described as massive, reinforced concrete, monolithic structures with a static live load of 1000 lbs per square foot.[9] Their exterior walls and roof were to be poured, reinforced concrete with a supporting frame of reinforced concrete or structural steel. Critical process buildings were to be constructed of blast proof materials throughout. Reinforced concrete construction was selected for its ability to take stress, the protection it affords from alpha and gamma rays and intense heat, and the speed and economy it would lend to construction.

Class II buildings were considered to be of friable construction with a structural frame of reinforced concrete or structural steel and expendable wall materials. If bombed, the structural frame remained intact while the exterior walls were considered expendable. Fifty percent of a building's exterior wall area had to be covered with friable materials to suit this class of construction. Roofs were poured concrete and designed for a live load of 150 pounds per square foot; all floors were of poured reinforced concrete. If equipment or areas in these buildings required further protection concrete blast-resistant walls were added or floor levels were placed below grade.

Extensive tests were undertaken at Sandia National Laboratory in New Mexico to identify possible friable wall materials by exposing the candidate materials to TNT explosions that simulated atomic bomb blasts. After analysis, Transite™, a short fiber, cement-asbestos siding material, was chosen because it broke into small pieces on impact.[10]

Transite™ was sold in the form of flat and corrugated sheets.[11] As an exterior sheathing it reduced the load bearing factor considerably from 120 to 20 pounds per square foot when compared to masonry walls and it was further desirable as it did not rot, rust, burn and was impervious to insects and rodents.[12] Advertised as smart, modern, and economical in period advertisements, Transite™ boards became the primary building material for exterior wall sheathing between 1950 and 1956 at SRP. The presence of the smooth, natural cement color exterior board is the hallmark of the Site's first generation of buildings for this class of construction.

Class III construction, which provided no protection from blasts, was considered normal construction carried out under the building code. All service buildings, shops, and change houses were considered expendable. This category included a plethora of prefabricated metal buildings manufactured by Butler, Hudson, Mesker, and other firms. Examples of Class I, II, & III constructions can all be found in the reactor areas.

Standardized Construction in a Unique Industrial Context

As noted, facility designers sought to standardize design as a cost saving measure, to promote uniformity, and to aid the construction force in adhering to a tight construction schedule. Building types allowed replication and as most of the building areas were to be self-sufficient, this potential was essential. The reactor areas are a good example of this standardization.

Between 1950 and 1956, Du Pont and VWFS created a repertoire of types, mostly in the service or support categories, that could be duplicated when and where needed. In terms of the design process, Du Pont's design division gathered design data, which was then transferred to VWFS for resolution into a building or facility. Consultation between the architectural firm, the Wilmington Office, and the on-site engineers was undertaken via teletypes, telephones, and face-to-face meetings. Power-related and water treatment facility types were handled by Gibbs and Hill. The use of Class II construction also played into standardized construction. Transite™ walls offered unlimited potential for door openings and fenestration so that standard building types could be easily altered to suit new needs.

The numbering applied reflected the building types and their function to a large degree. The 700 building series, for example, referred to facilities associated with administration and support functions. In this series, buildings duplicated often such as gatehouses were all referred to as 701 buildings; a suffix such as the -5A in 701-5A indicated its geography and the number of gatehouses in a building area. This numbering system allowed for expansion should more of a given building type is needed. With the exception of the 700 and 600 buildings, the hundreds place in each buildings' three digit number indicated a process area. The remaining places in the numerical label indicated a building's function. Thus, a powerhouse in a 100 Area was 184-R, a cooling tower 185-R. The same building types in the 700 Area would have been labeled 784-A and 785-A.

THE CONSTRUCTION ERA IN SEPARATIONS, 1951-1955

Construction of the Savannah River Plant began in early 1951, after initial surveys laid out the process areas and transportation corridors. While work began on all areas almost simultaneously, emphasis was given to those areas that would be needed first in the process. As such, the earliest work concentrated on CMX, D Area, and the river pump houses, followed almost immediately by the river water pipes and the reactors. The two Separations areas were technically last in the Savannah River process sequence, so they were the last to be finished.

Construction in F Area began in June of 1951, followed by H Area that September.[13] By September of 1952, the total construction force at Savannah River reached its peak of over 38,600 workers.[14] Even though this number would decrease in the months and years to follow, it would still be in the thousands by the time the construction era wound down in 1954 and 1955. During this period, when A Area was also under construction, the massive

project was coordinated from the huge temporary construction (TC) buildings located in what would later be called B Area. In fact, the first buildings constructed in the separations areas were also TC buildings, put up in the summer of 1951. These included the First Aid Building (8314-F) and the firehouse (8330-F).[15] TC buildings were not considered permanent and most were taken down at the conclusion of the construction period.

Du Pont had its own engineering and design facilities, as well as its own construction division. Even so, the speed of the construction required that Du Pont use subcontractors. The major subcontractors used in the Separations Areas included Blaw-Knox, the Lummus Company, and Voorhees Walker Foley & Smith (VWFS).

Blaw-Knox Construction Company of Pittsburgh, Pennsylvania, was one of the first involved in Separations. It was given a number of architectural responsibilities within the separations areas. This did not last. Because of their work load, Blaw-Knox was relieved of its separations responsibilities in April of 1952 and was replaced by VWFS.[16]

Work in the 200 Separations Areas was added to VWFS's scope of work in April of 1952. The company was responsible for the design and procurement for many of the buildings in both F and H areas, namely 217-F, 232-F, 291-F and H, 292-F and H, 294-F and H, and 295-F. Soon afterwards, 232-H was added to the list as well.[17] These buildings were peripheral to the main canyon buildings.

Another subcontractor involved in Separations design work was the Lummus Company, an architectural and engineering company based in New York. Lummus had already worked with Du Pont on the Dana Plant, and they were brought on board in January 1951, very early in the Savannah River construction period, when they did the design work for D Area. In the 200 Separations areas, Lummus was assigned to work on A-Line, originally referred to as the "Oxide Recovery Plant." This became Lummus Job No. 3269, which began in March of 1952 and was basically completed in August of 1953. Another smaller contract for "A-Line spare parts" (Job No. 3451) pushed their involvement into September of 1953. Lummus design work for Separations was then basically complete by August of 1953.[18]

In early 1951, both F and H areas had been agricultural fields, as was documented by Du Pont's photographers before construction began. As was commonly done in Project 8980, construction began before the design work was finished. F Area, the first to be designed, was also the first to begin construction. F Area was graded and laid out, beginning in June of 1951. H Area followed, in September of that same year. After that, work on F and H overlapped.[19]

Survey work found seven depressions in the general vicinity of F and H areas, assumed to have been natural sinks. The local soil was considered adequate for supporting the massive canyon buildings, waste tanks, and other facilities. Local soil included the Hawthorn formation at the top, around 50 feet thick; the Barnwell Formation, 70 to 95 feet thick below that; followed by the McBean Formation. Just to be on the safe side, after the area was graded, grouting was done beneath the largest complexes in F Area, namely the 221 canyon building and the 241 waste tanks.[20]

Former Agricultural Fields Chosen for the 200-F and 200-H Separations Areas. F Area (at right), May 28, 1951, SRS Negative DPESF 2-108, and H Area (at left), Taken the Same Day, SRS Negative DPESF 1-101.

Grading was essential to create a series of steps or platforms for the various building clusters in F Area. The highest elevation, along the ridge at the north end of the area, was around 330 feet above sea level, with the lowest elevation, in the southwest corner, at 280 feet. Building 221, the canyon building, was located on one of the highest. Also high was the powerhouse and reservoir. The lowest was the 241-F waste tank farm and, incidentally, Building 717-F, the Mock-Up Building. A huge amount of earth was moved in the course of this operation, estimated to be around 300,000 cubic yards.[21] A massive thunderstorm in the late summer of 1951 led to a number of logistical problems in the graded areas, but despite this setback, construction was underway by late 1951.[22]

H Area grading and layout began in September 1951, just three months later than F Area. As in F Area, the high elevation was at the north end, around the 221-H canyon building. The ground sloped to the south, the location of the 241-H waste tanks. Some 450,000 cubic yards were moved in these two areas alone. As in F Area, final grading resulted in a series of terraces. Building 221-H and adjoining 211-H were at the higher elevation, at 308 feet above sea level. The 241-H waste tanks were low, with top of the tanks at 300 feet above sea level.[23] As in F Area, this propsed arrangement allowed for gravity flow from the canyon building to the waste tanks. Construction of both 221-H and 241-H was underway by 1952.[24]

Construction of both F and H areas continued through the early 1950s. The peak construction force was reached in F Area in November of 1953, with a total of 4,155 workers; H Area followed in July of 1954, with a total of 3,836. This included Du Pont employees and those of the other subcontractors.[25] It was during this period that both F and H areas achieved their general appearance, which has remained basically intact even though there have been many additional structures built since the construction era.

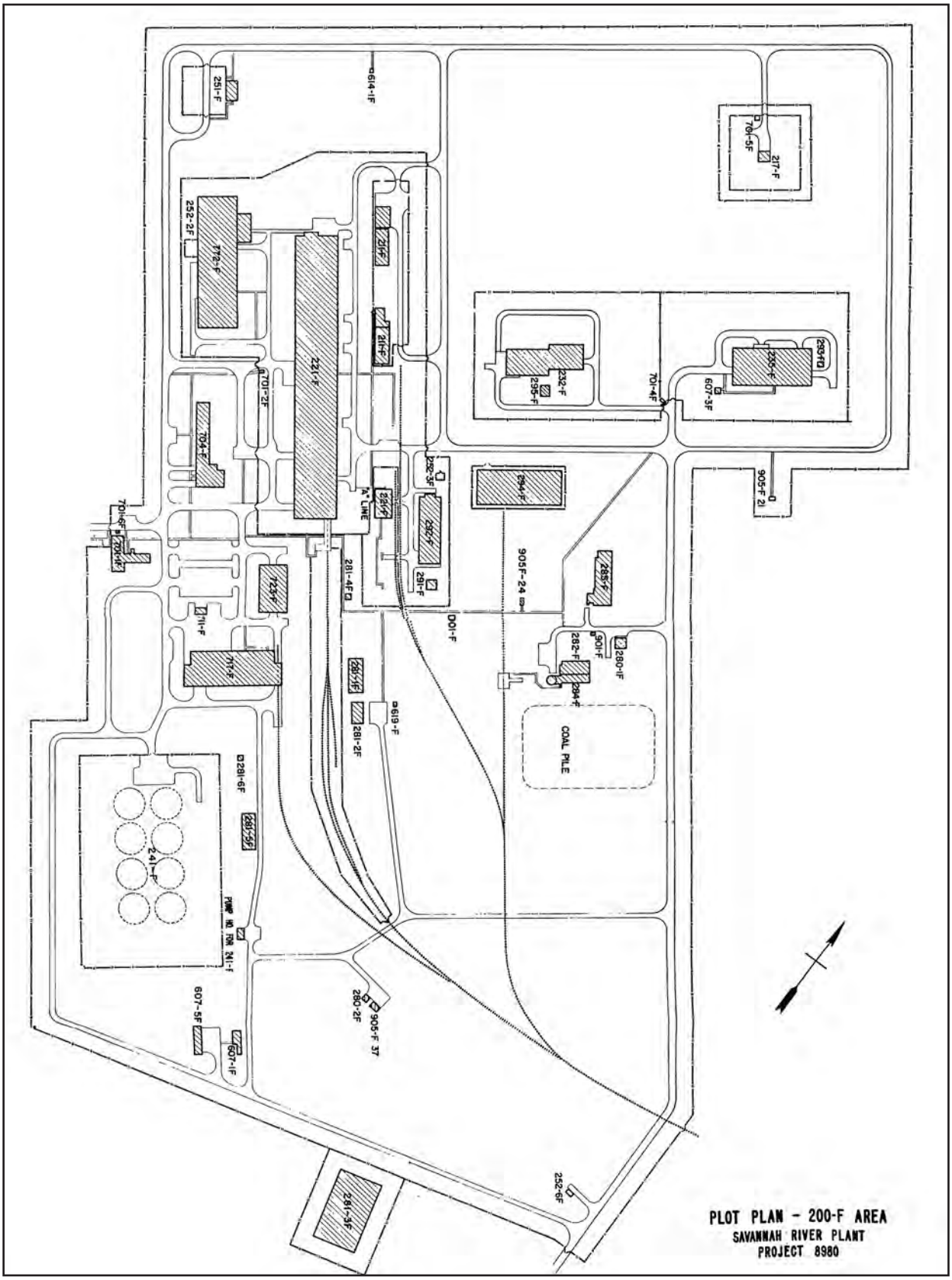
IV. SEPARATIONS AREAS: DESIGN, LAYOUT, AND OPERATION, 1951-1956

The canyons are the centers of the separations process at Savannah River. Almost everything of importance that was produced by the Savannah River Plant was processed in these buildings, or exited these buildings. The F and H canyons are virtually identical, differing only in small details. The F and H Areas, however, are not exact copies of one another. F Area was the first to be built and the first to go into production, and F Canyon (221-F) was always considered the primary separations facility, especially in the early days. In fact, early planners considered H Area to be little more than a back-up for F Area. For this reason, many of the unique facilities required for the separations process were placed in F Area: the Mock-Up Building (717-F), the Laundry (723-F), the Analytical Lab (772-F), and the Storage Magazine (217-F). C-Line, if it had been installed in Building 235-F, would have been in F Area. The tritium portion of the separations process was first operational in F Area.

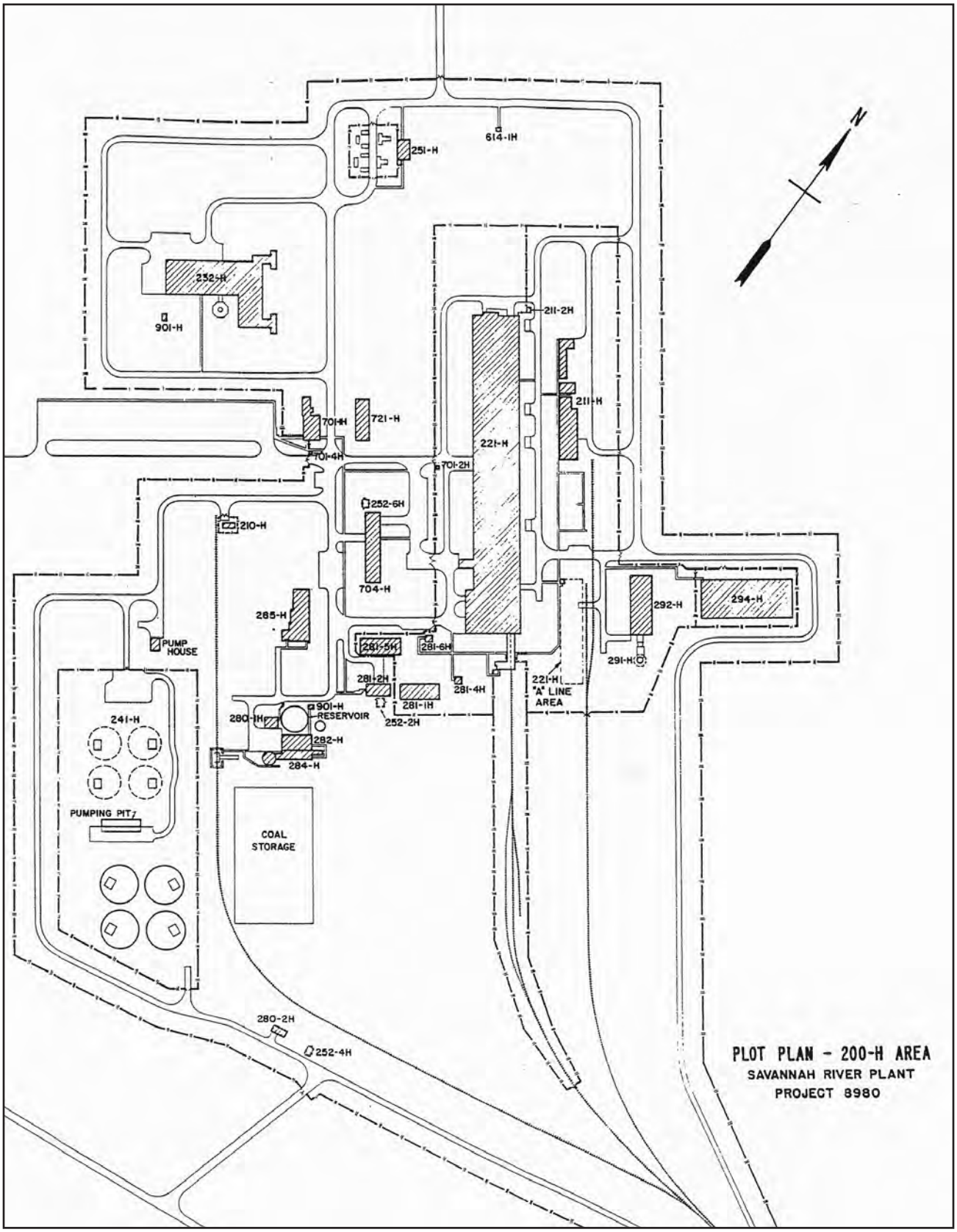
From the first planning stages, it was assumed that F Area would have the full range of production facilities, while H would be limited to basic facilities.[1] This would also explain why F Area had eight underground waste tanks at the end of Project 8980, while H only had four.[2] This was not a big drawback. H Area was adjacent to F Area and always had access to any F facilities that it lacked. The only exception here were the waste tanks, since there were no connections between the F and H waste tank farms in the 1950s.

By the end of Project 8980, F Area was larger than H Area and contained more buildings,. This can be seen in a comparison of the two separations areas as mapped at the end of 1956. Despite the predominance of F Area, it was assumed from the beginning that both F and H would produce the same materials: weapons-grade plutonium-239, made from natural uranium elements irradiated in the reactors, and the left-over uranium. The plutonium was finished in the B-Lines located inside the canyon buildings, while the uranium was finished in the only complete A-Line in F Area. In most other regards, the F and H canyons were virtually the same to allow for redundancy and greater efficiency.[3]

Canyon Length, March 20, 1963, SRS Negative DPSPF-8927-4.



200-F Area, January 1956



200-H Area, January 1956

Not only were the canyon buildings virtually the same in size and construction, they had the same basic group of service buildings around them. These included the Chemical Tank Farms (211-F & H) that provided chemical feeds to the canyon buildings, the Waste Tank Farms (241-F & H), and the air ventilation system. The air system included the Sand Filters (294-F & H), the Fan Houses (292-F & H), and the Stacks (291-F & H). These were used together to remove air-borne contamination. Beyond these were other outlying support facilities.

CANYON DESIGN ISSUES

A great deal of thought went into the design and planning of the F Canyon building. As Ed Albenesius described it:

> It was a magic facility. It was operated with shielded cranes, with operators behind great shield walls, and they could turn things on a dime, make connections, disconnect, put piping in, pull piping out, take new tanks in, take old tanks out. I mean, they could do anything.[4]

It took a lot of work and many designers to make it work so well. A wide array of companies worked on the canyon building design. Naturally Du Pont was involved, but there was also Blaw-Knox, a Du Pont subcontractor for architect and engineering services. Other features of the design work were done by Lummus, Voorhees Walker Foley and Smith, American Machine and Foundry Company, and Gibbs and Hill. Still other companies involved included Allstates Engineering, Schutte-Koerting, Penberthy Injector, and the General Engineering Laboratory of General Electric.[5]

Some of the design requirements were already established, given the radioactive nature of the work. The flooring, walls and roof would have to be concrete and they would have to be thick enough to block alpha and beta particles and penetrating gamma rays. Operations in the canyons would have to be conducted remotely, since workers could not be exposed to direct radiation. The goal was to have workers exposed to no more than 1/1000 rem per hour in the operating areas, and no more than 6/1000 rem per hour in all other areas.[6] In the early 1950s, it was established that the gamma ray dose was not to be greater than 0.008 roentgens in an "occupied space" over an eight-hour period, and 0.08 roentgens in "occasionally occupied spaces."[7]

Almost everything else– the extreme shielding, the concern for ventilation and waste disposal, the need to check for radiation levels at every step of the way—all flowed from this concern. Control of radiation exposure was considered very important and taken seriously by Du Pont. The major design problems were always shielding issues and ventilation issues. Creating the optimal layout for the process always had to work within those parameters.[8]

Shielding was the greatest concern. The basic ingredients needed for the shielding were thick concrete walls, with steel and lead plates to serve as doors. Much of this had already been worked out at Hanford, even though the buildings at Savannah River would be put together in a different way. It was originally thought that curtain walls, cantilevered walls, and shielding doors, would be sufficient protection from the process. Later it was determined that the process cells themselves should be covered by concrete slabs ("covers") for greater ventilation and contamination control.[9] In later years, this shielding arrangement would be called "confinement," since no

attempt was made to completely seal the facility from the outside environment, a concept that came to be known as "containment." In the 1950s, no nuclear facilities were constructed with containment in mind.[10]

The remote operation of the Purex process, and remote handling of all the materials that resulted from it, was an important consideration. In the areas of highest radiation, namely the Hot Canyon, it was early on decided to use overhead cranes, operated behind cantilevered walls, using periscopes.

Standardization was another important design issue. Early on, it was determined that the canyon building "should not be designed for any specific piece of equipment." All working sections and piping arrangements were to be uniform. Everything was to be standardized, so that equipment could be replaced easily and moved around as needed for the process. The analogy made at the time was to create equipment that could be "plugged in," like the vacuum tubes on a radio set. Interchangeable parts made repairs easier. This also required a mock-up building that would later be 717-F. Here, all equipment could be tried out in a dry-run before installation in the canyon building. Cell tanks might have different sizes, but it was essential that they all have the same nozzle arrangement. Nozzles had to be attached and removed easily, since both operations would have to be done remotely by crane.[11]

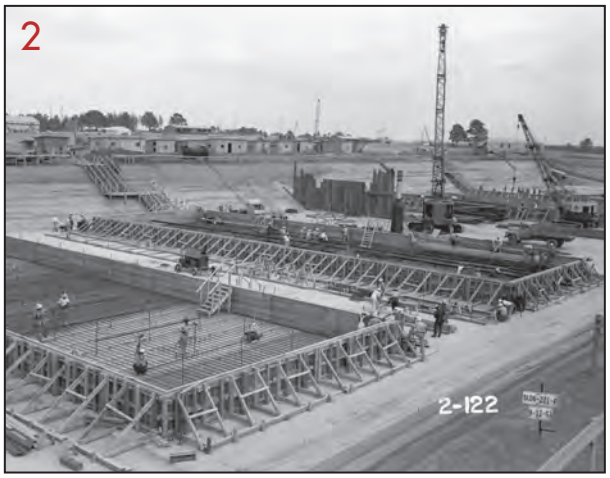
While all of these details were being worked out, there was a larger concern over the optimal arrangement of the canyon building itself. The original prototype for the canyon building was Hanford's 221-T building, known as the Cell Building. There, the most radioactive portion of the operation took place in 221-T Cell Building, with less radioactive portions done in Bulk Reduction and other buildings. Hanford's 221 building was one long "canyon," where the work progressed in a single line, with working areas divided into cells.[12] Much would be different in the Savannah River arrangement, but Du Pont kept the "221" number for the separations building, and it used the same colloquial term for that building, which was called a "canyon."

At Savannah River, Du Pont's original plan called for the separations process to be carried out in four separate but adjacent buildings, devoted to extraction, concentration, purification, and recovery. This was similar to what was used at Hanford, where the separation process was spread between four different buildings: 221, 271, 224, and 231. At Savannah River, the original plans called for these four buildings to be placed around a fifth building, the center of operations, which would have offices, solution preparation areas, control rooms, and change houses. The five-building arrangement was soon changed to a single building with four "wings," with a central control and service area in the middle.[13]

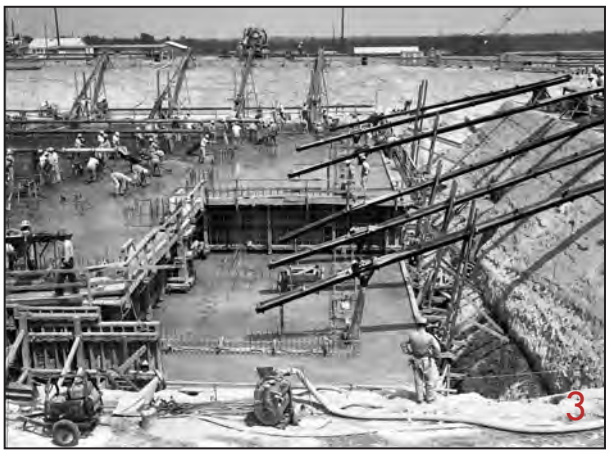
The "wheel spoke" idea was soon dropped, but not the idea of a single building. At first, the idea was to have a single long continuous process "canyon," where everything would happen in a straight line. This was followed by the idea of doubling back and placing two halves of a single canyon side by side, separating the two canyon halves by a common service and control facilities area. A number of potential layouts were worked up based on this idea, with modeling work done by Blaw-Knox.[14]

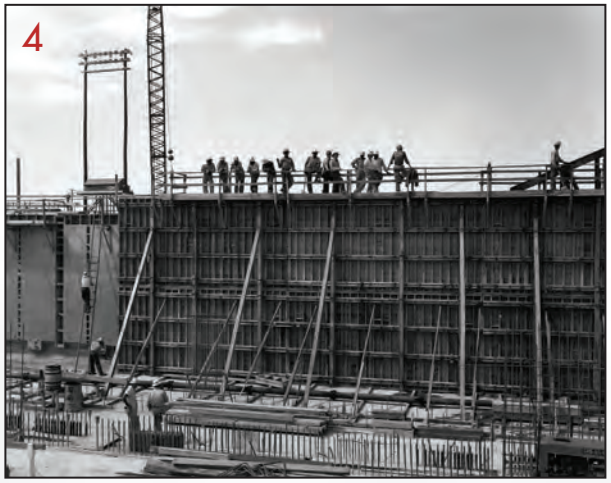
What was eventually created was a single canyon building that was actually comprised of two canyons, a Hot Canyon and a Warm Canyon. The most radioactive portion of the process would occur in the Hot Canyon. This

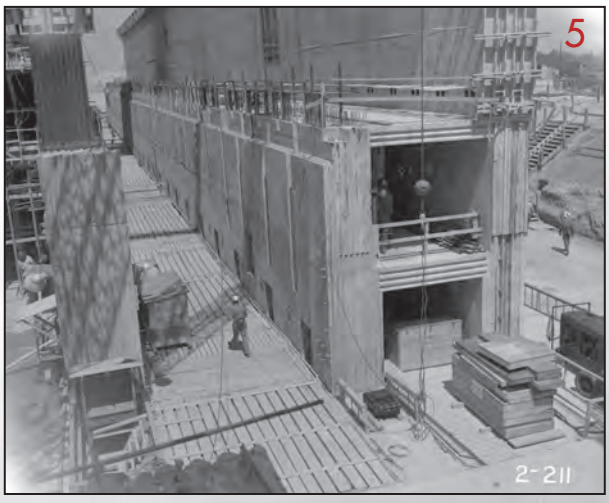
Constructing...



1. (at bottom) Earth moving equipment levels the ground prior to the construction of the 200-F canyon building, August 29, 1951, SRS Negative 2-118.
2. Work on the foundation is underway on September 12, 1951, SRS Negative 2-122.
3. A massive concrete pour at H Canyon, September 8, 1952, SRS Negative 2-317-6a.





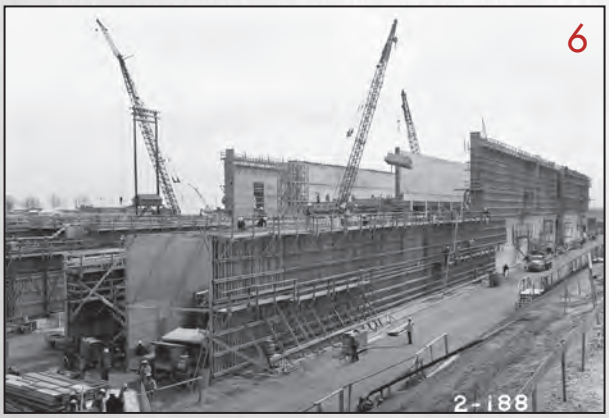


4. Workers take a break on the canyon wall, August 27, 1952, SRS Negative 2-291-2.
5. A close-up view of the warm canyon during construction, April 10, 1952, SRS Negative 2-211-1.

...THE CANYONS

6. A view looking down the length of the canyon, February 28, 1952, SRS Negative, 2-188-2.

7. A cross-section view of the canyon under construction; the hot (at left) and warm (at right) canyons are already clearly visible, February 28, 1952, SRS Negative, 2-188-1.



8. The interior of the warm side of the canyon under construction in F Canyon, July 7, 1953, SRS Negative 2-507-2.

9. The south end of F Canyon, showing the railroad tunnel under construction, August 26, 1953, SRS Negative, 2-543-4.

10. The north ended of F Canyon (completed), October 28, 1954, SRS Negative 2-776-2.

was where irradiated fuels would be dissolved, fission by-products removed from the process, and the plutonium would be separated from the uranium. The less radioactive work would transpire in the Warm Canyon, where any remaining fission products would be removed during the purification process. Other chemical work, such as solvent recovery, could take place there without the need for the heaviest shielding.[15] The process would flow down the canyon, with feed lines moving solutions and chemicals into place, and from canyon to canyon, as needed by the process.

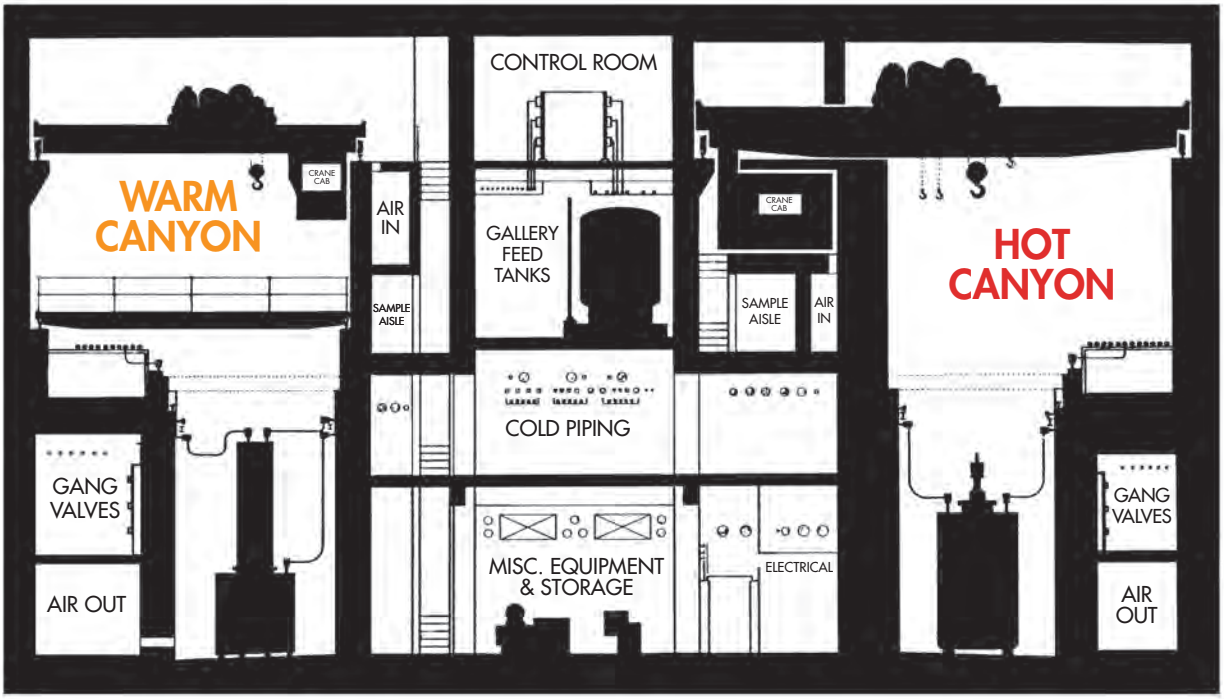
Another Hanford idea that was considered and later dropped was the "cellular" division of the process areas within the canyons. Cell divisions at Hanford made it easy to monitor radiation levels, but were otherwise less efficient than the canyon flow-through idea proposed for Savannah River. This required a change in the way radiation was monitored at Savannah River. At Hanford, Du Pont had used ion chambers pushed through the tubes in the walls, and it was hoped to use the same system at Savannah River. While this was fine for the cellular arrangement used at Hanford, it did poorly in the open canyon system at Savannah River—it was difficult to isolate radiation readings to just one location. As a result, it was decided to put the ion chambers into the shield walls, with additional lead and steel blinders so that the ion chambers could concentrate on a particular part of the process.[16]

Another consideration in the final design of the canyon building was the blast classification. All buildings in Project 8980 were classed as I, II, or III, based on their ability to survive an atomic blast. Class I was the most blast-resistant category, with buildings made entirely from reinforced concrete. Original plans called for the canyon building to be a hybrid, with both Class I and II construction techniques. This was changed to Class I, since it was decided that the loss of the final product would simply be too great in the case of a nuclear attack.[17]

The flexible design allowed for equipment to be moved not only up and down the canyon, but also back and forth from Hot Canyon to Warm Canyon as needed. It also allowed for the expansion of the canyon building itself. As it was finally designed and built, the 221-F Canyon building was oriented basically south to north, with railroad facilities bringing irradiated materials from the south into the Hot Canyon side of the building, which was on the east side of the building. The Warm Canyon was on the west side. Building 221-H was laid out the same way, with the same orientation. Both were laid out so that it would be possible to expand the buildings to the north, if that was ever found to be necessary. The building foundation mat on the north side was constructed to accommodate that possibility.[18] The fact that this was not necessary, that there was always ample room, with flexible tank arrangements, to do all that had to be done to meet the AEC quotas, speaks volumes to the advanced planning that went into the Separations buildings.[19]

BASIC 221-F BUILDING LAYOUT

The outside dimensions of the canyon building, particularly 221-F, have been variously stated in different sources over the years. Some of these differences could be the result of changes made to the building since it was first constructed in the early 1950s. One of the earliest sources records it as 819 feet long by 122 feet wide, and 66 feet tall, with at least a quarter of the building located below grade. This early source gives the total building area as 102,854 square feet, with total floor space, including the four levels in the center, at 329,532 square feet. The total volume: 7,810,000 cubic feet.[20]



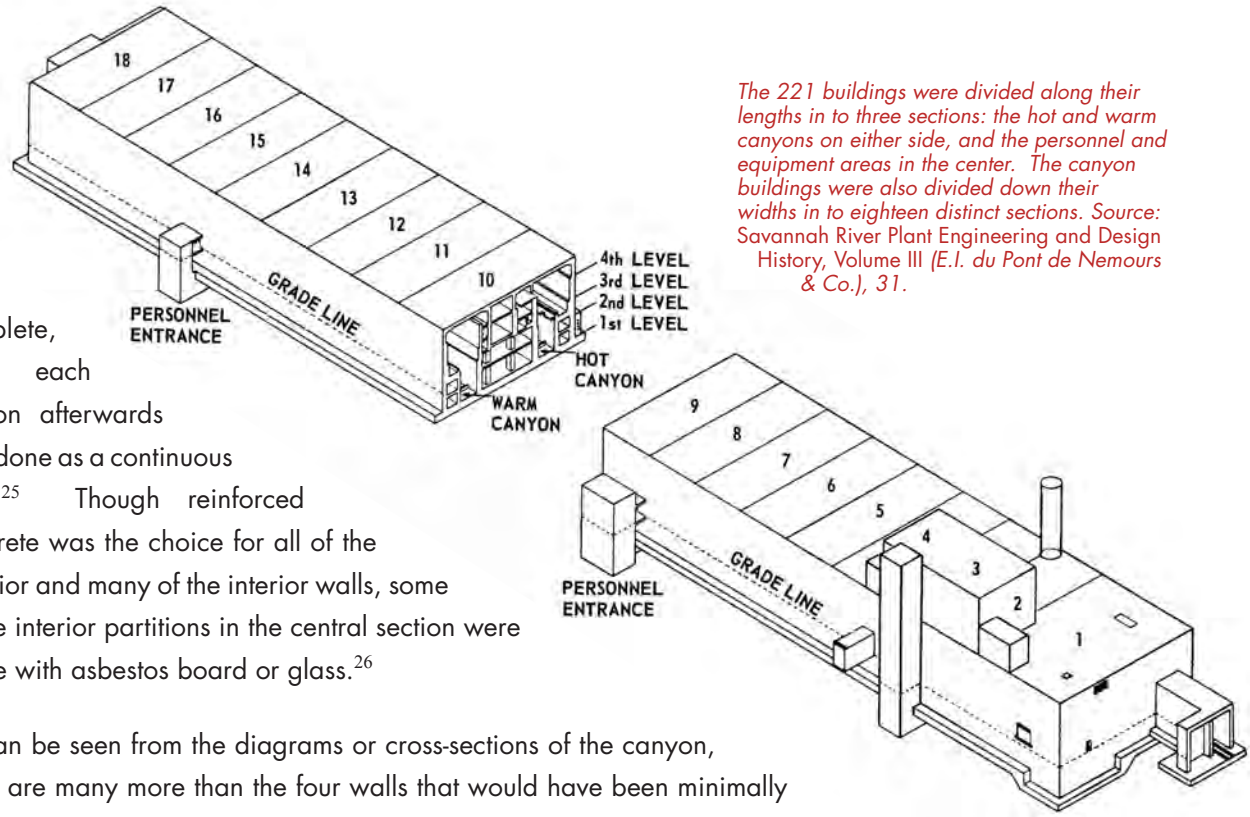
Canyon Cross-Section (Source: SRP Construction History, Volume III, 253).

William Bebbington, in a later source, claims that the canyon building is 800 feet long and 120 feet wide, but it appears that he was mentioning these figures in a general way.[21] A still later source, gives the building dimensions as 255 meters (850 ft.) long by 37 meters (122 ft.) wide, and roughly 20 meters high.[22]

The interior space in this huge building was organized in two ways. Horizontally, in plan, there were three long thin divisions: the Hot Canyon on the east side, the Warm Canyon on the west side, and the Central portion in the middle. Vertically, in section, the Hot and Warm canyons were set up for equipment to be located at the bottom. This was also the location of a small corridor for gang valves and for air exhaust. Above the equipment was a concrete slab known as a "cell cover," a movable work platform (only on the Warm Canyon side), and a work crane for each canyon, located near the top of the building. The central portion of the building was for personnel, feed tanks, and control. This was divided into four stories, containing everything from feed tank galleries, sample aisles, and control rooms.

There are 18 sections to the canyon building, numbered from south to north. The numbers applied equally to the Hot and Warm canyon sides, effectively skipping over the central area. The first section (Section 1) at the south end was 85 feet long to accommodate the special facilities needed for the beginning of the process, followed by 16 sections, each 43 feet long, followed by one final section (Section 18) that measured 45.5 feet long at the north end. The processing equipment was located within the Hot and Warm canyons from Sections 5 through 18.[23] Each of these sections, in each canyon, contained four cells or modules. Each module was set up to accommodate one piece of equipment, and there were no walls between the modules.[24]

The majority of the canyon building was built using reinforced concrete, which was poured in sections, literally the 18 sections mentioned above. The main base slab was poured even before the rest of the building design was



The 221 buildings were divided along their lengths in to three sections: the hot and warm canyons on either side, and the personnel and equipment areas in the center. The canyon buildings were also divided down their widths in to eighteen distinct sections. Source: Savannah River Plant Engineering and Design History, Volume III *(E.I. du Pont de Nemours & Co.), 31.*

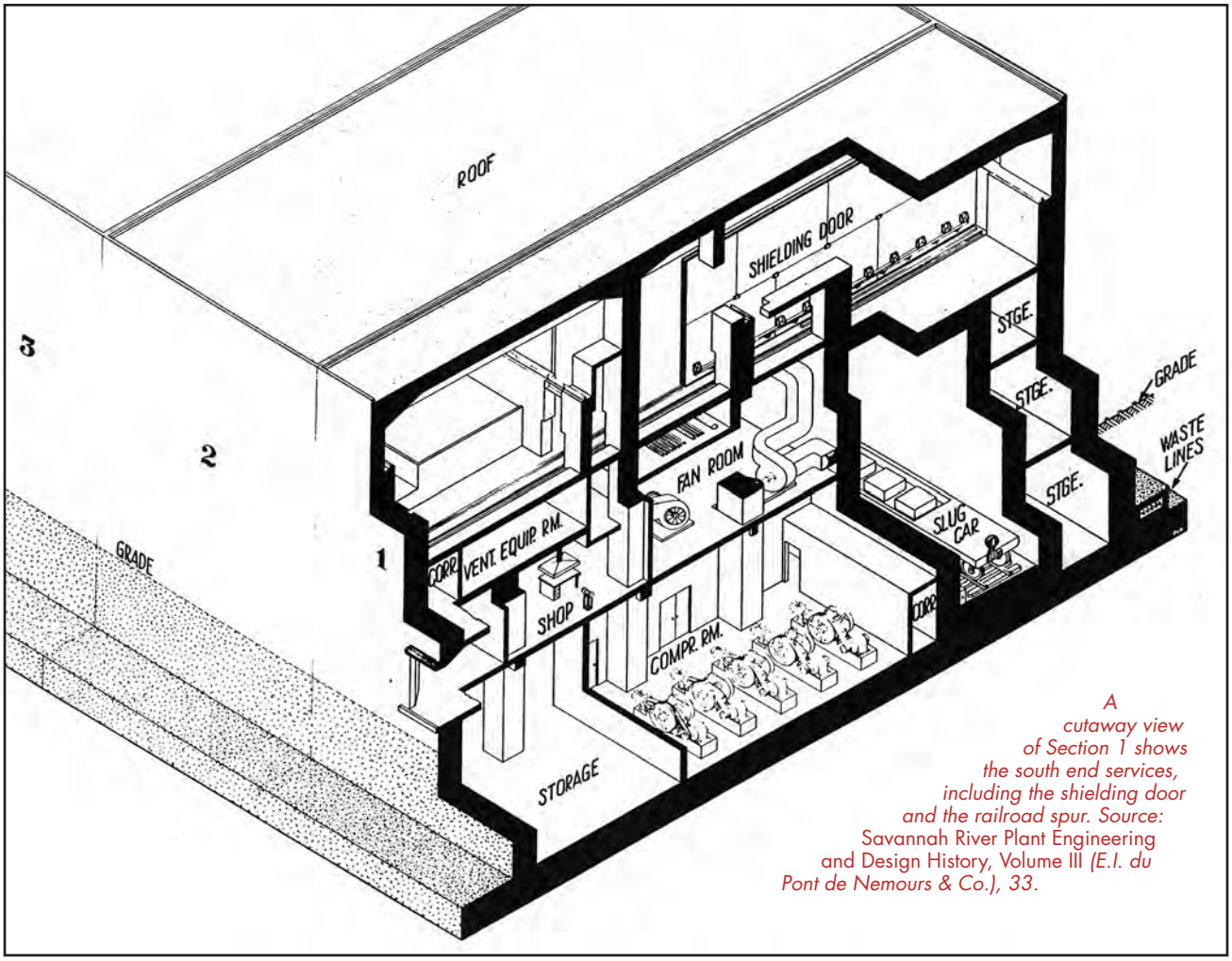
complete, and each section afterwards was done as a continuous pour.[25] Though reinforced concrete was the choice for all of the exterior and many of the interior walls, some of the interior partitions in the central section were made with asbestos board or glass.[26]

As can be seen from the diagrams or cross-sections of the canyon, there are many more than the four walls that would have been minimally necessary to hold up the building and separate its three long parts, the Hot and Warm canyons and the central portion. Four other walls were needed to provide the space for small corridors like the gang valves, the sample aisles, and the cantilevered cab associated with the Hot Canyon crane. These eight walls, all running north and south, were referred to by letter, from "A" in the west, to "H" in the east. During construction, the interior walls were done first (C, D, E, and F). These were followed by the outer walls. The very last wall to go up was the north wall that sealed up the building.[27]

Because of the differential radioactive levels that would be found in the building, and the nature of the feed lines that went into them and exited them, some canyon walls were referred to as "hot," while others are referred to as "cold." Because the cold chemical feeds, electrical lines, lubrication lines, and instrument lines all entered each canyon from the central portion of the building, the main interior walls between the central portion and the canyons were referred to as "cold walls." The "hot walls" were the exterior walls, especially the east wall, adjacent to the Hot Canyon.[28] "Mummy casings" were the concrete bump-outs that shielded the hot pipes that extended out of the building on the east side.[29]

A good concluding description for how all of this works together is provided in Du Pont's Engineering and Design History for Savannah River.

"The separation is accomplished in primary and auxiliary processing equipment located in the Hot and Warm canyons, which are separated by, and serviced and controlled from, a four-story center section containing the feed gallery, control rooms, and administrative areas. The canyons form the main separations areas and provide facilities for processing material over two ranges of radioactivity. The more highly radioactive processing steps



A cutaway view of Section 1 shows the south end services, including the shielding door and the railroad spur. Source: Savannah River Plant Engineering and Design History, Volume III *(E.I. du Pont de Nemours & Co.), 33.*

are housed in the Hot Canyon, while those of lower intensity are contained in the Warm Canyon. Canyon mechanical operations and maintenance are performed remotely by two cranes. Telescopic vision is used on the Hot Canyon crane and direct vision on the Warm Canyon crane."[30]

South End Service Entrances

Irradiated raw materials enter at the south ends of the canyon buildings; tools and equipment enter the building here as well. The south end also contains a number of large service areas, such as the "swimming pool" and the crane maintenance area. Irradiated raw materials entered the building through the railroad tunnel, which was an extension off of the south end of the building on the east side. This extension measured 74 feet by 22 feet wide and was 35 feet high. A shielding door at the entry point was roughly 49 feet wide and 35 feet high. Once inside, the railroad spur line extends through Sections 1 and 2, with the Hot Canyon crane accessing the railroad cars in Section 2.[31]

Railroad cars entered the tunnel via a remotely operated mine-type electric engine, with lead-shielded casks tied to well-type flat cars. In the early days, these casks would have contained buckets that held irradiated slugs, which would have been unloaded by the overhead crane and taken to storage or directly to the beginning of the process.[32]

The south end of the canyon and the electric engine, also know as a "dinky," which brought in the irradiated materials from the reactor areas to be processed, circa 1956, SRS Negative DPSPF 4002-6.

Adjacent to the railroad entrance were the Bucket Storage Area and the "swimming pool." Irradiated materials could be stored in the pool if they were not ready to be processed in the canyons. As a rule, irradiated materials would be transferred from the swimming pool directly to dissolution. In 1955, a work platform was added over the pool to facilitate working on materials there.[33]

Materials and equipment for the Hot Canyon entered the building through the railroad tunnel, but materials for the Warm Canyon usually entered through the truck well. The truck well was located on the west side of the building at Section 4. It was one of the few parts of the building that had to be altered early in the construction period. After the walls were poured, clearance for the truck well was found to be too small. There was some consideration given to moving the truck well to Section 18, but in the end it was decided to enlarge the one at Section 4.

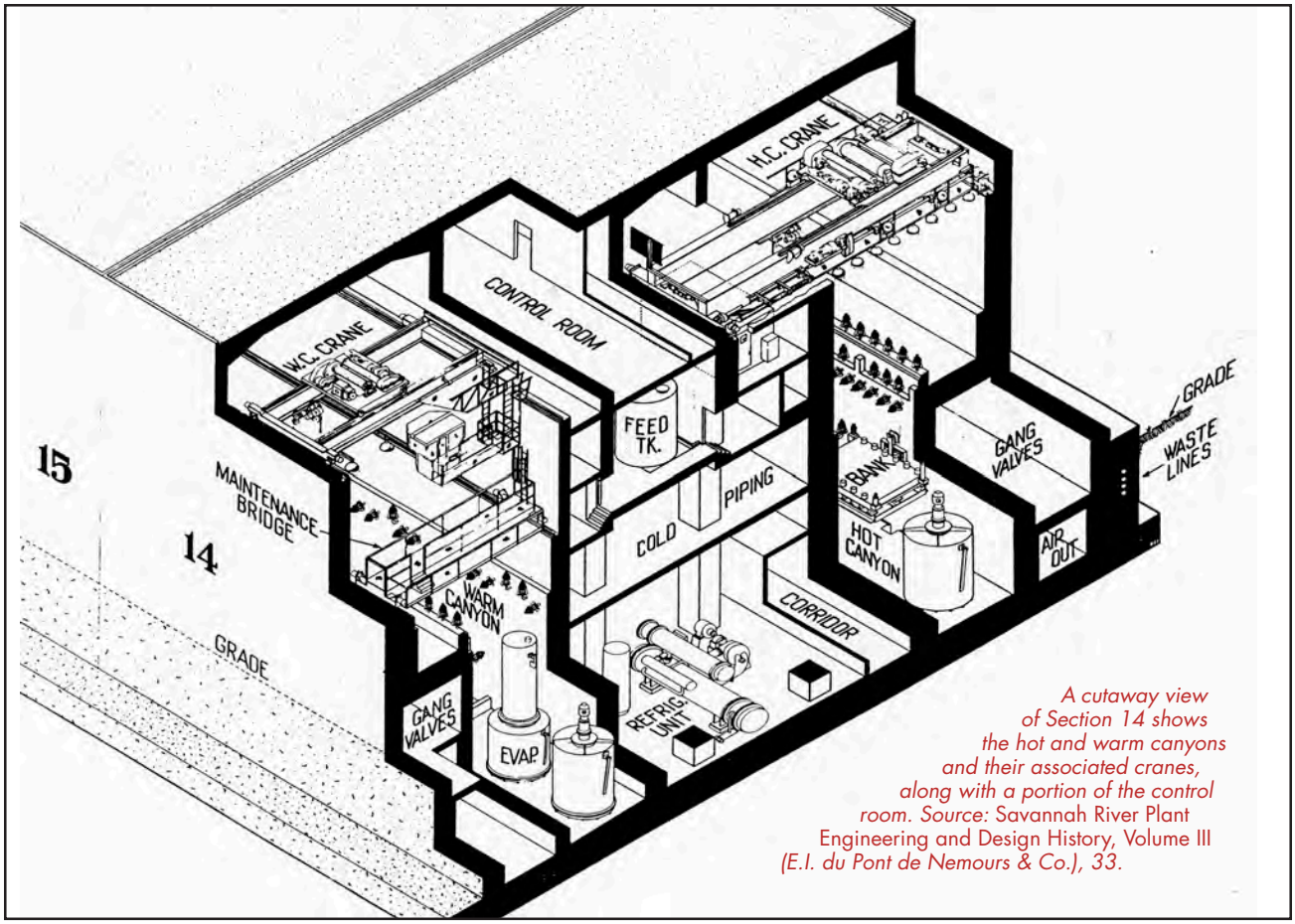
The truck well also posed a ventilation problem. The opening caused unexpected air flow into the Warm Canyon, which had to be kept at negative air pressure. Initially, a canvas curtain was installed to rectify this problem, but this was later changed to an air lock.[34]

Adjacent to the truck well was a loading platform, added to the southwest corner of the canyon building in 1954. This was to facilitate the delivery of work clothes and other materials to the freight elevator, located on the west side of the building at Section 1.[35]

Personnel Entrances and General Areas

Workers entered the building by means of three entrance towers located at Sections 3, 9, and 15. All of these connected to the central portion of the building by way of tunnels built under the first level. Access to the central part of the building was then provided by stairwells located at the middle of the tunnels. In addition to these major entrances, there were a number of smaller portals to special parts of the building, providing extra access to the gang valve corridor or the truck well area, for example.[36]

There were elevators at the west tower at Section 9. This tower was often referred to as the head tower. There was also an elevator in the center of the building at Section 9. This last elevator provided access to each of the four floors of the central section. The freight elevator at the southwest corner of the building also provided access



A cutaway view of Section 14 shows the hot and warm canyons and their associated cranes, along with a portion of the control room. Source: Savannah River Plant Engineering and Design History, Volume III *(E.I. du Pont de Nemours & Co.), 33.*

to the four levels, including the crane maintenance level on the fourth floor.[37] Years after the conclusion of Project 8980, another freight elevator was added to the north end of the building. There was also another special elevator located adjacent to the north elevator on the west side that ran between the second and third levels. This was to facilitate the movement of samples and sample carts. After Project 8980, another elevator was added to the west side of 221-F to better access the JB Line that was added to the building in the late 1950s.[38]

Facilities and Control Rooms

To serve the workers in the central part of the canyon buildings, there were lockers, bathrooms and change areas located on the first and fourth levels. On the first level there was a small lunchroom and a large lunchroom for 40 people. A cafeteria that served all of F Area was located in Building 704-F.[39]

A number of specialized facilities were located at the south end of the canyon buildings, and these were often referred to as the Shop Facilities. They included the Hot Shop, the Decontamination Facilities, the Warm Canyon Shop, as well as various storage rooms. The Hot Shop was equipped with manipulators to work with small items whenever there were problems loading into the dissolver. The Hot Shop had access to the canyon itself.[40] The Decontamination facilities were located at the south end of the Hot and Warm Canyons, and it was here that contaminated equipment could be cleaned up and fixed. This included Tool and Mask Decontamination rooms, personnel decontamination rooms, as well as a counting room and change room.[41]

Other Shop Facilities located at the south end of the building included the Crane Maintenance Shops for the Hot and Warm Canyon cranes. The crane maintenance area was originally considered for the first level, with an elevator to raise the crane back into position at the top of the canyons, but this idea was dropped, keeping the crane maintenance area on the same level as its normal functioning track. For this reason, the Crane Maintenance Area was located on the fourth level, protected from the canyon by sliding steel doors. In late 1954, after initial construction, it was decided that more shielding was needed around the Hot Canyon doors, so extra carbon steel baffles were added to the east wall in that area.[42]

Most of the other facilities in the central part were separated into levels and these will be examined here, beginning with Level 1 and ending with Level 4. Level 1, the lowest level, contained chemical solvents for the canyon process. This included Cold Feed Prep No. 1 and No. 2.[43] There were also four electrical control rooms on the first level that were part of Mechanical Services. The first control room, located at Section 1, was for the 600kW diesel generator that provided the back-up power to the building. The second, at Section 8, was for motor control equipment. The third was a substation, and the fourth, at Section 17, was a substation and a motor control system.[44] Exhaust fans were also located here.[45]

Level 2 contained the cold piping, which included chemical streams and cooling water. For the most part, these were the pipes that connected the tanks in the canyons with the cold feed tanks on the third level. The Cold Feed Tanks, also known as the Gallery Feed Tanks, were located on the third level. These tanks contained the non-radioactive process liquids that are fed into the canyons through the piping in the cold walls. These lines were equipped with seals to prevent flow from ever coming back to the gallery after use in the canyons.[46]

The location of the Gallery Feed Tanks was of some concern during the design process. It was originally considered to put these tanks below the canyon vessels, or even on the roof. For logistical reasons, this became unworkable, so was decided to put them on the third level. The issue that followed was how best to connect these tanks to the instrumentation in the main control room, located on the fourth floor. For this connection, it was decided to use "standardized transmitting scales."[47]

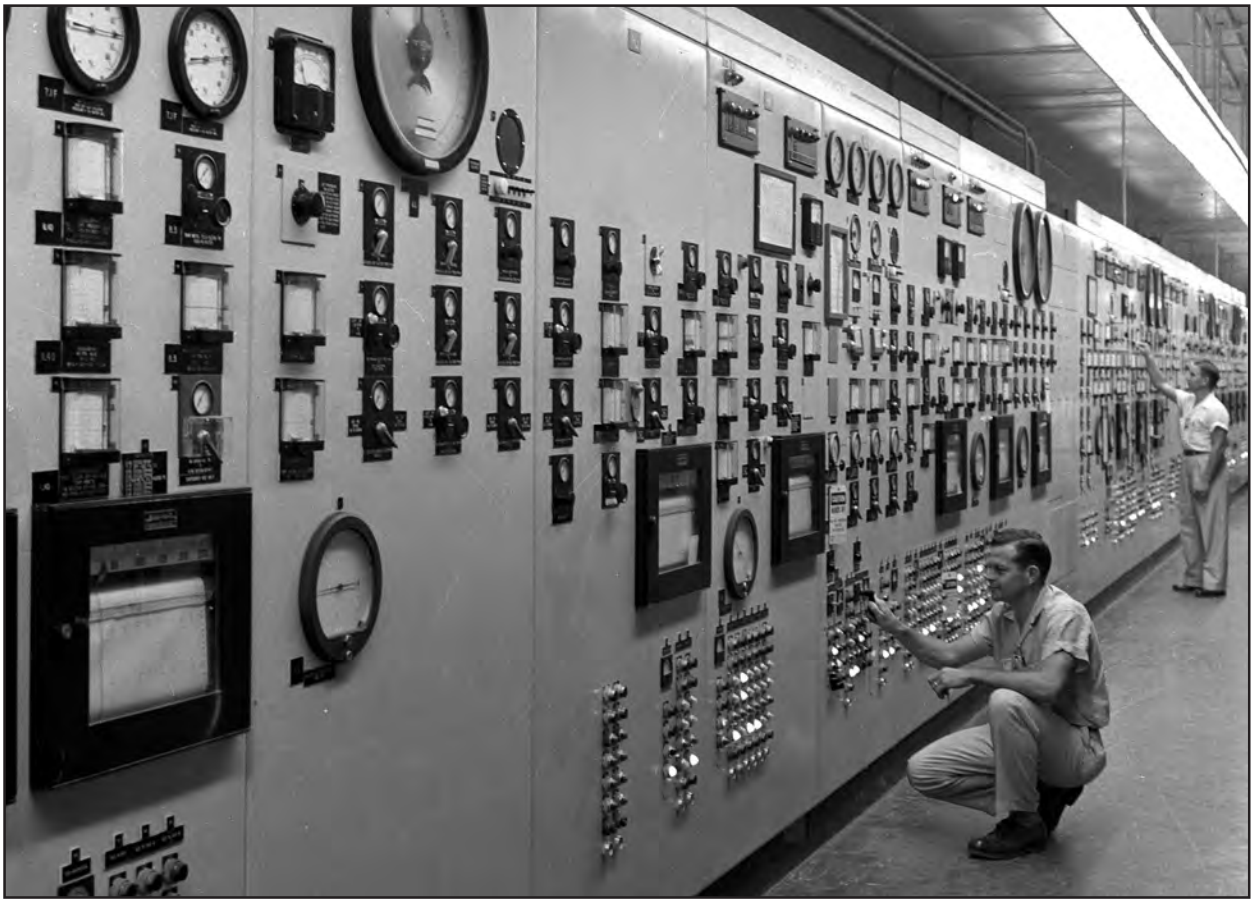
Small Lunch Room, SRS Negative DPSPF 10142-7.

Locker Rooms, SRS Negative DPSPF 10142-12.

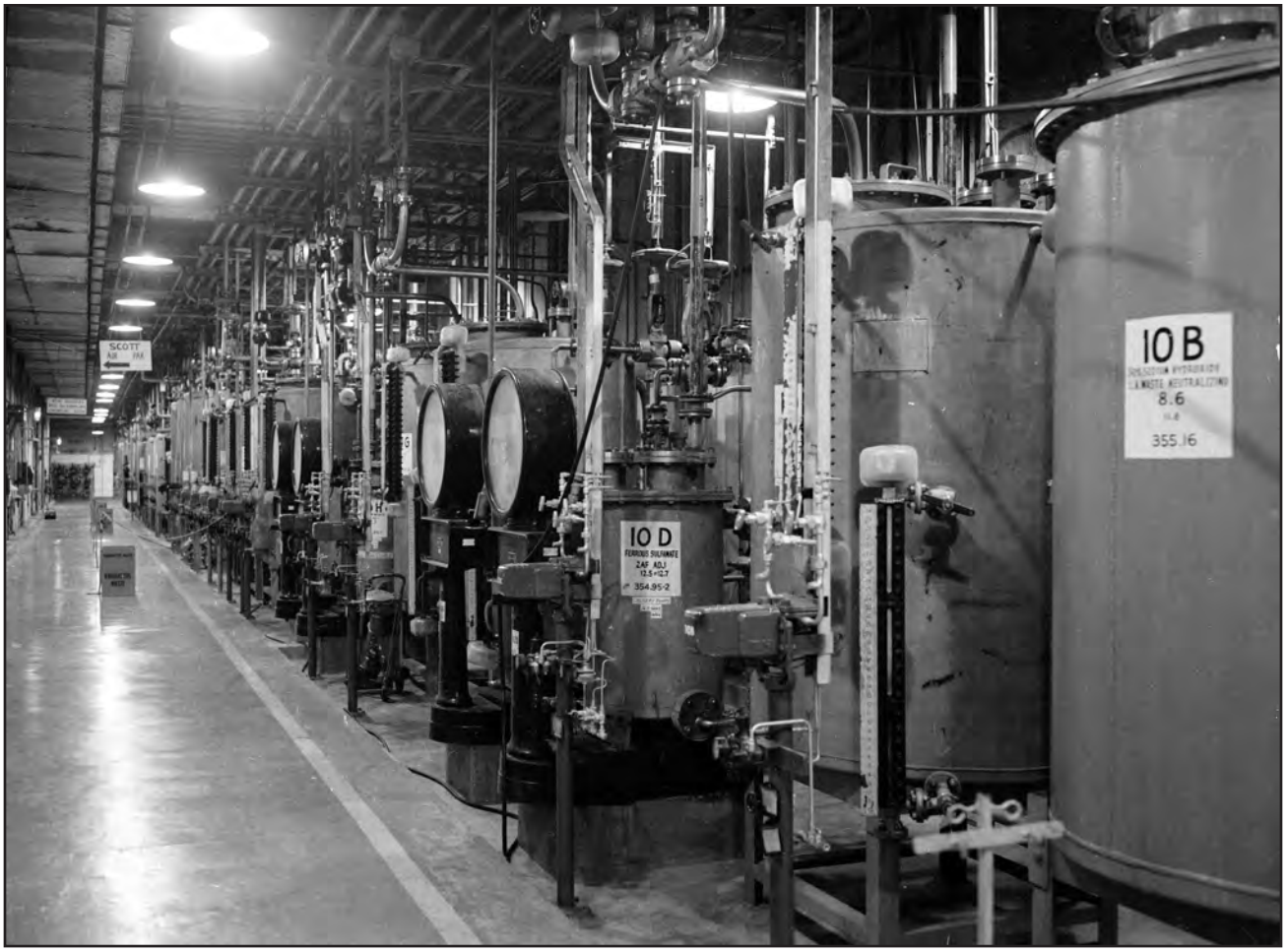
The two original B-Line facilities in 221-F were located on the third and fourth levels at the south end of the building, within the area of Sections 1 through 4. Chemical solvents for the B-Line were found on Level 3.[48] Much more will be said about the B-Lines in later sections of the report.

The main operational control room, where the Purex process was supervised, was located at the north end of the fourth level. Here were the panels that guided the operation of both the Hot and the Warm Canyon sides.[49] Control charts were prepared by hand, and there were control mechanisms that extended through the canyon walls.[50] Security was tight in the control room and the work was compartmentalized. People at one end might not have had a clue what was transpiring at the other end. But it was here that every stage of the process, from dissolving to the final product for B-Line, was controlled and reviewed.[51]

Some of the most potentially dangerous places to go were the small corridors where people came into the closest contact with the Purex process. These included the sample aisles and the gang valve corridors. The sample aisle was technically on the third level, but it was separated from the rest of that level. Located just above and to the side of the Hot Canyon and the Warm Canyon, the two sample aisles were where laboratory personnel would draw radioactive samples directly from the canyon process. In the early days, this was done using a big syringe. Even though sample aisle workers had to dress-out for protection, the potential for accidents was greater than in most other areas. Though dangerous, this was a very important task, since it provided the only way of



Control Room Operators Marion Legrand, left, and Wade Murdaugh, right, August 21, 1956, SRS Negative 3673-12.

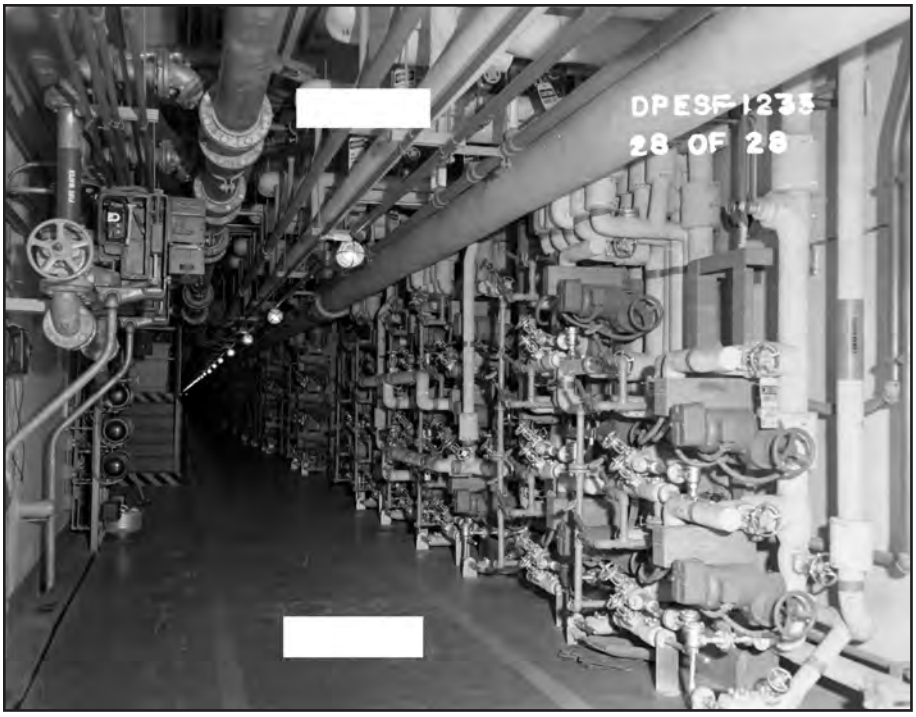


Cold (or Gallery) Feed Tanks, March 20, 1963, SRS Negative DPSPF 8927-38.

knowing exactly what was in the solutions at any given time. Samples were taken regularly and sent to the 772-F Analytical Laboratory for analysis.

In the design process, it was first considered to have just one sample aisle, but it was soon decided to have two, one for each canyon, so that the sample readings might be more accurate. The sample aisles were also used as exhaust ducts for the central portion of the building. During construction, it was first thought that the structural concrete would be sufficient as protection from the radiation expected from the canyons, even the Hot Canyon. Later, as radiation levels became higher due to increased throughput, an extra four inches of lead were added to the shielding for greater protection.[52]

Gang Valve Corridors are located in a small side corridor between the exterior walls of the building and the Hot and Warm Canyons. The gang valve corridors are roughly at the same elevation as the second level, but they are not technically speaking on the second level, since they are isolated to themselves, away from the central part of the building. The gang valve corridors extend between Sections 5 and 18, under the canyon rack piping. Here the gang valve assemblies provided the steam needed to operate the jets that moved the liquids through the Purex



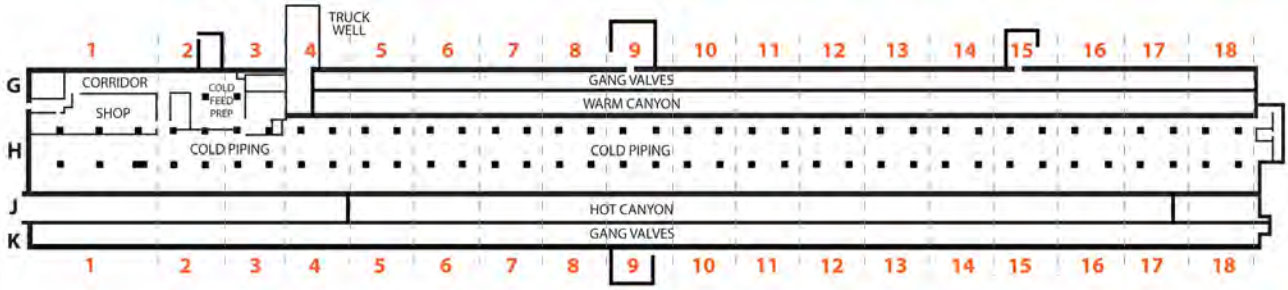
Gang Valve Corridor, September 20, 1954, DPSPF 1233-28.

process. To do this, steam jet siphons operated without moving parts, and were controlled from the control room.[53] In case of problems, this area had to be accessible to canyon operators and workers.

Sections and Modules

On either side of the center portion of the building were the Hot and Warm Canyons, the Hot Canyon on the east side and the Warm Canyon on the west. This huge process area had to be segregated into manageable subdivisions, and this was done through the use of "sections" and "modules." Most of these sections, 2 through 17, were exactly the same size. Beginning in Section 5, they also used exactly the same sized piping, which was located in exactly the same positions.[54] This was an essential part of the building design, since it was imperative that every piece of equipment could be positioned in any of the work areas. Anything less would negatively impact the flexibility of the process and the building. It would also impact the ease with which equipment and vessels could be positioned remotely, since this would have to be done by overhead crane and viewed from a distance.

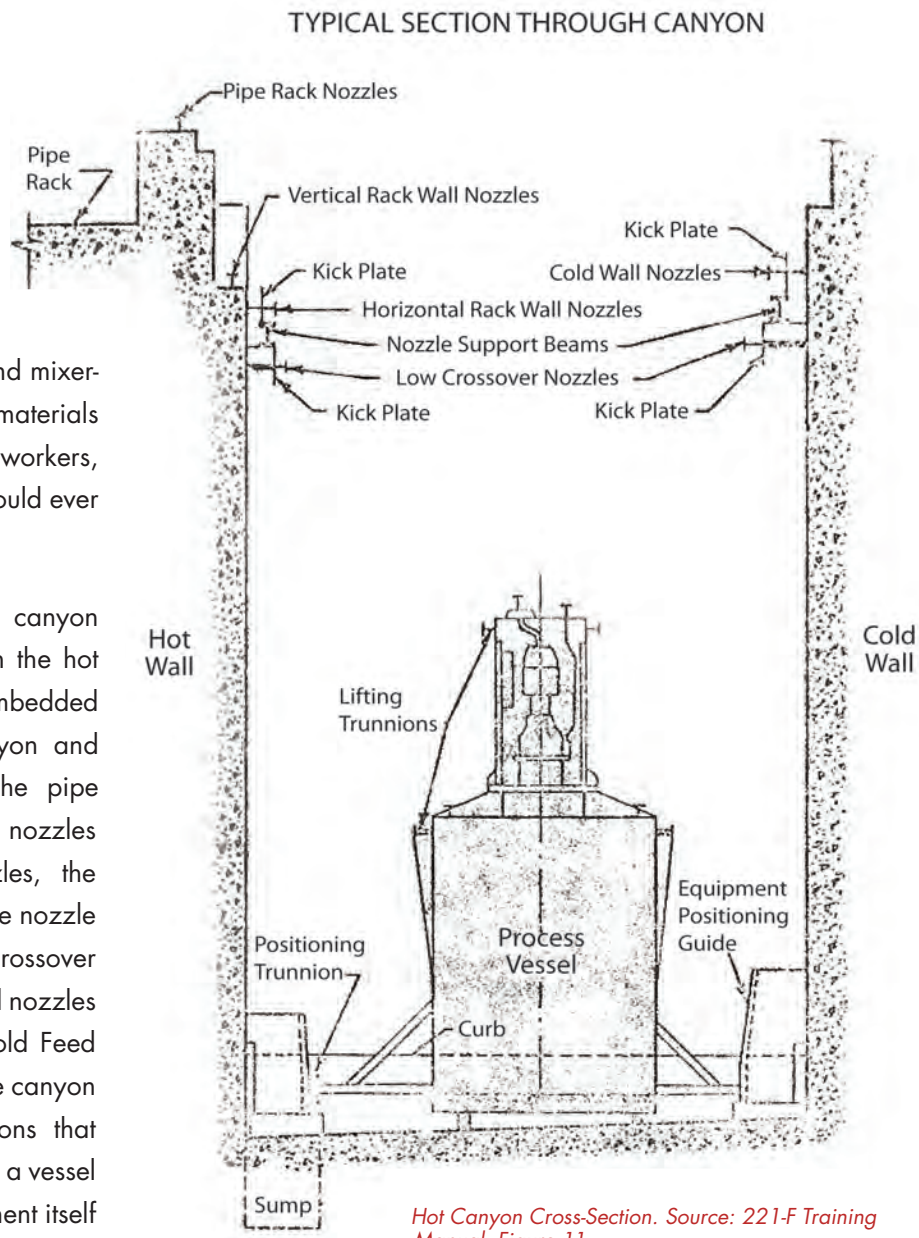
The original plans called for every single section to be 43 feet in length, with canyon widths ranging from around 30 feet at the top, to around 15 feet at the bottom. Later, the first section, located at the south end, was made 85 feet in length to accommodate all of the support facilities that were needed at that end of the building.[55] As mentioned earlier, casks on the railroad cars were accessed by the Hot Canyon overhead crane in Sections 2 and



A Plan View of the Second Level of the Canyon, Showing the 18 Sections. Each section of the hot and warm canyon sides (except 1 and 18) contained four modules, within which would be placed a process vessel. Illustration adapted from 221-F Training Manual, Figure 4.

3. Otherwise, the first four sections were devoted to support facilities, storage facilities, and, on the third and fourth levels, the two B-Lines (in 221-F). The Purex process itself began in Section 5 and continued through Section 18, with dissolvers, evaporators, and mixer-settlers. Once the first hot materials entered the process lines, no workers, with a few major exceptions, could ever go back into these spaces.

A typical cross-section of a canyon section is presented here. On the hot wall side was the pipe rack, embedded in the wall between the canyon and the gang valve corridor. The pipe rack contained the pipe rack nozzles and vertical rack wall nozzles, the horizontal rack wall nozzles, the nozzle support beams, and the low crossover nozzles. The cold wall also had nozzles to supply material from the Cold Feed Gallery. Near the bottom of the canyon walls were positioning trunnions that guided a piece of equipment or a vessel to its proper place. The equipment itself would have lifting trunnions to allow the overhead cranes to move them.



Hot Canyon Cross-Section. Source: 221-F Training Manual, Figure 11.

Below the positioning trunnions, the floor of the canyon was sloped so that any run-off would go towards the hot wall, where the run-off would be collected in a sump. The floor of each section was sloped 3/8 of an inch per linear foot. The vessels and their footings were constructed to accommodate this slope, so that the vessels would remain vertical after installation.[56]

Beginning with Section 5, "each 43-foot section has four crossover wall connections, with the exception of Section 9, which has two."[57] Don Orth recalled that Section 9 was unique for another reason: it was here that the plutonium solution was fed up to B-Line for finishing.[58] In addition to the process piping, which will be discussed in greater detail in the following section of the report, each of the operational sections contained 16 water protectors

Empty Canyon Section in 221-H, May 1, 1961, SRS Negative DPSPF 7441-7.

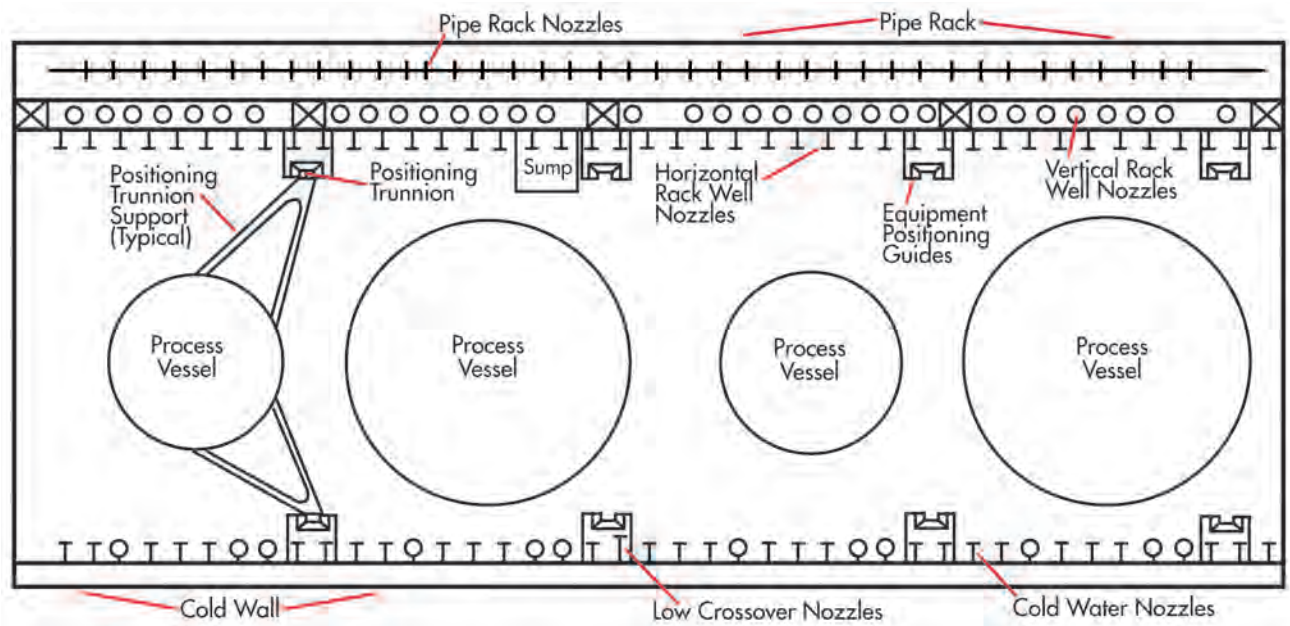
for fire suppression and eight sprays to flush the floors. There were also additional sprays on the pipe rack.[59]

Two foot-high curbs separated each section from the other. These curbs served two purposes. Since each section was poured as a unit, so that there would be expansion joints between each section, these low curbs served to seal the expansion joints. They also acted as a fire curtain between the sections. Other fire curtains between the sections could be installed and removed as needed, and these were especially useful to isolate the evaporators.[60]

Within each section, there were four "modules." These modules were sometimes called "cells," but this term appears to have been a holdover from Hanford. Unlike the Hanford cells, these areas were not enclosed, which is perhaps why modules seemed to have been the preferred term soon after construction. Each module comprised 10 linear feet, with a useable height of up to 17 feet for each vessel. Everything was designed so that one vessel would conform to one module. Each module had a complete and standard set of pipes.[61] This pattern was identical in each section, with the exception of the space for the dissolver off-gas equipment in Sections 6 and 7 in the hot canyon.[62]

The numbering system was designed to accommodate the modules, as well as the sections. Starting at Section 5, at the beginning of the Purex process, the modules on the hot canyon side were labeled 5.1, 5.2, 5.3, and 5.4. The first number in the series, in this case "5," would have identified the section; the second number in the series was used to identify the module, labeled 1 through 4 going from south to north. On the warm canyon side, the process started in Section 6, and the numbering would have been 6.5, 6.6, 6.7, and 6.8. To reduce the margin of error, it was determined that .1, .2, .3, and .4 would always identify modules on the Hot Canyon side, while .5, .6, .7, and .8, would always identify modules on the Warm Canyon side.[63] That way, with the designation 6.3, for example, an operator would instantly know that the module was on the Hot Canyon side.

Even the nozzles embedded in the walls had numbers, and there were many nozzles, at least 121 per section. Each process section in each canyon, whether warm or hot, contained 84 wall nozzles as part of the basic process.[64] The numbering system began with the cold wall (inside wall) nozzles, starting at the south end, and going from 1 to 42. The numbering continued on the hot wall side with the horizontal rack wall nozzles, 43 to 84, coming back from north to south. The numbering resumed with the vertical rack wall nozzles on the hot wall side, numbered 85 to 121. These too were numbered from north to south, overlapping nozzles numbered 43 through 84. The nozzles numbered 85 through 121 were generally for steam lines and steam jets, used to heat and move liquid in the process. In addition to these 121 nozzles, there were also extra horizontal wall nozzles on



Typical Plan of a 43-foot Canyon Section. Source: 221-F Training Manual, Figure 12.

the hot wall side, located beneath nozzles 20, 41, 44, and 65. These were identified with those same numbers and the suffix "A."[65]

As a result of this complex arrangement, each 10-foot module had access to over 30 different nozzles: at least 10 on the interior wall (cold wall) and at least 20 on the exterior or hot wall side.[66] These nozzles served different purposes, whether it was for electrical, water, carrying process solution, or providing steam. There was considerable redundancy. It was clearly designed so that each piece of equipment would have ample access to what it needed in the process.

Hot Wall Nozzles. Visible in this photograph are nozzles 44-66 (horizontal rack wall nozzles). The faint numbering can be seen on the front of the nozzle box. Also visible are nozzles 85-104 (vertical rack wall nozzles), numbered in black type above the nozzle box. December 23, 1964, SRS Negative 10084-8.

As a rule, concrete slabs, referred to as "cell covers" or "canyon covers," covered the canyon vessels, so that normally they could not be seen. One foot thick and covering a section, a cover could only be moved by the overhead crane by means of two lifting lugs. The covers were brought into the hot canyon through the railroad

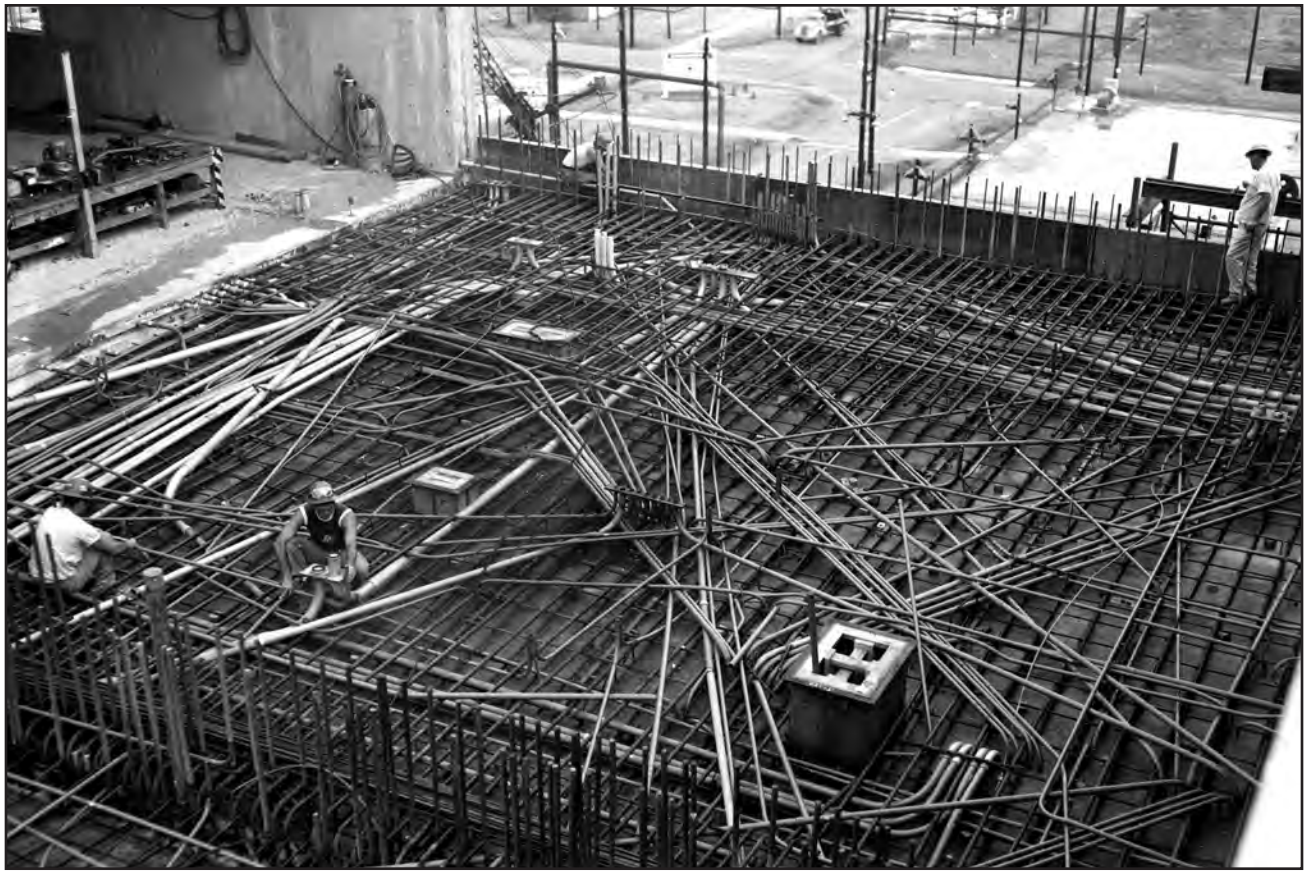
Canyon Cell Covers. The workers in this photograph help provide some perspective in the size of the canyon operation. May 14, 1954, SRS Negative M-3464.

Section 18, with Half of its Cell Covers Installed. October 20,1954, SRS Negative DPSPF 1465-1.

tunnel, and were then rotated 90 degrees by a swivel hook for final placement over the canyon. Covers on the warm canyon side came in via the truck well, with no rotation required. These covers provided extra protection from process radiation, and protected the module vessels from items that might be dropped from the overhead cranes.[67]

Finally, there was the north end of the canyon building, which had some features unique to that area. This was the last part of the building to be sealed. The enclosure at the north end of 221-F was 40 feet long, 65 feet high, and included an 8-foot extension north of the main part of the building, containing a stairwell, elevator, and hoist. There was also an observation platform or deck located at roughly the third level. Known as the "blister," it was located on a cantilevered concrete slab that was around 95 feet long and extended 13 feet beyond the edge of the building. Originally serving as an observation deck, the blister featured an area of thick lead glass for a view onto both the hot and warm canyons.[68] The glass window served this purpose for around 10 or 15 years, after which it became clouded from the radiation and is now permanently blackened. Understandably, there has been no attempt to clean it. Currently, the blister serves as an office.[69]

The "Blisters," which Originally Served as Observation Decks, on the North End of the Canyon.



Pipes in Place Prior to the Floor Being Poured for JB Line, July 17, 1957, SRS Negative M-4599.

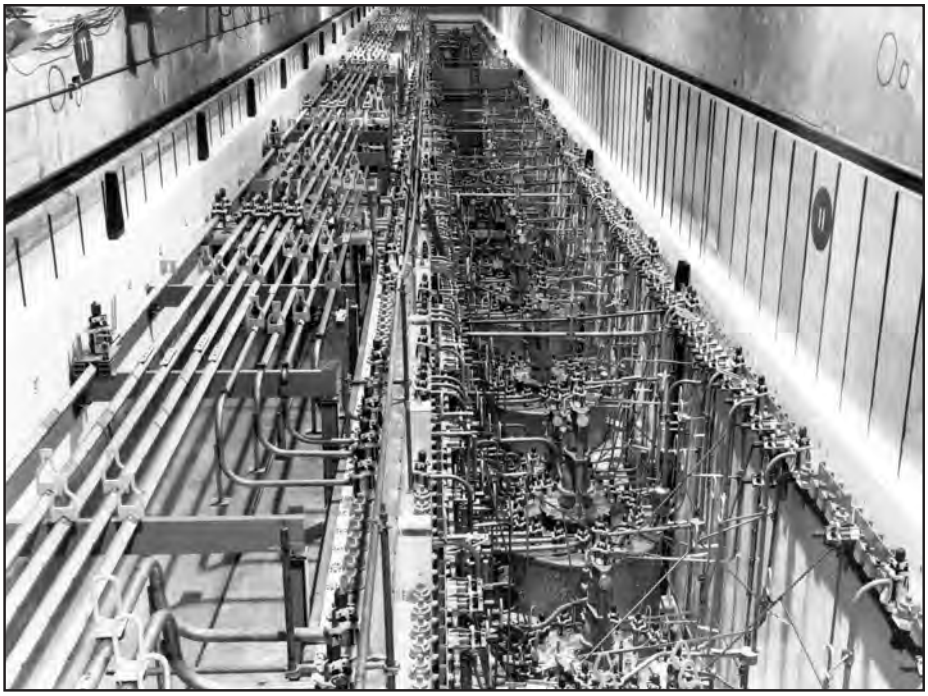
Piping

Because of the nature of the building and what would be processed inside, piping was a major issue in the design and construction of the canyon buildings. Pittsburgh Piping and Equipment Company did the stainless steel piping for the canyon buildings, and for the waste tanks. The first shipment of this piping arrived via motor freight on September 6, 1952; the last shipment arrived in April of 1954.

Chemicals and solutions of all sorts had to be transported to and from the vessels, and this work had to be done remotely due to the radiation. Vessels and their connections also had to be replaced remotely as well. To carry out this function, pipes were set into the walls before the final concrete pouring, with access provided by the nozzles mentioned above. To access the vessels and other equipment, separate piping connections known as "jumpers" were used to connect the nozzles to vessels.

Like the nozzles connected to them, the embedded pipes were found on both the hot and the cold wall sides. Most were stainless steel. Within the cold wall, or the wall between the canyon and the center portion of the building, were pipes for the cooling water and the cold feed chemicals needed for the canyon equipment. There were also pipes for samplers and other instruments, lubrication, and electrical connections. In the hot wall, or wall between the canyon and the outside of the building, there were steam lines to feed steam to the jets, pipes to remove

condensate and cooling water from the canyon, the transfer fluids to the rack piping, and pipes to remove water and process waste to locations outside the building. There were also special lines for carrying the plutonium solution to the B-Lines for their final processing.[70]



The pipe rack is on the left in this photograph down the length of the warm canyon. May 4, 1954, SRS Negative DPSPF 1156-9.

The importance of the embedded piping can hardly be over-emphasized. It had to be constructed and located correctly before the walls were poured, because any errors after the pour could adversely affect the use of the canyon itself. The specifications for the process piping were worked up by Blaw-Knox and Gibbs and Hill, with the whole operation supervised by Du Pont.[71]

The pipes were arranged on a rack in an elevated area along the hot canyon between Sections 5 and 18. This was the header piping or rack piping, and it was connected to the imbedded piping directly in the walls. Header or rack piping was arranged so that it could be removed in sections using the overhead crane.[72]

Every effort was made to stabilize the imbedded pipes before the walls were poured. The nozzle ends of the pipes were originally held in place by a nozzle support beam that extended the length of each section, 23 feet above the canyon floor. Jigs were used to align the pipes along that beam to within 1/10,000 of an inch. A similar row of horizontal nozzles was located on the opposite wall. There were also vertical nozzles set on a ledge slightly above the horizontal rack wall nozzles.[73]

Once the concrete was actually poured and the wall hardened, any piping variances were recorded on as-built drawings for future reference. This was done from module to module, and from section to section. All vessels had to conform to these variances, if any, and it has been noted that the differences from one module to another were never more than 1/16 of an inch.[74]

Steam Jets

Steam jets, which used the imbedded piping, were essential to the process because they moved liquids from place to place in the canyons. Because of the radiation levels that would be experienced after start-up, early on it was decided not to use pumps, which would only break down and have to be replaced. The alternatives were either

vacuums or steam jets. Based on what had been used at Hanford, it was decided to go with steam jets. Blaw-Knox's initial specifications called for 25 different jet sizes, but these were later reduced to six different types of constant rate jets and 5 different types of transfer jets. The design work for these prototypes was done at TNX, with weekly progress reviewed by a Du Pont "jet committee." This testing and review period resulted in the consolidation of transfer jets and rate jets into standard types.[75]

The two types of steam jets did two different tasks. The transfer jets, based on the basic Hanford design, actually moved the materials from place to place within the process, and did it quickly. The constant rate jets were designed to work slower, moving the feed stream at a regular rate through each stage of the process as required: to the mixer-settlers, the evaporators, and centrifuges, etc. The constant rate jets used at Savannah River were developed by Schutte-Koerting Company and Penberthy Injector Company, with testing at both TNX and the Du Pont Engineering Research Laboratory.[76]

Steam jets, of course, do not work without steam, and steam was required to run the process in at least four buildings within the separations areas: 221, 211, and 222. It also provided heat for process vessels and cold-weather protection. Steam also created negative pressure for evaporators and other vessels. It powered the steam-driven back-up pumps. Almost all of the other area buildings required it for heating and other ventilation systems.[77]

In the canyon buildings specifically, steam was the heat source for dissolvers, evaporators, and the process solution. It was also essential for the gang valve operation. In 221-F, for example, 150 psig (pound-force per square inch gauge) steam entered the building at the second level, via a 14-inch line located in Section 2. At Section 5, this line split into two parallel headers that ran the length of Level 2, until they reached Section 17, where the two parallel headers were joined by a cross connection. Another line entered the building at the north end, at Section 18, to provide steam to the Hot and Warm Gang Valve corridors.[78]

The gang valves, located along the hot walls (exterior walls) of the canyon buildings, controlled the steam jets, and these were located in the Gang Valve Corridors. A similar arrangement at Hanford had been operated manually, but it was decided at Savannah River that the gang valves would be motorized and remotely controlled. In order to perfect such a system, testing and re-design work was done at TNX.[79]

Electrical Wiring

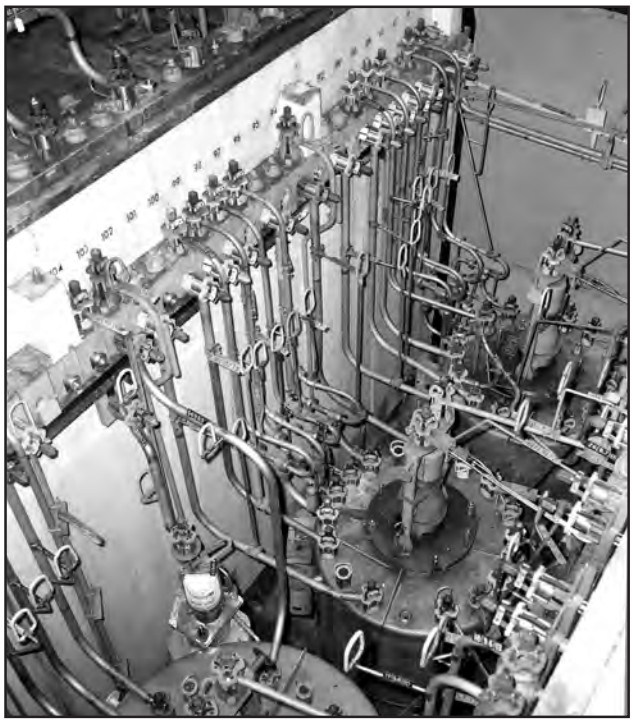
The equipment required for the canyon had not been completely decided at the time of construction. This had an impact on the electrical wiring placed within the building. Because the wiring requirements were not finalized during construction, only the basic lighting system wires were embedded in the canyon walls. The rest of the electrical wires were usually not buried in the walls or floors. It was also thought that embedding the other electrical lines would interfere with the regular piping, which had to be embedded. As a result, the final motor feeds were placed in exposed conduits. At Hanford, each building section had its own instrument control panel, which kept conduits to a minimum. This was not possible at Savannah River, where electrical connections had to be accessed from the control room. Wiring was designed to be suitable for all possible motors, the largest being the 40-horsepower centrifuge motor with a No. 4 wire.[80]

Canyon Equipment

The importance of the Separations equipment is hard to over-state. The canyon building itself was a shell, a very important shell, but still a shell or an envelope for containing the equipment used to actually run the Purex process. The equipment– the vessels, the mixer-settlers, the various connections—all of these things were the true guts of the process.

Jumpers

Jumpers, together with connectors, form a special category of equipment. They are not a direct part of the canyon building, since they can be moved around as needed for the process. They are absolutely essential, though, and they connect the building, with its embedded piping, to the vessels of the Purex process. As such, they were a vital piece of equipment.



Metal piping, "jumpers," was specially designed and standardized in order to connect the nozzles on the canyon wall to those on the process vessels. December 23, 1964, SRS Negative DPSPF 10084-6.

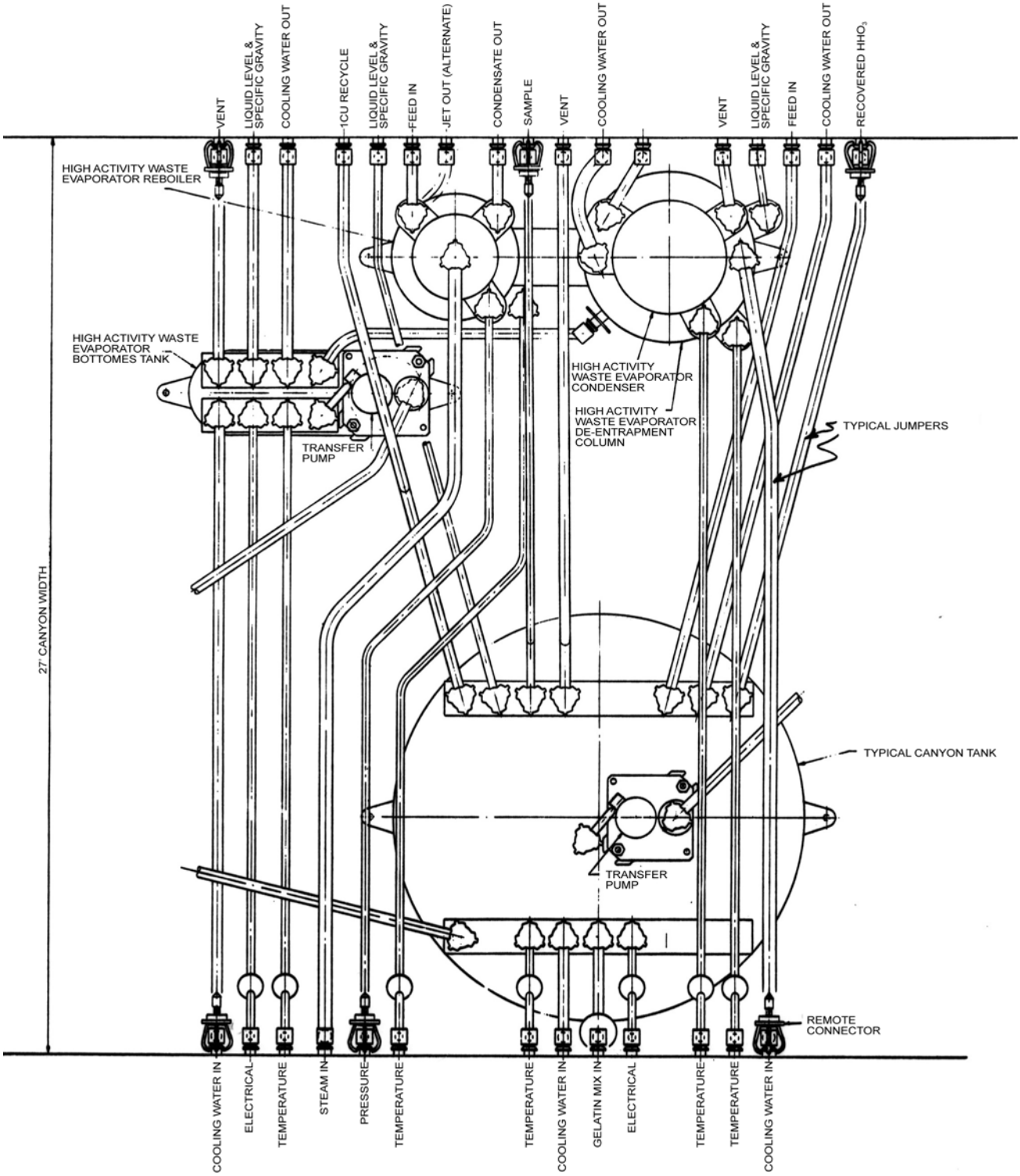
The design of the jumpers began with the work done previously at Hanford. Additional work was needed for the greater standardization required at Savannah River. Like all of the other equipment designed for the canyon buildings, these were tested in 717-F before installation.[81]

As developed at Savannah River, the jumpers were the shaped pipe segments that provided the direct connection between the vessels and the rack and the embedded piping. An integral part of the jumpers were the "connectors" that actually sealed the joints of the jumper pipes to the embedded and stationary piping along the canyon walls. As was stated in the Du Pont Engineering and Design History:

"Jumper piping is designed for remote installation and removal by means of angle-type or in-line connectors. These jumper pipes are pre-fabricated in sections of various lengths and shapes, designed to effect the required connections between wall nozzles, vessels, and pipe rack connections.[82] These individual lengths are equipped with lifting bails and special connectors welded onto both ends to allow the remote coupling of the jumpers to the pipe nozzles."[83]

Connectors

Connectors were used to unite the jumpers with the building piping, on the one side, and the process vessels, on the other. This allowed vessels to be moved as needed, using the overhead cranes to pop the connectors in and out of position. The first connectors used at Savannah River, and the most popular over time, were the "Hanford

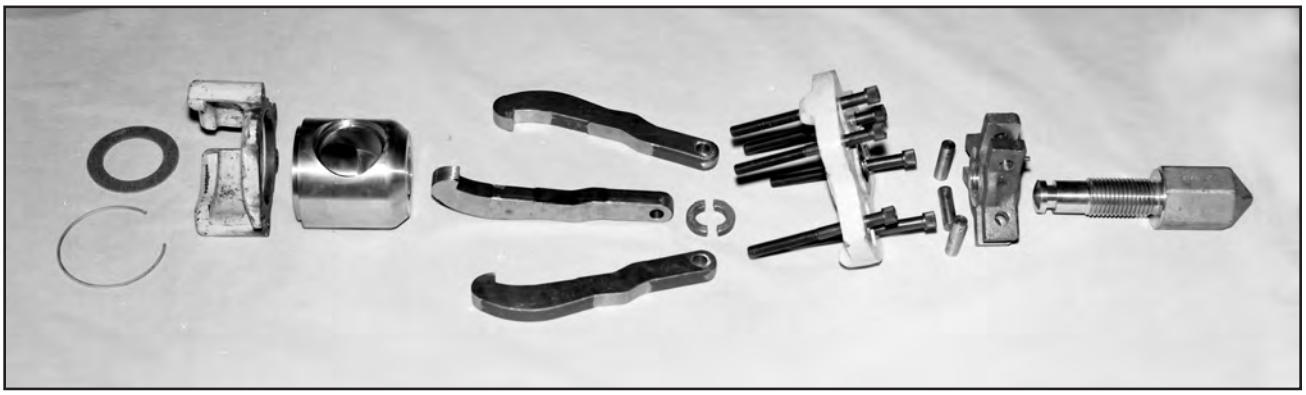


TYPICAL CANYON JUMPER ARRANGMENT - PLAN

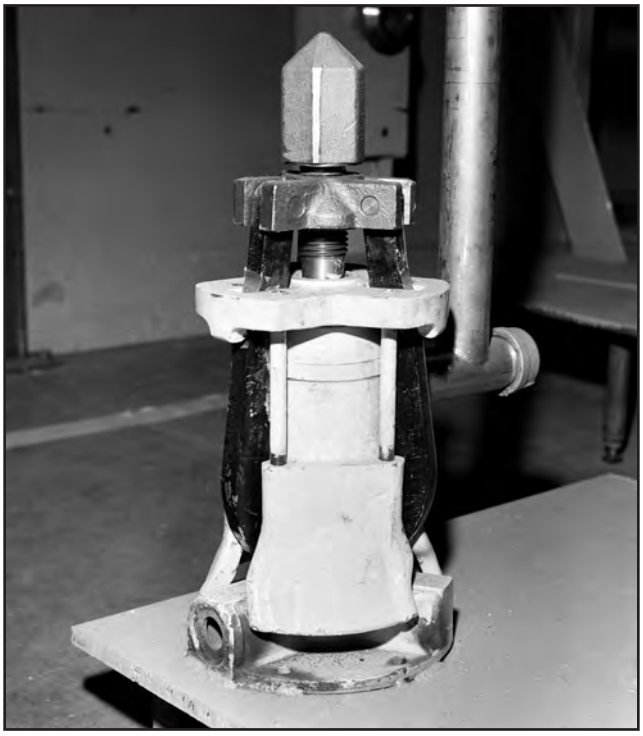
connectors," first developed at Hanford as the name suggests. These connectors were jaw-type devices welded onto the ends of jumpers.

The critical element of the Hanford connector were the horizontal and vertical screws that were simple enough that a crane operator, viewing the connector remotely, could make the adjustments using the crane and two tools carried on the crane: an impact wrench and a hook.[84] The electrically-driven impact wrenches were of basic Hanford design and were mounted on the crane:

In this operation, the impact wrench is lowered on the actuating screw of the connector as desired. The rotation of the screw in the connector actuates a nut carrying three jaws, which engage the back surface of the connector flange and draw together the face of the flange and connector block, which is part of the connector assembly.



A disassembled connector, February 10, 1958, SRS Negative DPSPF 4999-1.



An Assembled Connector, February 10, 1958, SRS Negative DPSPF 4999-6.

Vertical and Horizontal Connectors in situ, *September 2, 1955, SRS Negative DPSPF 2375-1.*

The jaws pass through a jaw guide in the connector assembly and are shaped so that the jaw guide forces them against the flange when the jumper is installed. In removing a jumper, the last few turns of the screw force the jaws against a kick plate located in back of the connector flange which will force the gasketed surfaces apart.[85]

In order for this connector to work well, it was important to use the best materials possible to make the seal. Hanford had used regular steel in the actuating screw and in the jaws, which made it subject to rust. To avoid this problem, Savannah River connectors used stainless steel. This, however, had its own problems, such as the "galling of the screw threads." This problem was the subject of considerable study.

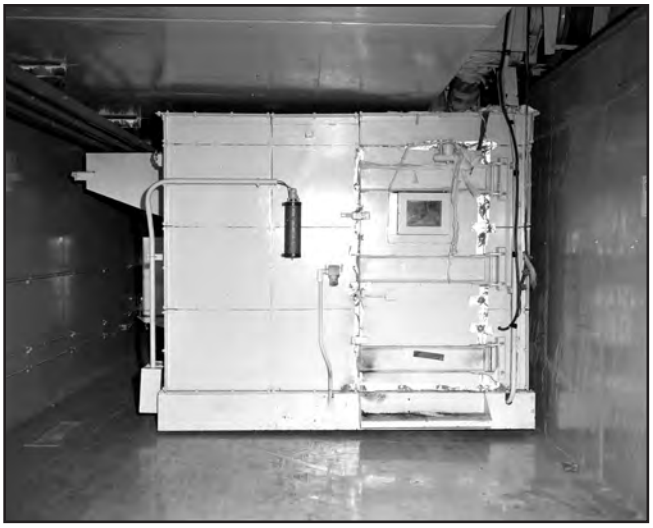
This led to the search for the optimal combination of materials for the connectors and their gaskets. The tested materials included asbestos, fiberglass, and a new product, "Teflon." Most of these combinations were found to be deficient at Hanford. Johns-Manville Company and the Du Pont Engineering Research Laboratory did a survey to identify the best materials for this job, and they ended up with a mixture of Teflon and woven Blue African asbestos. The search for a back-up material was also done by Johns-Manville, working at 717-F and TNX. The gasket that was finally approved from all this work was "JM-719," comprised of Teflon with white asbestos.

In addition to the Hanford connector, work was also done on a variant, called the In-Line connector. Similar to the Hanford connector, the In-Line had what was called "in-line flow and with off-center geared drive" rather than direct drive. Du Pont's Mechanical Development Laboratory did the design work, beginning in September of 1952. In the end, the In-Line connectors were only used with the two-inch rack piping.[86]

Cranes

Since the jumpers and connectors cannot be installed without the overhead cranes, this would be a good time to discuss the cranes. Canyon operation itself would not have been possible without the cranes. They were essential to the operation. The canyon cranes were similar to those used at Hanford, but with a few extra features. The crane over the Hot Canyon was a 50-ton crane; the one over the Warm canyon was a 15-ton crane. Both were operated by electric motors.[87]

Warm Crane Cab, May 25, 1956, SRS Negative DPSPF 3516.



Hot Crane Cab, November 1, 1961, SRS Negative DPSPF 7824.

Warm Crane. The operator is visible in the cab at center. September 20, 1954, SRS Negative DPESF 1233-2.

Radioactive levels were so high in the Hot Canyon that the crane operator could not ride with the crane directly over the canyon. He worked in a small cab attached to the crane but on the west side, protected from the crane and the canyon by a cantilevered shielding wall.

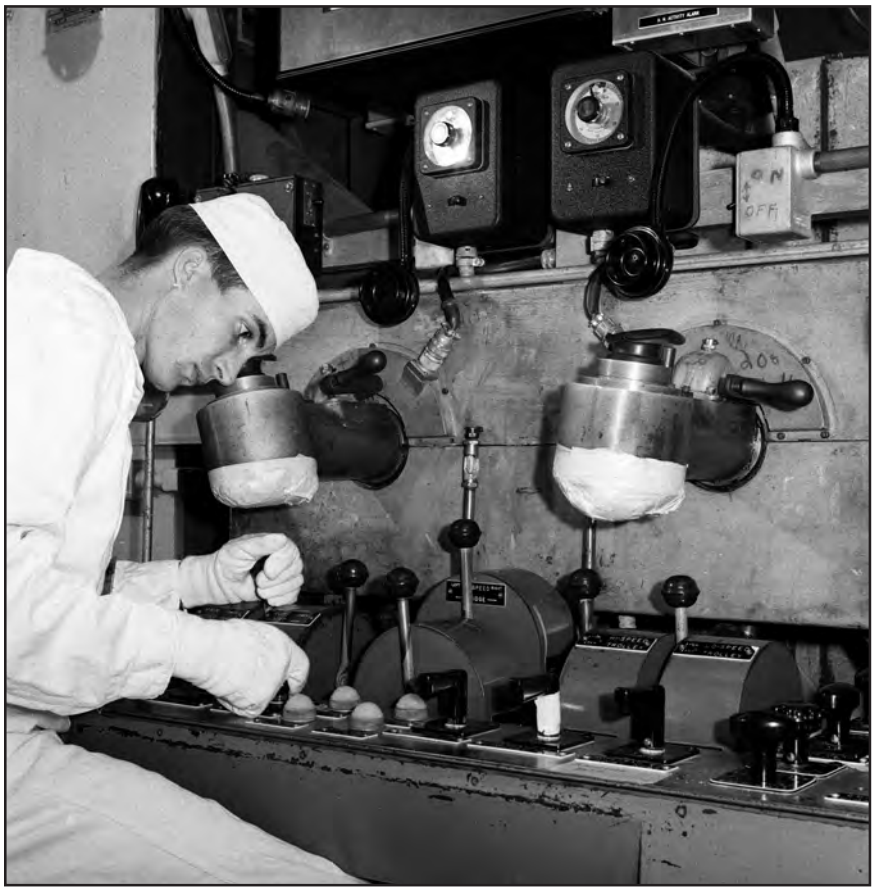
The roof of the hot canyon is a cantilevered concrete slab, which leaves only a narrow opening on one wall through which the cab suspension projects from the crane. A vertical concrete curtain wall also hangs from the ceiling so that a relatively narrow opening exists between this wall and the top of the cantilevered slab.[88]

As a result of this arrangement, the crane operator could not view the canyon directly, but had to rely on periscopes. It was a difficult job, one of the hardest on the site, and it required a great deal of training.[89]

The Hot Crane optical system relied on two large periscopes with magnification lenses, placed under the crane girders. At Hanford, there had been two such lenses, but at Savannah River, there were three, which provided a better perspective. Considerable research was also done on the placement of crane controls in the cab to ensure the best control arrangement for the operator.[90]

Illumination lamps attached to the underside of the crane provided the only available lighting in the Hot Canyon. These lights could be changed whenever necessary by moving the crane to the Crane Maintenance Area, located over the receiving basin at the south end of the canyon.[91] The Hot Canyon did have regular ceiling lights, which were used during equipment installation but after the canyon began operation and the lights gradually burned out, they could never be replaced.[92]

Hot Crane. Lamps on the underside of the crane provide the only illumination in the hot canyon. August 5, 1954, SRS Negative 1209-16.



Hot Crane Operator, April 24, 1957, SRS Negative DPSPF 4379-11.

Another unique feature of the Hot Canyon crane were the extra options. The cab could be moved away from the crane bridge and trolley in case of emergency, and this could be done manually by cable or by small motor. There were also additional access features.[93]

Radiation was not such a problem on the Warm Canyon side. There, the crane operator did not have to work behind a cantilevered wall, but could ride with the crane itself. The operator still worked within a shielded cab, but could look directly down onto the operation area without periscopes.[94] Due to the lower radiation levels, this crane could also have a maintenance bridge, which provided an extra platform to assist the crane, particularly with the entry and exit of materials via the truck well. The maintenance bridge also provided a platform for suited workers to access canyon equipment directly by means of long handled tools. The bridge was operated by direct-current battery, since the track was too long for regular cables and it was thought that any trolley conductors might pose an explosion hazard.[95]

Canyon Vessels and Jumpers Awaiting Installation. November 3, 1953, SRS Negative M-3021-4.

Process Vessels and Tanks

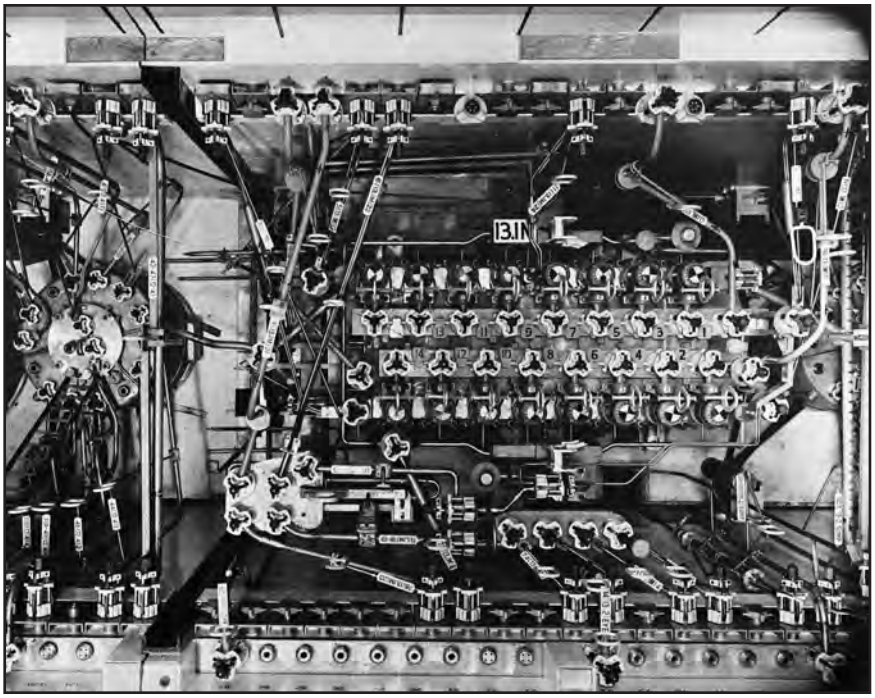
Process vessels and tanks were vitally important to the canyon operation, and there was no process vessel that was more important than the mixer-settler. There has already been considerable discussion of mixer-settlers, if only because they were so important to the Purex process, and were considered crucial right from the beginning. Here, they will be discussed again, with less emphasis on their function and more emphasis on the design issues and design history.

It might be recalled that Du Pont very early in the process decided on the use of mixer-settlers rather than columns because the shape of the mixer-settlers agreed more with their concept of the canyon design. It was also thought that they would be more compact and easier to replace.

It was originally thought that Purex would require 20 mixer-settlers to accommodate three cycles. After considerable research, it was found that the process would work adequately with just eight mixer-settlers in two cycles. These became three mixer-settlers of 16 stages, and one mixer-settler of 12 stages in each canyon of the canyon building, for a total of eight.

The three mixer-settlers in the first cycle extraction were Banks 1A, 2A, and 3A. In early 1951, it was thought possible to combine all three into one super unit, but later study suggested that the maintenance problems would be too great. In August of 1951, the mixer-settlers were standardized to two types: Type A, which had 16 stages and Type C with 12.[96]

Beyond that, the design called for stainless steel construction, multi-stage compartments, with counter-current flow. Agitation at each stage would be provided by an agitator-pump, and this design work done by KAPL, Blaw-Knox, TNX, and Du Pont's Design Division and Engineering Research Laboratory. Mixer-settler impellers were also studied, with testing done at TNX. The impeller vanes posed a problem that required some design work, and the speeds had to be varied by electrical generators for each bank.[97]



Mixer-Settler in situ, *1955, SRS Negative DPSPF 2320-97.*

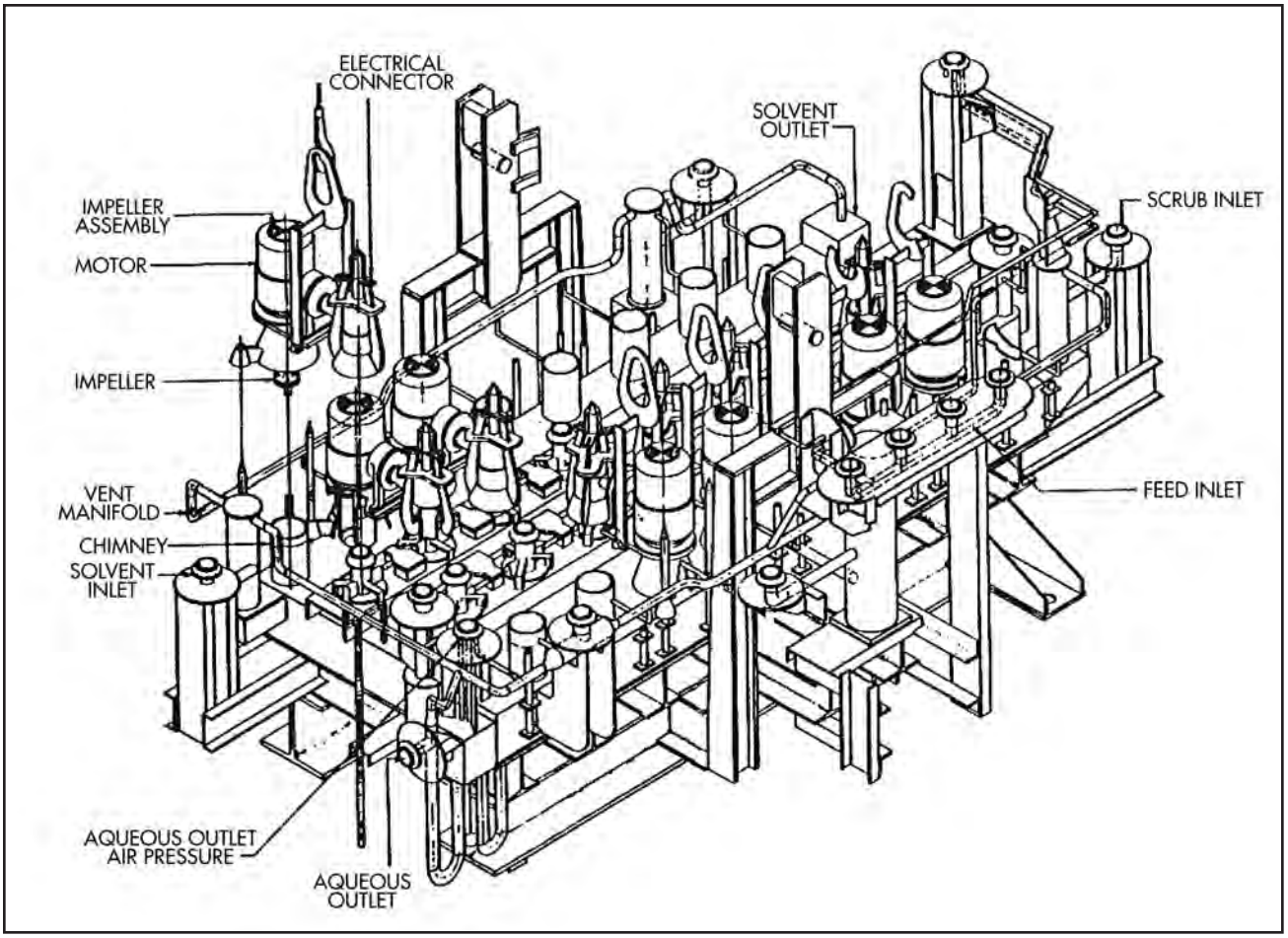
In March of 1954, Du Pont asked Blaw-Knox to find a way to lower the temperature of the feeds going to the 1A and 1D banks. This led to heat exchangers being installed for the feeds to Banks 1A, 1D, and 2A. This was considered a better solution than pre-cooling the feed before it was jetted into the mixer-settlers.[98]

The mixer-settlers were the most important consideration in the design of the equipment needed for the Purex process, but many other vessels had to be studied as well. Most of the basic specifications were based on those used at Hanford and later improved through use at Los Alamos, Oak Ridge, Argonne, or KAPL. Du Pont design groups were also involved in this work, with assistance from Blaw-Knox. More specialized equipment was worked up by American Machine and Foundry Company, Gibbs and Hill, Schutte-Koerting Company, Penberthy Injector Company, and Allstates Engineering Company.[99]

Early on, it was determined that all of the process tanks and vessels would be made of stainless steel to accommodate the acids used in the process. Standardized sizes had to be determined, as well as the methods of control. For example, the gallery feed tanks at Savannah River used gauge glasses, while Hanford had used scale tanks. Throughout the process, all vessel connections would be made through the top of the tank, to minimize leaks.[100]

The vessel that received the most attention, aside from the mixer-settler, was probably the dissolver. It was here that the solid irradiated materials had to be de-clad and then dissolved to make possible the rest of the liquid Purex process. The basic dissolver design consisted of two vertical stainless steel vessels, based on those that had been used at Hanford. The main improvement at Savannah River was the use of a mechanical device to insert the slugs through an opening into the dissolver. This was done by the "charger," which loaded slugs into the dissolver through a 12-inch opening. Designed and tested by American Machine and Foundry, the charger had a funnel-like hopper that was relatively simple and easy to use.

Process heat for the dissolver was also studied. Early on it was decided to use steam for the heat, rather than electricity. Given the radioactive environment in the Hot Canyon, steam was determined to be simpler to use and operate over the long haul.

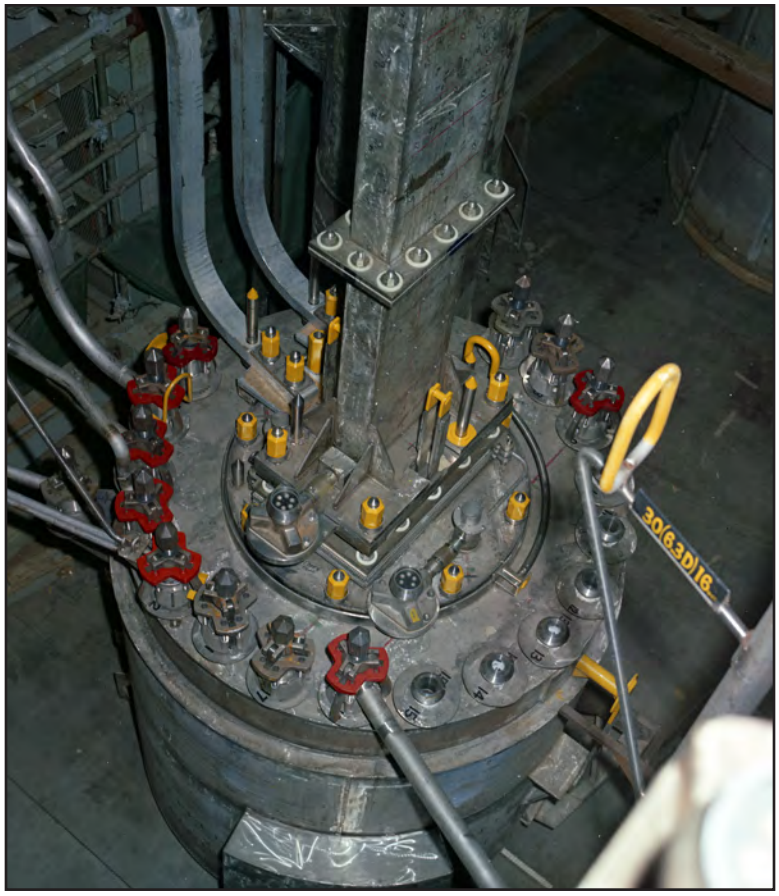


Type A (2B) Mixer-Settler Illustration. Source: 221-F Training Manual.

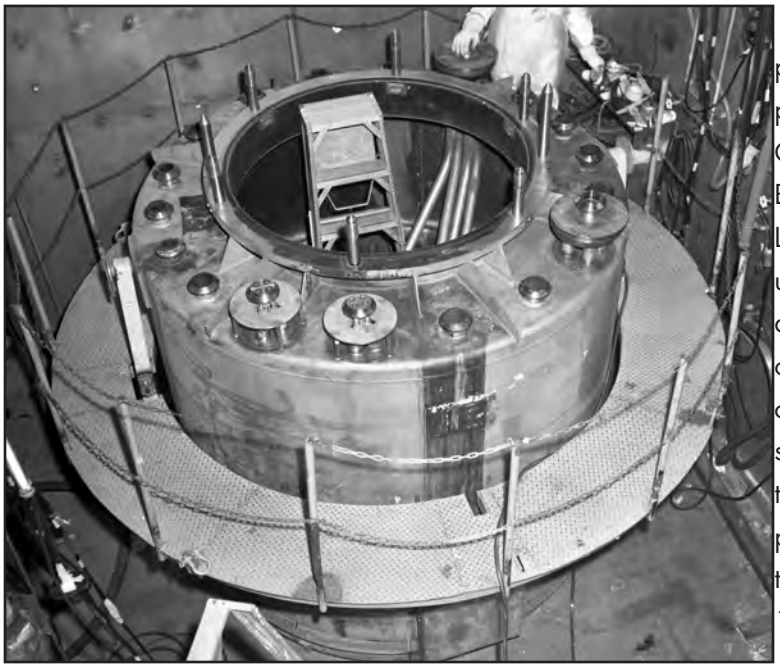
Savannah River also worked to control the off-gasses that resulted from the dissolver process. Research was done on a fumeless dissolver that would remove the inert gases from the radioactive gases, and limit those releases to the outside atmosphere. The original plans called for storing the off-gassing krypton and xenon in metal containers in large tanks designated "242-F," but the amount to be contained would have been too great and too costly. In December 1951, it was decided that these gases would be cleaned up in A-Line and then sent through the stack.

The task of capturing the off-gases was done by the Closure, which was effectively a conical lid that sealed the vessel and kept acidic gases from escaping. This closure lid was lowered into place by the crane after the dissolver had been charged with slugs. Once the process started, off-gases then went through an iodine reactor and filter and then to the 221-F A-Line absorber for processing and then through the fan house (292-F) and up the stack (291-F) if the amount was small and safe enough.[101]

The "iodine reactor" was an important element in the dissolver process. In April 1951, very early in the design work, it was decided to use a silver nitrate reactor, just like the one that had been recently installed at Hanford. Silver nitrate was found to be 99 percent effective at removing radioactive iodine from the off-gasses generated by



Electrolytic Dissolver. December 7, 1966, SRS Negative DPSPF 11624-12.



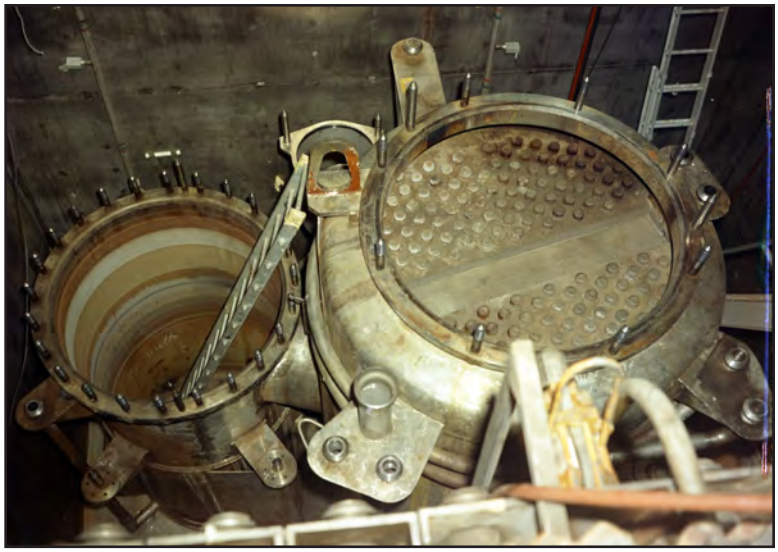
Batch Evaporator. April 11, 1968, SRS Negative DPSPF 12610-3.

the dissolver.[102] This saved having to store a huge quantity of iodine gas.

After the dissolver, the dissolved material went to Head End, where there were two centrifuges employed as part of the process. These centrifuges were stainless steel, basket-type machines, like the Bird Machine Company's design that had been used at Hanford. This was tested at TNX and improved before being installed at 221-F.[103] Here, it might be worth mentioning that these Head End centrifuges were not the same as the "Centrifugal Contactor" centrifuges that were installed in 221-F as part of the improvements to the Purex process that were done in the 1960s. These centrifugal contactors were often called centrifuges, but they should not be confused.

Another aspect of the Head End treatment called for the use of evaporators. These reduced the volume of materials to be processed through the rest of the Purex process. These evaporators were tested at Oak Ridge, with other data coming in from Brookhaven National Laboratory and Mound Laboratory. The design of all the evaporators used at Savannah River came under scrutiny after the TNX evaporator explosion that occurred on January 12, 1953. In the case of the Head End evaporators, some small changes were made, but the basics of the process were considered sound. As a precaution, the steam pressure was reduced to keep the operating temperature below 130 degrees Celsius. This reduction made it necessary to have two 1CU evaporators rather than one.[104]

Decanters were another aspect of the process, essential in the solvent recovery systems, and in the full separation of the organic and aqueous phases during re-run. Design work for the decanters was done at KAPL, Oak Ridge, and by Blaw-Knox and Du Pont, with the final results tested at TNX.[105]

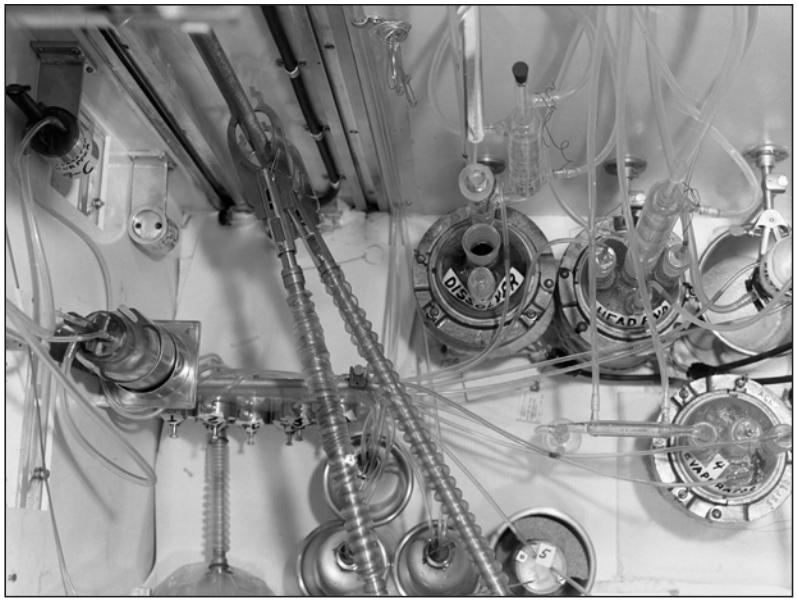


Continuous Evaporator. November 11, 1965, SRS Negative DPSPF 10770-1.

Another important piece of equipment, this time at the end of the Purex process, were the ion exchange columns, which were used to concentrate the plutonium that came out of the Second Cycle and make it ready for the B-Line. For the most part, this meant reducing the amount of the nitric acid that was still in the solution. The initial idea for this part of the process was to use evaporators, designed by Blaw-Knox in 1951 and tested at Oak Ridge and KAPL. Another option was to use ion exchange columns to achieve the same effect. Both pieces of equipment were possibilities by the end of 1951, and a decision had not been made either way until the TNX explosion of January 1953. Just two months later, it was decided to drop the evaporators and go with ion exchange for the reduction of the plutonium solution.[106]

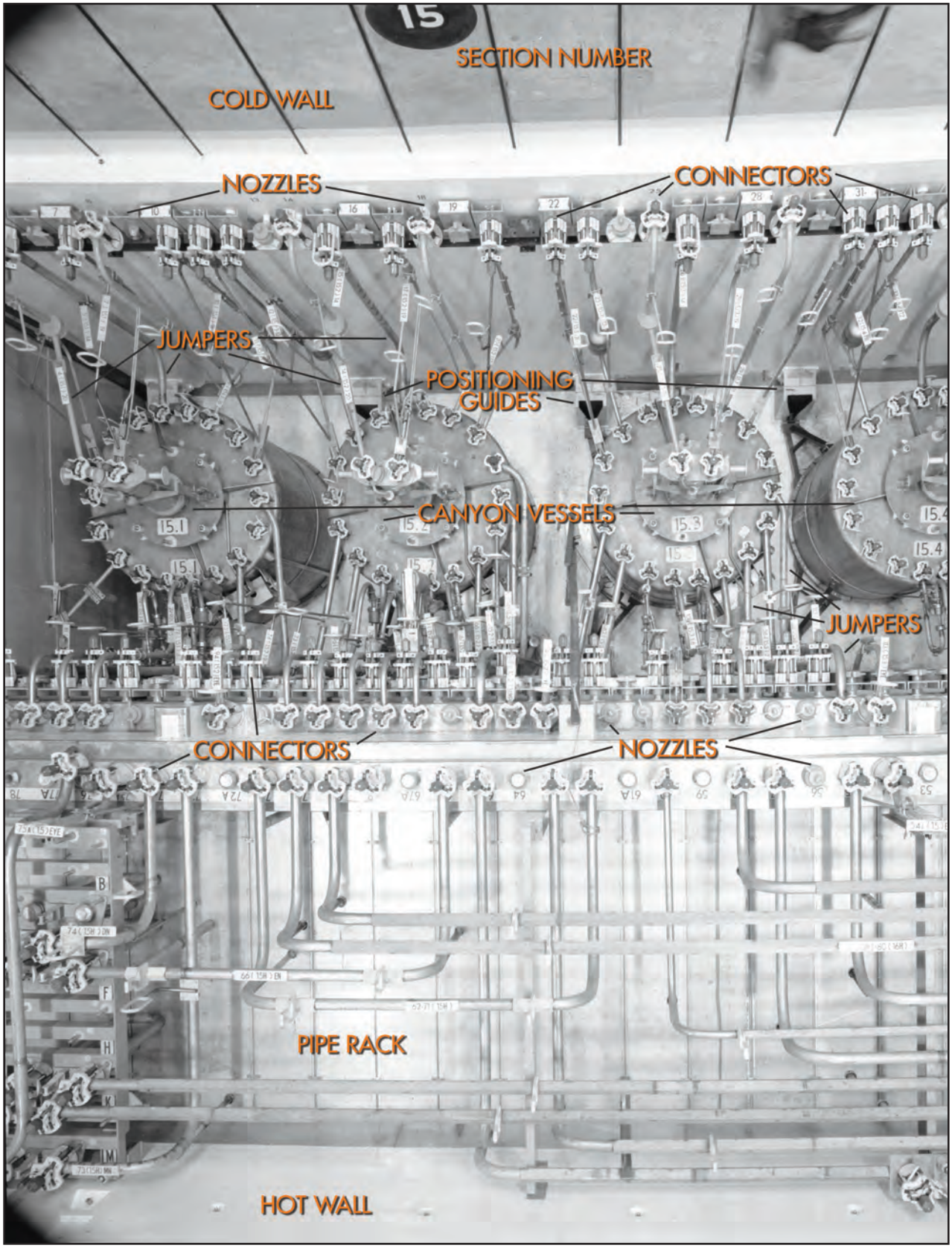
The ion exchange columns (cation exchange columns) that were used to concentrate the plutonium solution were first developed at Oak Ridge. They were long tubes that contained small beads of resin that contained exchangeable hydrogen ions. After the plutonium solution had its valence adjusted, the plutonium ions would adhere to the resin as the solution passed through. Then sulfuric acid is passed through to remove any residual uranium. Sulfamic and nitric acids then go through to extract the plutonium from the resins, resulting in a concentrated solution of plutonium.[107]

There were many other pieces of equipment used during this period, and usually they had a small prototype that was tested in a pilot plant. The smaller, more experimental pieces were often the subject of photography more often than the larger pieces that were actually installed. One example was the "cave dissolver," with a miniature dissolver and head end tanks, set up in the High-Level Caves of the Savannah River Laboratory.



Miniature Cave Dissolver, March 6, 1958, SRS Negative DPSTF 1-1464.

Putting the Pieces Together...



Section 15, Hot Canyon, with Equipment Labeled. October 20, 1954, SRS Negative DPSPF 1465-69.

All of this gives the reader some idea of the difficulties involved in designing the whole of the Purex process. That process has now been examined from different aspects, first through the construction of the canyon buildings, the use of sections and modules in the building, followed by the various pieces of equipment and their connections to the piping within the building. Just before start up, Du Pont photographers documented every step of the process, module by module, and section by section, and this information is still preserved on glass plate negatives stored in the SRS Photography Archives and in the SRS Curation Facility. To see the whole thing put together in these early photographs is to be reminded of the complexity of the Purex process, and what a daunting task it was to assemble it in the canyon buildings.

Instrumentation and Control

The instruments used to regulate the Purex process required a great deal of research and were ultimately developed by Blaw-Knox and Du Pont's Engineering Department. Much of the testing occurred at TNX, and there were problems almost every step of the way that had to be solved. Some of the major issues included: the Fireye detection system, temperature monitoring, the centrifuges, monitoring of the radiation in the canyons, regulating the dissolvers, the mixer-settlers, the off-gas system, the evaporators, decanters and even the feed tank galleries.[108]

All of these processes had to be controlled, and in most instances this was done by operators in the huge control room located on the fourth level in the central portion of the building. This control room, also referred to as the "central instrument control office" or the "control gallery," contained a centralized instrument control panel that was 210 feet long and 15 feet wide.[109] Much of this work was coordinated through the Dispatcher's Desk, located in the canyon control room. The many aspects of the control system were examined there. The dispatcher could even limit access to the control room itself, since he had the ability to seal the control room doors, if necessary.[110]

Much of the work done in the control room was documented on what was called the "Canyon Scroll." This large scroll, set up on rollers, was situated on a control room wall. It documented information merged together from various sources in the control room. The scroll was kept updated and served as a record of the decisions made in the control room.[111]

If visual contact had to be made of the canyons from the control room, this was done using a periscope very much like that used on a submarine, except that this one also contained heavy shielding. This was the best that could be arranged in the early 1950s.[112] Television monitors, now standard, were introduced later.

An essential part of the control process was done in the sample aisles, where samples were drawn from the process itself and examined for content in the Analytical Laboratory in Building 772-F. Without this work, there might be no reliable feedback on the process until it was too late to make any changes. The Hot Canyon Sampler, designed to pull this material from shielded positions in the Sample Aisle, was an important piece of equipment to ensure control of the process.

There were five types of samplers used in the canyon buildings: hot samplers, warm samplers, cold feed samplers, air samplers, and screw-type samplers. Most of these were modeled after similar pieces of equipment used at Argonne, and improved by Du Pont's Engineering and Research Laboratory, Oak Ridge, and Blaw-Knox. The

Dispatch Desk in the Main Control Room, May 4, 1954, SRS Negative DPSPF 1156-2.

Instrument Wall in the Main Control Room, May 4, 1954, SRS Negative DPSPF 1156-1.

earliest hot sampler was a serum bottle, a hypodermic needle and a Hanford-style "sample cup." A number of changes were made to the process over time, and special sampling carts were designed to facilitate the trek from 221-F to the Analytical Lab in 772-F. These sample carts had lead containers called "door stops," designed to hold the samples.[113]

Working in the Hot Canyon sample aisle on Level 3 was considered one of the most dangerous jobs in Separations. If the needles used to extract materials from the process came into contact with skin or, worse, pierced the skin, the sample-taker would come into direct contact with radioactive materials. This was to be avoided at all costs. Training and good dress-out practices became essential in this work area.[114]

Communications, Lighting, and Fire Prevention

The communication system established for 221-F was a dedicated dial-type telephone system. For security reasons, it was kept separate from the rest of the regular Bell system used at the plant. There was also a safety alarm system, equipped with loudspeakers, with connections to the building and area dispatcher. In F Area, the safety alarm system was controlled from 701-1F, the security and guard house.[115]

Within the canyon buildings, communication between the Hot Canyon supervisor's office and the Hot Canyon crane operator was an issue of study. At Hanford, this communication had been done with simple telephone cable, but this had not worked out well, and the distances to be covered at Savannah River's canyon buildings were even greater. Blaw-Knox and Du Pont engineers visited U.S. Steel's Homestead Plant in Pittsburgh to examine the carrier current-type system used there. This formed the basis for what was used at Savannah River. For the Hot Canyon, two high frequencies were used, and put into 60-cycle power feeders; two different frequencies were established for the Warm Canyon.[116]

Lighting in the canyons was given considerable thought as well. As already mentioned, the only light in the Hot Canyon after start-up came from fixtures on the bottom of the crane. The Warm Canyon did have accessible

ceiling lights. These were mercury-vapor and incandescent. Other lighting was designed to accommodate space size and use. The control room and most of the offices were equipped with fluorescent lights.[117]

Even though the canyon buildings were constructed of concrete, there was still the danger of fire from the Purex process itself. This had not been a major concern at Hanford, since the materials used in that process were not particularly flammable. It was a problem at Savannah River, since the Purex solvent could burn. Ventilation helped cut back on this danger, as did the use of explosion-proof motors in the canyons. The motors were also painted with "Amercoat" to reduce corrosion and the risk of short-out fires. The fire detection system also had to be studied. Since the canyon buildings relied on an "open" design rather than a cellular design, it was decided to use modulated photo radiation for the basic fire detection system, rather than thermal radiation, which could only discern large fires.[118] In the case of fire, there were spray pipes and headers set into the concrete above the canyon vessels and the rack.[119]

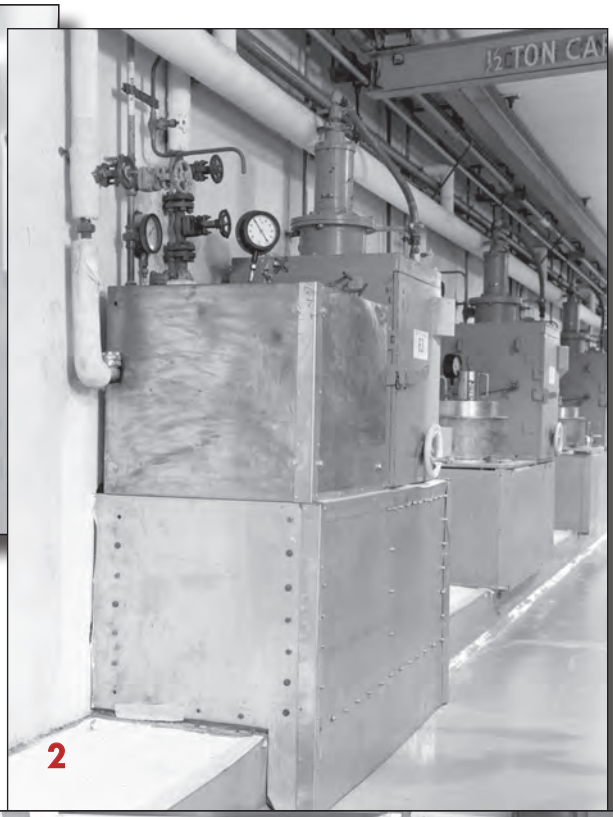
Air Cooling and Ventilation

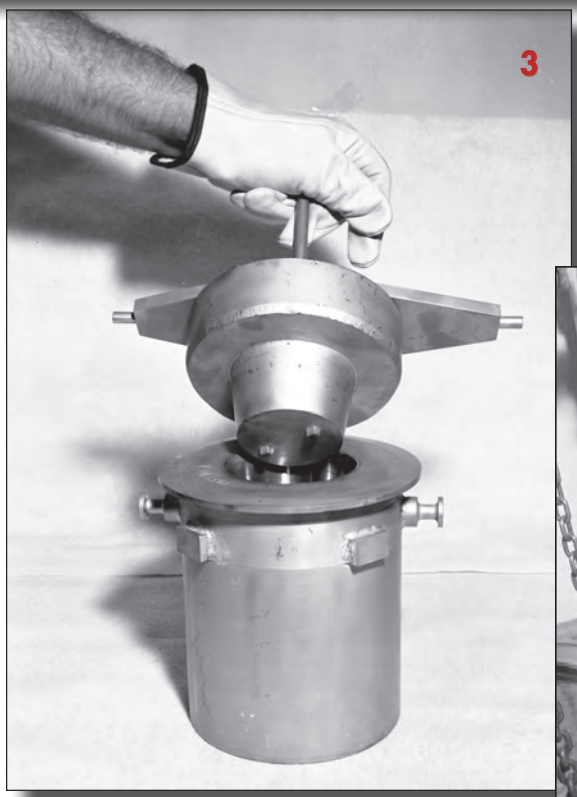
Heating and cooling were also issues. Studies were conducted to determine the upper heat limits for the Purex process. This was of special concern for the solvent, which was assumed to be the most sensitive solution in the system. It was soon discovered that the best Purex results occurred at 105 degrees Fahrenheit, measured at the time of exit from the process. It was discovered that the temperature could go up to 115 degrees F. for short periods at the height of the summer, but should not exceed that level. To control the temperature would require either insulation or air-conditioning (or "refrigeration," as it was referred to in the early 1950s). For practical reasons, it was decided to go with air-conditioning. Refrigeration units were placed outside the building to cool the intake air during the summer. The temperature was measured by thermocouple-actuated temperature monitors placed throughout the building.[120]

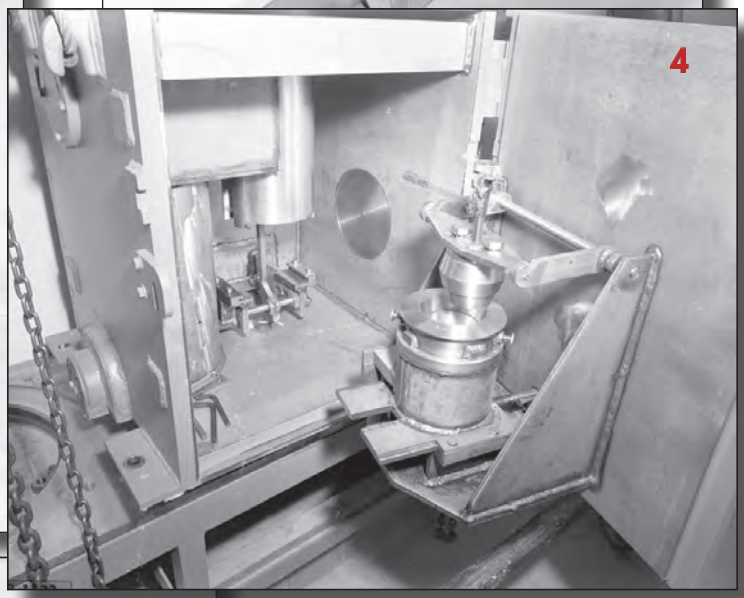
There were actually separate ventilation systems for the two canyons and the personnel areas in the center portion of the canyon buildings. This was done to prevent any possible air-borne contamination crossing from one to the other. Air pressure differences were also maintained to ensure that air always flowed toward contaminated canyons and away from the personnel areas in the center.[121] To maintain air purity for the personnel areas, the canyon building was divided into four zones (Zones 1-4). The most contaminated areas, the Hot and Warm canyons, were identified as Zone 4. This had the lowest air pressure. The areas in the center of the building were Zones 1 through 3, with the most commonly visited personnel areas being Zone 1.[122] Zone 1 always received the freshest air.

Originally, the ventilation systems in the Hot and Warm canyons were to have been exactly the same, but a revision was made to Hot Canyon ventilation in the middle of 1954. New caustic scrubbers and a caustic circulation tank was added to help remove the ruthenium and iodine from the Hot Canyon ventilation header, and there were a few other changes made to the headers and filters.[123]

Sampling the Process...







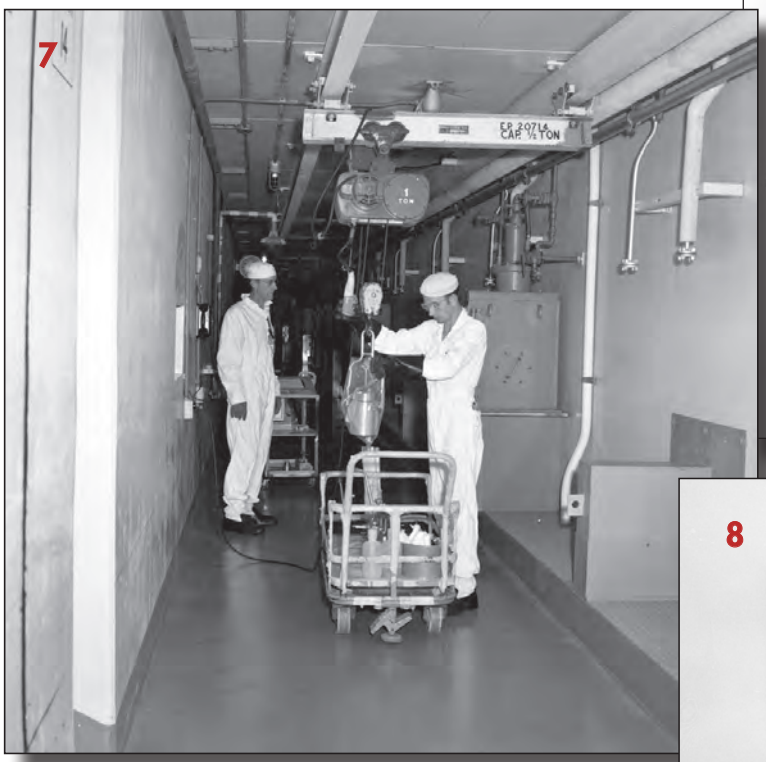
1. Hot Sample Aisle, September 20, 1954, SRS Negative DPESF 1233-20.

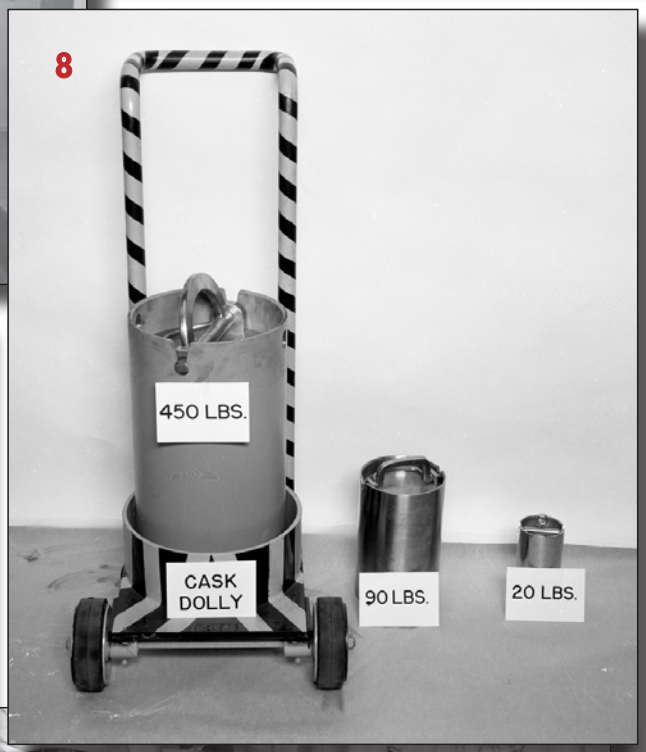
2. Warm Sample Aisle, Many 4, 1956, SRS Negative DPSPF 3282-1.

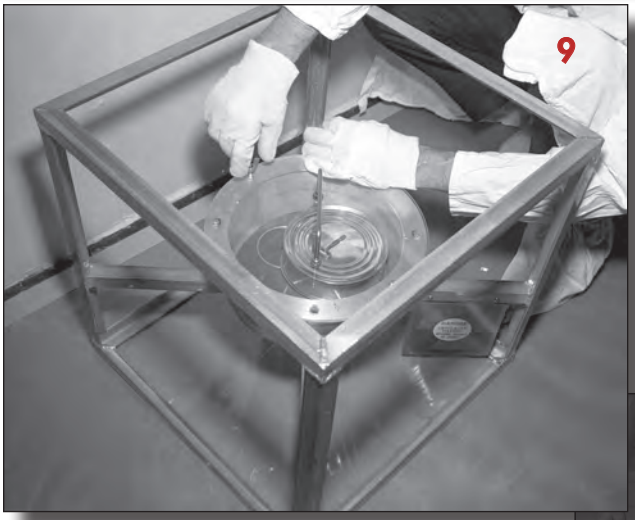
3. "Doorstop" Sample Container, April 6, 1961, SRS Negative DPSPF 7675-2.

4. "Doorstop" in Sampler, December 4, 1954, SRS Negative 2-772-2.

5. Warm Sample Containers, March 6, 1958, DPSTF 1-1447.







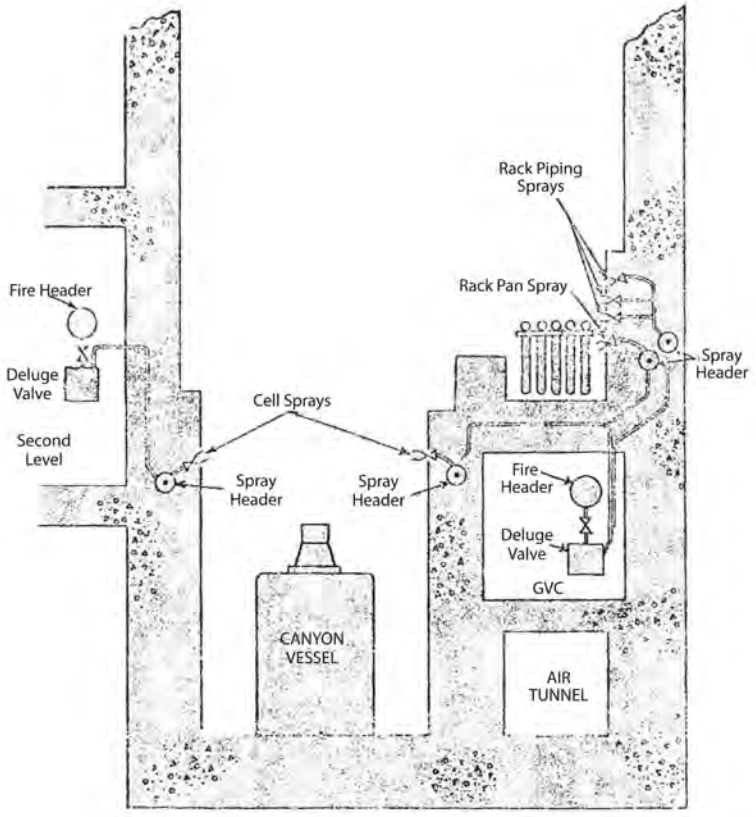
6. Close-up of a Hot Sampler, July 19, 1958, SRS Negative DPSPF 7005-19.

7. Workers placing samples in cart for transport to the lab, circa 1956, SRS Negative DPSPF 4002-22.

8. Sample Casks or "Pigs" and Dolly, March 6, 1958, SRS Negative DPSTF 1-1449.

9. Close-up of "Birdcage" and "Tuna Can," March 20, 1963, DPSPF 8927-69.

10. Workers carrying "birdcage," March 20, 1963, DPSPF 8927-19.



Canyon Spray System, Typical Section. Source: 221-F Training Manual, Figure 13.

To push the air around the canyon building, there were three compressor rooms for ventilation and air-conditioning. There were other rooms for blowers, filters, and heating coils. Exhaust blowers in the 292 fan house also helped pull air out of canyon buildings.[124] The movement of air was too critical for personnel safety to be compromised by any possible power failure. For that reason, auxiliary emergency power was provided by 600kW diesel generators provided by Gibbs and Hill and located in Section 1.[125]

There were air exhaust tunnels that extended from canyon to the exhaust complex, which was comprised of the 294 sand filter, the 292 fan house, and the 291 stack. There were also different tunnels from the personnel areas and the canyons. The central portion of the building had its own vent to the central air filters and then to the stack, while the canyon air always went to the sand filter before going to the stack.[126]

Waste Lines out of Canyon Building

Part of the original layout of the Separations areas was based on canyon buildings being placed on the highest available ground and the waste tanks being situated at a lower elevation. This would allow the liquid waste stream from the canyon building to flow to the waste tanks completely by gravity.[127] For this to happen, there had to be process waste lines had to connect the canyon buildings with the 241 waste tanks.

To collect the waste that left the canyon building, there were four 10-inch waste headers just beyond the east wall of the canyon building. These headers were encased in concrete and buried below ground. The pipes that exited the building passed through the hot wall on the east side and then turned 90 degrees to go into the ground to the headers. These exposed sections of pipe were enclosed by shielding that could be moved as needed. The shields were known as "mummy cases." The headers were then connected to buried 3-inch stainless steel lines that carried the waste to the 241 tank farm.[128]

PUREX PROCESS IN 221-F

Prior to this section of the report, the Purex process has been discussed. Separately, the canyon buildings at Savannah River have been discussed, but there has been relatively little discussion of how the Purex process actually fits into the building, section by section. Some of this is by design. It was easier to explain the process without getting into the details of the building, and it was easier to explain the building shape and compartmentalization without having to discuss the process at the same time.

Construction workers work on the canyon exhaust tunnel leading to 292-F, September 26,1952, SRS Negative 2-331-1.

This approach also conformed to security concerns dating back to the 1950s, where information of this nature was highly compartmentalized and restricted. The major research source from that era, the Du Pont Engineering and Design History of the Savannah River Plant, Volume 3, which dealt with the engineering and design issues of the Separations areas, does combine this information, and this was almost surely not an oversight.

The most that Volume 3 gives the reader is an overview of the Purex process as it occurs in the canyon buildings. The irradiated uranium slugs are brought over from the reactors, after which the aluminum cladding is dissolved from the uranium slugs, after which the metal itself is dissolved into a mixture of uranyl and plutonium nitrates and various fissions products. After dissolving, the metal solution goes to head end treatment, where 90 percent of the zirconium, niobium and iodine are removed. After that, the uranium is separated from the plutonium, and the two elements go in different directions for different processing. The plutonium nitrate, the most valuable of the two solutions, is purified and concentrated before being turned into metallic buttons in the B-Lines. The uranyl nitrate goes to the A-Line to be transformed into uranium oxide.[129]

Based on this description and on others provided in this and similar sources, the whole process could be characterized as a slow moving of process materials down the canyon, moving from south to north in the Hot Canyon. The direction of flow appears to be less obvious in the Warm Canyon side, but it could still be described as from north to south—back to the B-Lines and the A-Line. During this progression, auxiliary streams were flowing into the process and flowing out of the process at almost every step of the way. Some of these auxiliary processes were: solvent recovery, re-run, various evaporation steps, and waste concentration. The Purex process generated large amounts of waste and in different forms– liquid, semi-liquid, and gas– and all of this has to be moved out of the way and either processed immediately or stored for future processing.

There are at least two diagrams that provide some information on the internal arrangement of the Purex process within the various sections of the canyon buildings. The more general of the two is found on page 372 in *Savannah River Site at Fifty*. A more specific treatment is provided in a training manual for 221-F, believed to date to around 1975.[130] The diagram here is identified as Figure 3. Neither one is necessarily specific to the process as it was carried out in the 1950s.

Based on these two sources, and some of the verbal descriptions provided in Volume 3 of the Engineering and Design History, it is clear that the dissolving process is found in Sections 5 and 6, with a waste stream leaving that area for the 241 waste tanks. The main part of the process, and certainly the parts that were most radioactive, were located further north on the Hot Canyon side. The centrifuges were found in Sections 10 and 11, but it is not clear whether these are the Head End centrifuges or the centrifugal contactors added in the 1960s. Bank 1A is found in Section 13, followed by the 1B and1C banks. MPPF (Multi-Purpose Processing Facility), located in Sections 17-18, was not part of the original arrangement in the 1950s, but was a later addition. The Warm Canyon was largely devoted to various auxiliary banks, feeds, runs, and evaporators, and this appears to have always been the case.

The diagram in *Savannah River Site at Fifty* is perhaps more useful for our purposes. Here the information, while general and not very specific, is based on unpublished notes provided by Donald Orth, who would certainly have known the process. Here, dissolving, venting, high activity waste processing, head-end, and First Cycle, were all carried out on the Hot Canyon side. As soon as materials could be pulled out of the process for purification and concentration, then this was done on the Warm Canyon side. The Warm Canyon side included, from north to south, the Second Cycle uranium, solvent treatment, Second Cycle plutonium, and low activity waste processing.[131]

Solvent recovery and treatment were essential for the maintenance of the solvent. Re-run stations were also essential to maintain purity throughout the process. High activity waste was evaporated down to manageable volumes in the Hot Canyon. These included dissolver wastes, head end condensate, and the 1AW stream from the 1A Bank. Low activity waste was evaporated down in the Warm Canyon. This material came from 1DW run tank, the 2AW run tank, and column waste tanks.[132]

The evaporation of laboratory waste led to an interesting change made to Section 18 on the Warm Canyon side of 221-F. Early in 1953, after the TNX evaporator explosion, an Evaporator Safety Program was set up, which in turn led to the set-up of a laboratory waste evaporator to handle waste from the 772-F Analytical Lab. This required extra handling equipment, since the Warm Canyon crane could not reach the last section of the building. As a result, a small electric monorail hoist and trolley were placed on a beam suspended from the canyon roof to service that section.[133]

While the layout of the Purex process within the canyon building might be rather vague, it is sufficient to provide an idea of how the process was arranged in the Hot and Warm canyons. It should also be remembered that the process was changed from section to section, and certainly from module to module, as the process itself was altered and as equipment was changed or replaced over time. In many cases, there was no established

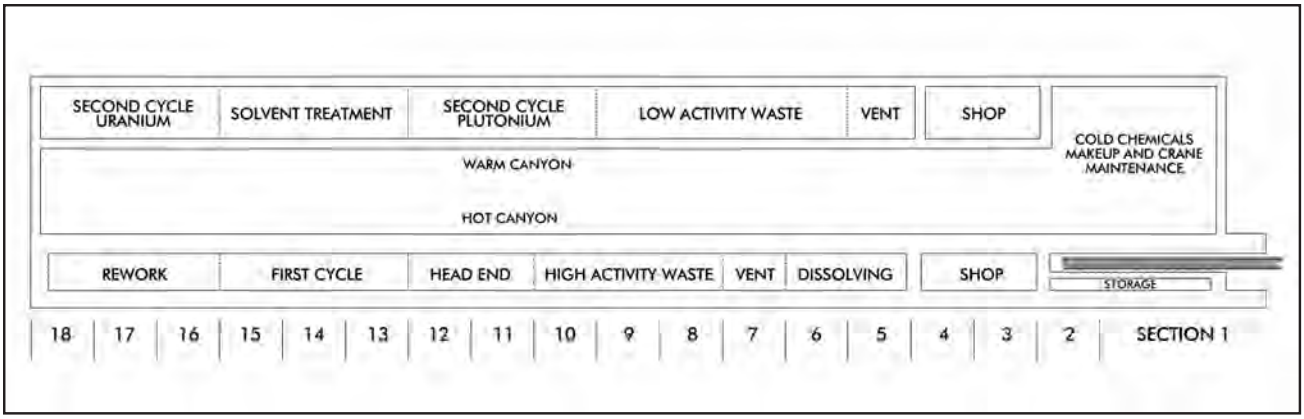


Diagram Illustrating the Arrangement of the Purex Process within the Canyon Building. Source: Savannah River Site at Fifty, *Reed et al.*

or required location for each stage of the process. Both the building and the process were designed to be flexible, and canyon operators took advantage of that flexibility. It might not be possible to tie the process down to individual sections and modules that were always the same over time. It is certainly not essential to our understanding of either the process or the building.

B-Line

The two products that came out of the Purex process in the canyon buildings were plutonium and uranium, element B and element A. Both elements were finished—transformed into solid forms—in their own processing lines, known as B-Line and A-Line. The B-Lines, often called "Button Lines," were actually located inside the canyon buildings (two B-Lines in 221-F and one in 221-H). A-Line was located in a building adjacent to 221-F. Because plutonium was by far the most important of the two materials produced in the canyon building, it will be discussed first, followed by A-Line.

When the Separations areas were first started up in 1954-55, there were three B-Lines, two in 221-F and one in 221-H.[134] These B-Lines were located on the third and fourth levels of the 221 buildings, within the area of Sections 1 through 4. Even though B-Line was separate from the rest of the Purex process, it still had access to many of the same facilities and feeds.[135]

B-Lines in 221-F

Most of the operations in B-Line were performed in glove boxes and cabinets, some of which were 50 feet long. Small amounts of plutonium material were moved from station to station, often by hand but also mechanically.[136] The basic parts of the B-Line were the Final Concentration Room, the Final Process Rooms, the Feed Prep Room, the Waste Recovery Room, and the Feed Tank mezzanine. There were also associated offices, a vault, a health physics storage room, and a heating and ventilation room.[137]

The basic B-Line process began with receipt of the plutonium nitrate solution from the Purex process, and ended with plutonium metal for use in the nuclear weapons program. Speaking in general terms, the basic steps involved were: concentration, precipitation, fluorination, and reduction. The first step in this process was concentration and clean up, which was needed to reduce the volume of the original stream and to purify it from contaminants.

What followed next was precipitation with peroxide, sometimes called "liquid processing," as the plutonium nitrate was changed over to plutonium peroxide by adding hydrogen peroxide to the plutonium nitrate solution. Fluorination followed, with fluoride added to the plutonium peroxide to make plutonium tetrafluouride. This was then reduced to metal form.[138] This basic process, divided into the four steps, was called the "peroxide process." It was the original method used in all the B-Lines.[139]

The peroxide process was developed at Los Alamos.[140] In fact, the Savannah River B-Line process was similar to what was used at Los Alamos for the very first B-Lines, which were up and running there by the end of 1951. The Los Alamos facilities were not set up for full production. There were many glove ports and little mechanization. Most materials were moved by hand.

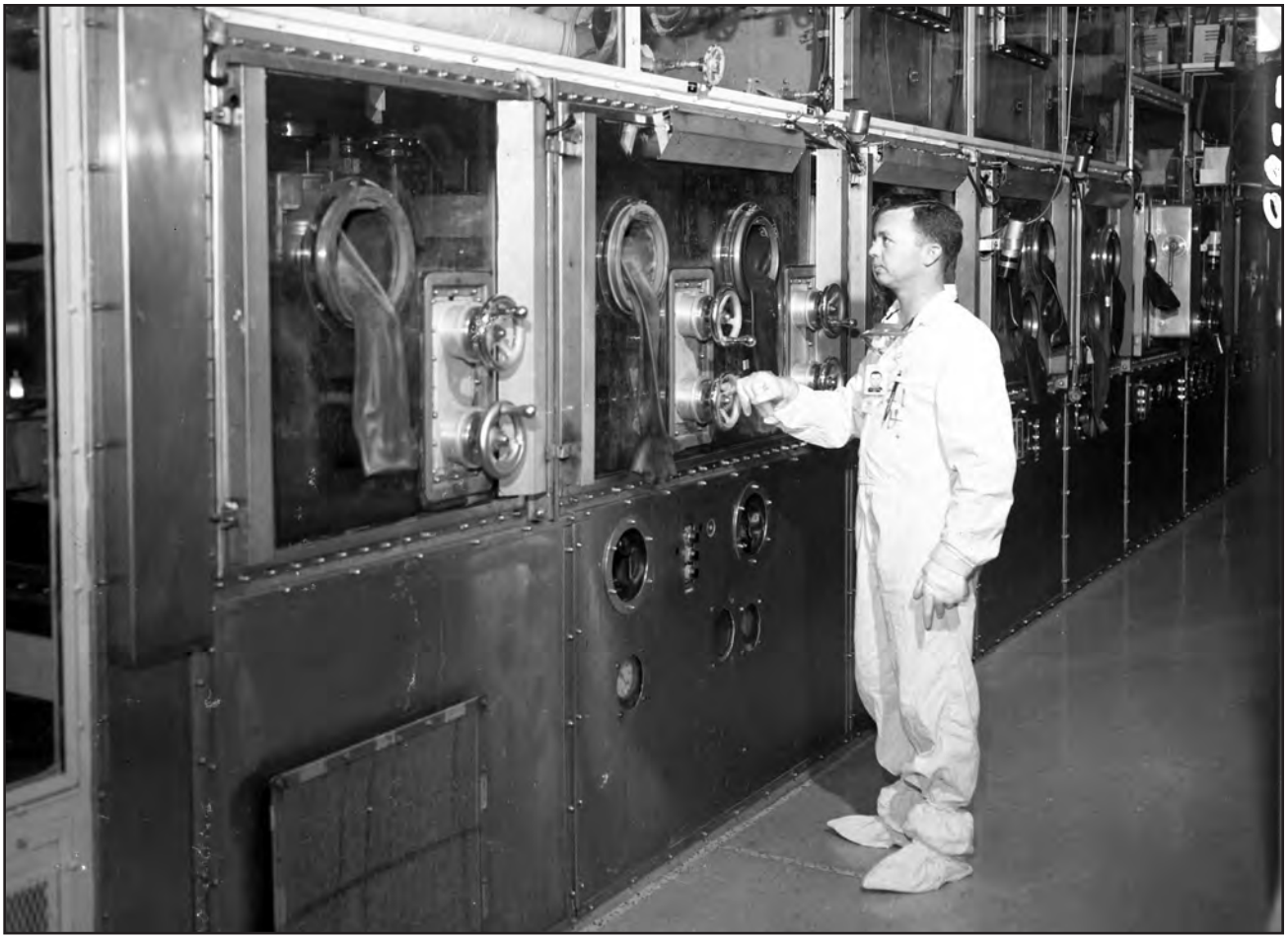
Du Pont reviewed the Los Alamos arrangement, as well as Hanford's "Remote Mechanical Line," and selected the parts that promised the least exposure to operators and other workers. The overall design was then compiled by the Mechanical Development Laboratory, with details supplied by Blaw-Knox and Allstates Engineering. Du Pont made the general equipment and cabinets in their Wilmington shops.[141]

According to the original designs, the first phase of the plutonium conversion, the concentration of the plutonium nitrate solution, was to be achieved through evaporation, the time-honored method that had been used at Hanford. The new three-stage evaporators had been designed by Blaw-Knox, with input from Fansteel Metallurgical Corporation, with features so that plutonium nitrate crystals would not form on the heating elements.[142]

These evaporators had already been ordered when TNX was rocked by the explosion of one of its evaporators on January 12, 1953, due to an unexpected build up of organic material in a heated solution. The use of evaporators was re-examined throughout the site. Many were moved to safer locations, or replaced if possible by other pieces of equipment. In the case of the B-Lines, evaporators were replaced by ion exchange columns (cation exchange columns), which was the method preferred at Oak Ridge.[143]

The cation exchange columns used at the B-Lines were first developed at Oak Ridge National Laboratory by D. C. Overholt, F. W. Tober, and Donald A. Orth, among others. Once brought to Savannah River, they were modified by Tober and G. W. Burney. This became the primary piece of equipment for this part of the process at all of the B-Lines, and it remained basically unchanged for the next 50 years. There are few pieces of equipment at Savannah River with that sort of track record.[144]

With the addition of the ion exchange column, the first iteration of the Savannah River B-Line process was basically established. The plutonium nitrate solution was concentrated in the cation exchange, followed by precipitation with hydrogen peroxide. This forms plutonium peroxide, which was then filtered out in a filter boat. This created a cake of plutonium peroxide. While still in the filter boat, this cake went to the conveyor belt, which was the beginning of the Mechanical Line that dominated the rest of the process. The plutonium cake was dried in the filter boat on its way to a furnace, where the solution was converted to plutonium tetra-fluoride via "hydro-fluorination," which was the addition of hydrogen fluoride and oxygen. Reduction to plutonium metal was achieved by adding calcium and/or iodine. This mixture was then sent to the "bomb," a pressure chamber



B-Line Worker and Glove Boxes, March 3, 1963, SRS Negative DPSPF 8927-68.

with a magnesium crucible. The bomb went into a reduction furnace, where the air was replaced by helium, then heated to form metallic plutonium. When the crucible was broken, the resulting form was called a "button," although it really looked like a hockey puck. The button was then bathed in nitric acid to remove any remaining contaminants and was packaged in a container that resembled a tuna can. These containers would then go to the 217-F Storage Magazine, eventually to be shipped off-site. The crucible and any slag went to the recovery system, located on Level 4.[145]

The "skull dissolver" was an important piece of equipment added to the B-Line waste recovery system as early as December 1951. Shaped like a funnel and lined with platinum, the skull dissolver was designed to handle waste that was already basically high-quality plutonium, free from impurities. This to keep clean plutonium scrap from having to go back to full-fledged dissolver to be re-worked.[146]

B-Line in 221-H

The B-Line facilities in H Area were basically the same as the two lines in F Area, but there were some differences. Before 1954, plans for the B-Line in 221-H were identical to those being prepared in 221-F, except that there

would be only one B-Line, not two, and there would be no skull-dissolving facilities. After 1954, some other modifications were made. Improvements were made to the cabinets and piping arrangements, and the waste recovery system was eliminated altogether. It was decided to transfer that material over to 221-F for processing, rather than having a second facility in H Area.[147] Also, because B-Line in H Area went into operation after F Area, small improvements were made to the peroxide process that helped make the B-Line in H Area more effective than those in F Area.[148]

B-Line Equipment

The cation exchange column was perhaps the most prominent piece of equipment in the B-Lines, but there were many others. B-Line was a "glove box facility," and every step of the peroxide process had its required set of equipment, usually encased in a glove box or a cabinet.[149] In most cases, these pieces of equipment had been perfected and used at Los Alamos, Oak Ridge, or Hanford, with details tweaked by Du Pont engineers. The basic list of the B-Line equipment included: precipitators, filter boats, conveyors, furnaces, a mixer-dumper, pressure chambers, dummy bombs, cutting units, end dumpers, separation stations, sampling and weighing facilities, waste recovery facilities, waste solids dissolver, counter-current scrubber and stripper, reflux condenser, iodine scrubber and trap, and skull dissolvers. The separation station, where the plutonium button was separated from the crucible, was a manual operation that used glove-ports. This was done to avoid the problems that were experienced at Los Alamos when they tried to mechanize the procedure.[150]

Safety was a major concern in the B-Lines, since work was being done on a material that would go directly into a weapon and always had the potential for going critical. The vessels, most of which were made of stainless steel, were kept small, with 7-inch diameter or less, to hold down the danger of criticality. Corrosion was always an issue, especially with the use of hydrogen fluoride, nitric acid, and sulfuric acid. Non-porous stainless steel was common, but so were even more expensive materials, such as platinum. Shielding was given special consideration, especially around the cation exchange columns. Radioactive toxicity was kept to a minimum through the use of glove boxes, cabinets, and an effective ventilation system. Cabinets in particular were considered a potential health hazard, so it was essential to maintain negative air pressure in them at all times.[151]

An important distinction in the B-Line process was "wet" and "dry." Equipment was usually segregated into one or the other category, usually wet cabinets or dry cabinets, referred to as "W.C." or "D.C." Wet cabinets were for liquid processing, usually done remotely through safety glass. Dry cabinets were for working with the solid forms, usually through glove ports set in plexiglass, positioned on frames three feet above the floor. Wet cabinets included the final concentration cabinet and the alternate coupling feed tank cabinet. Dry cabinets included the vessel-receiving cabinet, the waste-receiving cabinet, and the skull-dissolving cabinet, among others.[152]

Building 221-H: the Differences with F Canyon

From early in the planning stage, it had been determined that both canyon buildings would make the same materials—taking natural uranium slugs irradiated in the reactors and processing them for the recovery of

plutonium and uranium. The B-Lines would finish the plutonium using the peroxide process. Both basically used the same plans, each had 18 sections, four modules to a section in the process portion, and all were the same size. The F Canyon was built first, while the H Canyon building followed, with small changes made along the way, based on what was found to work best in F Area.[169]

While relatively few changes were made to the building itself, there were some changes made to the Head End equipment, the high-activity waste equipment, and solvent recovery.[170] There were major changes made to H Area outside of the canyon building, and this caused some delays. Speaking about the design changes to H Area, Bob Romine stated that frankly, "we couldn't get the place built." There were so many design changes coming from F to H that, "they finally closed it down for a year and a half" until they got the plans finalized.[171]

As it turned out, H Area was more sparse than F Area. As already mentioned, most of the unique buildings required for Separations were located in F Area. These included the 717-F Mock-Up Building, the 723-F Laundry, the 772-F Analytical Lab, the 217-F Storage Magazine, and A-Line. By comparison, the 221-H building was almost alone in H Area at the conclusion of Project 8980 (Figure –; Map of H Area, c.1956; DPED3:10).

At the end of Project 8980, there were only four waste tanks finished in H Area, versus the eight in F. Too much significance should not be made of this, since clearly the number of waste tanks in both areas were going to increase in the years to follow. In fact, four more waste tanks were added to the original four in H Area, with construction beginning as early as 1955.[172]

Despite the general paucity of facilities, there were a couple of unique features in H Area. There was a liquid nitrogen storage facility, 210-H, that was located northwest of 221-H. More importantly, in the same direction from the canyon building, there was a second 232 building: 232-H. At the end of Project 8980, this was simply a stand-by building for the first tritium facility at Savannah River, then located in 232-F.[173] In the years to follow, though, 232-F would be closed down and 232-H would become the primary tritium facility. Eventually an entire tritium complex would develop around this building.

Even though the 221-H building was almost identical to 221-F, there were a number of smaller changes made to the facility. As a result of problems that cropped up with the F canyon building, a tolerance study was performed in 1953 for H Canyon in hopes of making some corrections. Better designs were developed for the use of gaskets, nozzles, and pipe jumpers. This was part of a design modification program done by Du Pont's Engineering Department.[174]

The design modification program made other changes as well. In the cold feed preparation area on the first level, the solvent holding tanks were reduced from six in 221-F to four in 221-H. Then all four were relocated to 211-H. In the piping areas and the feed tank gallery, on the second and third levels, the process pipe supports were changed from rod-type hangers to trapeze-type hangers. The pipe headers were also elevated to make the area less congested. The electrical wiring arrangements were also made simpler. Feeder trays were used in 221-H to hold the electrical conduits, and these were made large enough to hold any new lines that might be required. Changes were also made to the gang valve aisles, with the adoption of a "plug-in type valve." This was easier to install and fabricate than the type used in 221-F.[175]

There were even some changes in the Purex process portion of the canyon building, even though these were small. There were some pipe diameter changes made to the mixer-settler hook-ups. In the solvent recovery system, continuous solvent washers were chosen over the older batch system in the 221-H Warm Canyon and in 211-H. This new system was installed in H Area in late 1955. Plans were made to do the same for F Area, but this had not yet been done at the close of Project 8980.[176]

ADDITIONAL CANYON FACILITIES

211-H Canyon Auxiliaries

The area immediately east of the 221 canyon buildings contained various chemical feeds for the canyon, including systems for washing the process solvent, storing bulk chemicals, and handling and evaporating low-activity waste water.[216] All of this area was lumped into one building designation, which was 211, originally known as the "tank farm". F Area also had a tank farm, but it is no longer extant due to the decommissioning of F Area operations during the last two decades.

Constructed between January 1953 and April 1954, the 211-H was designed to be a slightly reduced facility in comparison with 211-F, to meet the minimized scope of production for H Area; however, the principal components

211-H Canyon Auxiliaries (Tank Farm) during construction, February 26, 1954, SRS Negative 2-677.

for both facilities included Transfer Tanks, Chemical Storage Tanks, and water handling facilities. All of the tanks were mounted on concrete slabs. The 211faciliteis were also situated on the railroad spur running alongside the Canyon Building. Besides the tanks, there were other support buildings constructed, including a control house, sample house, and check station. These buildings were designed as Class III, one-story, and rectangular shaped buildings.

This "chemical storage area" was not particularly controversial, and all of its calibration logs and other records were approved by November of 1953. The calibrations and water testing was complete by April of 1954.[217] The basic design for the 211 area was done by Blaw-Knox and Du Pont with some additional input from Oak Ridge and KAPL.[218]

The facilities at Savannah River were more elaborate than the 211 facilities at Hanford, but they were similar and certainly performed similar functions. By the end of Project 8980, 221-F contained tanks for holding the liquid chemicals required in the canyon processes. They also had facilities to treat the low-level waste process water released from 221-F and the waste water from 772-F and 723-F. There were eight transfer tanks, eleven chemical storage tanks, in addition to process water storage tanks, acid recovery facilities, control houses, sumps, evaporators, an extensive overhead pipe rack, and a sample house. The nitric acid, caustic, TBP, and ultrasene required for the Purex process was stored here when it was not required in 221.[219]

The 211-H tank farm was smaller than the one in F Area, since it had to serve fewer facilities. There was also no waste handling. General improvements were made to the overall system, based on what was found to work best in 221-F. H Area, however, did contain one system that was not found in F Area, and this was 210-H, Liquid Nitrogen Storage. This facility provided liquid nitrogen for both F and H areas. Located in a special fenced in area, it contained a horizontal storage tank 34 feet long and 11.5 feet diameter.[220]

The various tanks used in the 211 area were identified by their series numbers. The 500 series tanks dealt with recycled water and were particularly designed to remove unwanted organics; the 600 series tanks were part of an "acid recovery unit" (ARU), while 700 series tanks were general purpose evaporators for low-level waste. Tanks with two-digit numbers were usually for cold chemical storage. Also stored in the area were the so-called "Hanford containers," located on storage pads. Now empty, they were used to store depleted uranium, which only had very low levels of radioactivity. One of the newer facilities, 211-27H, is where uranium is currently loaded for shipment to TVA and other locations.[221]

211-2F Control House and Check Station (Demolished)

Located to the east and adjacent to the Canyon Building, the Control House and Check Station was actually two buildings attached to create a single structure. Built in 1954, the Control House, housed the control instrumentation for the tank farm, along with offices, toilet, and storage. Located behind the Check Station, it was a Class III, one-story building measuring 30 feet by 28 feet. The building had a prefabricated structural steel frame with corrugated asbestos panels on the exterior walls and a reinforced concrete foundation with spread footings and concrete slab. The windows were commercial metal sashes while the doors were industrial steel. Attached to the east side of the Control House was the Check Station, through which personnel entered the fenced area

211-2F, Photograph taken Prior to Demolition, 2003.

211-3F, Photograph taken Prior to Demolition, 2003.

211-4H, Photographed in 2012.

of the tank farm facilities. Also a Class III building, the Check Station was a small rectangular shaped building measuring 8 feet by 10 feet. Originally clad with corrugated asbestos panels, the wood-framed building had a concrete block exterior by the time of its demolition in 2003. The building stood on a concrete slab foundation.

211-3F Truck Unloading Building (Demolished)

The Truck Unloading Building, built in 1954, was located north of 211-2F and was a support building for the 211-F Tank Farm. A Class III building, it was a one-story rectangular building measuring 40 feet by 42 feet with a mean roof height of 26 feet. The building was constructed with a structural steel frame with an exterior clad in corrugated asbestos. The building rested on a reinforced concrete foundation with spread footings. The building's east elevation had a large open garage bay with a height of 15 feet. The floors of the building were concrete, with the truck stall area floor covered with stainless steel-lined sumps.

211-4H Sampling House

The Sampling House was also built as a support facility for the 211-H Tank Farm. Its function was to intermittently sample the process off-gas emanating from the Hot Canyon dissolvers in the 221 canyon building. Built in 1952, the Sample House is a Class III building measuring eleven feet by thirteen feet. It rests on a reinforced concrete foundation with spread footings, and it has a steel frame covered with corrugated asbestos shingles. Transite covers the exterior of the building, which has a single leaf half-light metal door providing access to the interior. Windows with four-light metal sashes are found on the remaining elevations.

221-1F A-Line

The building is a Class II structure built of reinforced concrete, with a three-story section, a two-story section, and a fourth story penthouse located at the north end of the building. A single story addition was added in 1955, along with the basement because of increased production schedules. The building rests on a reinforced concrete foundation with spread footings, measures 49 feet wide and 87 feet long, and has a deep basement under part of the building. Flat asbestos cement board sheathed the Stran-Steel brand framed walls, and the building has no windows.

A-Line was located immediately southeast of 221-F. Even though it is outside the canyon building, it is still considered a part of that building complex. Generally speaking, "A-Line" means the A-Line facilities at 221-F, which is considered the only full-fledged A-Line facility. Technically, there is an A-Line on the southeast side of 221-H, but this is only a small tank farm and has no buildings. The A-Line in F Area was the only one that processed the uranium that came out of the Purex process.

A-Line Process and Building

The basics of the A-Line process are not difficult to explain. The concentrated uranyl nitrate that results from Purex was processed through thermal de-nitration to remove the nitrates and transform the uranium to an oxide powder form that was relatively easy to store in drums. This was its primary function. A secondary function was the recovery of nitric acid, given off in the de-nitration process.[153]

To get into a little more detail, the A-Line process began with uranium in the form of uranyl nitrate solution from Second Cycle uranium. From storage tanks, the solution went to a continuous evaporator (1EU evaporator) where extra liquid was boiled off, raising the percentage of the solution from 9 percent to 40. This concentrated uranyl nitrate (UN) solution then went to a silica gel column to remove any radioactive contaminants. Then the solution went to the hydrate evaporators for more volume reduction, raising the percentage of the solution from 40 percent to 80. The concentrated solution then proceeded to de-nitration, which was done in pot-type denitrators. While heated in the denitrator pots, the solution became viscous, requiring constant agitation or stirring so as not to harden. Water vapor and nitrogen oxide are recovered from this de-nitration process, and these are then cooled and the vapor is sent through an absorption tower to recover the nitric acid. Meanwhile, back in the pots, the solution was transformed into a powdery oxide. After cooling, the uranium oxide powder was vacuumed out of the pots, pulverized, and blended. Packed into steel drums for storage, it was eventually shipped off-site.[154]

There is hardly a segment of the Separations process that went through more design changes than A-Line. This is in spite of the fact that the process was fairly straightforward and held few mysteries. The earliest designs for the A-Line process called for two complete A-Lines, on in F and the other in H area. In June of 1952, this was determined to be redundant and most of A-Line was eliminated in H Area, with the exception of the nitric acid recovery part. Everything else from 221-H would be shipped over to A-Line in F Area.[155]

Before that decision was made, A-Line design plans had been the responsibility of Blaw-Knox, using a basic design borrowed from the Mallinckrodt Chemical Works plant in St. Louis, Missouri. Because the process did not

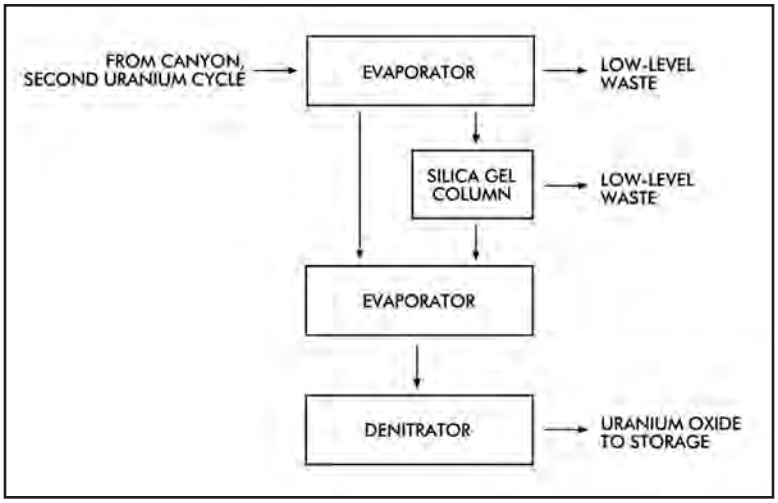
A Line, Shown During Construction, with F Canyon and the 211 Tank Farm Behind it. In the foreground, construction workers have begun work on a railroad spur. The 292 Fan House is just visible at right. Photograph taken May 26, 1953, SRS Negative 2-500-2.

require special shielding, A-Line could be located outside the canyon building, in its own facility. In 1951 and early 1952, three different building arrangements were considered for the lay out of A-Line. No decision had been made on the three possibilities by April of 1952, when Blaw-Knox was removed from the A-Line project and the Lummus Company assigned to the work. Lummus favored Blaw-Knox's Scheme No. 3, which called for one three-story building above ground, with six denitrator pots and three hydrate evaporators, all large enough to serve both F and H areas. This became the basis for A-Line's over-all design. For Lummus, this work became Job No. 3269 and 3451 (for spare parts), with the whole project identified as the Oxide Recovery Plant. Lummus finished its design work in August of 1953.[156]

Lummus adopted the basic three-story design first proposed by Blaw-Knox, but made a number of other changes to A-Line. The acid recovery system was revised in July of 1952. By October of that same year, the basic design was established for the complete A-Line in F Area, and the much truncated A-Line in H Area.[157]

Lummus added a fourth floor penthouse and a basement to the original three-story design, and this was what was constructed. The first level was for the de-nitration pots, also known as de-nitration reactors. The second and third levels were for the hydrate evaporators that would feed their materials to the pots, and the offices and control room. The fourth floor penthouse was constructed for the extra gravity flow needed to get the uranium oxide powder

from the cyclone to the pulverizer and blender and the drum loading area. The basement was for the furnaces that would heat the pots and auxiliary equipment for the de-nitration gas heaters, air ducts, and blowers. The ventilation scheme was changed from having several units around the building, to having one large unit with extensive ducts. This was done in case it was decided to install air-conditioning in the future. After these decisions had been made, it was then decided to change the classification of the building from Class III to Class II, which would make it a more stable construction to better to control the dust. Dust control also required that all interior surfaces were to be made as smooth and as plain as possible.[158]



The A-Line Process. Source: Savannah River Site at Fifty, *Reed et al.*

The evaporator explosion at TNX in January of 1953 had consequences for the A-Line process. In March 1953, The 1EU evaporator was moved out of the Warm Canyon in 221-F, to the area around A-Line, and the A-Line hydrate evaporators were moved outside the building. In 1954, this evaporator was changed to a "continuous-type 1EU evaporator" to deal with the increased volume of uranyl nitrate solution expected from 221-F. This new evaporator was installed on the south side of the A-Line building, near the original batch evaporator.[159]

In early 1955, a one-story structure with a basement was added to the southwest corner of the original building, to help meet increased production. This housed an extra three de-nitrators, one hydrate evaporator, and a separator. Also in 1955, air-conditioning was added to the office space on the second floor.[160]

The Absorber Area for acid recovery was outside and adjacent to the A-Line building. Also outside was the silica gel equipment. A car spot and a 10,000-gallon tank were added to the outside facilities to house the uranyl nitrate shipped from 221-H to F Area by tank car. After it was decided to eliminate electric burners and use Selas-type gas burners for the de-nitration pots, another car spot and a propane gas storage tank were added as well.[161]

The silica gel facilities, located south of the A-Line building, were in early 1953, after it was discovered that the solvent extraction alone was not removing all of the fission products from the uranyl nitrate coming from 221-F. Since it was capturing radioactive materials, the silica gel facilities required radiation shielding. Provision also had to be made to dispose of the oxalic acid and water washes that were used to clean out the fission products. This material was eventually sent to the waste tanks.[162]

A-Line Equipment

Much of the basic design work associated with A-Line was tied to the equipment needed for the process. It was in fact the heart of the process. As with the building, the basic equipment was pulled from the Mallinckrodt Chemical Works, which was first visited on March 12, 1951. In choosing Mallinckrodt, it was decided to go

A-Line, Photographed in 2005, Fom the Roof of F Canyon.

with a process that already worked. Other details could be altered as needed, pulling from the knowledge and experience of Harshaw Chemical Company in Cleveland, Ohio, and from Hanford.[163]

This certainly happened with the hydrate evaporators, which were stainless steel vessels with columns. The original Blaw-Knox design called for two of these vessels, based on the Mallinckrodt model. After the TNX explosion, when the 1EU evaporator was moved out of 221-F to the vicinity of A-Line, the hydrate evaporators were also moved outside the building along the west wall, protected by concrete barricades. A third hydrate evaporator was added to the roof of the addition built at the southwest corner in 1955.[164]

The core of the A-Line process rested with the de-nitrator pots, also known as "reactors." The original plans called for just three of these pots, but three more were added to the new southwest addition in 1955. The design for the pots was based on elements from both Mallinckrodt and Harshaw. In the end, the Mallinckrodt pots were considered too small, so it was decided to use the larger Harshaw vessels. The design of the agitator was also borrowed from Harshaw. Another concern was the process itself: whether to use a continuous or a batch method for the de-nitration. Mallinckrodt used the batch method and it was decided to stick with that. Mallinckrodt usedgas burners, but it was originally thought to use electric heat at Savannah River. After an economical evaluation of the options, it was decided to go with propane-fueled Selas burners.[165]

Denitrator Pot and Furnace, April 15, 1955, SRS Negative DPSPF 1563-1.

Acid absorbers were also important, since they captured the nitrogen oxides that came off the denitration process. The equipment Mallinckrodt used was not considered adequate for Savannah River, so Du Pont engaged Eastern Laboratory to obtain an absorption column for their operation. In May of 1951, Eastern suggested a single column 30 feet high and 8.5 feet in diameter, or two columns of smaller size. Du Pont's final design used two standard towers with 6-foot diameter and 22 bubble-

cap plates, stacked to form one column. These were worked in conjunction with the discharge pressure controllers which were put on the reactor pots to control the flow.[166]

Other equipment had to be found or modified for this specialized use. This included cyclone separators, pulverizers, "gulpers," dust collectors, and blenders to deal with the uranium oxide powder. The designs for these pieces of equipment were borrowed from Hanford or Mallinckrodt. Any uranium oxide found to be sub-standard had to be reprocessed, and an oxide dissolver was needed to begin that work. Feeding uranium oxide powder into this machine proved to be a problem that was eventually solved by using a screw feeder to load the dissolver.[167]

There were other features that bore some examination. There were samplers that were designed to test the quality of the solution, as well as the final uranium oxide. Instrumentation had to be studied, especially for thermocouples to measure temperatures in the denitrator pots. A whole range of safety features were also studied, ranging from shielding to features in the ventilation system for the collection of uranium dust.[168]

222-F Cold Feed Preparation Area

222-F, Photographed in 2003.

The 222-F building, completed in 1960, was designed as the Cold Feed Preparation Area as part of a larger expansion of F Area in the late 1950s that increased the production capabilities of F Area. Construction of the expansion began in 1956, when reactor output had been increased, resulting in minor modifications of the F Area, and introducing new facilities, such as the JB-Line. 222-F is located east of the Canyon Building, and north of 221-1F, the A-Line Building, and adjacent to F Area interior access roads and a railroad spur. This building was designed with a shed roof and open sides and an adjacent closed warehouse section. The main part of the building houses a 60-foot wide by 69-foot long mixing area, with a height clearance of 15 feet. The main purpose of 222-F was to contain tanks, pumps, and other equipment that prepared chemical solutions for transfer to the Canyon Building.

CANYON VENTILATION FACILITIES

The air exhausted from the canyon operation had the potential for being both highly acidic and highly radioactive. Its clean-up and safe expulsion to the general atmosphere was considered one of the most important safety features perfected at the Savannah River Separations areas. This work was done by a combination buildings, all connected to each other and to the canyon buildings. These facilities, critically important, were found on the east side of the canyon buildings.

291-F Canyon Stack

The canyon stacks (291-F and H) were virtually identical, and were set up to receive exhaust air from the canyon buildings and vent exhaust from the 211 tank farms. The stack was 200 feet high, with an inside diameter of 16 feet at the base and 12 feet at the top. The outer cylinder of the stack column was concrete, while the inner core was corrosion-resistant brick. An air space separated the two. The stack is situated on a reinforced concrete foundation, with an octagonal base measuring 33′6″ deep by 5′6″ thick at the lower end, and an upper portion measuring 20′ deep by 3′2″ thick. Condensate was collected by a steel pan.[184] These pans drain to stainless steel 100-gallon tanks located in concrete pits near the foundation.

The basic design of the 291 stacks at Savannah River was based on the stacks used at Hanford, but with the idea that they would be larger in scale. The main design consideration was whether to use stainless steel or acid-proof brick as the inner liner. Du Pont eventually went with brick due to cost considerations. They also added a monitor to check for the release of any radioactive iodine.[185] There was also special equipment designed to clean and examine the interior of the stack. This included a "stack cage," large enough to hold a worker who could be lowered into the stack.

Worker and Stack Cage. February 16, 1962, SRS Negative 0226-3.

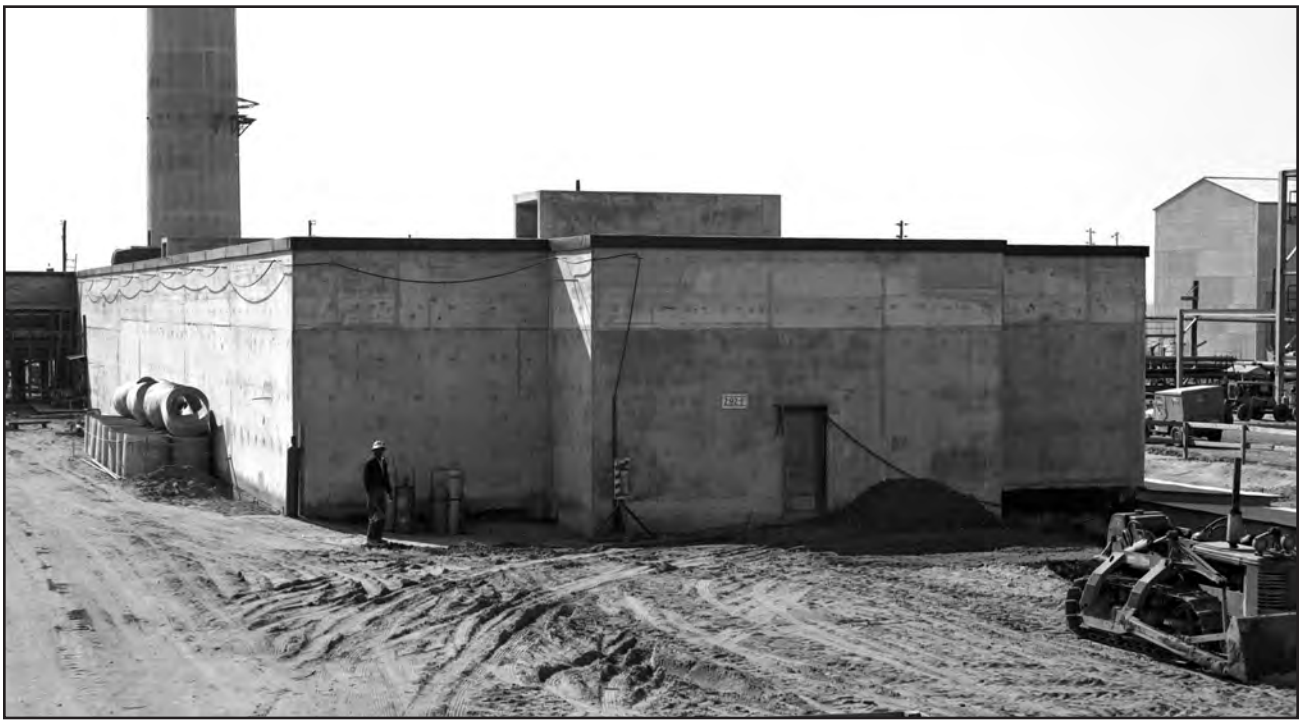
A worker scaling the side provides some perspective on the size of the 291 Canyon Stack. April 6, 1966, SRS Negative DPSPF 11056-1.

292-F and H Fan Houses

The 292 fan houses contained the fans that pulled the exhaust air out of the canyons and through the sand filters, and then pushed the air to the top of the stack. This work was aided by other fans in the canyon buildings that pushed the air out, but the lion's share of this work was done by the 292 buildings.[181] Constructed between August 1952 and July 1954, 292-F is a one-story Class I building. The rectangular building measures approximately 62 feet by 192 feet. There are two additional sections of the building, including a section on the north end measuring eight feet by 29 feet, and a filter pit on the southwest corner, measuring seven feet by 34 feet. The building rests on a reinforced concrete foundation with spread footings, and reinforced concrete walls and roof.

The original Blaw-Knox design for the 292 fan houses called for an enormous structure with two major divisions: a filter area and an exhaust area. It was proposed that these exhaust fans would run continuously. By early 1952, the size was reduced when it was decided to include sand filters. By this time, Blaw-Knox had been relieved of its design responsibilities and this work had been transferred to Voorhees Walker Foley and Smith. In 1954, after the construction of 292-F, it was decided to add a subsidiary fan house identified as 292-1F. A similar structure was added to H Area. These new buildings contain two process vent header exhaust fans that were moved out of 292-F to the newer building, where any possible contamination could be better controlled. There was also the addition of iodine monitoring facilities at the south end of the fan house. An emergency Diesel generator was situated in 292-F to provide power to A-Line if necessary.[182]

The 292-H fan house was basically the same as the earlier 292-F fan house, except that it was smaller, with more equipment located outside on concrete pads. It also had blast doors, something lacking in 292-F.[183] An additional change from 292-F was that remotely controlled blast doors were installed in the intake and exhaust



292-F Fan House, March 27, 1953, SRS Negative 2-482.

292-1F Vessel Vent Fan House, Photographed in 2012.

tunnels. By altering the design, the amount of concrete required for construction was substantially reduced. Construction of 292-H took place between October 1953 and November 1955.

292-1F Vessel Vent Fan House

Originally called a Fan House, just as 292-F was known, the Vessel Vent Fan House is located north of 292-F. Constructed in 1954, the Vessel Vent Fan House houses the fans that exhaust the process vent gasses from Building 221-F to either the sand filters or the stacks. It is a one-story, reinforced concrete Class I building measuring 21 feet by 26 feet. A large portion the building is located below ground, with the above-ground portion appearing as an asymmetrically shaped concrete façade attached to a later gable-roof, metal panel-clad building. The foundation is a subsurface reinforced concrete exhaust tunnel that extends between the 221-F building and the 292-F building.

292-2F Sand Filter Fan House

The Sand Filter Fan House, constructed circa 1985, is located adjacent to building 294-2F, on the east side of F Area. It expanded upon the capabilities of the original Sand Filter Fan House, 292-F, which was part of the original construction of F Area. It is a Class I building constructed of reinforced concrete. The building is asymmetrical, comprised of a series of

292-2F Sand Filter Fan House, Photographed in 2012.

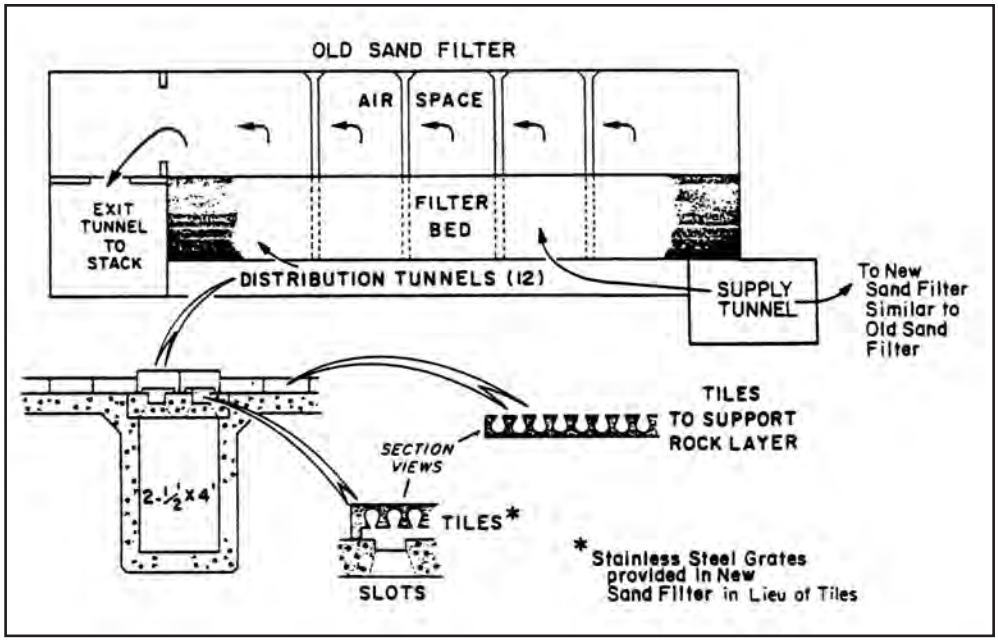
rectangular forms, with a flat roof and a tall metal venting stack towering over the building on its north side. The stack is secured to the ground with guy wires.

294-F and H Sand Filters

Based on a Hanford installation, the original Sand Filter was located east of Building 221-F. It was constructed between July 1952 and March 1954, with the purpose of removing radioactive particles from the canyon cooling air before it passed through exhaust fans and on to the stacks. The Sand Filter is a Class I building located below grade. It is rectangular and measures approximately 100 feet by 240 feet, with a reinforced concrete floor, ceiling, and walls. The roof slab is supported by 44 reinforced concrete columns. The floor has slotted precast concrete covers that are positioned over distribution tunnels. A special sequence of 22,000 tons of stone and sand was layered inside the structure, with tile covering the concrete floor and positioned in a way to allow air to enter the structure evenly. The acquisition of sand for the massive sand filters was a construction activity that required considerable pre-staging. Sand shipments arrived by rail in covered gondolas and were stored under enormous tents measuring 300 feet in length. The Sand Filter roof and a small rectangular structure at the roof center are the only features of the structure that are seen at ground level. The 294-H Sand Filter is identical in construction and function and was built between May 1953 and November 1955.

Process air from the canyon buildings was sent to the sand filters by way of an underground tunnel connected to the lower part of the structure. The contaminated air then flowed from the tunnel into the underside of the sand filter building. There it spread through the underside of the structure by means of distribution tunnels covered by concrete grates and clay tiles. On top of these grates were seven layers of gravels and sand, with coarser materials at the bottom and finer materials at the top. These grades were designed to catch particulate matter as the air coursed upward through the sand filter. After passing through these layers, the air exited the facility from the top layer of the building, on the opposite side from the intake and traveled on to the fan house (292-F and H) and the stack (291-F

A tent was erected to store sand during the construction of the sand filters; the roof of the 294-F sand filter is in the foreground. December 12, 1953, SRS Negative M-3190.



Process air entered the sand filters through a tunnel form the canyon building, then passed out to the Fan House, and from there was vented to the stack. Once in the filter structure, the air was distributed underneath the filter bed by small distribution tunnels covered by slotted concrete covers, above which were set die-formed clay tiles. Above the tiles were seven layers of graded gravel and sand that removed radioactive contaminants. A bypass tunnel allowed the air to be routed around the sand filter if needed. Source: Savannah River Site at Fifty, *Reed et al.,375.*

and H). The fan house provided most the force that pulled the contaminated air through the sand filter and then pushed it into the stack, where the cleaned air could be dispersed to the upper atmosphere. There was also a by-pass tunnel to allow the air to be pumped directly up the stack in those cases when the sand filter was not needed.[177]

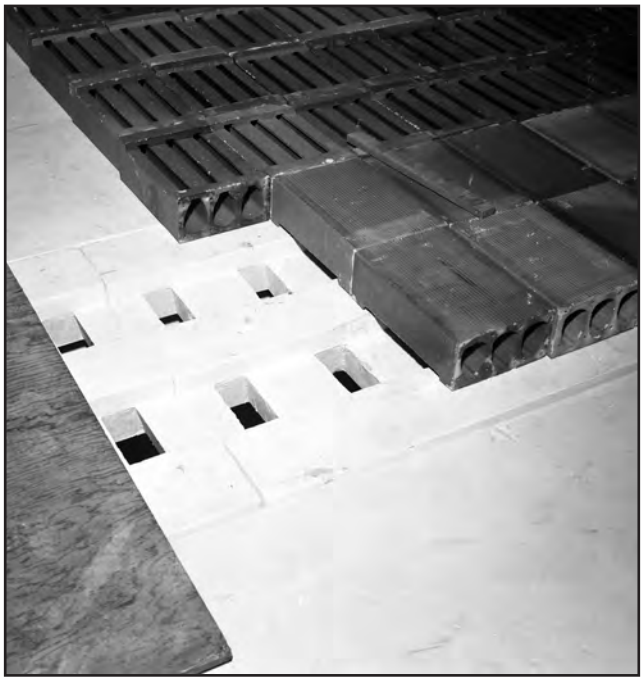
The origin of the sand filter is an interesting one. It was understood from the beginning that some sort of filtration system would be needed for the process air exhaust. The original idea was to have the filtration system located in the canyon buildings themselves. Soon it was apparent that there was not enough room in the canyons for the size of the filters required. Artificial filters were also considered, particularly HEPA filters, but these had limitations. They were not fireproof, and they could not withstand repeated exposure to water or smoke. And there was the issue of frequent filter changes, which could prove costly over time. Soon there was a growing interest in sand.[178]

Hanford had used small filter units comprised of both sand and fiberglass. The larger size required at Savannah River steered designers toward a structure that might be different from this prototype. A specialist, Dr. C. E. Lapple of Ohio State University, was called in to assess the situation. He recommended the use of fiberglass or synthetic fibers. Du Pont studied the issue some more, particularly sand versus fiberglass. Du Pont eventually chose sand, because it had proven to work at Hanford and its filtration characteristics were better known than those of fiberglass. To compensate for any unforeseen problems, the sand filters were made large, with the possibility of additions. The areas east of both the F and H area sand filters were left open in case more sand filters had to be added later.[179]

The original sand filters only had a concrete support structure, topped by concrete grates and tiles. It was later learned that concrete could be corroded by acids in the contaminated exhaust air. Part of the H Area sand filter collapsed in 1969, after 15 years of service. This was corrected by adding steel supports to the concrete, and by adding an additional sand filter building on the east side of both 294-F and 294-H.[180]

Workers on the Roof of 294-H. February 22, 1954, SRS Negative 3337-12.

Workers place concrete grates over an air distribution tunnel in 294-H. February 22, 1954, SRS Negative 3337-1.



Clay tiles line the floor of the sand filter prior to be covered with layers of gravel and sand, February 22, 1954, SRS Negative 3337-3.

294-1F & H Sand Filters

294-1F is an additional Sand Filter facility adjacent to 294-F. Engineers were aware that after a time the original sand filters would become somewhat ineffective, and provisions were made for additional in the future. Constructed in 1969 using the same basic design and construction principals of the Original Sand Filter, 294-1F is a larger facility than 294-F. The design and construction schedule for the new sand filter was completed by 1964. As with the original San Filter, the roof and a small rectangular structure at the roof center are the only features of the structure that are perceptible from ground level. 294-1H is identical in size and function.

Type "C" Filter Material Being Deposited in 294-H, SRS Negative DPESF-3475-5.

The interior of the 292-F Sand Filter prior to being filled. Lines demarcating the different levels of gravel and sand to be deposited are visible on the columns. Photograph taken December 4, 1954, SRS Negative 2-773.

294-F (foreground) and 294-1F (background) sand filters as seen from the roof of F Canyon, photographed in 2012.

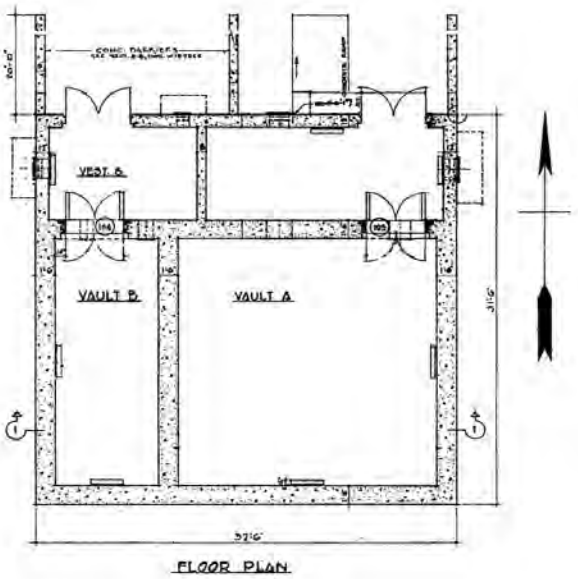
AUXILIARY SEPARATIONS FACILITIES

217-F Storage Magazine

There was one storage magazine, 217-F, to serve both the F and H areas. It was designed to hold all the final products prepared in Separations and awaiting shipment off-site. No longer extant, the building was located in the northeast corner of F Area and was enclosed by an electrified double fence. It also had its own guard-house, 701-5F. The Storage Magazine was a Class I building, measuring 32 feet by 33 feet with a ceiling height of 11 feet. The building was constructed of reinforced concrete walls, with a concrete roof slab. To form blast resistant ventilation openings, concrete hoods extended beyond the building face just below the roof. The foundation was a multi-layered structure, starting with a 2-inch concrete slab that was covered with a two-ply membrane waterproofing material, followed by a one-inch thick coat of plaster, all of which lay on top of 19 inches of reinforced concrete. The building's concrete exterior was treated with a coat of transparent silicone damp-proofing material.

The storage magazine contained two vaults, labeled "A" and "B." The A Vault was for plutonium; the B Vault, for tritium. The vaults were accessed by vestibules labeled the same way, which also housed the heating, ventilation, and monitoring equipment. Concrete walls extending 20 feet out from the building provided a visual barrier for the loading and unloading of trucks. In all other respects it was an unremarkable construction. It was windowless and rectangular, with a flat roof. It was shielded from general observation by the concrete visual barriers, as well as overhead tarps.[222]

217-F Storage Building, September 29, 1953, SRS Negative 2-553.



Plan of 217-F. Source: SRS Engineering Drawing W157357.

Built in 1953, 217-F was one of the few buildings at Savannah River that was under the direct control of the U.S. Atomic Energy Commission, not Du Pont. The storage magazine was the point at which the finished products were transferred directly to the client. The storage magazine was used until 1983, when it was replaced by another facility built elsewhere. Vacant after that, it was documented in a 1997 HABS report, and demolished shortly thereafter.[223]

From the beginning of the design process, it was understood that the storage magazine would require two vaults, one for plutonium and another for tritium. The original plans called for the magazine to be heated with hot water unit heaters, but this was changed to electric panel heat in June of 1952. Another idea to have raised concrete pads for holding the products was dropped as too specific. Because the building was relatively isolated, it was decided early on to maintain radio contact with security guards.[224]

235-F Metallurgical Building, September 29, 1953, SRS Negative 2-557.

235-F Metallurgical Building

Building 235-F was constructed to house the facilities that would fabricate plutonium metal into the shapes necessary for nuclear weapons.[226] Specifically, it was to house the "Component Fabrication Line" or "C-Line," a facility conceived the same time as A-Line and B-Line associated with the canyon buildings.

235-F was constructed between December 1951 and August 1954. Located east of the Canyon Building, on the far east side of F Area, 235-F is a Class I, two-story, rectangular building constructed of reinforced concrete. The 13,467 square foot building measures approximately 109-feet wide by 222-feet long and 28-feet high. The building rests on a reinforced concrete foundation with spread footings and has a flat concrete roof. The ceiling height is raised about 6 feet for two areas on the first level to accommodate equipment. The interior walls are of concrete construction, with some clad in cement asbestos board on metal studs.

The general layout of the building includes offices, shops, process rooms, and testing and inspection rooms on the first level process area; locker and change rooms, compressor and transformer rooms, and personnel decontamination rooms on the first level service area; and offices, shops, and lunch rooms on the second level.

Building 235-F was made large enough to enclose two C-Lines, each of which was to contain a steel cabinet 28 feet wide by 106 feet long. These were designed to be flanged sections subsequently bolted together. Designed by Du Pont with assistance from Blaw-Knox and the Peter F. Loftus Company, this building was one of the few in Separations that was not modeled after an earlier building. Had it been finished, it would have been the only plutonium-239 fabrication facility on site.[227]

After the building was constructed, but before the innards were installed, the AEC decided that Pu-239 metal fabrication would not occur at Savannah River, but rather be conducted elsewhere. Soon, Rocky Flats, in

Colorado, became the preferred location that stage of weapons production. In the meantime, 235-F was idle for a number of years.

Years later, 235-F would play an important role in the plutonium-238 program. This development came to the fore in the 1960s and 1970s. The first real use of the building came with the Alloy Line in the early 1960s, followed later by the Actinide Billet Line (ABL) and by PuFF. These and other developments in 235-F will be treated later in this report as part of the Pu-238 developments.

244-H Receiving Basin for Offsite Fuels

The Receiving Basin for Offsite Fuels (RBOF), is located near the 241-H area, west of 221-H. Plans for RBOF began taking shape in 1958, and the building was completed in 1962. The facility was designed to receive and store off-site spent fuels, but plans changed to also accommodate failed fuel elements from SRS reactors and other facilities on site. 244-H was specifically located near the 241-H waste tanks in order to facilitate the disposal of contaminated wastes and a railroad spur connects with the northwest corner of the building. The facility has a number of components that provide for the unloading of spent fuel casks from trucks or rail underwater, a basin in which the fuels are stored, and facilities for disassembly and inspection of suspect fuels, as well as facilities to repackage fuels for shipment.

The building is constructed of reinforced concrete, with Transite panels covering its exterior. It is a rectangular building, void of windows, with a large garage bay located on the west elevation. Later single-story additions were added over time, as is evident on the east side of the building. The building contains the following principal components: 1) Carport and area for receiving casks from railroad cars or trucks; 2) Cask Wash Pit, an area for cleaning vertical or horizontal casks; 3) Cask Unloading Basins No. 1 and 2, basins filled with water with overhead cranes used to transport the casks into the basin; 4) Fuel Storage Basin, where fuels are stored underwater; 5) Disassembly Basin, a water filled basin where fuels are disassembled underwater; 6) Inspection Basin, a basin for underwater inspection of fuels; 7) Repackaging

244-H Receiving Basin for Off-site Fuel during construction, May 29, 1962, SRS Negative DPSPF 8320-3.

244-H, photographed in 2012.

Basin, a water filled basin for the repackaging of fuels; 8) Transfer Canals, canals measuring 3 feet wide and 30 feet deep that connect all the basins for the transport of fuel through an overhead monorail system; 9) Decontamination System, submerged basin pumps that remove contaminants in the basin water; 10) Control Room, where all process operations are performed remotely; 11) Waste Tank Cells, two storage tanks for contaminated wastes located in a shielded concrete cell; and 12) Offices, Health Physics Lab and Change Rooms, including a supervisor's office and locker rooms for personnel.

244-1H RBOF Storage Building, photographed in 2012.

260-1F Monitor Building, photographed in 2012.

244-1H RBOF Storage Building

Located just northwest of 244-H and along the north side of a railroad spur leading to 244-H, RBOF, the RBOF Storage Building was constructed in 1980. It is a single-story, gable-roof building clad in prefabricated metal panels. A large garage bay is located on the east side of the building, while two half-light pedestrian doors occupy the north elevation. One of these doors is sheltered by a flat-roof awning.

260-1F Monitor Building

Built in 1955, the Monitor Building is located on the railroad spur, south of the Canyon Building, and was designed to house the equipment used to monitor the remotely operated electric locomotive that transported irradiated uranium slugs from the reactors to the Canyon Building. It is a single-story, small rectangular Class III building with a single door entry. The steel frame is clad in prefabricated metal panels, as is the gable-pitched roof. The building stands on a poured concrete foundation.

293-F Metallurgical Building Stack

The Metallurgical Building Stack is located adjacent to building 235-F, the Metallurgical Building. Both are located on the east side of the F Area complex. The current stack was constructed in 1982 of reinforced concrete, replacing the original stack, which was constructed in 1952. The original stack was much taller than the current stack, with a height

293-F Metallurgical Building Stack, December 30, 1952, SRS Negative 2-419.

of 75 feet, while the current stack is about two stories in height. The stack exhausts air from the Metallurgical Building to the atmosphere.

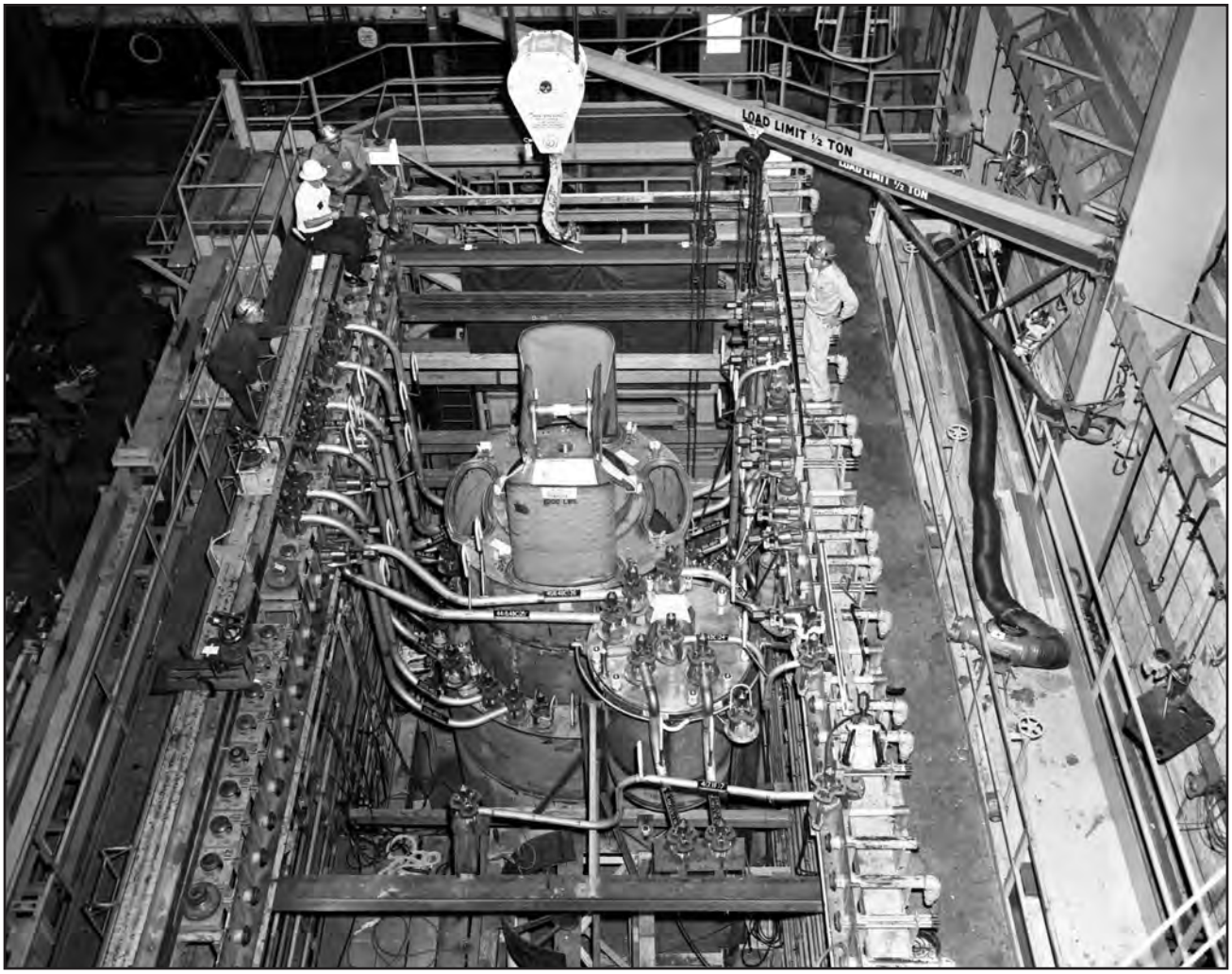
717-F During Construction, April 23, 1952, SRS Negative 2-222.

717-F, Photographed in 2012.

717-F Mock-Up Building

The 717-F building was commonly known as the "Mock-Up Building." It was an exact replica of two regular sections of the canyon, which made it the main facility for the fabrication and testing for any equipment that would have to be placed in the canyons. As stated in the Du Pont Construction History for the Separations Areas, "the mock-up of all pieces of equipment that would be remotely operated and maintained in the 200 Areas was accomplished in Building 717-F." [186]

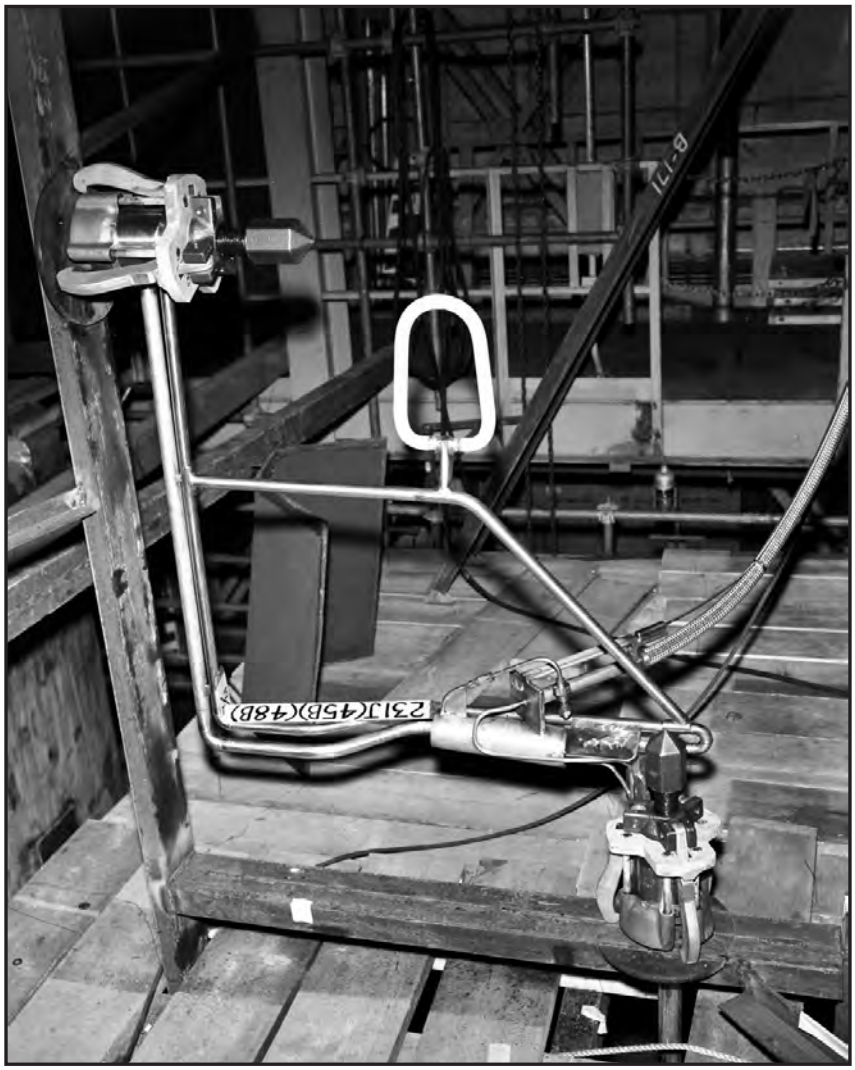
Located south of F Canyon, 717-F was built between September 1951 and July 1954, concurrent with the construction of the canyon. It is a Class III building composed of two bays, a high and low bay, that run the length of the building. The high bay measures approximately 283 feet long and 64 feet wide, designed to have the capacity to handle canyon vessels and equipment. The low bay has a shed roof at a height of about 21 feet,



Workers oversee activity involving an annular dissolver in a replica of a canyon section in the Mock-Up Building. July 6,1964, SRS Negative DPSPF 9804-23.

a length of 242 feet and a width of 39 feet. The high bay is comprised of pre-assembly facilities, a forge, and a welding and pipe shop, while the low bay contains offices, bathrooms, and change rooms. The total building area is 27,640 square feet.[187]

The building rests on a reinforced concrete foundation with spread footings. The building structure has a frame of structural steel covered with corrugated cement asbestos board; the exterior walls are insulated. The exterior of the building has largely been covered with modern prefabricated metal panels in recent years. The truss roof is covered with prefabricated metal panels. Interior walls are constructed of flat cement asbestos board, and Masonite wainscoting in the shops. Hollow metal doors are found throughout the building, which has no windows, while the railroad and truck entrances have rolling steel doors. Since its original construction, single-story additions were added on the north side of the building, and a higher bay component was added to the west end of the original building.



Jumper, DPSPF 7611, July 24, 1961.

Loaded A-frames, November 3, 1953, SRS Negative M-3021-3.

The 717-F building served both F and H areas. Every piece of equipment that had to go into the canyons had to first go through Mock-Up, and it had to fit perfectly. The equipment also had to be installed by crane, just as they would have to be in the canyons themselves. It had nozzles in the exact same location as those in the canyon buildings. Even the floor sloped the same way. The only difference was that the piping in 717-F was not encased in concrete. The installation tools were the same as well: an impact wrench and a hook.[188]

The basic design for 717-F was borrowed from a similar facility at Hanford. Unlike the Hanford precursor, 717-F had no windows.[189] Because of its critical importance to the operation of the Separations, it was one of the first buildings finished in F Area. The outside frame and the shell were basically up by May of 1952.

Jumpers were one of the most critical pieces of equipment that had to fit in 717-F, and they were stored here and in Central Shops. Since they were less sensitive than some of the other pieces of equipment used in Separations, they were photographed more frequently.

In the 1980s, additional mock-up facilities were added at the west end of the high bay in order to test equipment that would fit into the

Defense Waste Processing Facility (DWPF). Even today, an extra DWPF melter is located in this portion of the building in the southwest corner. Other equipment currently located within the building include a large bi-cell tank, a smaller decanter, and a series of large crane hooks located in the northeast corner.[190]

723-F Laundry (Demolished)

Constructed between 1951 and 1954, the Laundry Building contained the equipment and facilities needed for the laundering and maintenance of all protective clothing for process and service personnel who worked in contaminated areas. The Laundry Building, no longer extant, was located west of the Canyon Building and east of 717-F. Protective clothing worn by employees for protection from radiological contamination, dirt, or physical damage was sent to the Laundry. Possibly contaminated and clean laundry were washed in separate machines. In fact, clothing arrived at the Laundry in two separate streams and remained segregated. Decontamination

723-F Laundry Building with 717-F in the Background, June 28, 1952, SRS Negative 2-259.

Laundry Worker and Equipment, July 2, 1952, SRS Negative 4498-12.

Laundry Worker and Equipment, July 2, 1952, SRS Negative 4498-12.

was done by acid solution baths.[215] Beginning in the 1990s, some non-radiologically contaminated laundry generated by the plant was sent out to commercial laundering services.

The Class III building was one story and measured approximately 82 feet by 142 feet with a height of 14 feet. The building had a structural steel frame with the exterior covered with corrugated asbestos panels, while interior walls were covered with a combination of Masonite wainscot and flat cement asbestos board. Windows throughout the building contained steel sashes, with a mixture of fixed and projecting sashes. Doors were made of hollow metal. The interior was divided into several spaces, each serving a different function within the Laundry Building. These include a receiving room, washroom, monitoring, mending, storage area, and office.

772-F Analytical Laboratory

The 772-F building, located almost immediately west of 221-F, was originally referred to as the Control Laboratory. Later it was more commonly referred to as the Analytical Control Laboratory, or simply the Analytical Laboratory. The Analytical Laboratory served both F and H areas by providing quick analysis of materials that were used or created in the canyons and in the B-Lines. The Analytical Laboratory did not normally deal with the tritium process, but did cover the other things that pertained to Separations. Any difficult problems could be forwarded to the main laboratory in 773-A.[191] It is interesting to note that the first analytical research done for Savannah River Separations, which involved equipment and personnel training, took place in the Ellenton Public School, before that building was demolished at the end of the Construction period.[192]

Design work on Building 772-F began in July of 1951 and continued until May of 1952.[193] Construction overlapped the design process, beginning in October of 1951, and the facility was turned over to Operations in early 1954.[194] From the very beginning, the building was paired with 221-F. The main purpose of the Analytical Lab was to ensure the purity of the plutonium and uranium that came out of the canyon processes.[195]

The Lab building was designed to be versatile, since many of the nuclear control and testing methods were in their infancy at that time, and it was always understood that they would change. For this reason, the work spaces within the Analytical Lab were set up using a cell arrangement, with small cellular labs and offices located on either side of hallways known as "service halls."[196]

The as-built structure was relatively large, with general dimensions that measured 113 by 368 feet.[197] This Class I building had one story, with ventilation trailers on top, and it had a basement, usually referred to as a service floor. The main part of the building, located on the first floor, was divided into three basic parts.

The first part, located at the south end, was the Uranium Oxide Section, which included such facilities as uranium oxide handling line in Room 110, and the heavy water research in Room 103. The second part, which roughly formed the middle third of the building, was identified as the Purex Section. Here there were facilities for checking plutonium purity (Room 146) and other aspects of the Purex process. In later years, after the Pu-239 mission wound down, this section became the home for other facilities too, such as Pu-238 handling (Room 130) and blend-down work in Room 142.

772-F Analytical Laboratory with F Canyon in the Background, September 29, 1953, SRS Negative 2-576.

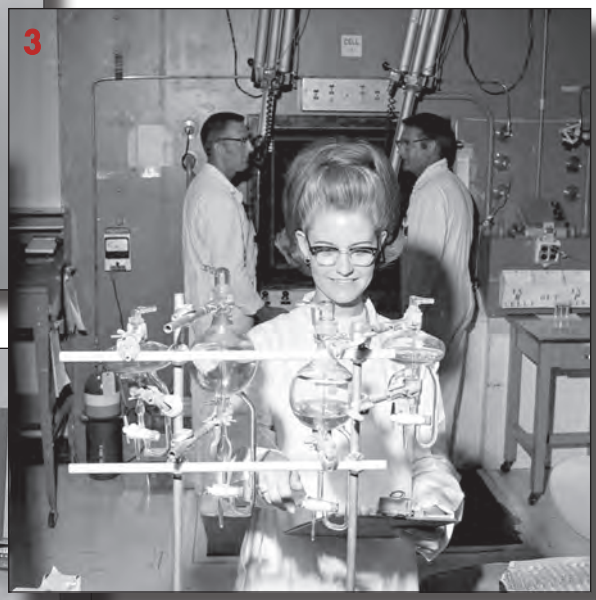
The final third of the building, at the north end, was the Product Section. This contained the americium-curium lab (Room 158), the mass spectrometer room, another Pu-238 program (Room 174). An old fluorometer from the 1950s is still located in Room 127. Other, more modern equipment is located in Room 131, especially to check for impurities.[198]

The service level, located in the basement below all of these facilities, had a ramp and a roll-up door to receive materials from ground level. It also contained the HEPA filters required for the ventilation system, in addition to most of the motors. There was even some office space.[199]

The 772-F Analytical Lab building was attached to the 221-F canyon building by means of a ground-level covered causeway that was often referred to as the "tunnel." The causeway was connected to the north end of 772-F, and was 9-feet wide and 167 feet long.[200] Samples pulled from 221-F might be placed in "doorstops," special carrying compartments made of stainless steel and lead, that would then be transported through the tunnel to the Analytical Lab for examination. Samples were also taken over in "pigs." These compartments would have been transported in special carts. Samples from the 221-H canyon building would have been brought over by truck.[201]

More is known about the personnel that worked at 772-F than perhaps any other building in the Separations areas. In many ways, the Analytical Lab was the nerve-center for Separations. Chuck Goergen noted that the place ran around the clock in support of the process, and was capable of rapid turn-around.[202] Perry Holcomb was at Sep Tech Lab from 1981 to December of 1992, and during that time he was in Building 772-F.[203]

In Support of the Process...



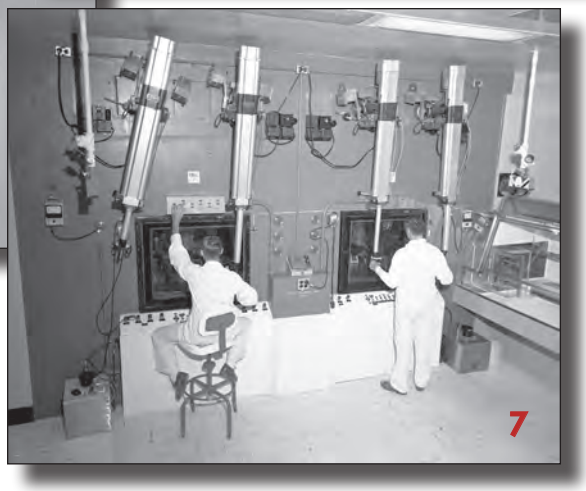
1. March 11, 1970, SRS Negative 13975-2.

2. November 9, 1965, SRS Negative 10742-2

3. Lab Worker Holly Kearse, July 7, 1970, SRS Negative14210-5.

4. James McKibben with lab equipment, JUly 27, 1967, SRS Negative 12086-1.

The Lab.



5. September 19, 1956, SRS Negative DPSPF 3727-1.
6. November 9, 1965, SRS Negative DPSPF 10742-4.
7. August 9, 1966, SRS Negative DPSPF 11333-10.

Some informants go back long before that. Elsie Wood Smith, who was interviewed years earlier, recalled her early work in 772-F. She had transferred to the F Area Analytical Lab around 1954, after a year spent in the 400 Area. At the Analytical Lab, she worked at a glove box, where she practiced with dummy samples before graduating to the first hot samples. She recalled that she and Betty Johnson analyzed the very first hot sample brought over from 221-F in a pushcart. Elsie Smith's main task at 772-F was to check the purity of the plutonium-239. She remembered that her group even wrote their own process procedures, which were kept in special notebooks. She then got pregnant, took a leave of absence, and returned to work six years later. She was surprised to learn that almost all of her co-workers were still in the same positions. When she retired in 1995, she had spent most of her career in F Area, and most of that in Building 772-F.[204]

In addition to Betty Johnson, Smith worked with four to five other women and some 30 men, and was acquainted with another 200 or so who worked in the 221-F building. Many of these men would bring samples to the lab, and she recalled that the women in 772-F often got asked out on dates. There were softball games, trips to the beach, and visits to the Wagon Wheel, a popular bar located where the Wal-Mart is now on Whiskey Road, south of Aiken.[205] It seems pretty clear from all this that the 772-F Analytical Lab was something of a social hub for all of F Area, and maybe H Area too.

Around 1985, before Du Pont left Savannah River, building 772-1F was constructed immediately north of 772-F. This new building served as an annex for the Analytical Lab, with extra offices and a modern control room, or "control center," that served not only the 772 lab but also a number of other facilities in F Area.[206]

OTHER LABORATORY FACILITIES OUTSIDE OF SEPARATIONS

773-A, Savannah River Laboratory

Building 772-F was the analytical laboratory for F and H areas, but always in the background was the main laboratory facility for the entire site: Building 773-A, the home of the Savannah River Laboratory (SRL). If problems arose that could not be dealt with in 772-F, there was always recourse to the facilities and researchers at 773-A. It was here that research and design work was done on new equipment and processes. Over the years, alterations to the basic chemistry of the Purex process were made in 773-A. The development of centrifugal contactors, a crucial improvement to the Purex process in the 1960s, was done at the Savannah River Laboratory. Ion exchange work was coordinated at the lab. The process for obtaining plutonium-238 was done there as well.[207]

A critical area in 773-A for this sort of research were the High Level Caves, characterized by a number of heavily-shielded cells, referred to as Upper and Lower cells. These cells were highly versatile. It was said that literally anything could be done with any sort of radioactive material within the High Level Caves (Holcomb interview). In the 1950s, new fuel elements were regularly designed and tested in the Caves. Solvent degradation work was done there, particularly the testing of various products like the TBP, ultrasene, and later Adakane. Centrifugal contactor work was done here. The HM process was developed here as well. Later still, much of the initial process work for the Defense Waste Processing Facility (DWPF) was done here too.[208]

TNX

The Laboratory in 773-A was the center for all Savannah River research dealing directly with nuclear materials and processes, but a lot of the bulk research, especially the non-radioactive work, was done at the SRL's outlying facility located along the river, known as initially as CMX-TNX. Only in later years did this facility acquire the designation that is favored today: T Area. CMX and TNX were actually two different facilities that were immediately adjacent to each other. CMX did reactor research, and TNX carried out separations research. In the early days, the area contained just two main buildings with outlying facilities. CMX was in Building 679-G; TNX was situated in Building 678-G. In both cases, every effort was made to keep the facilities free of unnecessary radioactivity. As a result, there was minimal shielding in most areas of the buildings.[209]

These buildings, and the areas around them, were added to over the years, with the addition of new buildings and building additions. The first additions to TNX were made as early as 1954-55. Building 677-G was added to TNX in the 1950s, and this building was added to in 1957-58, as staff increased and new facilities were required.[210]

Albert Kishbaugh worked at TNX for a number of years, and as a result was acquainted with many different Separations processes and pieces of equipment. The facility helped perfect the Purex process as it was to be

used at Savannah River. And this was especially true for the equipment. Steam jets were tested here for use in the canyons, and ways were found to get around their big disadvantage, which was to dilute the solution in the course of operation. Mixer-settlers and their impellers also figured in much of the early research. Solvent behavior both in and out of the mixer-settlers was studied. There was also work on instrumentation and control for 221-F; this was so critical that it was said there would have been start-up delays without this work.[211]

Explosion at TNX, January 12, 1953, SRS Negative 6-236-34.

Work was also conducted on the original centrifuges used in the Head End treatment at the beginning of the Purex process. These centrifuges were based on the Bird Machine Company's design previously used at Hanford. But there were some unnecessary features that were not needed at Savannah River. The "plows" used in the Hanford centrifuges were removed, since the residue "cake" left over from the operation of the centrifuge no longer had to be cut from the centrifuge bowl, but rather was washed out with sprays. The braking system was also improved.[212]

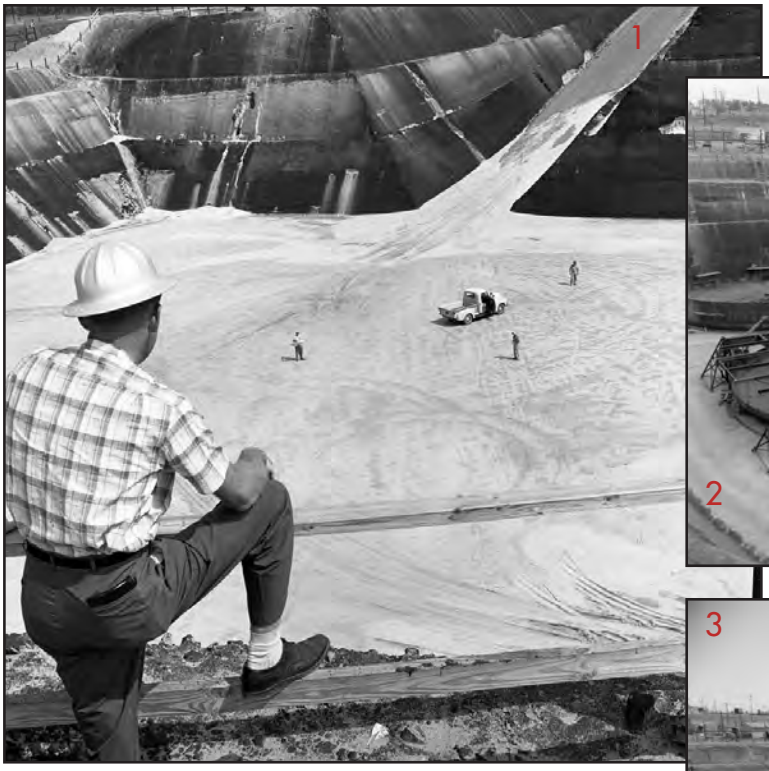
One of the biggest impacts TNX had on the Separations process was unintentional, the result of an explosion in a test evaporator that blew out the wall of 678-G on January 12, 1953. The explosion occurred because of an unexpected presence of organic materials in an aqueous phase that was being subjected to evaporation. Some of the TBP in the organic solution, which should ride on top of the aqueous solution, became degraded into di-butyl phosphate and dropped through the aqueous phase. There, the organics picked up nitrates and pooled at the bottom of the solution. This resulted in a chemical combination referred to as "red oil."[213] As a result, some organic phase material got transferred into evaporators that should have only been cooking aqueous phase solution. In reaction to the heat, the degraded TBP exploded.

The results of this blast were almost immediate. Within a couple of months, new procedures were drawn up for the processing of the aqueous and organic phases coming out of the mixer-settlers. In addition, the use of evaporators was re-considered. Their use in the B-Lines was curtailed, in favor of ion exchange columns, and process evaporators were moved outside of the A-Line building.[214]

WASTE FACILITES

241-F and 241-H Waste Tanks

The waste tanks at Savannah River represented the tail end of the separations process, at least as it was understood in the 1950s. The tanks were designed to hold all the materials that could not be used but were too dangerous to release. Aluminum cladding for the elements in the reactors, ended up as aluminum waste in the tanks.



1. Frank Murphy, Production, overlooks the future site of the 241-1F Type IV Waste Tanks, August 21, 1956, SRS Negative DPSPF 3673-18.

2. Progress, December 7, 1956, SRS Negative 2-841-1.

3. Progress, December 26, 1957, SRS Negative 2-857-2A.

4. Progress, waste tanks partially buried and near completion, July 10, 1958, SRS Negative 2-857-1P.

The radioactive fission products pulled out of the processing of irradiated uranium would end up in the waste tanks. Low-level water waste did too. The entire process resulted in a soup of different materials sent to the two waste tank farms, identified as 241-F and 241-H. And the "soup" stayed there. As was stated in the Du Pont Construction History, the 241 waste tanks "provide permanent underground storage for radioactive liquid process waste from the 200 F and H areas."[228] In the 1950s, no one was really concerned about how these materials would be cleaned up or processed to render them harmless. The task at hand was to produce materials to win the Cold War; clean-up was a task for the next generation of nuclear scientists and engineers.

A series of photos documenting the construction of the Type 1 Waste Tanks constructed in F Area. These eight tanks were the first constructed at SRP. The last photo shows the tanks completely buried with just the risers visible above ground.

1. January 15, 1952, SRS Negative 2-172.

2. July 23, 1952, SRS Negative 2-270.

3. February 11, 1953, SRS Negative 2-455-2.

4. August 21, 1953, SRS Negative 2-540-4.

5. March 31, 1954, SRS Negative 2-687.

Built in groups of two, four, or eight at a time, Du Pont and Blaw-Knox designed the carbon steel waste tanks based on the tank farm already in use at Hanford. The catch basins, or "saucers," were features to help deal with any leaks in the main tanks. The first concept was to have one central farm, fed by gravity flow from both separations areas. The grade, however, was not sufficient to allow for that, so it was soon planned to have two waste tank farms, one for F Area and another for H Area. Still designed for gravity flow, they were set up at slightly lower elevations south of the canyon buildings. There they could receive flow from both 221 and 211 buildings by way of stainless steel pipes. Both waste tank farms were situated to allow for the construction of additional tanks, since it was understood from the beginning that there would need to be more tanks.

By the end of construction for Project 8980, there were eight waste tanks in F Area and four in H Area. Each of these original tanks was constructed entirely below grade. The tops of the storage tanks are the most visible

components of the tanks, which were 75 feet in diameter, 24.5 feet high and could contain 750,000 gallons each. The tank walls were made of 0.5-inch carbon steel. Along the bottom, each tank was enclosed in an 80-foot diameter concrete vault that was lined along the bottom five feet with 0.5-inch thick steel "saucer." Each tank was capped with a concrete roof supported by 12 steel-encased concrete columns. Each discrete group of tanks was surrounded by its own berm and control facilities. These included pump houses (one in each area), valve houses, and diversion boxes. The diversion boxes were located below grade to shunt the material from tank to tank as needed.[230]

The four original tanks in H Area, two of which had cooling coils, were constructed like the ones done previously in F Area. Another four tanks were added in 1954-55. These had a different design. They were larger: 27 feet high with diameters of 85 feet, they could hold 1,070,000 gallons each. Since gravity flow was found to be inadequate here, pumping facilities were installed to carry the waste stream. The 12-column design was replaced by a single central column, which would allow the tank bottoms to expand and contract more easily, given the extra heat given off by the waste material. Each tank had a steel saucer, surrounded by a concrete shell, as with the original tanks. Heaters were placed in the open space between the tanks and the concrete casings to keep the area dry. This would make leaks easier to detect.[237]

During the design phase of these tanks, steam jets as well as pumps were studied for the best means of transporting waste from the canyons to the waste tanks. Pumps were found to be better since steam jets would only contribute to the waste volume through their condensate. The pump for these tanks had to be large and vertical, with no seals, and with special bearings, since it could not be revisited for repairs. It had to last an estimated 25 years before replacing.[238]

Another design consideration was the piping that serviced the waste tanks. The piping was important enough to receive its own building number, in this case 805-F and 805-H. Based on what was used at Hanford, Du Pont decided on stainless steel pipes, encased in concrete. Leaks were kept to a minimum by special attention to the welding, which was x-rayed. Pittsburgh Testing Lab did the first x-ray work, beginning in February 1952, resulting in 60,000 different films of 50,000 different welding seams.

The construction of waste tanks would continue throughout the operational history of Savannah River. Designs and sizes would change as well. These changes will be fully discussed in Chapter 10. By the time waste tank construction was finished at Savannah River in the late 1980s, there would be four basic types of waste tanks, and a total of 51 tanks.

240-F Compressor House

Constructed in 1967, the Compressor House is located south of 717-F, the Mock-Up Facility. It is a Class III building clad in prefabricated metal panels with a shallow-pitched gable roof. The building rests on a poured concrete deck foundation. The building is accessed through a double-door windowless entry, while the building is void of any windows. The small

240-F, Photographed in 2012.

241-1F Control Room, Photographed in 2012.

241-11F Gang Valve House, Photographed in 2012.

241-18F Control House, Photographed in 2012.

241-20F Cooling Towers/Pumphouse, Photographed in 2012.

rectangular building houses the air compressors for the F Area facilities.

241-1F Control Room

The Control Room, 241-1F, is located within the 241-F tank area. Added to the facility in 1971, this is a small rectangular building that houses the Waste Storage Tank controls. The Control Room is a one-story Class III building clad in prefabricated metal panels. There are two sections of the building that are joined together, each with a single-leaf access door so the building can be entered at either end. The smaller building portion contains an office area, while the larger contains the control panels. The building rests on a poured concrete foundation.

241-11F Gang Valve House

Built in 1969, the Gang Valve House is located in the southeast corner of the 241-F area. This is a Class III prefabricated building resting on a concrete pad foundation. It is a small rectangular building with a gable roof sheathed in prefabricated metal panels. The building is clad in aluminum siding. There are two half-light doors that access the building. The Gang Valve House houses the multi-unit valve that facilitates the transfer of wastes to the tanks.

241-18F Control House

Built in 1976, the Control House is located on the south end of the 241-F area. The building is composed of two parts, a one-story section and a two-story section. It is a flat-roofed Class III building clad in prefabricated metal panels. The building houses control panels and equipment related to the Waste Storage Tanks of 241-F.

241-20F Cooling Towers/Pumphouse

Built in 1974, the Cooling Towers and Pumphouse ensure the waste stored in the tanks does not overheat. 241-20F is located on the east end of the 241-F area, along the railroad spur. This is a series of two structures

situated on a poured concrete foundation. The structures contain the cooling equipment and are not sheltered by a building.

241-28F Change House

Built in 1976, the Change House has a personnel area for changing into protective gear, as well as an area serving as a control house. Located on a berm in the northwest corner of the 241-F area, this is a single-story Class III building clad in prefabricated metal panels. The gable roof is also covered in metal panels. Various doors found on two of the building's facades provide access to the interior, with single pane windows located along the main facade.

241-28F Change House, Photographed in 2012.

241-28H Evaporator Control Building

The Evaporator Control Building is located on the south end of the 241-H area. Evaporator facilities began to be constructed in the mid 1950s to concentrate radioactive wastes from 221-H Separations Building in order to reduce the volume prior to storage in the waste tanks. The Evaporator Control Building houses a control room lined with control panels that direct and monitor the evaporator facilities. Constructed in 1978, 241-28H is a single-story, long rectangular building with a gable-pitched roof. The building is clad with prefabricated metal panels, as is the roof.

241-28H Evaporator Control Building, Photographed in 2012.

241-31H DB No.7 and Gang Valve House

241-31H is the Diversion Box No. 7 and Gang Valve House Building, located in the 241-H area. A support building for the 241-H waste storage tanks, 241-31H was constructed in 1977. The Gang Valve House contains the multi-unit valve that facilitates the transfer of wastes to the tanks.

241-31H DB No.7 and Gang Valve House, photographed in 2012.

241-34H IX/RO/Evaporator OH Tank Containment

The IX/RO/Evaporator OH Tank Containment facility is located to the east of the 241-H area. Constructed in 1977, the facility is comprised of several liquid storage

241-34H IX/RO/Evaporator OH Tank Containment, photographed in 2012.

tanks situated under a steel superstructure with a set of stairs and various pipes and tubing. The tanks and superstructure are open to the elements.

242-F & H Evaporator

Built in 1959, 242-F is located in the north central section of the 241-F Waste Storage Tank area. It is a reinforced concrete box-like structure that rises at least two stories in height and contains equipment only. Evaporator facilities began to be constructed in the 241-F area in the late 1950s to concentrate radioactive wastes from 221-F Separations Building in order to reduce the volume prior to storage in the waste tanks.

The 242-H Evaporator is located west of 221-H, in the 241-H area. The facility is a metal structure, approximately three stories in height. Its exterior is wrapped with two levels of mezzanines, providing access to workers.

The Evaporator Being Placed in 242-F During Construction, October 13, 1959, SRS Negative DPSPF 6279.

242-1H Evaporator/Containment Building

Originally called Waste Evaporator Control House, the Evaporator/Containment Building is located in the 242-H area west of 221-H. It is a small rectangular building with a gable roof. The exterior is partially clad with Transite, with the majority clad in aluminum siding. A single half-light door covered with an awning occupies the east elevation of the building, while the rest of the building is void of windows. Located inside the building are several control panels. Just to the front of the building is diversion box H-DB3.

242-1H Evaporator/Containment Building, Photographed in 2012.

242-16F Evaporator House

Built in 1982, the Evaporator House is located in the southwest quadrant of the 241-F area, in the center of a group of waste tanks. Like 242-F, equipment housed in the Evaporator House concentrates radioactive wastes from the canyon building before they are stored in the waste tanks. This is a Class I reinforced concrete building with the main section hollow and containing equipment. The hollow section can be entered on the west elevation of the building while an upper story exterior mezzanine allows access to the top part of the building.

242-16F Evaporator House, Photographed in 2012.

242-16H Waste Evaporator No. 2

Serving the same function as 242-16-F, Waste Evaporator No. 2 is located in the 241-H area, southwest of 221-H. Constructed in 1978, it is a large rectangular facility void of windows. With an approximate height of three stories, it is a metal clad facility with a series of tubing and piping located along its exterior. A metal exterior staircase leads up to the rooftop, to access other equipment located there.

242-16H Evaporator House, Photographed in 2012.

260-4H Monitor and Change Building

Constructed in 1958, 260-4H is the Monitor and Change Building and appears to be of Class III construction. It functions as a support building for the waste storage tanks. It is located west of the railroad spur and the Canyon Building and is a small gable-roof building clad in aluminum siding. Both side-gable oriented elevations contain a single-door entry with half-light metal doors. The remaining two elevations contain windows with single-light fixed sashes. The roof is covered with prefabricated metal panels.

260-4H Monitor and Change Building, Photographed in 2012.

V. EARLY SEPARATIONS, 1940s-1952

When the canyon buildings began operations at Savannah River, the main part of the process was to produce plutonium-239 (Pu-239) by irradiating natural uranium in a reactor. This was basically the same function that separations had during the Manhattan Project, when Du Pont ran the Hanford Plant in Washington State. There, Du Pont made enough plutonium to fashion into the "Fat Man" bomb that was dropped on Nagasaki on August 9, 1945 - just three days after the uranium-235 (U-235) bomb had been dropped on Hiroshima.

Hanford and the rest of the Manhattan Project were not only secret operations, but also were conducted with the utmost speed. Until Nazi Germany's surrender in early May of 1945, it had been assumed that the United States was in a neck and neck race with the Germans to develop the atom bomb. U-235 was the first substance known to be fissile enough to make a bomb, and this had been discovered in Berlin just before the war. U-235 was, however, difficult to collect in usable quantities, since it had to be harvested atom by atom from natural uranium by means of electromagnetic processes or by gaseous diffusion. Before the war, it had been grasped by both sides that even though a bomb could be made from this uranium isotope, the practicalities of harvesting the raw material would be maddeningly difficult.

By contrast, plutonium, a man-made element, was not even known until late 1940 and early 1941, when Glenn Seaborg, Edwin McMillan, and others discovered and named the substance in a laboratory at the University of California, Berkeley.[1] The most stable form of plutonium has an atomic mass number of 244, with a half-life of 80 million years. This variety, though, was not useful for a bomb. That duty fell to Pu-239, a relatively common isotope and the best fissionable variety. It also has a long half-life, over 24,000 years. By contrast, Pu-241, which is also fissile, only has a half-life of 14 years.

The process of creating Pu-239 was different from that for U-235. Plutonium can only be made in industrial quantities in a reactor, where natural uranium can be exposed to slow-moving thermal neutrons, bumping up the atomic number of the exposed materials, creating Pu-239. Unsure which fissionable material would be the easiest to make, U-235 or Pu-239, the directors of the Manhattan Project decided to hedge their bets by proceeding with both. This was the reason two different atomic bombs were dropped on Japan at the end of World War II.

In the years that followed, plutonium came to be favored over U-235 as the preferred fissionable material in the U.S. weapons arsenal. Plutonium had a long half-life and could be recovered by chemical means, since it was a different element, not just an isotope of uranium. From this point on, separations became crucial to the production of nuclear weapons materials, and separations began with the bismuth phosphate process.

BISMUTH PHOSPHATE PROCESS

During the Manhattan Project, the recovery of plutonium was paramount; recovery of the other materials left over from the process, even the uranium, was not. The separations pilot plant at Oak Ridge came up with the method used at Hanford by which plutonium could be pulled from everything else, including the uranium. This method was based on a precipitation process using bismuth-phosphate, with purification based on lanthanum-fluoride.[2]

Every effort was made to keep the separations process simple at Hanford, since it would be hard enough to do anyway. The entire process was highly radioactive and would have to be remotely operated. It would also be costly. The separation was based on using simple batch techniques, like those first developed by Glenn Seaborg. The irradiated uranium rods would be dissolved in acid, "leaving an aqueous solution in which plutonium ions were extremely dilute." Bismuth and lanthanum were added as "carriers," so that:

> When bismuth phosphate and lanthanum fluoride were subsequently precipitated out, they would carry with them plutonium phosphate and plutonium fluoride in quantities of precipitate large enough to separate.... By repeated dissolutions and precipitations, with intervening changes in oxidation state, plutonium was separated from uranium and fission products. Simple tanks were used for the dissolutions and precipitations; centrifuges were used for separating the precipitates.[3]

In this manner, 95 percent of the created plutonium could be recovered. All of the uranium left over from the process was discharged with the waste, which also contained bismuth phosphate and lanthanum fluoride.[4]

This basic process, which has come to be known as the bismuth phosphate precipitation method, was the original separations process at Hanford. This process drove the design of the first separations buildings. Three separations buildings were built during the Manhattan Project: two were put into use, with the third held in reserve. Each was 800 feet long, 65 feet wide, and 80 feet tall, which is why it was given the name, "canyon." There was just one process line inside each canyon. Each had 40 process pools or tanks to provide mixing areas to separate and purify the plutonium. Bismuth phosphate was used for the basic separation, while lanthanum fluoride was used for the final concentration. The final product was a plutonium nitrate that was shipped to Los Alamos, New Mexico, for the final transformation into plutonium metal, the form used in the bomb.[5]

Separations has come a long way since the days of World War II, but the Hanford legacy to Savannah River separations is huge. Both procedures were based on the use of long, thick-walled "canyon" buildings, with the process plumbing embedded inside the concrete walls. Piping was based on the use of standard positions for the pipes, augmented by the use of jumpers. Remote operation and maintenance was an essential part of the proceedings, and cranes traveling on rails were required to move or change equipment. Liquids were used in every step of the process, and they were moved around by means of gravity flow or steam-jet ejectors. There were a number of ingenious safety features, such as gang valves that allowed steam lines to be purged with air so that condensation would not force contaminated solutions out of the protected areas.[6]

The bismuth phosphate precipitation method was used in conjunction with the standard laboratory batch process. Mal McKibben, Analytical Laboratory supervisor, recalled that, "it was messy but it worked."[7] Don Orth, who worked in Separations Technology for most of his career at SRS, called it "classic laboratory chemistry, applied on a very large scale."[8] One reason it was considered so messy is that it was slow and did not recover the uranium, which went out with the waste stream. While this was tolerable for a war-time operation, it was considered highly wasteful in the years that followed. Even before the end of the war, other methods were under study to recover the uranium as well as plutonium. This led to the development of the next method used at Hanford, called the Redox process.[9]

REDOX PROCESS

Bismuth phosphate worked through batch precipitation, which was lengthy and costly, and was only able to separate plutonium. There was soon a search for a new method of processing irradiated material using a continuous process that could recover both plutonium and uranium. Separations research along these lines began during the Manhattan Project, and continued after the war at the Hanford Works, Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL), and Knolls Atomic Power Laboratory (KAPL). This led to an examination of "solvent extraction," based on the idea that elements could be mixed together in a solution that would then separate into lighter and heavier layers, each carrying different materials that could then be run off separately.[10]

The first "solvent extraction" process was Redox, conceived in 1944 and seriously studied immediately after the war. It was a definite improvement over bismuth phosphate, since it could pull out both plutonium and uranium from the dissolved solution. The Redox process was further improved during the so-called "Plutonium Project" (1948-49) that involved Du Pont as well as the new Atomic Energy Commission. In addition to improving Redox, this project suggested that Redox itself might not be the best solution to use for separations.[11]

The AEC wanted Hanford to switch to Redox, and this was pushed in late 1949, in response to the new Soviet bomb.[12] Despite this, it was not implemented until 1951-52, when it became the first solvent extraction process used on a large scale for nuclear separations.[13] At Hanford, the Redox process required the use of ion exchange columns.[14]

Redox was based on the use of Hexone (methyl isobutyl ketone) as the organic solvent. Acting in conjunction with the aqueous solution, the organic and the aqueous would mix and then separate and flow in opposite directions through a column or some other mixing chamber. The organic and aqueous solutions were referred to as "phases." Because the plutonium and uranium would have to be pulled from one phase to another during the time they were mixed, the oxidation states of the solutions were important considerations. A favorable oxidation state helped the elements transfer from one phase to another. This fact contributed to the name of the process; Redox was just a shortened version of "Reduction Oxidation." The process used a great amount of nitrates, since nitrate ions were required to move oxidized ions of uranium and plutonium into the solvent. This raw material was provided by nitric acid.[15]

Though an improvement over bismuth phosphate, Redox was not without its own problems. Not only was Hexone flammable, but also it was soon found that Hexone did not work well with high concentrations of nitric acid. Eventually aluminum nitrate had to be used instead. This ended up producing huge volumes of waste.[16]

In addition to its other problems, Redox required the construction of a relatively high separations building to accommodate the pulse columns used in the process, and this clashed with the lower, "cellular" type of construction favored by Du Pont. By the time the Savannah River Plant was conceived in 1950, Du Pont and the AEC were casting around for another process more compatible with "cellular" pieces of equipment.[17] These concerns would lead to the development of the "mixer-settler," which proved to be such a critical component of the Purex process at Savannah River.

For all of these reasons, Du Pont was not in favor of using Redox for their new project. In contemplating the separations procedures needed for Savannah River, Du Pont studied an adaptation of the Butex process used by the British in the late 1940s. Named after the extraction solvent "dibutoxydiethyl ether," Butex was strong enough to handle nitric acid without resort to aluminum nitrate. It was also denser and less volatile than Hexone. It was, however, expensive.[18] By that point, the issue was almost moot, since a new process, Purex, designed to be used with mixer-settlers, was already in the wings.

EARLY PUREX

Origins of Purex

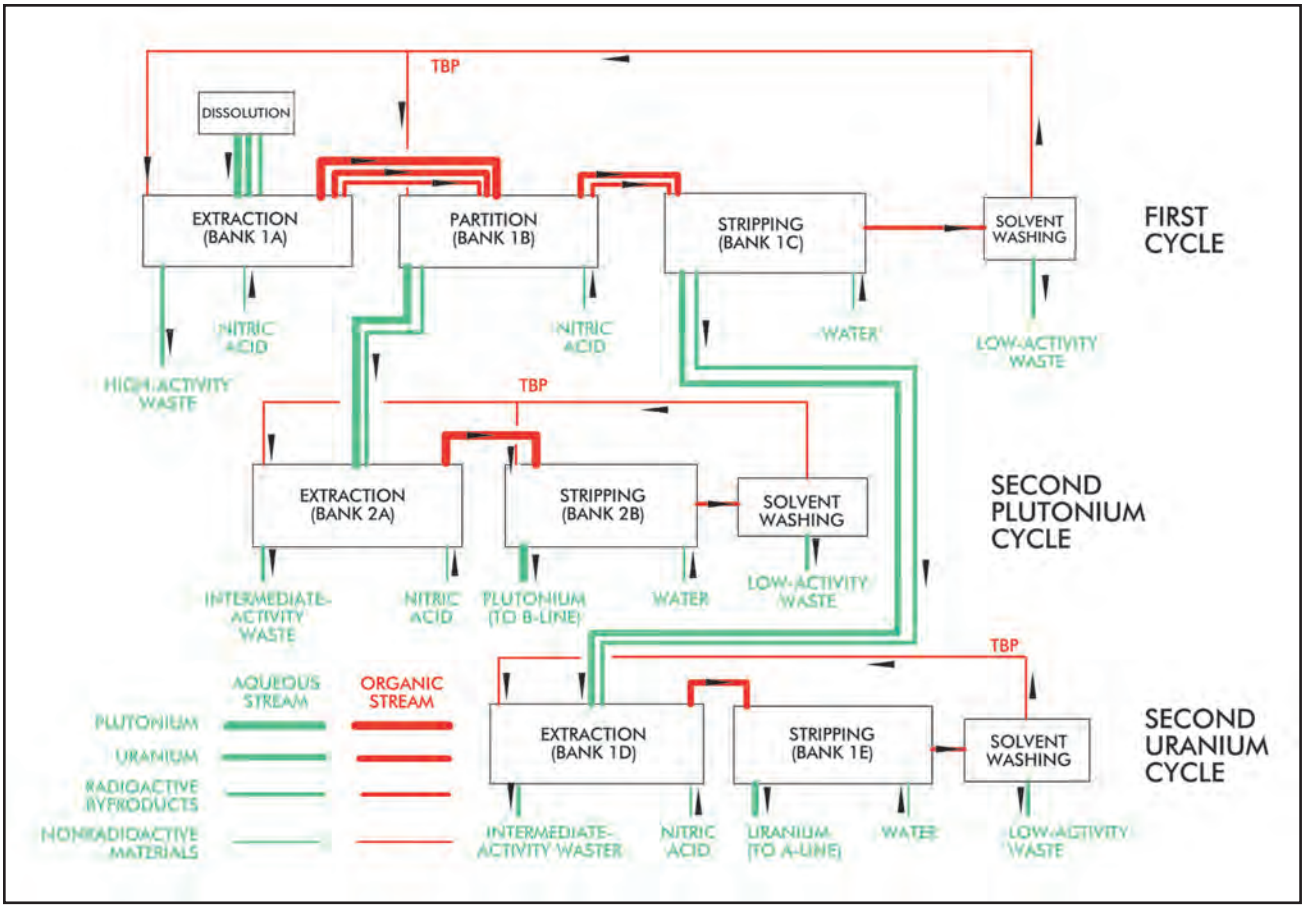
Purex takes its name from "plutonium-uranium extraction."[19] By most accounts, the process was developed in different stages at ORNL, ANL, and KAPL. Charles Goergen, who began working in Separations in 1974, pinpointed Building 3019 at Oak Ridge as the site of the first pilot plant work.[20] Others have pointed to research done at KAPL, as well as Oak Ridge. The Du Pont Engineering and Design History claims that Purex was developed at Oak Ridge National Lab and at KAPL.[21] William Bebbington, historian of the Du Pont years at Savannah River, claims that it was first worked out at the AEC laboratory in Ames, Iowa.[22]

All of these claims are basically correct; research occurred in all these places. The idea began at Ames Laboratory, with further research at both Oak Ridge and KAPL, followed by the first pilot works at Oak Ridge. Research on Purex began in earnest around 1948 and the first flow sheet was worked up by October of 1950. It was developed and operational by 1952, with additional testing and corrections done at the Savannah River Laboratory, after that facility was built in the early 1950s.[23] Work was also done in Building 678-G, the Separations pilot works at TNX.[24]

Basic Concepts

Purex was a chemical process that shared a number of basic features with Redox. Both were "liquid to liquid" separations, where elements were transferred from one solution or phase to another, and then back again as required for purification. There were two phases used to make these transfers. One was aqueous (water-based) and the other was organic (kerosene-based and lighter than water). Redox used pulse columns to effect the transfers between phases; Purex would use mixer settlers.[25]

Because so much will be made of organic and aqueous solutions in this report, it might be useful to identify and define all of the various terms used to describe these solutions, since many terms are used interchangeably. In Purex, the aqueous phase or solution contains water and nitric acid. It is the heavier of the two solutions. During the process, it contains the dissolved metals, held in solution. The other solution that floats on top of the first is the organic or solvent solution or phase. The organic solution consists of two parts: the extractant, in this case tributyl phosphate (TBP); and a kerosene product. Because the TBP by itself is almost as dense as water, kerosene or some other paraffin product is essential to dilute the TBP to ensure that it floats over the aqueous phase. Unless this



Purex incorporates three main steps: first cycle, where plutonium is separated from uranium; second–cycle plutonium, where the plutonium is purified; and second–cycle uranium, where the uranium is purified. Source: Reed et al., Savannah River Site at Fifty, 363.

happens after the solutions are forcibly mixed, there can be no separation. In the first years at Savannah River, the percentage of TBP to diluent in the organic phase was 30 percent TBP and 70 percent diluent.

Purex had certain advantages over Redox. It had a high "decontamination factor," which meant that it could separate plutonium and uranium better than the earlier process. The percentage of recovery was higher, resulting in less waste. And Purex was less flammable.[26] Not only was Purex found to be better for use at Savannah River, it soon became the standard for plutonium and uranium separation both in this country and around the world. Savannah River's F Area can claim to be the first large-scale facility to use the Purex process anywhere in the world.[27]

A number of researchers have described the basic process. Bebbington described the Purex process as having a solution of tributyl phosphate in a kerosene-like hydrocarbon. This was used to extract plutonium and uranium from the nitric acid solution, which contained everything that was dissolved from the irradiated uranium that came over from the reactors. This chemical extraction occurred through the counter-current contacting of the two solutions in multi-stage mixer-settlers, where the solutions are mixed together and then separated by settling.[28]

Dr. LeVerne Fernandez, who worked in the Separations Laboratory, writing about the versatility of the Savannah River canyons years later, described the Purex process as the first to use tributyl phosphate (TBP) in the solvent. Purex, he said, was a two-phased liquid system based on the counter-current flow of an acidic aqueous stream on the one hand, and an organic phase containing an extractant on the other. In the aqueous phase, nitric acid was used, and in the organic phase, TBP, which was dissolved in a lighter-than-water organic liquid, such as an n-paraffin. The two phases are then mixed and separated in multi-chambered tanks known as "mixer-settlers."[29]

Don Orth described the process a slightly different way, highlighting its versatility. Purex, he said, was:

> ...the first application of tributyl phosphate as a solvent in a system that contacted aqueous nitrate solutions of metals, with the solvent, and which would extract into the solvent, then by reversing the chemistry, one would back-extract out of the solvent. So it was just a series of such operations: extract, back-extract, extract, back-extract, that one could pull out specific elements: uranium, plutonium, neptunium, thorium, whatever it was you were trying to do.[30]

As Orth explained, using the same basic process and the same equipment, Purex (or a slight modification of Purex) allowed you to isolate and purify a whole range of actinide-series metals, not just plutonium and uranium.

The key to the Purex process was the extractant: tributyl phosphate or TBP. The idea for first using TBP has been attributed to Ray Fisher at Iowa State University's Ames Laboratory. Fisher then suggested TBP to Warren Eister at the Oak Ridge Chemical Technology Division, and the ball started rolling from there.[31] As a result of study, TBP was chosen as the active extracting ingredient in the aqueous phase, which was otherwise formed by a kerosene-like product that had to be lighter than water. TBP was cheaper than Hexone and more stable chemically than Butex, and eventually proved more effective than either one. TBP, and the Purex process itself, is now used around the world to separate and purify actinide elements.[32] In the beginning, the percentage of TBP to kerosene was at the ratio of 30/70, and this was the first arrangement used at Savannah River. In later years, that percentage would change, depending on the materials to be extracted.[33]

The extractant might have been TBP, but the solution that carried it was based on a form of kerosene. This comprised the organic phase of the whole Purex process. In fact, when Purex was first conceived and tested, simple kerosene was the diluent. By 1953, though, another form of high-grade kerosene, ultrasene, was chosen as the basis of the organic phase, since it had a higher flash point and was safer.[34] Ultrasene, a product of Atlantic Richfield Company, was used to initiate the Purex process at Savannah River.[35] As will be seen, with the increase in production, a number of problems developed with ultrasene, but it was not until the 1960s that a suitable substitute was found that could handle the high levels of radiation found the process.

The Purex process digs deep into the basics of chemistry in order to carry out its function, and this chemistry required a concern for the oxidation and valence states of the elements being separated. Valence and oxidation are determined by the electron status of the element's ions. Being electron-deficient allows both uranium and plutonium to leave its original aqueous solution and move into a TBP-hydrocarbon solution. Each electron stripped away increases the positive charge of the element by one, and this positive charge controls how well ions move from one solution into another.[36] Being "electron-deficient" is the same as being in a "highly oxidized state"; these terms are used interchangeably.

An ion itself is an electrically charged atom or group of atoms, either positive or negative, depending on the presence or absence of electrons. Ion valence is in these two different states, positive or negative. When an atom loses one or more electrons, it becomes a positively-charged ion, or "cation." When it gains electrons and becomes negatively charged, it is "anion."[37]

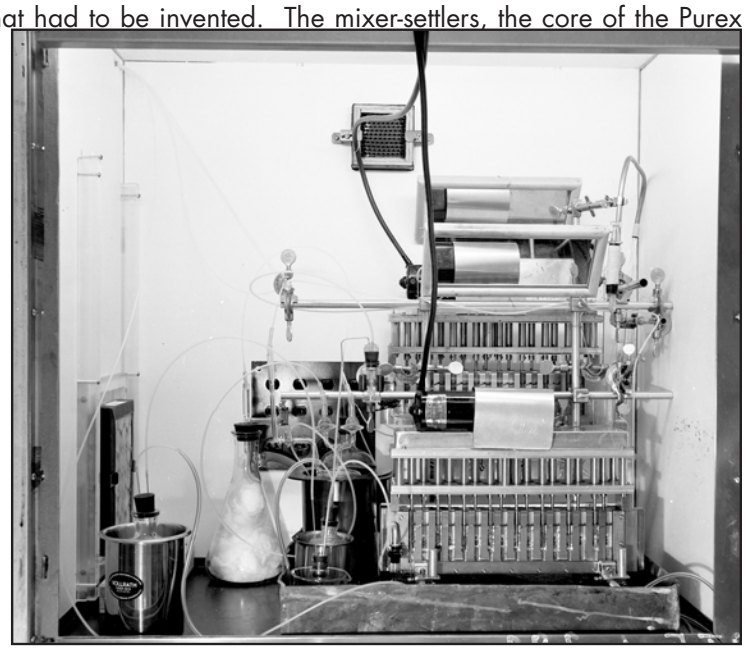
This can get complicated, since not all oxidation states are the same. For example, uranium +3 and uranium +4 act like different elements, and TBP reacts best with uranium in the +3 state.[38] The state of plutonium also has to be considered too. Not all plutonium ions can be extracted with organic solvents. Oxidation states often determine what is soluble and what is not. The uranium and plutonium oxidation states that react best with solvents are: hexavalent uranyl ions (UO_2)++, plutonyl ions (PuO_2)++, and tetravalent plutonium ions (Pu^4+).[39] For this report, suffice it to say that oxidation states are important in the separation of plutonium and uranium, but the details are not essential for the general reader to understand the function of the canyon buildings.

Once the chemistry has made the uranium and plutonium valences receptive to the transition, then they can be pulled out of the aqueous and into the organic phase. The highly radioactive waste by-products, also created by the irradiation process, have to stay behind, in the original aqueous solution, and are jettisoned with the waste stream. This was basically how the solvent method worked: it pulled out highly oxidized forms of uranium and plutonium from the aqueous feed solution and into the organic, leaving the fission products behind. Only then are the uranium and plutonium separated from each other, pulled back into aqueous phases, and purified. This is the basis of the Purex process and it was the separations method installed in the two separations canyon buildings at Savannah River in the early 1950s.[40]

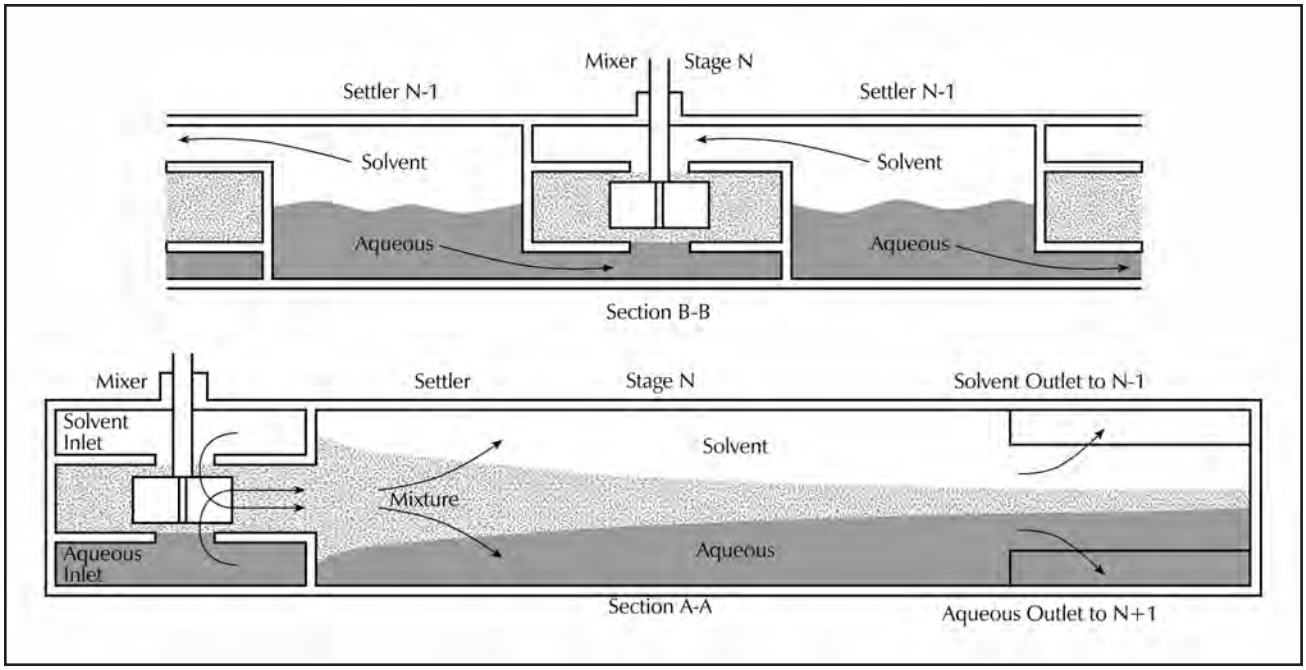
MIXER-SETTLERS

Separations, especially on the scale that would be done at Savannah River, was something that had never been tried before, and it required equipment that had to be invented. The mixer-settlers, the core of the Purex operation at Savannah River, were virtually new creations. There were many other pieces of equipment and all were important, but none more so than the mixer-settlers. It was here that the two solutions, the aqueous and the organic, were mixed and separated.

During the creation of the Purex process, KAPL is believed to have been the first place to use mixer-settlers as the basic vessels to mix and separate the aqueous and organic phases.[41] From the beginning, Du Pont preferred mixer-settlers to the Hanford pulse columns, and they were incorporated into the first designs of the separations facilities at Savannah River.



Photograph of a Miniature Mixture-Settler Taken at the Request of William Prout, date Unknown, SRS Negative DPSTF 1-281.

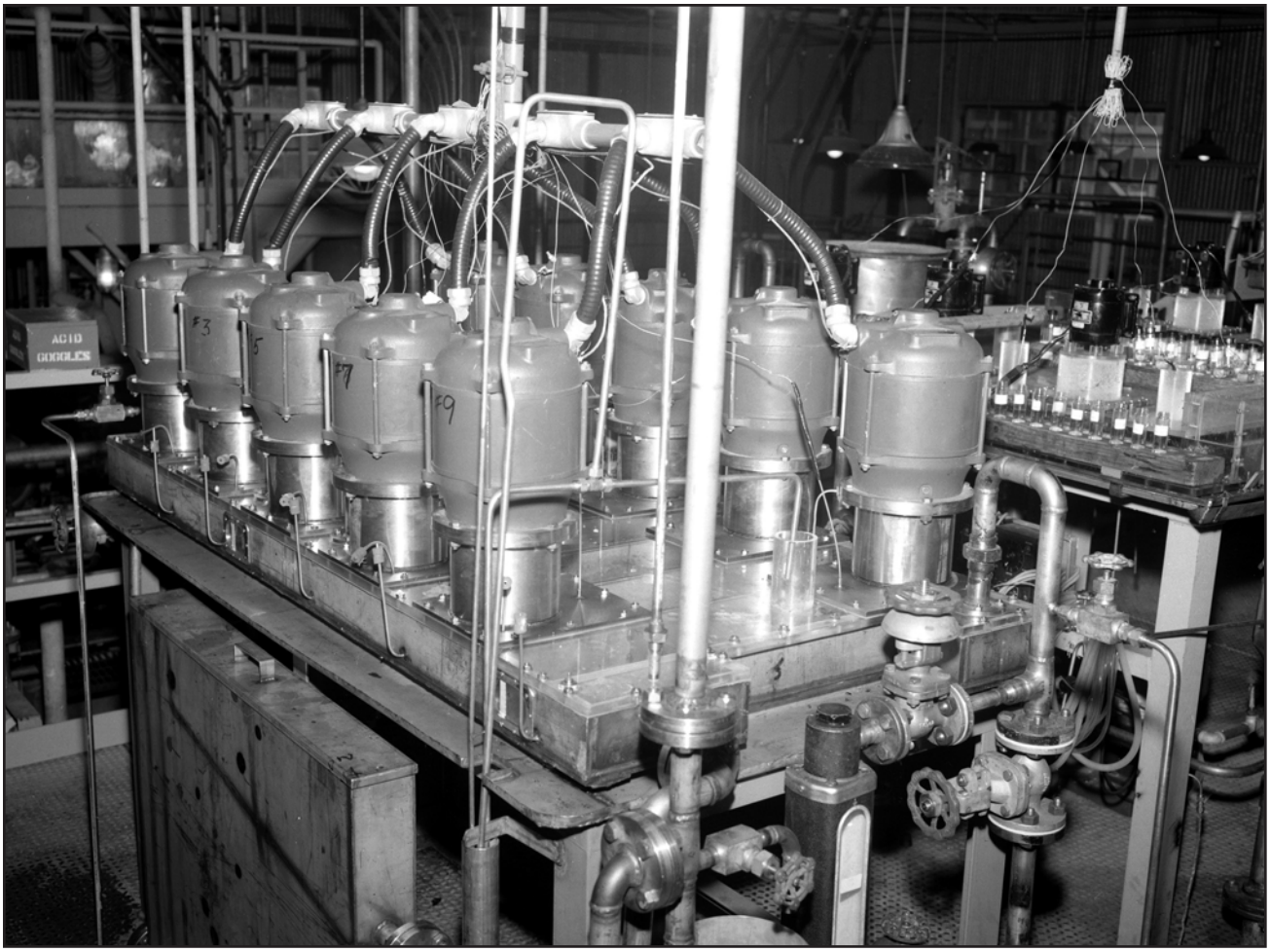


Line drawing of mixer-settlers. Mixer-settlers combine the aqueous and organic solutions in mixing chambers, then allow the two to separate into individual phases in settling chambers. Each pair of mixing and settling chambers is called a stage. The original mixer-settler units at SRS each contained 12 or 16 stages. Bebbington, The Reprocessing of Nuclear Fuels, Scientific American *235, No. 6 (December 1976), 35.*

Pulse columns and mixer-settlers basically do the same thing, but in a different way. A pulse column is similar to a distillation column, but with a pulse added to move the liquid back and forth in the vessel, often through a membrane, with materials drawn from the top and the bottom of the column.[42] Pulse columns, also called extraction columns, have the lighter organic solution flow through the column to the top, where it is drawn off, and heavier aqueous solution drawn off from the bottom. The taller the column, the better the separation between the two phases. Pulsing made the column more effective, with liquids mixed by being drawn back and forth through perforated plates located near the center of the column. Pulsed columns were used in the Redox process at Hanford, and even in the Purex plants that were later installed there, but the columns were not favored by Du Pont and were not put to use at Savannah River.[43] In the early days of Savannah River, everything was based on the use of mixer-settlers.

Mixer-settlers were basically low, broad boxes with various compartments called stages. Weirs were installed to help control the flow of the two solutions or phases, with the aqueous phase drawn off the bottom of each stage and the organic phase drawn from the top. The mixing was done by impellers or agitator pumps. The separation in the settling areas was done by gravity. It required several stages for a mixer-settler to complete its work, since no single stage could be made efficient enough to do the job on its own.

William Prout, during his training at KAPL in the early 1950s, was closely involved with early research on mixer-settlers. He worked up the first XY diagrams for the test-sized miniature mixer-settlers, since there were no computers to do that work back in 1951. Prout was also involved in the creation of the first flow sheets for TBP.[44]

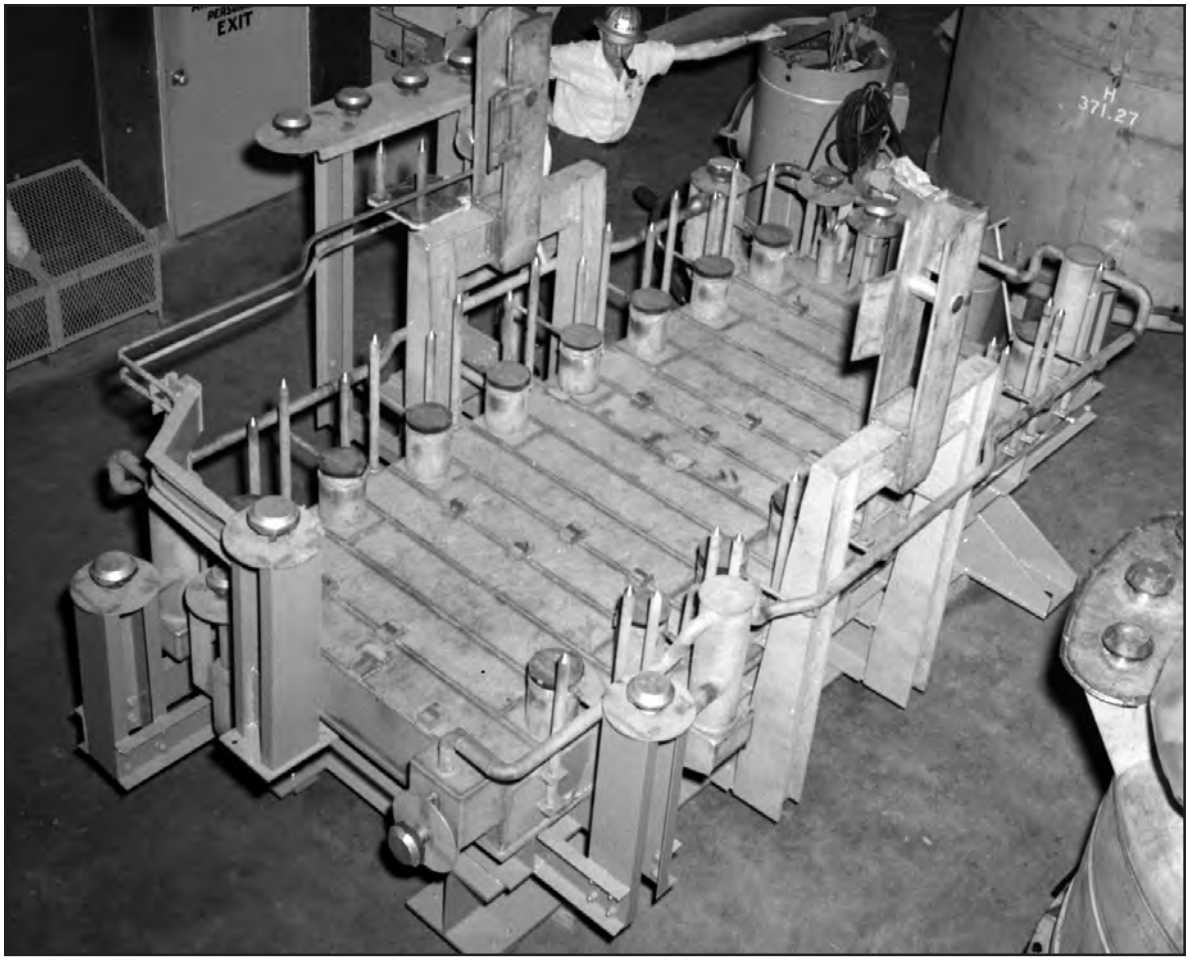


An original mixer-settler being tested at TNX, October 7, 1955, SRS Negative DPSTF 1-1014-2.

TNX Building, 1951, SRS Negative 6-157.

The first mixer-settlers at KAPL were experimental devices that measured flow in cubic centimeters. Later, pilot plant work on small mixer-settlers was done at TNX and at the main laboratory, in the B-Wing and C-Wing of Building 773-A. Romine remembered working on these early mini-mixer-settlers, also known as mini-banks, where flow could be observed through glass walls.[45]

From these beginnings, mixer-settlers grew in size, until the first regular sized mixer-settlers could hold up to 18 gallons. Years later, when there were Jumbo mixer-settlers, each stage could



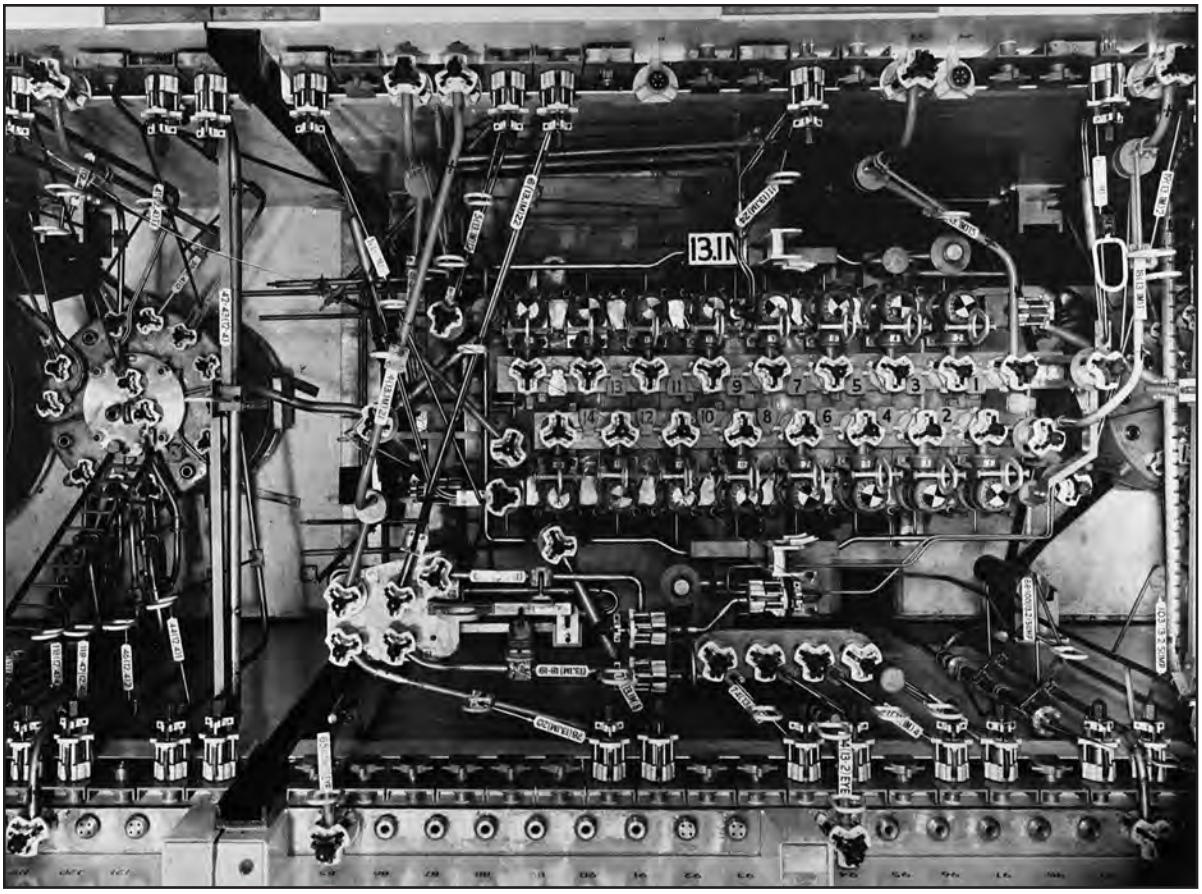
A Full-Size Mixer-Settler in 717-F, September 16, 1953, SRS Negative 2-550-5.

hold 18 gallons.[46] Impellers and pumps were very important to control and speed the mixing at each stage, followed by a period of rest and separation in a settling basin. Each stage had its own impeller and settling basin, and it was common for mixer-settlers to have 16 stages.

Mixer-settlers required these multiple stages or contact points to ensure that the materials would adequately separate. Multiple contact points were necessary, since early on it was discovered that a single contact area, no matter how big, could not manage the transition at one time.[47] The two solutions flowed from one stage to the other by means of weirs. Even so, there was always a small amount of residual material that could not be separated. This was anticipated and was corrected by a number of exit stream decanters.[48]

As described by Al Kishbaugh, separations engineer, a mixer-settler had:

> An impeller at each stage that pumps the aqueous phase up to the next phase and solvent from the stage on the other side flows into the mixing section, you beat up the two phases and shoot them out to the settling section; the aqueous is drawn off the bottom and it goes to the opposite



Mixer-Settler in Section 13 of the Hot Canyon, 1955, SRS Negative 2320-97.

> end from the stage it entered and the organic goes the other way. Within a stage you have concurrent flow, both the solvent and the aqueous are flowing down. Overall, in the bank, you have counter-current—the organic is moving one way and the solvent is moving the other. They come together in each stage and then they separate and move the other way.[49]

In the end you have overflow of the solvent phase and underflow of the aqueous, with most of the material separated out by the time it traverses the 16 stages.[50]

By the time mixer-settlers were installed in the canyon buildings, they were large but not tall, only about 1.5 feet in height.[51] There were a total of eight mixer-settlers installed in each of the two canyon buildings. Three were used in the First Cycle, and there were two each in the uranium and plutonium cycles. The final two mixer-settlers were placed in "re-run," or the re-work area, located in Section 15 or 16 of the Hot Canyon.[52] One of these original mixer-settlers, bearing the imprinted date of "1954," is now on display in the equipment yard on the west side of 221-H.

The mixer-settler was the key to the early success of the Purex process, especially as it first functioned at Savannah River. In later years, there were some other options for the separation of uranium and plutonium, but mixer-settlers, of one size or another, were essential to the early process.

VI. BASIC PUREX PROCESS AT SAVANNAH RIVER, EARLY 1950s

Purex was used at Savannah River to separate plutonium and uranium from the unwanted fission products, which were sent to the waste tanks. Plutonium and uranium were then separated from each other, decontaminated and purified. Plutonium was turned into a metal form for the Department of Defense; the uranium was turned into an oxide and stored for later use.

This very basic description will be explored in greater detail in this section of the report, but it might be useful to explain how this irradiated material was first treated in the reactors, before coming to separations. In some instances, the chemistry and the shielding required for Purex, and separations in general, were already determined by what had to happen in the reactors.

REACTOR IMPACTS TO SEPARATIONS

The operation of a nuclear production reactor is an inherently messy operation. The atoms of all the different elements present in the reactor targets are bombarded with thermal neutrons. Some atoms accept extra neutrons without splitting and become elements with higher atomic mass numbers. Others are split by the extra neutrons and form elements with much lower atomic mass numbers. Some of the new elements are desirable, but many are not. All of the actinide elements can be created in a reactor, given the right circumstances and a long enough exposure to thermal neutrons. How all that is done is beyond the scope of this report, but suffice it to say that you can create increasingly complicated elements in this fashion. The drawback, of course, is that all such creations are radioactive. The unwanted by-products, referred to as fission products, are also highly radioactive. All of these materials naturally decay, giving off alpha particles, beta particles, and gamma rays. This requires that the entire operation, from the reactor to the separation in the canyons, be heavily shielded to protect the operators.[1]

Another feature of the reactor operation was the use of aluminum cladding. Uranium is highly susceptible to water corrosion. Aluminum cladding was essential to protect the uranium fuel elements from the effects of the heavy water coolant and moderator. In the early days of Savannah River, fuel elements were fashioned as small solid cans that were stacked into tubes. Later, they were shaped as tubular elements themselves.[2] Either way, they were clad in aluminum, and this cladding had to be removed and discarded in the separations area before the Purex process could begin. Aluminum cladding could not handle a great amount of heat; this is why, later, aluminum cladding was not used in power reactors that produced steam for turbines. Aluminum also created a lot of waste after it was de-clad. Even so, aluminum cladding was a standard feature of the reactors at Savannah River, and separations had to deal with that.

BASIC STEPS OF THE PUREX PROCESS

The basic process did not change greatly over the life of the Savannah River, but this discussion will concentrate on the process as it was originally set up in the early to mid-1950s.

There were five basic steps to the Purex process: [3]

1. Dissolution/Dissolver
2. Head End Treatment
3. First Cycle Extraction (both uranium and plutonium)
4. Second Cycle Plutonium Extraction
5. Second Cycle Uranium Extraction.

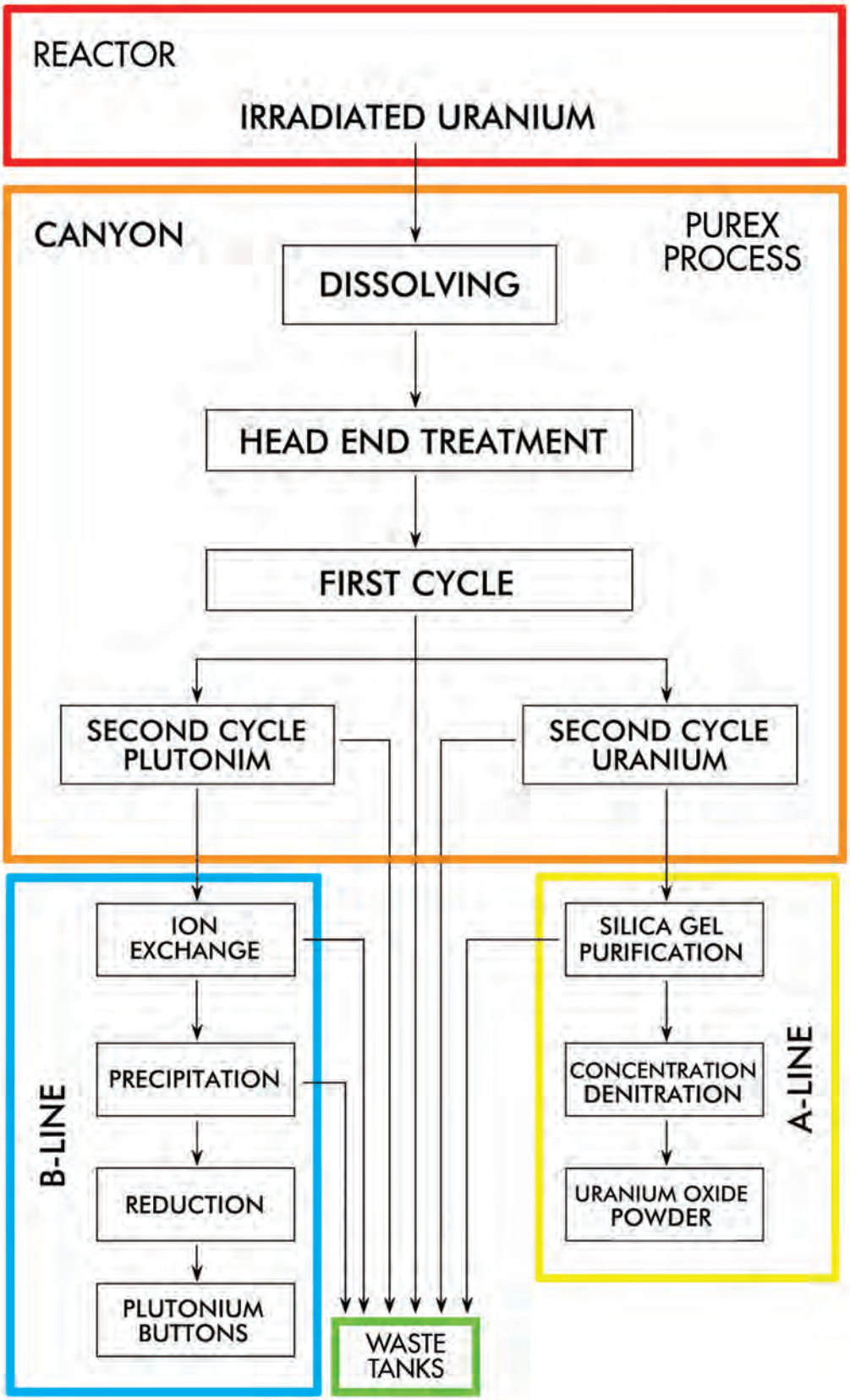
The first of the steps was called either Dissolution or simply Dissolver. In the early days, it was also called "raw metal solution preparation." Here, materials brought from the reactor were placed into special vessels to be dissolved in preparation for the rest of Purex processing. Two things were done in the Dissolver stage. First, the aluminum cladding was stripped away and removed, eventually going to the waste tanks. Second, the irradiated metal itself was dissolved.

This was followed by Head End Treatment. Here the dissolved solution was prepared for the main part of the Purex process. One of the most important steps here was centrifugation of the solution to separate the liquids and dissolved materials from any solids that failed to liquify in Dissolution.

What followed next was the First Cycle Extraction, where the plutonium and uranium were pulled out together from the rest of the solution. This left behind most of the unwanted fission products that eventually found their way to the waste tanks.

In the Second Cycle, the uranium and plutonium were separated from each other, purified and concentrated. The Second Cycle Plutonium Extraction pulled the plutonium from this solution and prepared it for B-Line. In B-Line, it was turned back into a metal form for eventual use in a weapon. Second Cycle Uranium Extraction isolated the uranium and prepared it for further processing in A-Line. Most of this material was purified and then stored.[4]

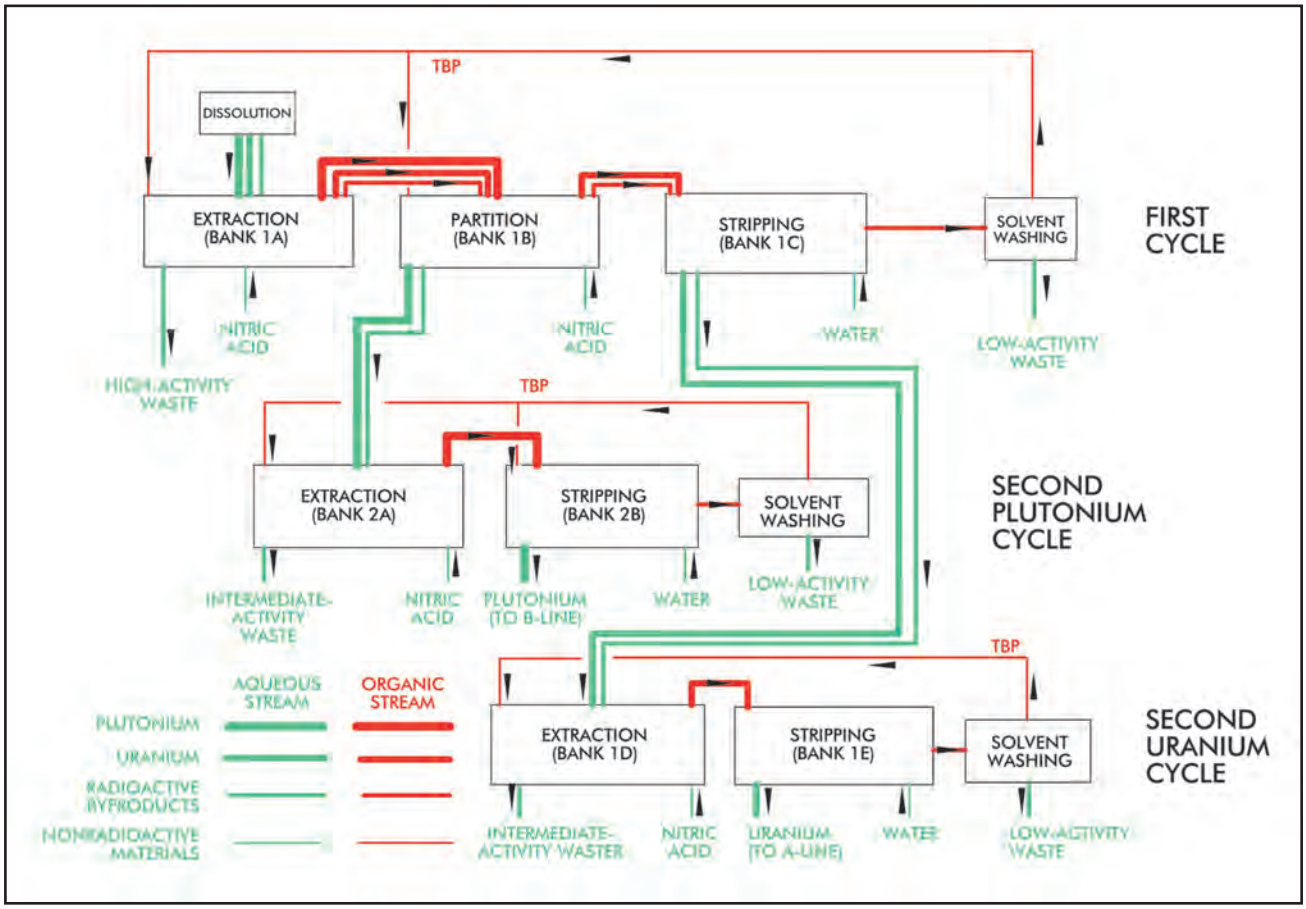
These are the basic steps of the Purex process that took place in the canyon buildings. It is without reference to any individual tanks or pieces of equipment, or the auxiliary processes that were required to recover and purify the solvents, evaporate and remove the waste, and vent the whole system. This basic system, with all five steps, as well as the A-Line and B-Line, can be seen in the flow chart on the opposite page, adapted from the Du Pont Engineering and Design History, Volume 3:23. A much more complicated diagram shows up later in the same volume, this time showing the same process with reference to the tanks and vessels involved in the task and all of the side-processes.



This flow-chart, adapted from the Du Pont Engineering and Design History, Volume 3:23, outlines the basic steps of the separations process.

As can be seen from the second of these two diagrams, the Purex process was quite complicated. For the purposes of this report, there is no need to explain the process at that level of detail. Even so, some of these steps should be discussed in greater detail than is provided in an outline. Before any additional discussion of the canyon buildings and the other buildings in both F and H areas, it might be useful to explore a few more details of each of these steps in the Purex process.

In the early to mid-1950s, the reactor assemblies were usually referred to as slugs, since they were solid cans, clad in aluminum. At the Dissolution stage, these slugs would have been charged to a hopper before being dumped into the dissolver, which was located in the hot canyon. Since this material would have been highly radioactive, the hot canyon crane would have done this work. In the dissolver, the slugs would be turned into liquid form. As mentioned, there were two steps to this process. Caustic solutions of sodium nitrate and sodium hydroxide were added to dissolve the aluminum cladding, which was then sent away to "dissolver coating solution hold tanks" before eventually being sent to the waste tanks. Once the slugs were de-clad, they were rinsed to remove any residual caustic; these rinses too were sent to the waste tanks. The slugs were then dissolved in nitric acid, which was heated by steam to speed the process. The use of nitric acid was essential, since it also provided the nitrate ions essential for the further separation of both plutonium and uranium. Reaction gases from the dissolving process were then pumped through silver nitrate coated saddles to remove any iodine, after which they were "scrubbed" for any particulate matter. The gases were then sent through the sand filter and up the stack.[5]



A more detailed look at the Purex process. Source: W.P. Bebbington, the Reprocessing of Nuclear Fuels, Scientific American *235, no. 6 (December 1976):32-33.*

The Head End process was designed to prepare the liquid solution as much as possible for the main part of the Purex process that followed. In the early planning stage of Savannah River, it was not certain if Head End was really necessary, but it soon proved essential to the success of the whole Purex process. The basic premise of Head End was to remove as much unnecessary material from the process as possible. This was done in two ways. Some unwanted fission products, such as zirconium and niobium could be removed by the addition of potassium permanganate ($KMnO_4$). This was followed by centrifugation, which removed any un-dissolved solids from the process stream. Stream concentration followed, and this was done by evaporation.[6]

The Purex First Cycle Extraction is where the plutonium and uranium are pulled from the solution by means of three mixer-settlers, referred to in the process as "banks." In the first cycle, there are three banks, identified as 1A, 1B, and 1C. Bank 1A does extraction; Bank 1B does partition, and Bank 1C does stripping.

Bank 1A was a 16-stage mixer-settler where both the aqueous and organic phases come together for a series of mixing and separation. The organic phase consisted of ultrasene and a 30 percent solution of tributyl phosphate or TBP. The aqueous phase consisted of the nitric acid and the dissolved material from Head End. By the end of the 16 stages, the plutonium and the uranium, now in the organic phase, have been isolated from the fission products, which stayed in the aqueous phase. The aqueous phase, with most of the fission products, is diverted to the 1AW run tank. Eventually it would go to the waste tanks. The organic phase, now containing the plutonium and uranium, is drawn off from the opposite side of the bank and on to Bank 1B.[7]

Plutonium is separated from uranium in Bank 1B. The organic phase with both elements goes into the bank, where a solution of nitric acid and ferrous sulfamate is brought into contact. Plutonium, now reduced to trivalent Pu^3+, is forced out of the solvent and into the aqueous phase. The uranium remains in the solvent. This part of the process is often referred to as "partitioning." The plutonium aqueous stream continues on to the 1BP run tank to be made ready for the Second Cycle Plutonium part of the process. The uranium organic stream goes to Bank 1C.[8]

In Bank 1C, the organic solvent, containing uranium, is mixed with acidified process water pumped from the 1CX feed tanks. The acidified water removes the uranium from the organic solvent. The uranium, now in an aqueous solution, goes to the 1CU run tank and eventually to the Second Uranium Cycle. The stripped solvent then goes to the 1CW run tank, after which it is then jetted to the spent solvent hold tank in the Warm Canyon to be restored in the solvent recovery facilities.[9]

The Second Cycle Plutonium is designed to purify the plutonium recovered from the First Cycle. This was done in two 16-stage mixer-settlers, referred to as Banks 2A and 2B. Before entering the first bank, the plutonium in the solution was oxidized to the tetravalent state, to aid the transfer process. In Bank 2A, the plutonium goes out with the organic stream after being exposed to TBP. Any remaining fission products and iron (from reduced ferrous sulfamate) are removed from the solvent by a nitric acid scrub. The aqueous, now with the fission products, goes to the 2AW run tank, where it is sampled. If within certain parameters, it goes to the low-activity waste evaporation facilities. In the meantime, the plutonium, in the organic phase, overflows into Bank 2B. In Bank 2B, the plutonium is reduced to the trivalent state and moved back to the aqueous by means of hydroxylamine sulfate from the 2BX gallery feed tank. This aqueous stream, with the plutonium, then goes to a holding tank, and eventually goes to the B-Line for conversion to a metal form. The solvent goes back to the solvent recovery facility.[10]

Uranium concentration is done in the Second Cycle Uranium. The uranium stream comes out of Bank 1C as a uranyl nitrate solution. After checking for any remaining solvent, this solution goes to the 1CU evaporators for concentration as required for the Second Cycle Uranium Extraction, which took place in Banks 1D and 1E. After evaporation, the solution is cooled and sent to two acid adjustment tanks. Here, sodium nitrate and nitric acid solution are added to the mix, which is then diverted to Bank 1D. In Bank 1D, the aqueous uranium solution is mixed with TBP, nitric acid, and a mix of ferrous sulfamate and nitric acid. The TBP pulls the uranium from the aqueous phase, and scrub streams remove any remaining fission products from the organic phase. The uranium, now in the solvent or organic phase, moves on to Bank 1E, where it is mixed with acidified water from the 1EX gallery feed tanks to pull the uranium back into the aqueous phase. This material is then checked for the presence of any remaining organics before it continues to the A-Line for further purification, concentration, and packaging.[11]

This brief description completes the run-down of the Purex process, especially as that process was established and run in the early to mid-1950s at Savannah River. Considering the changes that would be made to the process and the different nuclear materials that would be made in the canyon buildings in later years, the Purex process changed remarkably little. From this point in the process, plutonium and uranium went to their respective finishing lines, A-Line for uranium and B-Line for plutonium.

A-LINES AND B-LINES

Uranium left the Purex process to go to A-Line, while plutonium went on to B-Line. The origin of the designation "A" and "B" has been much debated over the years, but the consensus appears to be that these letters actually stood in for the words "uranium" and "plutonium" during the Manhattan Project and even into the early years of the Atomic Energy Commission. Since the words "uranium" and "plutonium" themselves were classified, the materials being produced in the reactors and processed by separations were commonly referred to as simply A and B. Uranium, being the oldest, was "A," while plutonium, only discovered in 1940-41, became "B."[12] The names A-Line and B-Line came from that practice.

A-Line was built just outside the F Area Canyon building. It was always considered a part of canyon building 221-F even though it was physically separated from it. Here, the uranium nitrate solution that left the Purex process was transformed into uranium oxide. This process was based on a similar design that had been perfected by Mallinckrodt Chemical Works, using de-nitration pots and evaporation techniques. The final A-Line product was transformed into uranium oxide for the simple reason that it would not liquefy in that state and so could be stored more easily.[13]

Even though there were technically two A-Lines, one in F and one in H, the one in H was very abbreviated and did not perform the same function as the 221-F A-Line. Basically, the A-Line in F Area processed uranium for both F and H areas, and performed that function for many decades.

B-Line was responsible for transforming plutonium into a metal, specifically into metal buttons. It was based on established practices then current at both Hanford and Los Alamos.[14] The original B-Lines, which were also known as "button lines," were located inside the canyon buildings themselves: two were in 221-F, while one was in 221-

A-Line Photographed from the Roof of F Canyon, 2005.

H.[15] The B-lines received plutonium nitrate solution from the Purex process, specifically from the warm side of the canyon. The plutonium was then transformed into plutonium metal, with most of this work occurring in a series of glove-boxes. The methods and equipment used to effect this transformation changed over time. Initially, in the early 1950s, the process was done by precipitation, with plutonium precipitated as a peroxide, then turned into a fluoride through reaction with hydrofluoric acid in a furnace. The plutonium was then reduced through reaction with calcium.[16] This process was changed in the early 1960s, as will be seen later in this report.

To complicate matters, there was also a C-Line, at least in the original plans. It was to be an extension of B-Line, and would take the plutonium buttons and fashion them into shapes or components that could be directly inserted into a bomb. This "component fabrication facility" was to have been located in 235-F, but after the building was erected, the AEC decided not to pursue the C-Line process at Savannah River. Abandoned for a while, Building 235-F would later be used for the production of plutonium-238.[17]

SUCCESS OF PUREX

The extensive testing and preparation that preceded the operation of Purex clearly helped make it a success. Savannah River became the home of the Purex process. F Canyon, under construction from 1951 to 1954, became the first large-scale facility built to use the process when it began operation in the fall of 1954. It proved so successful that very little was changed for H Canyon, which went hot the following year. In 1955, before production throughput became a major concern, it was estimated that less than 0.2 percent of the plutonium and less than 0.1 percent of the uranium was lost to the waste tanks.[18] No other separations process is believed to have this record of recovery.

Purex is now the standard separations process and is used around the world for the recovery of plutonium and uranium. Later, when 221-H was modified to handle the "HM" process, this turned out to be basically a modification of the Purex process.[19] Purex, or something close to it, is now the proven method of separating and purifying all of the actinide elements.

VII. PROCESS CHANGES

EARLY OPERATION AND PROBLEMS, 1954-1957

The first Savannah River reactor, R, began operation in December of 1953. The other four went on line throughout 1954 and early 1955. At that time, the original reactor elements were solid natural uranium (U-238) slugs with aluminum cladding. There was no distinction between fuel and targets; that would be a future development. Everything was a "single matrix charge."[1] In the early days, neutrons in the reactor bombarded the natural uranium and transformed some of it into plutonium-239. Not all of it could be transformed; not even most of it. The production of Pu-239 was inherently inefficient, since lengthy bombardment in the reactor also resulted in the production of Pu-240, an unwanted isotope that interfered with the fissile qualities of the Pu-239 (the amount of Pu-240 had to be kept to 6 percent or less). Out of all the irradiated material that was sent from reactors to separations, only a small amount was turned into plutonium at any one time. Everything else had to be reprocessed, recycled, or sent to waste.

As the reactors came on line and began production, the separation areas began to process the irradiated materials. F Area began production first, in November of 1954, followed by H Area in July of 1955. The material processed through the canyons was called "throughput," and throughout began to increase throughout the last half of the 1950s. In 1955, procedures for the separations operations were worked out in F Canyon, and the first throughput increases began. The designed capacity was around 3 tons per day. F Canyon processed 1.6 tons of irradiated uranium per day in January of 1955, and was up to 4 tons by May. Dissolver batch sizes were increased from 5.9 tons to 9.4 tons, and the concentration of uranium in the solution was increased, as was the amount of TBP in the solvent. After H Canyon went into operation, the designed throughput rate of around 3 tons of uranium per day was quickly more than doubled, to 7 tons per day, largely due to improvements to the process learned from the earlier operation in F Area.[2]

By the end of 1956, F Canyon was processing 4.5 tons of irradiated uranium per day, and H Canyon was up to 6.6 tons. At that time, it was recognized that the throughput could be increased, but not by enough to keep up with the reactors, which were stepping up production almost every month. The big limiting problem for the canyons was the solvent flow. It simply was not enough. This led to the first plans for the installation of new and much larger equipment in F Canyon.[3]

And there was much to keep up with. Throughout the mid to late 1950s, the reactors were experiencing their remarkable power increases. Rated at 378MW when they were designed and built, they increased their production through the rest of the decade, and this rise was reflected in the mega-wattage. In 1954, each reactor then on-line operated with less than 500MW. By 1959, with all the reactors running, the rate was up to around 2,400MW. This was the era of the first and greatest of the power ascension periods at Savannah River.[4]

Many changes were required to make these rises possible. In 1956, a second set of heat exchangers were installed in the reactors. New pumps were installed in the reactors and in the river water pump houses. Par Pond was created to increase the amount of cooling water for the most distant reactors, P and R (hence the name,

"PAR"). All of this allowed heat levels to rise in the reactors, from 80 degrees Celsius to 160 degrees Celsius, but this pushed the solid uranium slugs to the edge of what was possible.[5] New designs for the reactor fuel elements were clearly required.

All of this was made more complicated by an increased demand for tritium. The whole purpose of the Savannah River Plant was to produce both tritium and plutonium, but the proportions that were made varied throughout the decade, due to changes in the demand for the raw materials from the AEC.[6] During the Construction era and immediately after, emphasis was placed on plutonium, with tritium only produced in the control rods. In the later 1950s, production demands shifted back and forth between plutonium and tritium, but with overall increasing demands for tritium, certainly more than could be made in the control rods.[7] The reactors were designed to be versatile, but the original reactor elements were not. That would soon change.

REASONS FOR THE CHANGE: NEW REACTOR ELEMENTS

The demand for more tritium was one of the main reasons that led to the use of enriched uranium in the Savannah River reactors. "Enriched uranium" is uranium with more than the normal amount of the isotope U-235, which usually comprises only 0.7 percent of natural uranium (U-238). If "enriched," then the level of U-235 is made higher than the normal 0.7 percent, with the level varying from low enriched (2-5 percent) to high enriched (around 90 percent). A reactor element made with (low) enriched uranium would release a greater amount of neutrons. Such an element would serve as a "driver," providing the neutron "fuel" for other elements that would receive the neutrons. The elements receiving the neutrons would be the "targets."

This new arrangement in reactor elements, now divided into drivers and targets was not only useful for the production of tritium, it also made it easier to produce a whole range of other nuclear products. As a result, this became the new standard arrangement in the reactors: a "driver," also called a "fuel element," to provide the extra neutrons, surrounded by "target elements" to receive the neutrons.[8] The target elements were the ones transformed into new material.

As a result, enriched uranium fuels irradiated lithium-aluminum targets to produce tritium. Eventually this would lead to the first striped loadings of fuel and target elements, with enriched uranium slugs alternated with lithium-aluminum elements.[9] The use of enriched uranium fuel elements also led to the use of depleted uranium as the target elements for the production of Pu-239. Depleted uranium was natural uranium from which all or almost all U-235 had been removed. The two go together, since creating enriched uranium naturally leads to a supply of depleted uranium. Soon, however, the range of targets expanded beyond the production of Pu-239 to include a whole range of other materials, including cobalt-60, curium, and Pu-238.[10] By the 1960s, the reactors would even have "mixed lattices," producing a range of different materials simultaneously.

All of these developments occurred quite rapidly in the middle to late 1950s. Soon almost all reactor arrangements were predicated on the use of "fuels" (a.k.a. "drivers") and "targets." Fuels were enriched uranium, usually low enriched uranium (LEU), but sometimes highly enriched uranium (HEU). The fuel elements could remain in the reactor for a long time, in fact as long as possible. The targets, which were made with depleted uranium (for the

production of Pu-239) or other materials, had much shorter runs. This was certainly true for Pu-239, where short runs kept down the percentage of unwanted Pu-240.

Simultaneous with this development came changes to the physical appearance of the reactor elements themselves. The higher reactor temperatures made the solid slug form obsolete. This was followed by slugs with holes cut out of the middle, the so-called "hollow slugs." This in turn was followed by the development of thin tubes, followed by tubes inside of tubes.[11] The development of tubular elements raised reactor versatility to new heights. At first required because of the higher heat in the reactors made solid slugs unworkable, tubes offered better overall water circulation, both inside and outside the elements. They could also be arranged in more creative ways, for better neutron efficiency.

The evolution of tubular elements is important to the history of reactors. Still, it is important to note that this whole array of simultaneous developments—enriched and depleted uranium, fuels and targets, all positioned as tubes—had a great impact on the development of separations too. The original 221 buildings and equipment were not capable of dealing with the longer tubular elements, and the original Purex process was not designed to recover enriched uranium.[12] By 1956, it was clear that changes would also have to come to separations.

CHANGES TO THE CANYONS, 1957-1959

By 1956, it was clear that the Separations facilities would have to be added to or overhauled to accommodate the increased out-put of the reactors and the changes being made to the reactor elements. A brand new facility was contemplated, but it was soon decided that modifications to the existing facilities would be sufficient. Since there were plans afloat to improve F Canyon anyway, it was decided to do a major overhaul to 221-F to accommodate the rising demand for Pu-239. This would not entail any changes to the Purex process, but the equipment and other facilities would have to be enlarged.[13]

This left the matter of enriched uranium, which could not be processed by Purex. The other canyon building, 221-H, would have to be altered to deal with the new enriched uranium fuel tubes, and this led to changes to the Purex process. The equipment remained almost the same.[14]

The changes contemplated in both F and H canyons would be uncharted territory for Savannah River. Beginning in 1957, separations entered a new era. As Bob Romine commented about that period and the unique work environment: "everything we did had not been done before."[15]

Before launching into the changes themselves, it might be useful to recap some of the major dates. F Canyon was closed down first, in February 1957, and was not re-opened until March of 1959. During that two-year period, larger process equipment was installed in 221-F, and a new and enlarged B-Line, referred to as Jumbo B-Line or JB-Line, was built onto the roof. During that same two-year period, H Canyon carried out all of the Pu-239 processing, using the Purex process. Just as soon as F Canyon reopened, H Canyon was closed down. Since the process was altered more than the equipment, this alteration only took three months, rather than two years. The altered process became known as the "HM" process, which stood for "H-Modified."[16] The details of these 1957-59 changes are presented below.

F Canyon Changes

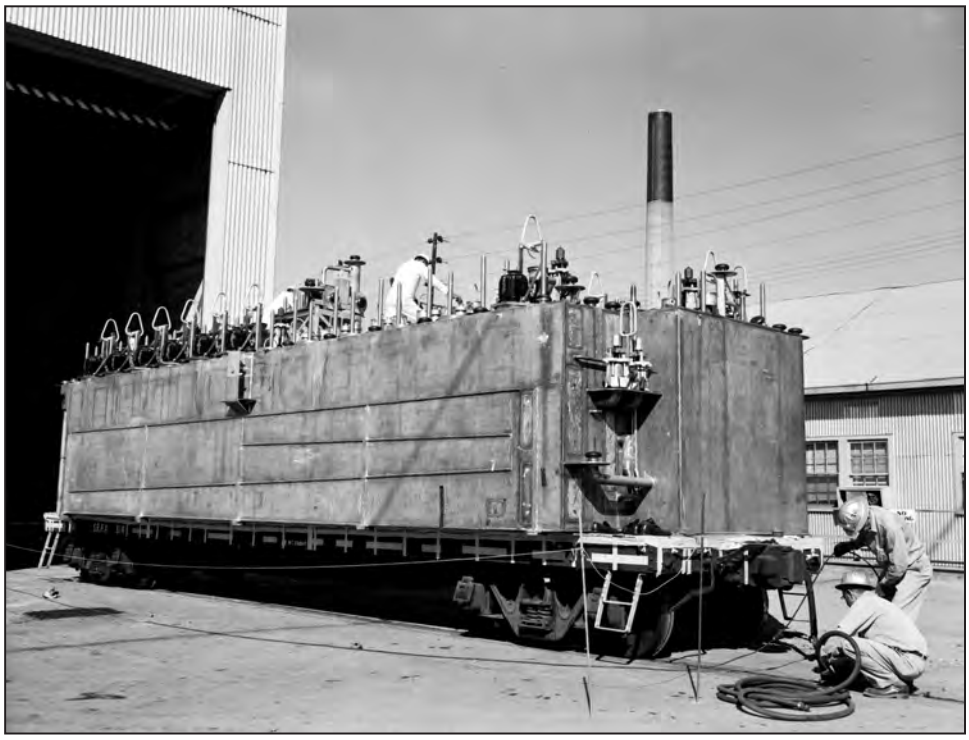
Design work on the upgrades required for 221-F began in early 1956, even though the first ideas for this were studied as early as November of 1954. This included work on new, much larger mixer-settlers, evaporators, and holding tanks.[17] The Purex process itself would remain unchanged, but the equipment would be made as large as possible to increase the throughout. The modification of 221-F for this purpose was part of Supplemental Project S8-1025, "one of the largest of the 'S' projects undertaken." This project ranged from modifications for the new equipment, to the new B-Line complex that would be added to the roof of 221-F, soon known as the JB-Line.[18]

Among the upgrades installed in 221-F, there were: a third slug dissolver, a greater lift capacity for the Warm Canyon crane, from 15 to 30 tons, and a new shielded crane cab.[19] There were also enlarged mixer-settlers, continuous evaporators, large capacity cell-tanks, and centrifugal pumps. The biggest change of all was the new JB-Line.

By far the most important of the equipment upgrades were the enlarged mixer-settlers, referred to as "jumbo mixer-settlers." The term "jumbo" quite possibly came from the expression "Jumbo Reactors," used to identify Hanford reactors KW and KE that had just been built.[20] The new jumbo mixer-settlers at Savannah River were designed at Savannah River Laboratory, with extensive testing done at TNX. A six-stage prototype was tested at TNX; uranium was used for the testing process, not any heavily radioactive materials.[21]

Originally, only a six-stage stainless steel pump mix unit and a six-stage stainless steel turbine contact unit were to be installed. However, a multi-stage vertical stacked type unit was added to the project plan. As the evaluation developed, it was determined that fabrication and testing of the stacked type unit could be eliminated.[22]

It was soon decided to design and build the largest mixer-settler that could possibly fit into the space provided by the section itself. The settling volume per stage increased dramatically, from 18 gallons to 220 gallons. Two decanters were added under the jumbo mixer-settlers to help process the increased volume. The weirs were also improved to ensure that the mixing levels were sufficient.[23]



Workers Ready a Jumbo Mixer-Settler for Installation in F Canyon. November 12, 2012, SRS Negative DPSPF 5540-6.

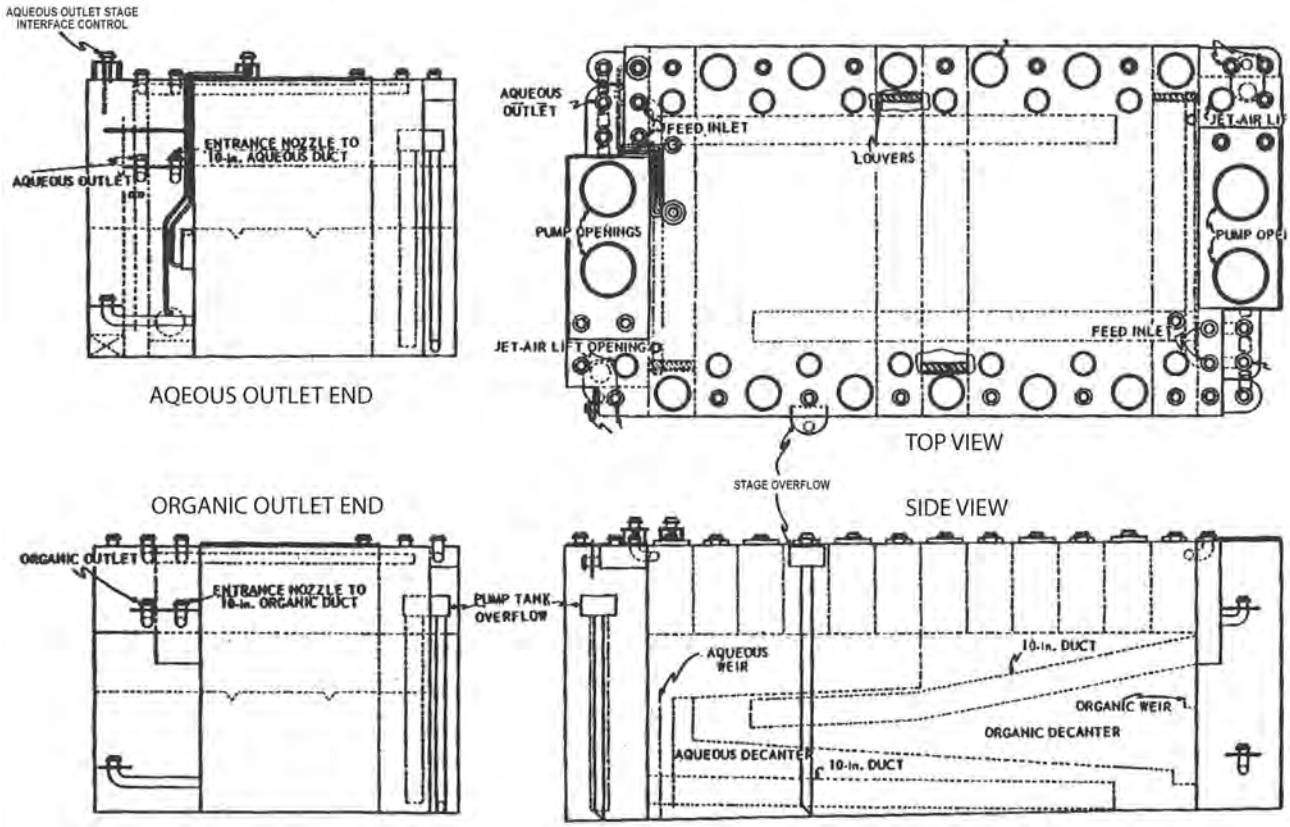


Illustration of a Jumbo Mixer-Settler. Source: 221-F Training Manual, Figure 20.

Five of these new mixer-settlers were installed in F Canyon, replacing the original mixer-settlers in the following banks: 1A, 1B, 1C, 1D, and 1E.[24] Because of the huge increase in the potential for radioactive contamination, a railroad tunnel air lock system and decontamination facility was installed, as were new decontamination facilities for the Hot Canyon crane.[25]

Another new feature of the enlarged Purex process was the continuous evaporator, which consisted of two elements: the large condenser and de-entrainment column, and the smaller re-boiler. Used in conjunction with the continuous evaporator was the Hackman Hat removable connection, part of the feed connection system that served the continuous evaporator.

All of the replaceable equipment was made larger for the enlarged Purex process, but the most distinctive change in the tank vessels would have to be the bi-cylindrical tanks, often called "bi-cells." These were basically two tanks that were joined on their sides, like Siamese twins. If looked at from the top, the two joined tanks formed a "figure 8." These were two-in-one cells that could achieve higher capacity and their shape allowed them to fit into two adjacent modules.[26]

All of these changes, monumental as they were, pale beside the development of the new JB-Line, constructed on top of 221-F. The original B-Lines inside of F Canyon were also improved, but the JB-Line, built from scratch, was designed for maximum efficiency. This was an absolutely critical development for the Purex process, for if the canyon throughput was going to be increased, then the finishing lines for plutonium metal also had to be upgraded.

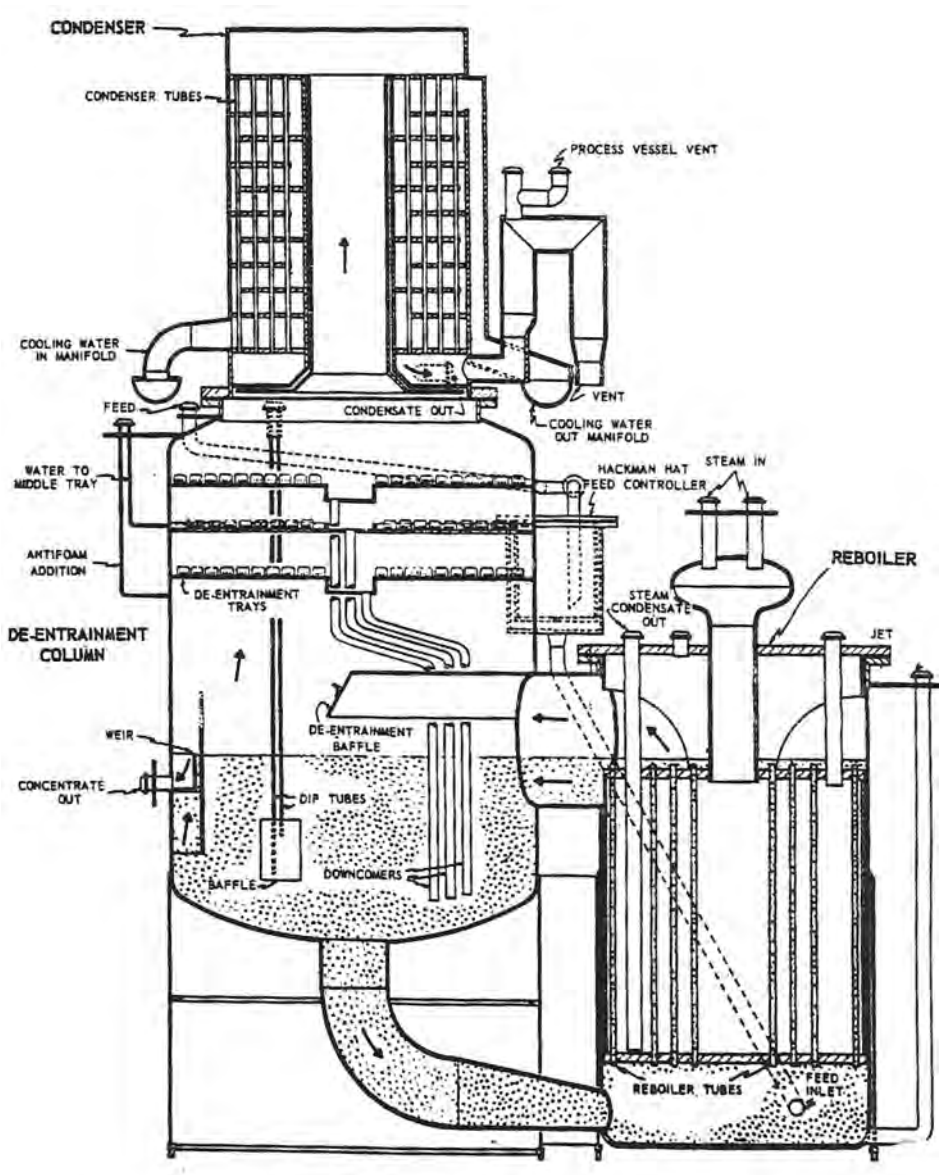


Illustration of a Continuous Evaporator. Source: 221-F Training Manual, Figure 28.

The original B-Lines, located on the third and fourth levels inside 221-F, were crowded and were not laid out efficiently. There were also a number of process tanks that had potential criticality issues with the accumulation of plutonium. Even the original chemistry, the peroxide process, had room for improvement.[27] All of this called for a brand-new, much larger facility that would not only augment the original B-Lines, but also far surpass them.

This might be a good point to speak of B-Line nomenclature, because "B-Line," "JB-Line," and "FB-Line," have all been used over time, and they are not always the same thing. As might be expected, the original finishing lines, located inside the 221 buildings, were simply referred to as B-Lines. The JB-Line was the new facility constructed on top of 221-F in the late 1950s. Later, the JB-Line was referred to as the FB-Line, which really just meant the B-Line in F Area. Presumably this was after the original B-Lines within 221-F had been closed down in the 1980s.[28]

The initial scope of work for the JB-Line came out on July 1, 1955. These plans called for a jumbo-sized mechanical line in the 235-F Metallurgical Building, with a waste recovery facility in the same building and other facilities in 221-F. A review of the mechanical line facilities at Rocky Flats in July of 1955 led to a revision of those plans, and by August 1955, Du Pont's Atomic Energy Division (AED) decided to use the existing footprint of Building 221-F. By December of 1955, the first studies were done for constructing the JB-Line on top of the 221-F building. This concept was studied and revised well into 1956. The scope was re-done in January 1957, and revised again in October of that same year.[29]

JB-Line's "Mechanical Line" was designed by the AED Mechanical Development Laboratory, Design Division. The first basic layout of the cabinet assembly was worked up in May of 1956, and was subject to revision until early in 1958. The overall arrangement was worked out by using a plywood mock-up. As was stated in the final write-up of the history of the project:

> The basic configuration selected for the Mechanical Line consisted of an integration of separate mechanical assemblies and conveying systems into a branch-type layout, which featured a straight-line conveying and material transfer section serving wing cabinets containing the operating stations.... All maintenance or replacement of components of the Mechanical Line in contact with the contaminated atmosphere was to be accomplished internally through glove ports.[30]

There were other design issues in addition to the JB-Line location. Some of the most important were the criticality issues as they played out in the process tank designs. To avert criticality problems, it was decided to use rectangular slabs rather than cylinders. The prototype was done in October 1956 and worked out well. Polyvinylchloride (PVC) piping was used in the process lines, and this was a first for Savannah River. Translucent plastic was used for the precipitator. The final model was worked up in the spring of 1957.[31] All of these features together made for bigger batches, now allowed because of better safety equipment; mechanical conveyer lines; better maintenance access for cleaning; and room partitions for better contamination control.[32]

A crane positions a bi-cylindrical tank in the 717-F. February 10, 1958, SRS Negative 4999-9.

These were new plans that applied to all of the B-Lines, when possible, but they were primarily drawn up for the JB-Line. Construction of the JB-Line on top of 221-F began in early 1957 and was basically complete by 1959. It was a two-story addition added to the top of the south end of Building 221-F above Level 4. The new structure would contain the new levels 5 and 6.[33] Even though most of the JB-Line was finished in 1959 and the B-Lines went into operation in April of 1959,[34] it is recorded that final completion of JB-Line was not until June of 1960.[35] Currently, the JB-Line is identified by the blue aluminum siding that marks the two top partial floors of 221-F located at the south end of the building.[36]

In addition to the physical changes, the basic B-Line chemistry was also changed. The original method for purifying plutonium and turning it into a metal was called the peroxide process. This was changed to the tri-fluoride precipitation process, which turned out to be faster and less expensive.[37] This method, which had been

F Canyon in 2012; the JB Line is located atop the south end of main building, designated by blue aluminum siding.

devised at Savannah River Laboratory, was more stable and could be performed using plastic vessels.[38]

To recap, the JB-Line process began with the stream of plutonium solution that was jetted up from the canyon. This went to a cation exchange, then to precipitation, drying, conversion to a metal form, reduction, resulting in a final button form. Another source reduced these basic steps to just three: ion exchange, performed in eight resin columns; precipitation, done in two precipitation units; and reduction, which is done in the Mechanical Line.[39]

The ion exchange work, which concentrated and purified the plutonium nitrate solution, was basically unchanged from the original B-Lines. The final reduction via reaction with calcium was also basically the same. The precipitation method was different. In the new method, precipitation was effected by turning the solution into plutonium tri-fluoride (PuF_3) through the addition of hydrofluoric acid. The plutonium was then precipitated out as a fluoride, not as a peroxide, as had been the case earlier. For various chemical reasons, this made the solution easier to filter for the plutonium, and it simplified the furnace roasting process.[40] The final product was poured into a crucible and took the shape of a button. The crucible was then broken to retrieve the plutonium metal button.

Plutonium-239 Button. As plutonium-239 only emits alpha radiation, the plastic covering and gloves offer the holder sufficient protection from exposure. Courtesy of SRS Archives.

Putting all the steps together, the new JB-Line process began with the plutonium concentrate from the canyon being sent to the cation exchange, followed by the precipitation step. After precipitation, the solution slurry went to filtration, where it was turned into a cake. After washing and drying, it was a concentrated peroxide cake. After anhydrous hydrogen fluoride is added to the cake in a conversion furnace, it is turned into fluoride cake. From there it goes to the mixer and the reduction furnace. The final plutonium button comes out of the furnace, with slag and the crucible debris taken to recovery for the salvaging of any plutonium remains. The button then goes to a series of pickling baths before being packaged for shipment off-site.[41]

This basic JB-Line process was improved over the years. Iodine boosters were used in the early days to improve the process, but these were eliminated after it became more common to use larger batch sizes. High humidity in the glove boxes led to lower than expected reduction amounts in the final product line. This problem was fixed by addition of an air-drying system that kept humidity low.[42]

Most of the F Area modifications occurred within the 221-F building, but there were some changes in the facilities around the canyon building. Larger capacity storage tanks were put in, and some of the cold feed preparation equipment was moved out of 211-F to a nearby facility, 222-F. Building 222-1F, a 20 by 40 foot concrete pad was added as a "vessel cleaning building." A "Segregated Solvent Area" was added to 211-F. This caused the official designation of 221-F to be changed from "tank farm" to "canyon auxiliaries" (in the years that followed, the term "tank farm" would come to be associated with the 241 waste tank facilities). Building 717-1F was added to 717-F, and there was an increase in the capacity of the main crane hoist and supports, allowing it to go from 15 to 30 tons. A new building, 717-2F, "Jumper Storage Facility," was built to house the extra machinery jumpers. A-Line acquired a new change house, 707-1F, and a new regulated shops building, 707-2F. Further out, additional steam generating capacity was added to the powerhouse, and two more cells added to the cooling tower.[43]

There was also an increase in the number of F Area waste tanks, even though this work was part of a different project. Where Project S8-1025 dealt with the 221-F Canyon facilities upgrades and the construction of the JB-Line, the 241 waste tank expansion was part of Project S8-1030.[44]

As expected, the modifications in F Canyon led to huge increases in the production capacity of the Purex process. The throughput increased from four tons per day to a maximum of 14 tons, with an average of at least 10 tons a day. Here was where the depleted uranium was useful, since it allowed very high throughputs of the dissolved targets. In the Purex solution, the depleted uranium acted as a neutron poison, tamping down the criticality in the plutonium. Once the targets were dissolved and went through the process, there might be hundreds of grams recovered per liter, with no ill effects.[45] Throughout it all, the JB-Line keep pace with the production schedule. In fact, it is recorded that the all-time peak production for any given year was achieved in 1983, just a few years before the Savannah River reactors would be closed down for the last time.[46]

Changes to H Canyon

Both F Canyon and H Canyon were modified during the late 1950s, but they were done in different ways. F Canyon was modified over a three-year period to become the super-Purex plant, devoted almost completely to the production of Pu-239. During that three-year period when F Canyon was down, H-Canyon produced Pu-239, using the Purex process.

After F Canyon and the new JB-Line opened back up in early 1959, then it was H Canyon's turn to close down for upgrades. This shut down was only for two to three months. Whereas F Canyon had equipment upgrades but used the same process, H Canyon used the same equipment and had the process changed.[47] For example, F Canyon changed to the new jumbo mixer-settlers, while H Canyon kept its original mixer-settler equipment.[48]

B-Line in H Canyon, 1957-59

While F Canyon was being renovated, the B-Line in H Canyon, usually identified as HB-Line, was able to handle the finishing of the Pu-239 that was going on in H Canyon. The HB-Line was able to do this because it was the last to be finished out of the three original lines. It capitalized on the improvements that quickly became apparent in the first two original B-Lines in F Area. Between 1957 and 1959, the HB-Line could handle the work previously performed at all three original lines.[49]

One of the safety improvements added to the B-Lines during this period was a new air sampling system. This was a continuous air sampling system, since it was discovered that the original devices often failed. Twenty individual air samplers were installed in H; 12 were placed into F.[50]

The original B-Lines in F Canyon were never opened back up after the JB-Line was activated in early 1959. Those areas on the third and fourth levels of 221-F were used for other purposes, often storage. That was not the case with the HB-Line. It was closed for the H Canyon renovations in 1959, but it was reopened. This time it worked closely with the new process that was developed for H Canyon, referred to as the "HM" process. The discussion of the HM process is presented below. Despite this, it was never completely divorced from plutonium finishing. In later years, it often did some of the preliminary work for the JB-Line as part of Pu-239 production.[51]

HM Process

In early 1959, after F Canyon went back on line, H Canyon was shut down for three months for its own set of upgrades, from February to May of 1959.[52] This shut down was much briefer than with F Canyon. Work continued during most of the transition period; the major shut-down was only four weeks.[53] With F Canyon designed to process plutonium-239 and depleted uranium, H Canyon was set up to deal with the enriched uranium, something that Purex was not designed to handle.[54] In the new reactor arrangement, enriched uranium was used in the fuels, so it was often said that H Area was converted to "run the fuel."[55] Its main purpose in this process was to take the old fuel, extract the remaining still usable enriched uranium and mix it with new material for new reactor fuel.[56]

There were more target elements than fuel elements in a typical reactor, and it was usual to burn the fuels longer than the targets. As a result, there were far fewer fuel elements to process than targets. Alternatively, even though there were fewer fuel elements than target elements, they were much hotter than the targets, with much higher radioactivity. Up to 90 percent of the fission products that came out of the reactors were found in the fuels, with only 10 percent in the various targets. As a result of this concentration, only small amounts of this radioactive material could be processed at a time. Usually it was just a few grams per liter, often as low as three to four grams. This was done to keep the concentration of U-235 at a safe, low level. All of these requirements led to the development of what was called the HM process, which stood for "H-Modified."[57]

The HM process did not require much equipment change, but it did require an alteration of the Purex process so that it could accommodate enriched uranium. What changed chemically were the process parameters. The biggest change was in the percentage of TBP. It was common to use 30 percent in Purex. HM required only

2.5 percent. This was later bumped up to 7.5 percent, but it was never used in the proportions common in F Canyon. As Chuck Goregen stated: "this was done to limit the amount of uranium that could be extracted up into the organic phase, so that you could control the concentration of U-235." Controlling that concentration was essential, since the criticality limit of U-235 is 11.8 grams per liter. To preserve a healthy safety margin, the HM process stayed within the production range of three to four grams per liter.[58]

Design work for the HM process began with the initial programs to deal with enriched uranium recovery, since it was known that Purex could only separate Pu-239 and natural uranium (U-238). The first work request for enriched uranium recovery was dated to September 1954, but this program was soon stopped. The work request was reissued in 1957, with studies to determine if it was feasible to use the existing 221 facilities or begin anew. It was quickly decided to make use of the existing facilities, whenever possible. By December of 1957, the work became known as the "HM process."[59]

Identified as Project S8-1081, the HM Process project, "authorized the design and construction of a facility for recovering uranium-235 from irradiated enriched fuel elements and preparing the dilute uranyl nitrate product for off-site shipment." The process used is principally one of TBP solvent extraction from nitric solutions, similar to the "Purex" process." The final product would be U-235 from the enriched uranium, which would have to be separated from the aluminum waste and the fission products. The final product would be in the form of a dilute nitrate solution—not an oxide as was done with Purex. There would not be enough plutonium in this material to warrant any sort of recovery effort for the Pu-239.[60]

An important part of HM was the accommodation of the new fuel tubes that now went into the reactors. These were long tubes, not slugs, and the uranium and aluminum was combined together in the tubes in such as way that they had to be dissolved together; de-cladding alone would no longer work. Mercuric nitrate was added to the process to help dissolve the aluminum.[61] As has been mentioned already, these tubes were developed as part of the shift to the use of enriched and depleted uranium in the reactor fuel and target elements that made it possible to expand the range of operations at Savannah River to include high production of tritium, as well as plutonium-239. In the period before HM, all enriched uranium tubes irradiated at Savannah River had been shipped to Idaho Chemical Processing Plant for the separation and recovery of the uranium.[62]

To accommodate the HM changes, there had to be a number of physical alterations to the 221-H building, and some facilities outside the building. Within Building 221-H itself the bucket storage racks in the water-cooled bucket storage basin had to be altered to receive the new 14-foot tubular elements. Even the storage racks used to hold these elements had to be changed to reduce the possibility of a criticality accident. The dissolvers had to be changed to accommodate the tubes. These were now placed vertically into the dissolvers, eight or so tubes per bundle. In other respects, though, the process was simplified. Because there was little plutonium to worry about, it was possible to drop the Second Plutonium Cycle previously used in Purex process. New chemicals were needed, like mercuric nitrate, and this required new tanks to hold them. More monitors were needed for criticality measurements. This led to the addition of colorimeters and neutron monitors for better concentration control. Changes were also made to the H Area A-Line, where silica gel area improvements were installed to prevent any criticality issues near the end of the process by removing any residual fission products. There was also the

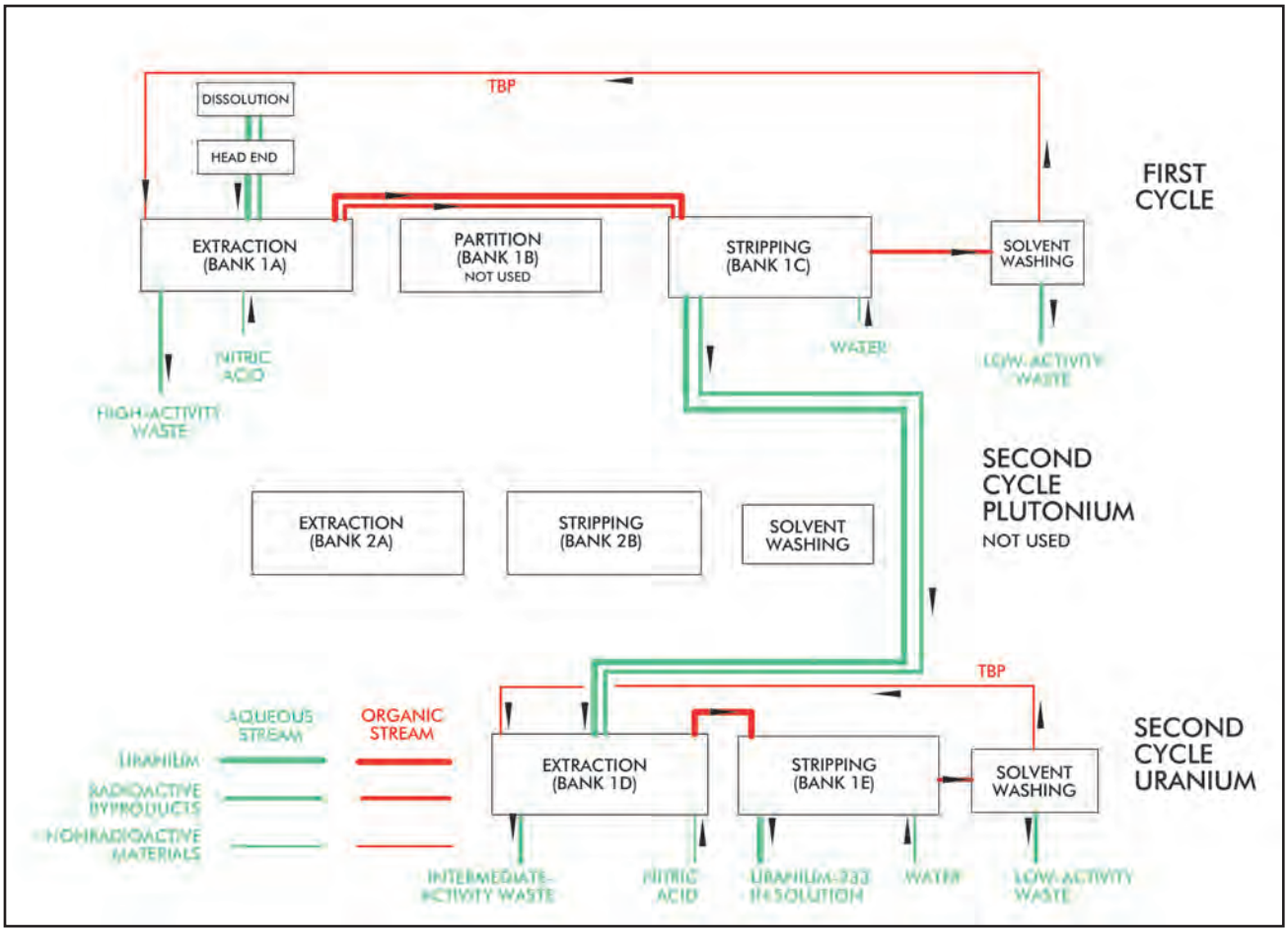
addition of three tank trucks to transport the dilute uranium solutions off-site as needed. There were even changes to the 772-F Analytical Lab, with improvements to the analytical equipment and extra shielding for protection from the higher amounts of U-235 that would be coming over from 221-H.[63]

One of three tanker trucks designated to transport dilute uranium solutions off-site. August 20 1959, SRS Negative DPSPF 6167-2.

The final HM process was similar to the Purex process, but without the Second Cycle Plutonium steps. Within the First Cycle, the 1B bank was not used. The Second Cycle Uranium would normally produce enriched uranium (U-235), but it could make other uranium isotopes as well—one of the first to be separated in the HM process was U-233.

The H Canyon building was started back up in May of 1959, and it quickly achieved a throughput of between 25 and 53 fuel tubes a day. As will be seen, it was not just limited to the processing of enriched uranium. In the future, H Canyon would be the home for a number of different missions, far from those conceived in the early days of Savannah River. Like the reactors, the separations buildings were designed to be flexible, and their flexibility would be taxed in the 1960s, as separations tackled the production of such materials as neptunium-237 and plutonium-238, a popular heat source for NASA's space program.[64] As one interviewee put it, F Area became the Pu-239 workhorse and H Area became an odd-jobs facility, and there were a lot of odd-jobs.[65] Pu-238 production may have turned into the most popular of these, but there were others. The HM process helped produce them all, and Major Thompson, a chemist and expert in solvent extraction at SRS, did much of the work in tailoring the HM process for these later missions.[66] Many of Major Thompson's HM process videos are still stored in the Carlisle E. Pickett Technical Library, located on the fourth level of Building 221-H.

After 1959, regular H Canyon operation, based on the HM process, called for processing enriched uranium. Even so, other materials were soon processed as well. The B-Line in 221-H, which had previously purified plutonium, soon switched to processing Np-237 and Pu-238 for the space program. Later, in the 1980s, a whole new facility was built onto the roof of 221-H, similar in that regard to the JB-Line built onto the top of 221-F. This new B-Line became known as the "HB-Line," and it was constructed over Sections 2 through 6 of the main canyon building. A two-story facility, it became the new fifth and sixth levels of 221-H.[67] The new HB-Line was built primarily for Pu-238 production.[68] More will be said about this development in the sections to come.



The HM process was similar to the Purex process except that no second-cycle plutonium steps were required. Adapted from D.G. Karraker, Solvent Extraction of Enriched Uranium in conventional Purex equipment, Document DP-481 (Aiken, South Carolina: Savannah River Laboratory, June 1960), 5.

FOUNDATION FOR THE FUTURE

When the dust settled in 1959, and both canyon buildings were back in operation, F Canyon was designed to handle depleted uranium and plutonium, while H Canyon was adapted to process the enriched uranium drivers (tritium, of course, was processed elsewhere). As Chuck Goergen put it, "F ran the targets and H ran the fuels."[69] This split cannot be overstated. F Canyon became the Purex plant, largely devoted to the production of Pu-239, obtained from depleted uranium targets. This was the main military mission, and it fell to F Area.

Alternatively, H Canyon processed and purified the enriched uranium from the fuel, which was recycled back into the Savannah River reactors. Since this was a lighter task than the Pu-239 work, H Area also became the focus for the various auxiliary programs acquired by Savannah River in later years.[70] This division of labor between F and H was not always clean, especially in later years, but it generally held until the reactors themselves were shut down in the late 1980s. The division was even reflected in the Savannah River monthly reports that documented plant progress in every year of operation.

As an example, as early as December of 1960, the basic work categories in Separations were 1) the production of Pu-239 in F Area, 2) the recovery of enriched uranium in H Area, and 3) the production of Pu-238.[71] Five years later, there was much greater diversity of product. In addition to the production of Pu-239, made in F Canyon, there was the recovery of Pu-238, the recovery of U-233 from thorium slugs as part of the breeder reactor program, the recovery of Pu-242, Am-243, and Cm-244 for the Transplutonium Programs, and the recovery of Pu-241. Aside from the Pu-239, the processes involved in most of these programs were centered around H Canyon.[72]

By December of 1971, the main work areas of Separations included the production of Pu-239, using Mark 30 targets; the production of U-235, using Mark 14 and Mark 16 fuel; the production of Pu-238, which was recovered from F Area by way of the PRC and Frame II-F, and from H Area by way of Mark 14 fuel. This monthly report also noted that the MPPF was under construction but was almost complete. The other main work for Separations was the relatively new "Waste Management."[73]

In January of 1975, the main work areas of Separations included, in the relative order of their significance: Pu-239, U-235, Pu-238, the Plutonium Fuel Form Facility (PuFF), Sand Filters, Receiving Basin for Off-Site Fuel (RBOF), and Waste Management. Pu-239 was made using Mark 31 targets, processed in F Area. The U-235 was recovered from the Mark 16 fuel in H Area. As for the others, it was clear that Waste Management, though traditionally listed last, was actually rising in overall importance to the operation of the plant.[74]

By this point, in the mid-1970s, Savannah River had reached a certain plateau in the production of its main nuclear materials. Through trial and error, and the use of dozens of new reactor elements, identified as "marks," the optimal set-up for the production of many nuclear materials had been achieved. For example, Mark V-R and Mark 15 were found to be some of the best for Pu-239 production. There was a U-236 program that was a preliminary step in the production of more Pu-239, and this used Marks 30A, 30B, 30C, 30D, 31A, and 31B. Pu-238 was made with Marks 52, 53, and 53A. U-233 was made with Marks 50A and 50B. By this time too, the Transplutonium Programs were reaching maturity, and there was now a series of californium programs, including Cf I and Cf II, using Marks 18, 18A, 18B, 18C, 40, 40A, and 51.

This has been an example of some of the operations that would occur at Savannah River in the decades after 1959. Some of this information will not be explored in greater detail than what has been presented here, since it is not directly pertinent to the operation of the Separations facilities. It is presented as a reminder that Separations did not operate in a vacuum but was tied to the operation of the rest of the plant. The materials processed in the canyons had to come from the reactors, which had to irradiate targets or marks manufactured in the 300 Area. The liquid waste that came from the canyons was stored in ever-increasing numbers of waste tanks. By the 1970s, this was posing a significant problem that would soon be addressed by the development of the Defense Waste Processing Facility (DWPF).

Many of these issues will be explored in the chapters that follow. The main thing to remember is that F and H areas are now separated into two different and distinct facilities. The facilities were still versatile, and nuclear programs could be porous, using either F or H depending on what was needed. But overall, F Area was now a

large Purex plant, devoted to the production of Pu-239 for the nuclear arsenal. Until the end of the Cold War, this mission had priority over everything else. But there were a lot of other things going on, and these other missions tended to cluster around H Area.

VIII. IMPROVEMENTS TO THE PUREX PROCESS AND F AREA, 1959-1980

THE PROBLEM OF "DO-BADS"

As one Savannah River researcher once noted, the solvent extraction process is based on a whole series of compromises. A number of outcomes might be desirable: high yield, low waste volumes, low contamination levels, for example, but many of these are contradictory. Not all can be achieved. During the Du Pont era, which was contemporaneous with the Cold War, the number one priority at Savannah River was to "recover the product."[1] In 1959, the most important of the products by far was plutonium-239, recovered in F Area. It was expected that problems would flow from that priority. And they did, almost immediately, in the interaction of the organic and aqueous phases.

As David Karraker, separations engineer, mentioned years later, many of the chemical ramifications of the whole nitric acid system used at Savannah River were not well understood in the early days. There had been relatively little academic research on the use of aqueous nitrate systems, since most researchers preferred to avoid the problems posed by reactive anions. Savannah River did not have that luxury: it had to use acid nitrate solutions as the basis of its separations work, if only because it worked well with stainless steel. As was said at the time, "stainless steel is stainless only to nitric acid."[2]

The method chosen at Savannah River to "recover the product" was based on the chemical extraction method, where dissolved elements were removed from a liquid solution after a series of mixings and separations between two different phases: an aqueous phase and an organic phase. The dissolved elements would enter the process in an aqueous nitric acid solution, but would be removed by entering into the organic phase.[3] For Purex, the organic phase consisted of a solution of 30 percent TBP, supported by the diluent, which would have made up the remaining 70 percent. This whole operation occurred in the mixer-settlers, which after the changes to F Area, were now enormous. The new "Jumbo mixer-settlers" became the focus of this new problem.

Even before re-start of 221-F in 1959, there were known problems with contamination in the organic phase. In 1958 it was noted that, "Purex solvent degrades when used for long periods of time, and forms ligands which (sic) complex zirconium." These ligands were not removed by regular washing and could accumulate in the solvent. Ligand formation was mostly due to the degradation of the "purified kerosene" diluent, ultrasene.[4] After the re-start, the quality of the solvent began to decline. By June of 1959, there were large increases in the gamma activity in both the washed and unwashed solvent. Alkaline permanganate washes were implemented to help clean the solvent, but this was not enough.[5] In December of 1960, the 1A mixer-settler was flushed to remove sludge in an attempt to reduce the gamma activity in the solvent.[6]

The crux of this problem was soon isolated to the diluent, which was "ultrasene," a commercial product that was basically a high-grade of kerosene. It was found that the ultrasene, now exposed to higher levels of radiation for longer periods of time, tended to break down chemically and fasten on to fission materials that would then

travel with the organic phase to solvent washing stations located outside the canyons. These stations were not particularly well shielded and soon became contaminated.[7] Put another way, the ultrasene, as it broke down, created nitro-paraffins that retained zirconium (and some ruthenium) in the organic phase. The zirconium was not removed by solvent washing, but rather accumulated in the organic phase, resulting in zirconium contamination of the plutonium and uranium that came out of the process.[8] Zirconium was one of a range of bad by-products that formed in the organic phase that tended to remain in the solvent and degrade it. This whole range of unwanted creations was called "do-bads," substances that did bad things.[9]

The diluent problem begs the question of why kerosene was needed in the first place. The kerosene itself was of no use in the chemical transactions, but it was essential to the proper functioning of the organic phase, which had to ride atop the nitric acid aqueous phase. The aqueous phase has the weight of water (1.0), and the organic has to be considerably less than that in order to separate effectively. TBP had a density of 0.98, far too close to water to be effective on its own. The kerosene simply diluted the TBP sufficiently so that it could float on water.[10]

The problem of organic breakdown had not been a major problem in the original mixer-settlers, but it became one with the new jumbos. The volume and the length of the exposures was too great. The kerosene problem was the biggest problem but it was not the only one. Under intense radiation, the TBP itself could turn into dibutyl phosphate and monobutyl phosphate. This required the solvent to be washed after separation with sodium carbonate and weak acid before it could be re-circulated.[11] It also affected the viscosity of the solvent, so that it no longer separated out as well.[12]

The mixer-settler design itself was part of the problem. The main advantage of a mixer-settler was that it was relatively easy to maintain in a remote setting. The mixing was done in horizontal stages, with mixing chambers followed by settling chambers. Mechanical agitators help mix the solutions and separate them, but the main part of the work had to rely on gravity and the separation was not fast. As mixer-settlers got bigger, the limitations of a gravity device became more apparent.[13]

One of the extra-volume elements that had been added to the jumbo mixer-settlers were large "decanters" or settling areas added to the underside of the jumbos. In the end, these decanters were closed off and were never again used after they were found to be counterproductive.[14] As Don Orth stated in his interview, with the jumbo mixer-settlers it was discovered that "bigger was not better." This discovery inaugurated a search for other options.[15]

There were a number of short-term solutions that were implemented to help correct this situation. Closing off the decanters was one. Another was to increase and improve the solvent wash stations outside of 221-F. The original station, which served all three separations cycles, was increased to three stations, one per cycle.[16] The new wash stations were also provided with radiation shielding. Permanganate strikes were added to the mixer-settler operation, since this helped break up the film that would form into "do-bads."[17] The greatest potential improvement, though, was the search for a new diluent.

SEARCH FOR A NEW DILUENT, 1959-1962

The solvent degradation problem was given top priority after the re-start and was a project tackled by researchers at the Savannah River Laboratory and throughout the Separations complex.[18] Bebbington said that the solvent degradation problem was the main concern of Savannah River Laboratory's Separations and Analytical Chemistry Divisions during the 1950s. During that time, the search was on to find replacements for both TBP and ultrasene. In the end, nothing was found to replace TBP.[19] Ultrasene, however, was another matter.

Ultrasene was a branching hydro-carbon, which meant that its molecular structure did not form a single or straight chain, but rather had branches off to the side. In the mixer-settlers, zirconium complexes would become trapped in a branching chain. Even washing with sodium carbonate might not remove this material. The search for a new diluent quickly zeroed in on the search for a straight chain product, often referred to as a normal paraffin. Another way to describe a straight-chain, normal paraffin is to say that it has "low aromatics."[20]

A normal or straight-chain (saturated) hydro-carbon was one where the carbon atoms were positioned in a straight line, with two hydrogen atoms at the ends. These were more stable chemically and could withstand greater abuse in a chemical process. After searching through a number of different products, the best results were obtained with a normal dodecane, often referred to as an n-dodecane, a straight chain with 12 carbon atoms. N-dodecane, which was a normal type of paraffin, was found to be far better than ultrasene. The best available commercial grade of n-dodecane was "Adakane." In later years, other n-dodecanes were found to be cheaper and just as good, but in the early 1960s, Adakane proved to be the answer.[21]

Adakane and many of the other usable straight-chained hydro-carbons came from the detergent industry.[22] By 1961, Savannah River had zeroed in on Adakane-12 as the new diluent for the organic phase; four out of five shipments made to the plant were accepted for service in F Area. As was noted at the time, Adakane-12 was "a mixture of n-paraffins, predominantly C-12, manufactured from coconut oil by Archer-Daniels Midland Company."[23] According to Major Thompson, writing in 1976, Adakane-12 was a 90 percent n-dodecane "with a small admixture of branched chain paraffins, aromatics, and olefins." Years later, a mixture of 12, 13, and 14-carbon normal paraffins were preferred to Adakane to help lower costs, but this was added as a boost to the Adakane already in the system, not as a replacement. As late as 1976 it could be stated that, "it has not been necessary to completely replace the solvent since Adakane-12 was introduced into the system."[24]

Despite the use of Adakane, there were always some problems with the diluent in the Purex process, even though these problems were now manageable. The commercial industry that provided Adakane and other n-dodecanes tended to increase the level of aromatics over time, and this led to problems in the Purex process. Testing had to be done to determine the functionality of new products, which were always added to the old diluent as make-up.[25] Contaminated solvent had to be eliminated, and this was done by burning prior to the late 1970s.[26]

Despite the success of Adakane and the other n-dodecanes, ultrasene continued to be used for the HM process in H Area. Here, the old mixer-settlers were still in use and ultasene continued to work satisfactorily. It was also found to inhibit the formation of di-butyl phosphate in TBP. Ultrasene was used in H Area until it became unavailable commercially. Only then was it replaced with an n-paraffin.[27]

CENTRIFUGAL CONTACTORS IN F CANYON

The discovery of Adakane solved most of the diluent end of the solvent contamination problem, but it did nothing to address the problem posed by the jumbo mixer-settlers themselves. As Don Orth phrased it, the jumbos turned out to be "disastrous."[28] The jumbo mixer-settlers were too large, the volume of radioactive material was too great, and the time involved for the separation was too slow. A device that relied on gravity was not sufficient for the level of work that had to be done in F Canyon. It took years to find a replacement for the jumbo mixer-settlers, but it was finally achieved in 1966, with the installation of centrifugal contactors in F Canyon.

The general idea for using centrifugal contactors was hardly novel. Centrifuges had been used as part of the Head End process since the beginning of plant operation. What was new was to use them in such a critical part of the Purex operation as the first bank of the First Cycle. The centrifugal contactors for this crucial part of the process were designed in the Savannah River Laboratory by the Separations Engineering Division, and at TNX, where the final testing occurred. For centrifugal contactors to work, the two streams or phases were thrown up into the bowl during the mixing stage. There they were spun at high speeds, mixed almost instantly, and separated out quickly. The volume involved at any one time was much less than that of the jumbo mixer-settlers, down from 220 gallons to just one. Even so, the general throughput was increased, since the problems surrounding the jumbo mixer-settlers had always been a major bottleneck in the process. Throughput was increased to 20 tons per day.[29]

Albert Kishbaugh did much of the basic design and engineering work on the new centrifugal contactors. There was no doubt that the

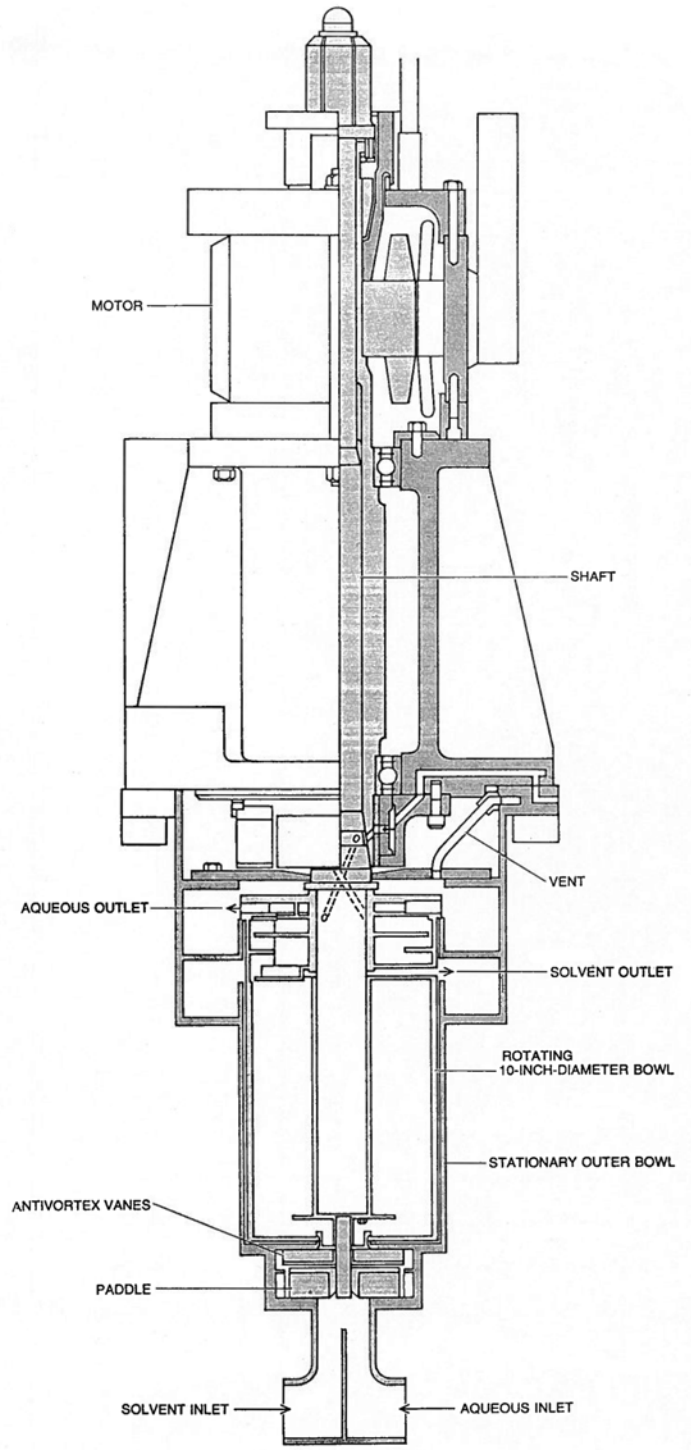
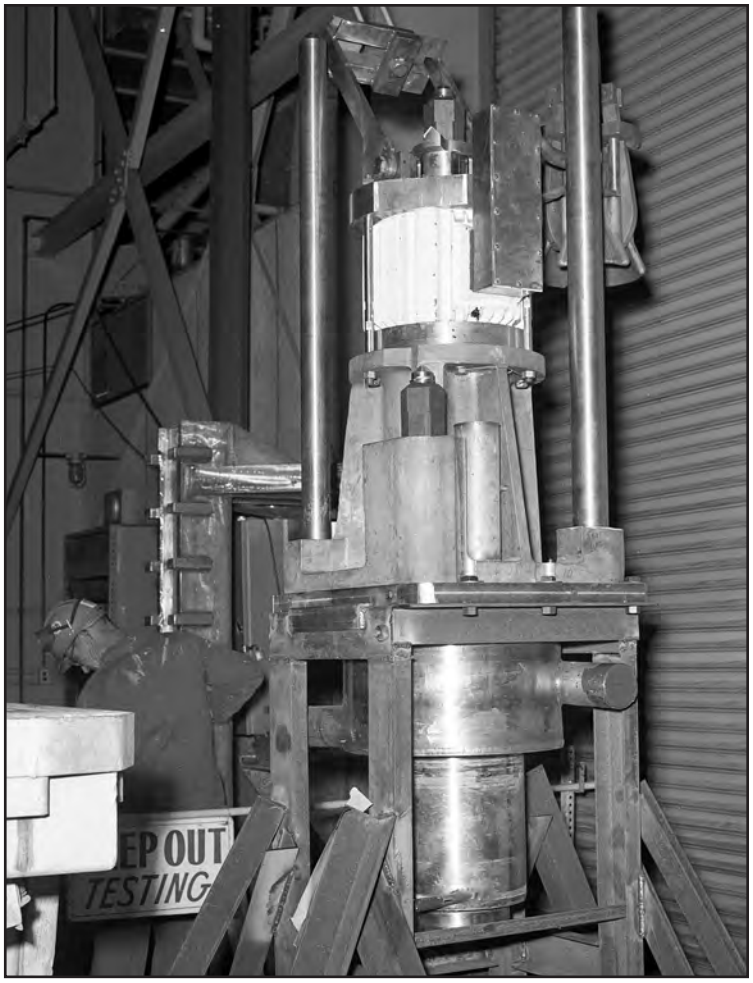


Illustration of a Centrifugal Contactor. Source: "The Reprocessing of Nuclear Fuels," Scientific American, *William Bebbington 1976: 36.*

centrifugal contactors would work more efficiently than the old mixer-settlers; the main problem was flow control. The flow was so fast that the control mechanisms had to be completely overhauled. Such overhauls required a lot of testing, conducted over a period of years.[30]



Centrifugal Contactor in 717-F. June 1, 1967, SRS Negative 11970-2.

Much of the non-radiological testing for the centrifugal contactors was done at TNX. This work began with a six-stage module prototype.[31] When work began on this prototype, in 1961, the equipment was referred to as a "centrifugal mixer-settler."[32] Later, the preferred term became "centrifugal contactor." By the time radiation testing was done at SRL, the device consisted of three six-stage assemblies. These three assemblies were then united into an 18-stage bank that replaced the 24-stage bank mixer-settlers.[33]

The advantages of the new centrifugal contactors were many. In addition to reducing the solvent's exposure to radiation, it also reduced the inventory required for both the aqueous and the solvent. The equipment assumed less space in the canyon. It also reduced the amount of flushing required between solutions. It was also more versatile, handling a variety of solutions with different viscosities. By the time they were installed F Canyon in 1966, centrifugal contactors were being proposed for use in H Area as well.[34]

The centrifugal contactors were installed as a bank of 18 on top of the first jumbo mixer-settler for the First Cycle in the Hot Canyon of 221-F.[35] This effectively replaced the 24-stage mixer-settler as the extraction contactor in F Canyon; "the role of settling chamber in the mixer-settlers was taken over by a bowl located on the same shaft as the mixing paddle."[36] Making use of the jumbos, which were never pulled out of the canyons, each of the centrifugal contactor's solid-bowl centrifuges was mounted above a mixing agitator of the old jumbos. The agitators were then used to spin the centrifuges, which operated much like a cream separator.[37] The mixed phases were separated with the heavier aqueous solution moving to the wall of the bowl, leaving the lighter organic phase in the center. The pumping, mixing, separating, and decanting were all done in one device, using the power of one rotating shaft. Air pressure had to be maintained in the weir chamber, but when all worked well, the centrifugal contactors achieved a level of efficiency rated at around 95 percent.[38]

This new centrifugal contactor was installed in F Canyon on September 7, 1966, and the first normal Purex feed material was run through the device on October 10, 1966. In 1967, it was noted that the device was still working well.[39] In the years that followed, it was found that the centrifugal contactors were better in almost every category of separations than the old jumbo mixer-settlers. Not only was the efficiency better, but also they were more versatile and safer to use. They were, however, more difficult to maintain. The seals on the shafts required considerable experimentation to fix.[40]

In the end, the centrifugal contactors worked well in F Canyon, but were never installed in H. This was basically because they were not needed there. The solvent in H Area was never put under the kind of stress found in F Area. In fact, Chuck Goergen stated that the solvent in H Area has not been changed out since the late 1970s; the solvent washing facilities worked well enough that all that had to be done there was occasionally to add some TBP as make-up solution.[41]

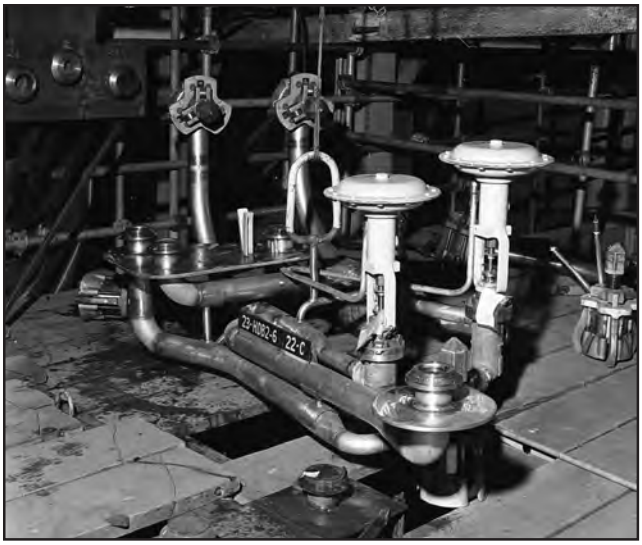
Even in 1983, it could be stated that, "no centrifugal contactors have been put in the plant since the F Area 1A Bank was installed in 1966." The other existing mixer-settlers were adequate for their jobs, and "therefore substituting the complex SRP centrifugal contactors for the simpler mixer-settlers was not justified." This 1983 report stated that this situation was being reconsidered, and that new centrifugal contactors were being considered for the First Cycle 1A Bank in H Canyon.[42] There is no indication that this plan was ever implemented, and there are no centrifugal contactors in 221-H today.[43]

OTHER UPGRADES, 1960S-1980S

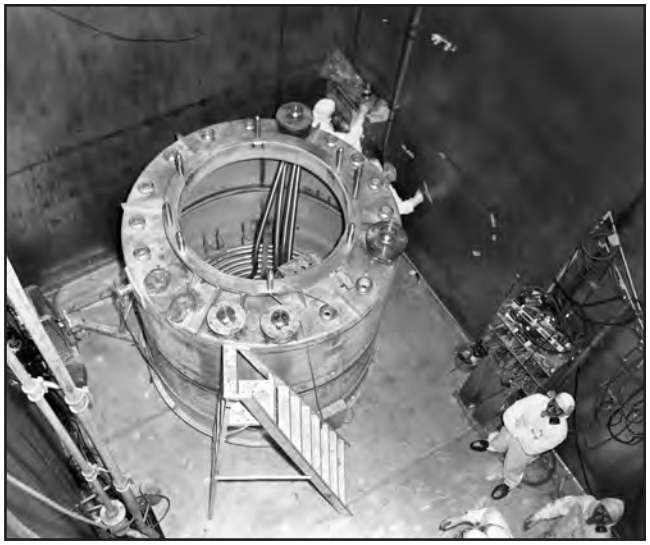
The search for a better diluent and the installation of centrifugal contactors were two major upgrades that were done in F Canyon in direct response to the contamination problem posed by the new jumbo mixer-settlers. Both were put into place fairly early after the re-start of F Canyon: the new diluent Adakane by 1961-62, and the centrifugal contactors in 1966. This, however, was just the beginning of the upgrades that would take place in F Area (and sometimes in both F and H). These upgrades would occur throughout the 1960s, 1970s, and 1980s, right up until the end of Du Pont's tenure at Savannah River.

A 3-Stage Dissolver Column, Photographed in 717-F, January 25, 1966. SRS Negative DPSPF 10897-14.

Du Pont had a corporate culture of fixing things, even if they were only a potential problem. Due to the nature of the free-ranging contract Du Pont had with the Atomic Energy Commission, the company did not have to ask the AEC for permission to make upgrades. They could be made on their own volition.[44]



A Spider Jumper, Photographed in 717-F, August 28, 1968. SRS Negative 12897-1.



A Batch Evaporator, Photographed in 221-F, January 17, 1966. SRS Negative 10884-1.

Some of these upgrades were relatively small, like the gasket resiliency problems that arose shortly after F Area was started back up. This led to a canyon gasket development program that tested many different gaskets.[45] Jumpers were always under study for improvements, as were batch evaporators and other pieces of equipment. These were usually tested out in 717-F before being installed in the canyon.

TV Monitors and Computers

A major change to 221-F, and later 221-H as well, was the addition of TV monitors in 1962. These were placed in the control room on the fourth level of Building 221-F. The television cameras were placed on the Hot Canyon crane. This allowed much better control over the observation of the process than what had been possible with the periscopes.

This was followed by the installation of the first computers. Computers came early to the main laboratory in Building 773-A, but never had the impact in Separations that they enjoyed in the Reactor areas, for the simple reason that computers were just not as essential for canyon operation as they proved to be for the reactors.[46] Computers in the reactor buildings began as early as 1964, but were later in Separations. In Separations, the first computers were simple and performed monitoring operations rather than control. They were a definite presence in the 221-F control room by the 1970s. Even in later years, the canyon buildings never moved beyond a combination of manual control

TV Monitors, Photographed In 221-F, May 30, 1962. SRS Negative DPESP 0262-9.

and computerization, with computers superimposed onto the hydraulic controls left over from the 1950s.[47] This situation can still be seen today in the H Canyon control room, with its original panel controls on the wall and the DCS computers on the desks.

This combination was not necessarily a flaw. Du Pont could have revamped the entire control process, if it had so chosen. It just was not required. As Edward Albenesius put it, "the Separations buildings worked so well, almost as a hands-on, chemical engineering thing, that computers, to my old-fashioned way of thinking, would just kind of get in the way."[48]

Don Orth had a similar opinion on the matter. "We [SRP] did not want to lead in this [computer] technology, in this instance. You would not want to mess up the canyon with an unproven technology." As he recalled, the first Separations computers were relatively crude and only did monitoring. Some level of semi-control followed, but it took years before there was anything more.[49]

According to David Karraker, the first calculations for Separations were done by analytical processes like the "time-honored McCabe-Thiele method." Only later were there computer codes like SEPHIS.[50] Goergen recalled that computer controls began to be implemented in the late 1970s, and were first developed in F Canyon for the Second Plutonium Cycle. Similar computer control was placed into H Canyon for the Second Uranium Cycle in 1988. On those occasions, the pneumatic instrument signals had to be converted into a digital system that could be read by the computer. Later, the computer system was designed so that an operator could hit a button and the process would effectively run itself. If anything went wrong, or if any part of the system began to operate outside of accepted parameters, the computer was designed to scram the cycle and flush the system.[51]

The first comprehensive computer system used in the canyons was the DCS, or Distributed Control System. The DCS was put into F Canyon in the early 1980s. The DCS received digital signals from all across the process: temperatures, flow rates, tank levels. This was all fed into the "process control computer, located in the central control room. It was designed so that one operator could view the entire process. DCS was not a complete computerization system, but it was considered better and safer than relying on manual controls. The rest of F Canyon was automated, beginning in 1986. The project to do the same for H Canyon was still on the drawing board when Du Pont left in 1989.[52] Westinghouse completed the computerization of H Canyon in the years that followed.[53]

Now there are computers at every step of what remains of the Separations process, now limited to H Area. Computers run the cranes and the processes, and there are even General Support (GS) computers to find your workers, and even your garbage cans. Computers have overrun the process. It has been said that there are now as many distributed control engineers as process engineers, and all to translate what process engineers want to do, to the appropriate computer code required to run the process.[54]

Continuous Analysis and Changes to 772-F Analytical Lab

Early lab work in the 772-F Analytical Lab was done inside shielding boxes called "junior caves." Samples were removed from their containers and dried and then placed into counters to measure radioactivity, or anything else that was required. The work involved was both tedious and potentially dangerous, but essential in order to

provide feedback to the canyon operators who had to make adjustments to the separations process. In cases where the results were very critical, two or more people might analyze the samples to ensure consistent results. These special runs were called "Blue Label Samples."[55]

The process of taking samples from the canyon process, sending them to 772-F, and analyzing them there, was inherently dangerous.[56] As Bebbington stated, "the risk of contamination and exposure to radiation was greater in these analytical operations than anywhere else in the plant." Sample size was usually taken in a one fluid ounce amount, placed in a glass vial. From the sample aisle in the canyon, the material was placed in a shielded container and was taken to 772-F, right next door to 221-F.[57] Sampling problems appeared very early in the process. In December 1955, sampler gasket failures in 221-F caused leaks that led to the search for a new gasket material mixing "Teflon" and stainless steel.[58]

As a result of these and other issues, there was always an impetus to make the sampling job safer. Analytical techniques improved throughout the period of operation. There was the introduction of the shake test, the use of sodium iodide, and other methods.[59] Radiation analyzers were more versatile than earlier equipment and were used with on-line computers. They could analyze a bottle of radioactive material placed in front of a sensor and identify the nuclides in the sample. This led to the development of the "black box," which was an idea conceived by Savannah River process engineers for analyzing radioactive samples almost instantaneously. "At-line" analysis called for discrete samples to be taken at certain points in the process, particularly in the B-Line. Analyzed by computer, "at-line" analysis was introduced about the same time as DCS was installed in the canyon control room.[60]

The first analytical computer in 772-F was the Digital Equipment Corporation (DEC) computer. Installed in the 1970s, the DEC was the size of a small room. It assumed the work of gamma analyses, a tedious task that had been previously done by hand.[61]

With the advent of computers, there developed types of continuous measurement that no longer required workers to take physical samples. This led to the process of continuous analysis based on on-line samplers and in-line analysis, as well as other pieces of equipment. On-line samplers measured density and acid levels in a solution that flowed constantly past a detector. In-line analysis relied on neutron monitors directly affixed to canyon equipment. "Continuous analysis" was the umbrella term for all of the new automated analytical methods used for studying the canyon process. By the 1980s, this analysis was put together by process control computers and could provide an accurate overall picture of what was going on in the canyon.[62]

Many people worked to perfect the continuous analysis techniques, but some of the more prominent researchers were Bob Smith and Syderis Burkett.[63] Burkett was a chemist in 772-F who worked with an analytical machine that took samples and analyzed them automatically.[64]

There were a number of other changes that took place in and around 772-F during this same period. The Sep Tech Lab was re-opened in 772-F in 1981, and Perry Holcomb recalled that he maintained his office in that building from 1981 to 1992. The purpose of this laboratory was to find solutions to problems that occurred throughout the 221 separation processes.[65] Many other people also worked at the lab in the later years, including two supervisors, Dick Bass and Patricia Padazanin.[66]

One of the greatest changes to 772-F was the addition of Building 772-1F, constructed immediately north of 772-F. Often called a "cell facility," it was put into service in 1987. Building 772-1F was a purely analytical lab, with minimal office space and storage. It took over the 24-hour analysis service required by the canyon operations that used to be done in 772-F.[67]

Crane Improvements

Canyon crane operators also had one of the most potentially dangerous jobs within the complex, and repair work on the cranes was potentially dangerous as well. The hot canyon crane, if it required repairs, had to be worked on in the Crane Maintenance Room, but only after removing as much radioactive contamination as possible. Workers in this area had short work-spans, and these necessary periods were made shorter and less frequent by repairing the crane with materials that were water and moisture resistant.[68]

As we have seen, the original crane operation was completely manual, with the crane operator sitting in a completely shielded cab for work in the Hot Canyon, and sitting over a less shielded area for work over the Warm Canyon. With the rise in canyon throughput in the 1950s, the shielding for the Warm Canyon cab had to be increased. Steel plates, one to two inches thick, were added to the bottom and the sides of the crane cab as a result of the higher radiation levels.[69]

By the mid to late 1980s, work was begun on replacements for all of the canyon cranes. Technology had advanced to the point where a totally manual crane, operated using optical observation, was no longer adequate for the job. Studies for replacing the cranes began around 1984 and work on the new cranes began soon after.[70]

The new cranes were installed in the late 1980s and early 1990s. The new Warm Canyon crane for F Area began operation in the middle of 1989, followed by the Warm Canyon crane in H Area later that same year. New cranes for the Hot Canyons soon followed. The cranes were equipped with multiple TV monitors, closed circuit radio control, and were connected to a central crane control room on the fourth level.[71] This allowed remote control for the cranes, with all activities recorded by monitors. Interestingly enough, the televised images that came into the crane control room were found to work better in black and white, since color images created some depth perception problems.[72]

CHANGES TO THE JB-LINE AND VICINITY

Beginning in 1978 and continuing into the 1980s, there were a number of modifications done to the JB-Line, which by this point is often referred to as the FB-Line in the contemporary literature. Most of these changes were done on the Mechanical Line. Old precipitators and cabinets were replaced with better containment cabinets.[73] Additional safeguards were installed, and some elements of the Distributed Control Systems (DCS) were installed as well.[74] This soon became the place for slag plutonium recovery in the nuclear complex. New trifluoride precipitators were installed in 1987, after the old equipment had been worn out by high levels of radiation. These were basically the same, but with superior control features.[75]

At some point during this period, John Porter worked on the filtration characteristics of the plutonium fluoride in the JB-Line. This research was required because it proved difficult to filter the small particles of plutonium fluoride using the new and larger equipment. Porter altered the precipitation method to allow the particles to become larger, which allowed them to be filtered more easily.[76]

Despite these changes, the JB-Line process remained basically the same. A solution of Pu-239 came into the facility in a nitric acid solution from the canyon. It was converted to a plutonium trifluoride solution and precipitated to a different form of plutonium. It was dried and taken to a reduction furnace where it was transformed into plutonium metal. That metal, in a crucible, was formed into a "button" shape. The button was then shipped to Rocky Flats for installation into a nuclear bomb.[77] This overall process only changed in 1997, when the FB-Line switched to a new plutonium packaging process, called "bagless transfer." This supplanted the button process, and this superior packaging process was first perfected at Savannah River.[78]

These were changes to the inside of the JB-Line. In the 1980s, two new facilities were added to the outside vicinity of the JB-Line. These were the Special Recovery Facility and the new Plutonium Storage Vault. The New Special Recovery was located on the roof of the F Canyon beside the JB-Line. Its main purpose was to recover plutonium residue for reprocessing in the JB-Line. Much of this plutonium was to come from Hanford's N Reactor and even weapons-grade plutonium scrap. Constructed at a cost of $86 million, it was almost finished by 1992, but it never had occasion to open with the end of the Cold War.[79]

The end of the Cold War also cut short the usefulness of the new Plutonium Storage Vault. Constructed on the roof of 221-F in the late 1980s, it was designed to replace the old 217-F Magazine Storage facility. Unlike the old magazine, it was fully automated and even had a computer-controlled robot to arrange the materials inside. It was designed to hold the plutonium made at Savannah River, and other places as well. The Cold War was basically over by the time this new facility neared completion in 1989. It was hardly used before it was closed down.[80]

CHANGES TO A-LINE

A-Line, which de-nitrated the uranium from the Purex process and turned it into uranium trioxide, was never as important as the various B-Lines that processed plutonium. It never saw the massive enlargements and overhauls that came with the JB-Line. Even so, it was an important part of the whole process, and it underwent alterations and changes throughout its operational history.[81]

One of the first of the changes occurred in the 1954-56 time frame. At the request of Oak Ridge, changes to the shipping facility were made so that off-site shipment of the uranium trioxide could be done in five-ton containers rather than the original 800-pound drums. This necessitated changes to the sampling screw conveyor, the lift truck, the platform scale, monorail, crane, and the hydraulically operated steel platform.[82]

The biggest change to A-Line came in the wake of the explosion of a denitrator pot on February 12, 1975. This chemical explosion took place as a result of solvent contamination in the uranyl nitrate solution, which blew up upon heating in the pot. The area had to be closed for six months to allow for clean-up and investigation.[83]

In the wake of the explosion, a number of small changes were made to ensure that degraded solvent could not find its way to the denitrators, but the major overhaul to A-Line occurred in the 1980s. At that time, the six original batch denitrator pots, heated with propane burners, were replaced by continuous denitrators, heated electrically. The first of these went on line in 1988, and there were three continuous denitrators in operation by 1990. In the case of this new equipment, uranyl nitrate was fed into the system and uranium oxide powder came out in the form of beads or "prills." This kept the process virtually dust-free. The entire operation was controlled from a new control room.[84]

IMPROVEMENTS TO THE SAND FILTERS

The sand filters were a silent but essential part of the decontamination process for both the Purex process and the HM process. They did their jobs without any major changes until the late 1960s, when corrosion became apparent in the concrete supports located on the underside of the sand filters. Corrosion, particularly in 294-H, began to show up in maintenance photographs as early as April of 1969, and part of that sand filter actually collapsed that same year.[85] As a result of this problem, the original sand filters were refurbished with new grates. In the years that followed, new sand filters, 294-1F and 294-1H, were added on the east side of the original sand filters.[86]

Despite the corrosion problem, the sand filters worked well, and there was no thought given to replacing them with another filtration system. Acid fumes, not radioactivity, had been the main problem in 1969, and sand had proven quite effective in filtering out any residual plutonium. It always worked better than a HEPA filter, which could clog up and could also burn.[87]

F CANYON IN LATER YEARS: GENERAL TRENDS

The entire Separations operation underwent a number of improvements in the years after 1959. As these years stretched into decades, a number of significant trends began to manifest themselves. The peak production of Pu-239 was reached sometime around 1960 and went into gradual decline in the years that followed.[88] This was certainly true in the years after 1964, when R Reactor was shut down. During this period, from 1961 to 1965, before the new missions in H Canyon really took hold, there were often alternating periods of operation in F and H canyons.[89] Pu-239 production was still important, perhaps the single most important thing made at Savannah River, and this remained true until the end of the Cold War. As the production rate declined, however, more time was devoted to making the Separations processes as safe as possible. This was especially true for the Purex process in F Canyon, but also true for the HM process in H Canyon.

Right from the beginning, safety was built into the process. There was direct technical support for every aspect of Operations, with more safety oversight than was common at a commercial establishment. There was also a great deal of planning for any new projects or campaigns, followed by testing and established procedures. Safety was also built into the organization. The process itself was performed by Separations, but everything they did was overseen by Separations Technology, which observed the operation, wrote up the procedures, and changed procedures where needed. The Laboratory approved all technical specifications and exerted the final authority.[90]

As production demands began to lessen, there was also a drop off in radioactive releases. Bebbington noted that these releases were higher in 1955, right at the beginning of plant operation, than they would be in later years.[91] There was also a serious spill in F Canyon in 1960, when contaminated water leaked into the Hot Gang Valve corridor, making some lower areas of 221-F off-limits for a number of years.[92] Greater concerns about leaks and greater concerns about personnel decontamination facilities, all helped reduce the danger of contamination.

The Purex process itself was tweaked throughout this period. This was especially true of the plutonium finish facility in the new JB-Line. As was stated in April of 1963, "the slurry-heel technique for the precipitation of PuF_3 was adopted for use on all shifts, the new facilities for dissolving Pu metal on sixth level completed and cold runs started."[93]

During part of this period, TNX went through a relatively slow spell. This was particularly true in the 1970s, when the larger issues were basically solved, but before testing work began on the Defense Waste Processing Facility.[94] In the early 1980s, a new steam line was constructed from the large D Area powerhouse to F Area, after it was decided not to restart the F Area powerhouse.[95]

By the 1970s, Savannah River had clearly taken over from Hanford the role as the nation's foremost producer of Pu-239. This was also the period of stabilization at Savannah River, both in production levels and in techniques. Most of the basic processes had been worked out, not only in Separations, but also in the Reactor and Manufacturing areas. The D Area production of heavy water was in the process of being shut down. The plant overall was run by a staff of around 10,000 employees, but most of these were not directly involved in Separations. During this period, Separations was being operated with a total work force of around 1500 to 1600 people. Out of that number, some 250 operators, engineers, and supervisory staff worked in the facilities in JB-Line.[96]

One of the largest trends at Savannah River was the advent of new people that came into the process in the 1970s and into the 1980s. Du Pont often shifted its employees around the plant, even in the early days, but this appears to have been done less often in Separations than in the other parts of the plant. As Elsie Wood Smith remarked about her early days in the Analytical Laboratory, even after a six-year leave of absence, she returned to find the very same people working in the very same positions. As Goergen said of those early days, the employees were "frozen in time."[97]

This changed, beginning in the 1970s, as many of the original Du Ponters who had opened the plant began to retire, and new people were brought in to replace them. The site had a reputation for being safe, with new computer equipment that was state of the art, and the latest equipment in the labs. And production demands coming from the AEC (later DOE) were low, allowing a wider range of work projects than would have been entertained in the early years.[98]

There were also market reasons for Du Ponters in other fields to be interested in Savannah River. The recession of the 1970s and its negative impacts to Du Pont's fiber market meant that Savannah River looked better to new hires than would have been the case in the previous decade.[99] At the same time, there was some downsizing of the staff.[100] One consequence of these somewhat contradictory trends was the need for new and updated operating

manuals for the Separations processes, in particular the Purex process. It is surely not a coincidence that the two most comprehensive manuals detailing the processes of F Canyon were compiled in the 1970s. These were a "221-F Training Manual" dated to around 1975[101] and "The Purex Process," a training lecture compiled by J. B. Starks, dated to January 1977.[102]

It was into this new world that the second generation of Du Ponters came to work at the plant. Among the people interviewed for this study, that generation was best represented by Charles (Chuck) Goergen and Vince Minardi. Goergen's Savannah River career began in October of 1975 in the Analytical Lab. There he reviewed samples and did remote cell work. Later he worked in other aspects of F Area, branching out to H Area and tritium.[103] Vince Minardi began his career in 1978, where he worked in the JB-Line, eventually becoming a manager. Later he did financial planning for Separations, including the budget.[104]

This influx of new blood continued into the 1980s. During the Reagan years, L Reactor was restarted after years of being shut down, and plutonium-239 production was again ramped up in a new arms race with the Soviets. During this same time, the Naval Fuels program was under construction in F Area (this facility was completed but was never put into operation). During this period of expansion, it has been estimated that up to 10 percent of all new chemical engineers hired in the United States, were recruited to Savannah River.[105]

The canyons, like the reactors, were designed to be flexible. They could do a number of different programs simultaneously. This was because the canyon was planned and constructed before there was overriding concern about nuclear proliferation and terrorism. Most modern nuclear plants are hard-wired and hard-piped to prevent any mistakes and thefts, but this also severely limits what they can do. The equipment in the canyons was designed to be removed, replaced, and relocated, and this happened often, especially in F with the insertion of jumbo equipment. As a rule, this was not done in H Canyon, where most of the equipment is still original.[106] The major exception here are the "frames" that played such a big role in the production of Pu-238. The frames will be discussed in the chapter that follows.

Everything began to change for F Area in the late 1980s and early 1990s. First off, by the late 1980s, the Cold War began to taper off. Coincidentally, in 1987, for reasons not related to the Cold War, Du Pont made the decision to leave Savannah River, effective in early 1989. During this transitional period, all of the reactors that were still running– K, L, and P– were closed down, at least provisionally, during the course of 1988.[107] Westinghouse assumed Du Pont's role as operator of Savannah River, and the facility was renamed Savannah River Site, the name it holds today. A number of consortiums have operated the plant since that time, but there has been a general continuity since 1989, and even before. Many people stayed on at the site in the subsequent years. Engineering was the major exception. Du Pont had its own engineering staff, which had been used at Savannah River Plant. Westinghouse did not, and Bechtel was brought in to fill that need.[108]

Westinghouse refurbished K Reactor for start-up in the early 1990s, but the collapse of the Soviet Union and the complete end of the Cold War made that development unnecessary. This had a direct impact on F Canyon, which was devoted to the production of Pu-239. Increasingly redundant in the 1990s, F Canyon was often closed down during that period. When it was open, its task was to process any left-over plutonium in the system and work on spent fuels that were stored in L Area. F Canyon was closed for the last time after the year 2000.[109]

A-Line was also shut down. This is believed to have happened in the late 1980s shortly after the reactors went down. Any uranyl nitrate that still required processing was sent to Oak Ridge.[110] In the end, even though some of the recycled uranium was sent to Paducah and to the Cascades, most of the uranium processed in A-Line was never put to use. As Goergen stated:

> When they started running the depleted uranium… the natural uranium was only depleted a little bit when it came out of the reactors. When uranium was scarse, some of that was fed to the Cascades. There was a report that was issued on uranium use by Lewis McCarty and it talked about who and what went where. Once you had depleted uranium, once it's 0.2 percent U-235, versus the natural 0.7 percent, you have to run a lot of that…. It was rejected from the tailings, that's why it worked so well as target material. So, if it was rejected originally, and even more was burned out of the reactor, was it worth sending to the Cascades, since uranium production had increased in the U.S. So we essentially accumulated 36,000 drums of depleted uranium on site, which has all been transferred out to Utah.[111]

Mike Holland, who has worked at 772-F for years, mentioned another reason. The uranium from A-Line contained trace elements of plutonium, and there was enough uranium from other sources that it was not necessary to use this slightly contaminated source.[112]

IX. H AREA AND OTHER PROGRAMS, 1959-1980s

HM PROCESS AND OTHER WORK

In the later 1950s, when it was decided to run the reactors with a regimen of enriched uranium fuel, surrounded by depleted uranium targets, it fell to H Canyon to process the fuel after it came out of the reactors, by which time it was referred to as "spent fuel." The HM process was designed to deal with spent fuel, and improvements to this process continued for years afterwards. Fuel elements almost always stayed in the reactors longer than the targets, and as a result they accumulated more fission products, which had to be removed from the process in separations.[1] These fission products ended up in the H Area waste tanks, and helps to explain why there were eventually more waste tanks in H Area than there were in F Area, even though H Area started out with less.

As a rule, the U-235 that was recovered from the HM process was sent to Oak Ridge, where it was purified and turned into metallic buttons, and then shipped back to the 300 Area at Savannah River to be made back into fuel for the reactors. It has been estimated that some 185 tons of highly enriched uranium (HEU) went to Oak Ridge and came back around through this cycle. This was different from the original set up. When H Canyon first went on line in the mid-1950s, the uranyl nitrate that ended up in the H Area A-Line was shipped over to the F Area A-Line by tank car for processing there. This arrangement ceased when H Canyon began processing enriched uranium.[2]

Like all other operations at Savannah River, the HM process was subject to constant improvements. One that was implemented in 1962, called for the elimination of the dissolver heel clean-out process, which took up one-third of all dissolving time, but only performed one-seventh of the work. The elimination of this step increased the capacity of the enriched uranium separations process.[3]

By the 1970s, most of the kinks had been worked out of the HM process, and it was considered safe to increase the percentage of TBP in the solvent from 3.5 to 7.5 percent.[4] By that time, Major Thompson had reworked the flowsheet used for the HM process, creating a process that could handle low-enriched fuels as well as highly enriched fuels.[5]

By this time, the HM process had "evolved to reject plutonium to the waste, and recover neptunium in the B Bank. Neptunium then went to a second product cycle, which purified the neptunium. The uranium from the C Bank went to a second cycle to purify it in D Bank."[6] This allowed for the development of the Pu-238 program, which relied on neptunium as the raw material. This became one of the major programs in H Area, perhaps the main one.

The main story of H Canyon in the years after 1959 was not so much the HM process as it was first established, but rather the way it evolved in the 1960s, 1970s, and 1980s, especially by the time that Chuck Goergen knew it. During those years, H Canyon did far more than process enriched uranium for re-use as fuel. It also produced

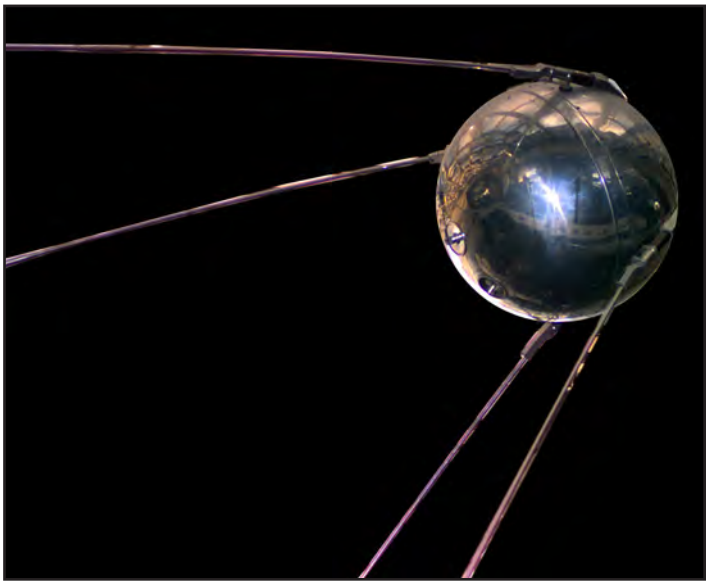
Pu-238, an important heat source for NASA. This became a huge mission, not just in H Area, but in F Area as well. H Area also contributed to the research for the various programs generated by President Eisenhower's "Atoms for Peace" campaign, which led to power reactors all around the country, and eventually led to H Area's own Receiving Basin for Off-Site Fuels (RBOF). H Area was also a major component in Glenn Seaborg's various Transplutonium Programs conducted at Savannah River. These missions grew to define H Area far more than the older mission of processing enriched uranium. This chapter is dedicated to these other missions.

THE PLUTONIUM-238 PROGRAM

The greatest of these various missions would have to be the growth of the Pu-238 industry. And it did indeed turn into an industry, one that had its heart in H Area, but soon spread to facilities in F Area as well.

The production of Pu-238 was driven by NASA's need for a reliable heat source to generate electricity for its deep-space vehicles, which might travel to distant parts of the solar system, too far from the sun to use solar panels. This work began in the 1950s during the search for a heat source for Arctic and cold climate applications, but this soon took a backseat to space exploration. After the Soviets launched Sputnik in October 1957, followed by the launch of Explorer I the following year, the need for heat sources to use in the "Space Race" became a paramount consideration.[7]

Beginning in the early 1950s, Cobalt-60 had been produced in small amounts for use as a potential Arctic heat source, and had even been tested as a food irradiator.[8] For a number of reasons, cobalt did not work out as planned, and this was particularly true in space. Another element tried was curium-244. This was first produced in the early 1960s as a heat source for space flights, but the demand for it was limited. NASA seemed to prefer another isotope that was also produced about the same time: Pu-238.[9]



Sputnik. Source: NASA

In the years that followed, Pu-238 became the preferred heat source isotope for space travel, not just in this country but also around the world. Placed into radioisotope thermo-electric generators or RTGs, Pu-238 provided the electrical source for many dozens of space flights, beginning with the 1961 Navy Transit navigational satellite. Pu-238 RTGs were used on various Apollo moon flights, and many more unmanned flights, including Pioneer (1972), Viking (1975), Voyager I and II (1977), the Galileo flights, and Cassini.[10] At least 24 U.S. space missions have used Pu-238-fueled RTGs over the years, and Savannah River produced more Pu-238 than any other industrial site in the nation.[11]

Workers install three Radioisotope Thermoelectric Generators (RTGs) on the Cassini spacecraft at Cape Canaveral Air Station, 1997. RTGs are lightweight, compact spacecraft electrical power systems. These generators produce power by converting heat into electrical energy; the heat is provided by the natural radioactive decay of plutonium-238 dioxide, a non-weapons-grade material. RTGs enable spacecraft to operate at significant distances from the Sun where solar power systems would not be feasible. Cassini traveled two billion miles to reach Saturn and another 1.1 billion miles while in orbit around Saturn. Source: NASA

Pu-238 had properties that made it almost ideal for use as a heat source for space travel. It had a lengthy half-life of around 88 years, far better than curium, which had a half-life of only 18.7 years. Like all radioisotopes, Pu-238 produced heat through decay, but its decay released mostly alpha particles. The gamma radiation was relatively low, so no excessive shielding was needed, and this was important for a lightweight space vehicle.[12]

The main problem with Pu-238 was not in its space application, but working with the raw material. Pu-238 was notorious for its "crawling contamination."[13] Almost everyone recalled that handling Pu-238 was a potentially messy operation. It was difficult to work with and had tendency to spread.[14] As Perry Holcomb described it, Pu-238 "had a mind of its own."[15]

Neptunium Facilities in Separations

Plutonium-238 was created in a reactor, using neptunium-237 as the target material. Neptunium itself is a by-product of uranium fission in the reactors. Some U-235 atoms acquire an extra neutron and become U-236. As the U-236 builds up in the fuel element, and is exposed to more neutrons, it can be bumped up to U-237, which then decays to neptunium-237. Neptunium became one of the main by-products of the HM process, and this was the raw material that was put back into the reactors to produce Pu-238.

The first Pu-238 work at Savannah River was done in the Savannah River Laboratory, in the High-Level Caves and in B Wing. When the basic process was honed and the necessary equipment was tested and put in place, the operation shifted to 221-H. Production began in 1960 and quickly expanded.[16] Plutonium-238 facilities developed throughout the 1960s, with work beginning in H Canyon. From the beginning, both neptunium and Pu-238 were processed in H Canyon and finished in the HB-Lines. In addition, some neptunium and Pu-238 was also recovered from the Purex process in F Canyon. Before the end of the decade, Building 235-F was brought into the picture. This building had previously been built but never put to industrial use. In 235-F, neptunium billets were made for the manufacturing area, and ultimately the reactors. One of the later additions, constructed inside 235-F, was the Plutonium Fuel Facility or PuFF, which started up in 1978. PuFF became the new finishing line for Pu-238, turning it into the final form required by NASA. The Pu-238 work done there will be explored later in this chapter.

H Canyon and the New HB-Lines

In the early days of Savannah River Separations, neptunium (Np-237) was an unwanted by-product that went to the high-level waste. In fact, the first means of obtaining neptunium at Savannah River was from the waste streams in both F and H areas. Recovery from waste, done by means of ion exchange, may have been the first method for getting neptunium, but as the process became larger, it was also done by means of solvent extraction in Building 221-H. The old Second Cycle Plutonium, which had been used to purify Pu-239, was no longer needed for that purpose in H Canyon. This became the new neptunium process line. Neptunium was separated from the enriched uranium in the First Cycle extraction, with neptunium going to what had been the Second Plutonium Cycle purification, now transformed into a neptunium processing line. The old mixer-settlers used in the line were employed here as well. This became the main source for the recovery of Np-237, using the HM process.[17]

After the neptunium was recovered, it had to be purified. This was done in the old HB-Lines, no longer needed for finishing Pu-239. There it was purified and converted to neptunium oxide.[18]

A number of changes were made to the old B-Lines in 221-H to accommodate this development. By 1960, the B-Line inside 221-H was converted to process neptunium and Pu-238, and turn both into an oxide. It would receive neptunium and Pu-238 in a nitric acid solution from the canyon, and convert them into neptunium dioxide (NpO_2) and Pu-238 dioxide (PuO_2).[19] In 1963, there was an addition to the B-Line that was designed to work on Pu-238 directly. This was the "Plutonium Fabrication Facility." This facility would operate for at least two decades, from 1963 to 1983.[20] In 1972, a Pu-238 Scrap Recovery facility was added adjacent to the B-Line. Located in Room 306, it was equipped with 21 stainless steel glove boxes, with glass windows. The recovery facility was equipped to process Np-237, Pu-238, and enriched uranium/Pu-239 scrap.[21]

Beginning in 1980, a new Pu-238 facility was constructed on the top of 221-H. Called the HB-Line, it was completed in stages throughout the early 1980s. By the middle of the decade, the new roof-top facility had totally taken over the tasks previously done by the B-Lines located on the third and fourth levels inside 221-H. The new HB-Line, located at the south end of the building, became the new fifth and sixth levels.

The new roof-top HB-Line facility was divided into three phases, which were constructed at different times: Scrap Recovery, built over Sections 2 and 3; the Np-Oxide Line, built over Sections 4 and 5; the Pu-238 Oxide Line, built over Section 6. [22] Scrap Recovery (Phase 1) was built first, with its own control room; the other two followed about a year later and shared a control room.[23]

The new HB-Line cost $70 million. As mentioned above, there were three process lines: Phase 1 was the Scrap Recovery Facility, which recycled plutonium scrap for purification and concentration. Phase 2 produced neptunium oxide, while Phase 3 produced Pu-238 oxide from nitrate solutions. By this time, the HB-Line was the only U.S. producer of Pu-238.[24]

Some of the major pieces of equipment in the new HB-Line were filter boats, various furnaces ("calcination cabinet"), and of course ion exchange columns. Many of these items were located on a trolley, with oxide resulting at the end of the process. There was also a small analytical lab in Phase 2, so analysts would not have to go over to Building 772-F all the time.[25]

All of these HB-Line facilities, Phases 1 through 3, were located on the fifth level. The sixth level was for the most part devoted to service equipment: compressors, hydrogen purges, electrical control rooms; air exhausters and filters, and a Halon room for fire prevention. The Precipitator Feed Adjustment Cabinet was the only process area on the sixth level.[26]

With the new HB-Line in operation, the old B-Line, located inside 221-H, was closed down in 1984. The old scrap recovery facility was closed a year before that. Decommissioning began that same year with the scrap recovery facilities, and continued for years. It was still underway in 1990.[27] Now the original B-Line is part of the "material support facilities."[28]

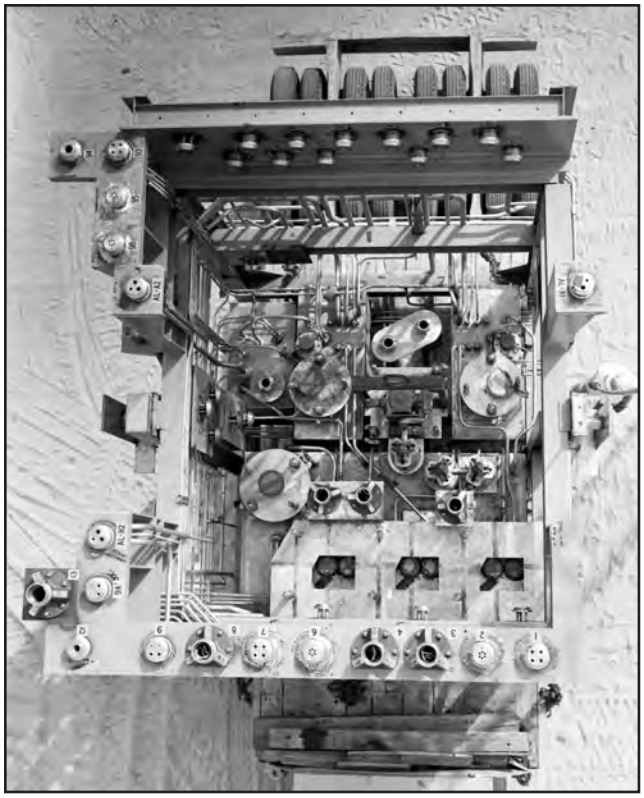
New Equipment for Pu-238

The processing of neptunium and Pu-238 required two new major pieces of equipment for the 221-H Canyon. One, the ion exchange column, was not new, but had to be adapted for use in the canyons. The other was a completely new piece of equipment, designed to fit directly into the 221 canyon buildings. These were known as "frames." Often they worked together, as will be shown below.

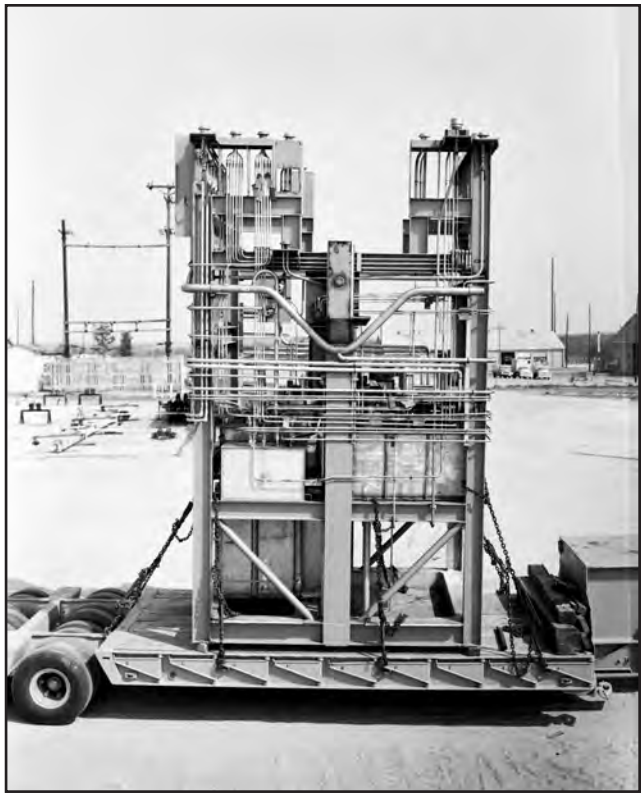
Ion Exchange Column

The processing of Pu-238 through the HM process had its own share of problems. The solvent often degraded, creating its own form of "do-bads" that gummed up the system (Holcomb interview). This led to the search for new equipment to replace some of the functions of the old mixer-settlers in 221-H. This led to the adaptation of ion exchange columns, which were eventually placed into both the canyons and the B-Lines.

The new ion exchange columns were basically adapted from existing applications, but they required some adjustments to be useful in this capacity. The resin beds in the columns tended to degrade due to radiation exposure. This was improved by running the resin flow as a slurry. This procedure was first tested at TNX before it was used in the canyon.[29] In 1969, it was proposed to remove the "follower plate" of two of the anion exchange columns to allow the resin beds to be changed more easily.[30]



Type II Frame, complete, top view. May 7, 1959, SRS Negative DPSPF 5925-2.



Type II Frame, complete, side view. May 7, 1959, SRS Negative DPSPF 5925-5.

These ion exchanges could pull out neptunium and plutonium from the solution and then separate those two from each other. The first anion exchange column in the canyon, RC-1, removed neptunium and plutonium from the other contaminated materials; the second anion exchange column, RC-2, did the final separations. These exchange columns were certainly in place by 1982.[31] They appear to have replaced many of the functions of the old mixer-settlers. One reason for this transition to ion exchange was that neptunium was only made in small amounts. As the process developed, it did not make sense to process such small amounts through the mixer-settlers.[32] Ion exchange columns became the new standard in both H Canyon and in the HB-Lines.

Frames

Many of these ion exchanges, especially the ones that went into the canyon, were placed onto "frames," which were then inserted into the canyon. These frames were totally new creations, specifically designed to fit into a canyon module.[33]

The frames were a unique piece of equipment that essentially carried a range of smaller pieces of equipment, all supported by a steel frame that measured 10 feet square and 17 feet high.[34] A frame was the largest square, blocky thing that could possible fit into the space provided by a single canyon module. There were two frames that went into H Canyon. They were designed to fit into the space originally made for two solvent extraction process vessels. Loaded up with all the equipment, the two frames in H Canyon could do the Np-237 and Pu-238 separations, all on their own.[35]

One of the frame's most important pieces of equipment was the new dissolver. These dissolvers liquefied irradiated neptunium oxide-aluminum targets from the reactors, as well as material from the ion exchange columns. The frames dissolver could hold a bundle of four irradiated targets, which were dissolved in boiling nitric acid, with mercuric nitrate and fluoride ions added to help catalyze the process.[36] Also included on the frame were eight ion exchange columns that were developed at the Savannah River Laboratory. Some of the ion exchange resin beds were negatively-charged (an-ion) and some were positively charged (cat-ion), depending on the valence being attracted.[37] Also included were 16 solution and collection tanks of various kinds.[38] All of this equipment, and the spares needed for replacement parts, were tested throughout the early 1960s at both TNX and 717-F.[39]

Since there were so many separate pieces of equipment on each frame, a way had to be invented to install a range of small tubes through the existing openings provided for each module in the canyon. This led to the invention of the "pull-through," which could pull up to four tubes through one regular jumper, creating four different feeds rather than just one. This, of course, had to be done remotely. Once this was worked out, the frames were placed into the canyon by the canyon cranes.[40]

The main purpose of the frame was to assist in the recovery and separation of neptunium and plutonium-238 coming out of the HM process.[41] Later, with the addition of dissolvers, they were able to process irradiated neptunium-237 targets and retrieve the Pu-238 totally on their own.[42]

By this time, the best description of the function of the frames came from Chuck Goergen, who described it as a "process module built on a frame," with tanks, instruments, and ion exchange columns. A frame was designed to take neptunium targets, which might have contained 80 percent neptunium and 20 percent plutonium when it went into the reactor. The ion exchange columns on the frame separated the resulting Np-237 and plutonium from the fission products, mostly aluminum nitrates. Another set of ion exchange columns would then separate the neptunium and the plutonium from each other, and each of these were then purified.[43]

The frames that went into H Canyon were known as Frame I-H and Frame II-H, and both were installed in December of 1960 and the first part of 1961. They were placed in the Hot Canyon of 221-H, Section 5, Modules 1 and 3, spaces usually identified as 5.1 and 5.3. The two frames became operational in March of 1961. They were designed to process irradiated Np-237 targets and purify neptunium from the Second Cycle. For the most part, this was always their mission, but they were occasionally drafted to work on other programs.[44]

Neptunium from Purex in F Canyon (Frame II-F and the PRC)

The major frames were always in H Canyon, but there was also a smaller frame in F Canyon to recover Np-237 from the Purex process. This was identified as Frame II-F. The purpose of this frame was to purify the neptunium recovered from the Primary Recovery Column, or PRC. Material recovered from this frame was sent to H Area for processing.[45]

Originally, any neptunium that resulted from Purex was sent to the waste tanks. There was not very much of it anyway, and there was no use for it in the early to middle 1950s. This changed with the Primary Recovery

Column (PRC), installed in F Canyon in 1960 to get neptunium and plutonium from the waste stream by means of an anion resin bed.[46] The material recovered was then sent to the F Canyon frame, identified as Frame II-F.[47]

Frame II-F purified the raw material that came from the PRC. This frame was installed in December of 1960, and was placed into Warm Canyon module 5.8. After trial water and cold chemical runs, the frame became operational in early 1961.[48] As designed, the F Canyon frame, working in conjunction with the PRC, recovered plutonium and neptunium from the F Canyon Purex process. The material was then sent to the HB-Line.[49]

The Frame II-F anion exchange columns were often tested to ensure their proper function.[50] This frame was used throughout the 1960s, when the inventory of Np-237 was desperately small. After the inventory rose, neptunium processing was dropped from the Purex process in F Canyon. Later, all the frames were shut down as part of the reactor closings that occurred in the late 1980s. At that point, there were plans to remove the three original frames and replace them, but this is not believed to have happened.[51]

Building 235-F: Early Work

Building 235-F had originally been constructed as part of Project 8980. It was built to house "C-Line," which would make bomb components from the materials produced in the A and B Lines. The AEC canceled plans for C-Line, but only after the shell for Building 235-F had been erected in 1954-55. Also erected at this same time was the building stack, identified as 293-F.[52] For the next few years, Building 235-F was used to store equipment.[53]

The rise of the Pu-238 program breathed new life into 235-F. Today, there are three major sections or subdivisions within the building, and all three were part of the Np-237-Pu-238 program. These are the Vault Area at the western end of the building, the Actinide Billet Line (ABL) in the center, and the Plutonium Fuel Form Facility (PuFF) on the eastern side of the building. These facilities are all located on the ground level or first floor. The second level contained the service area, while the basement contained the assay room and "Little PuFF."

The Vault Area has a central hallway, off which are three large vault rooms (101, 102, and 106), a metallography room, a hatchway, and the main entrance to the building.[54] This was probably constructed very early in the life of the Pu-238 program.

The Alloy Line was the first permanent process facility put into 235-F. This is believed to have been done in the early 1960s. Part of the Alloy Line was truncated when PuFF was constructed at the east end of the building in the 1970s, and the rest was converted to use in the ABL. In fact, the current ABL cabinets were originally part of the old Alloy Line.[55]

Processing of Np-237 to create targets was begun in 235-F in 1961, and that same year the first neptunium targets were irradiated in the Savannah River reactors.[56] In all likelihood, the old Alloy Line was used for the manufacture of these early Np-237 target slugs. These first targets were NpO_2-Al hot-press bonded slugs, which were solid neptunium-oxide targets clad in aluminum. Neptunium targets were made this way until the mid

1960s, but the slug form was not efficient, and the process soon switched over to tubular elements, which were already popular in other Savannah River programs.[57]

By 1968, production of neptunium targets had made the switch to tubular elements. These were more efficient because they could hold up to 20 percent more neptunium per target.[58] This marked the beginnings of the Actinide Billet Line, which began operation in 235-F in March of 1968. The name "Actinide" simply comes from the series on the periodic table that includes the elements neptunium and plutonium.

The new neptunium tubular targets had to be formed from billets, carefully prepared so that when they were extruded through a machine, they would come out as tubes with the right composition of elements, located in the right places. The billets were formed in the Actinide Billet Line, which was operated from 1968 to 1988, when the last Savannah River reactors were closed down. Some of the major steps in the process included blending NpO_2 and aluminum powder into cold compacts. Eighteen of these compacts were formed into a single billet. The billet then had to be welded, decontaminated, and shipped over to 321-M for extrusion through the M-Area presses. The most common neptunium form was the Mark 53 target.[59] Another unique feature was a pioneering use of powder metallurgy, which at the time was in its infancy.[60]

Mark 53, with NpO_2 target tubes, became the preferred reactor element for Pu-238 production. During irradiation,

PuFF Control Room, photographed in 2012.

Room 153, "Little PuFF," photographed in 2012.

between 12 and 20 percent of the neptunium would be transformed into Pu-238. After the target tubes were removed from the reactors and allowed to cool in the water basins for 100 days or more, they were sent to dissolution in 221-H, where they were dissolved in nitric acid. The solution then went to the anion exchange columns on the frames, where the neptunium and plutonium was absorbed onto the resin. The two elements are then separated and sent to B-Line. The Pu-238 was pelletized for NASA; the neptunium went back into the cycle for another chance at becoming Pu-238.[61]

PuFF in Building 235-F

Throughout the 1960s and well into the 1970s, the Pu-238 oxide powder produced at Savannah River was shipped to Mound Laboratory in Ohio to be made into the final fuel forms required by NASA. This changed in 1978, when the Plutonium Fuel Form Facility (PuFF) became operational. Constructed inside 235-F, work on PuFF began in the early 1970s, and was basically finished by 1975. The final checkout was conducted in 1977, with production beginning in December of 1978.[62]

With PuFF operational, the final Pu-238 forms could be fabricated at Savannah River. Usually, these were Pu-238 oxide spheres, about 1.5 inches in diameter, encased in iridium metal shells. The thermal heat given off from each sphere was the equivalent of seven watts. The Pu-238 pellets created at Savannah River were specifically designed for the Galileo and the Ulysses space missions. Another popular heat source form was a Pu-238-O_2 ceramic form.[63] This was prepared in the Plutonium Experimental Facility (PEF) immediately adjacent to PuFF– and sometimes considered a part of it. The PEF's main function was "for the conversion of plutonium-oxide powder into dense $^{238}PuO_2$ fuel forms."[64] Otherwise, PEF was a trouble-shooting experimental line closely associated with PuFF.[65]

PuFF was closed down for the first time around 1983-84, after producing several hundred spheres of Pu-238-O_2 to put into radioisotope thermo-electric heat sources.[66] In the years that followed, this type of work on the Pu-238 final forms was transferred to Los Alamos.[67]

The PuFF facility today is only a shell. The cells are still present, but much of the equipment used with the cells—the manipulators and the gloves—are missing. The control room is still there, but is largely gutted.[68]

"Little PuFF," located in the basement of 235-F, was a small facility that was run directly by Savannah River Laboratory. It was set up to deal with specific problems that might arise in the operation of PuFF, such as billet cracking and other production problems. The nine cells of Little PuFF were located in Room 153.[69]

The Pu-238 Process, early 1980s

By the early 1980s, the procedures for processing neptunium and Pu-238 had been largely worked out. All the neptunium-237 from the HM process in 221-H went to the HB-Line for final purification. The HB-Line also received all neptunium and Pu-238 from the frames in the H and F canyons. From the HB-Line came plutonium oxide and neptunium oxide, and these went to 235-F for fabrication. From 235-F exited the Pu-238 pellets or solid forms for NASA or other customers, and also the Np-237 billets.

The neptunium billets entered a looped process. First, they were sent to the 300 Area for extrusion, where they were turned into tubular targets. These went into the reactors. After irradiation, the targets went to H Canyon, where they were dissolved in the frames, the Pu-238 and Np-237 extracted and in a solution that headed back to the HB-Line, and then to 235-F. The plutonium-238 in the solution would eventually leave the loop as Pu-238 pellets or some other form, but the neptunium would go back again and again until it made the transition to Pu-238.[70]

As might be expected, Pu-238 required special shipping casks for transportation off-site. One of these was the PISA Shipping Cask Assembly, designed especially for the Pu-238 heat source. Another cask was called the "dog house."[71]

The End of Pu-238 Production at SRS

This basic procedure continued through most of the 1980s, but fell apart in the 1990s, with the end of the Cold War. Some parts of the process, specifically the PuFF operation, ended before that. When the reactors stopped running in 1988, there was no chance to make more Pu-238 from neptunium at Savannah River. The HB-Line was shut down for the first time in 1987.[72] It was started back up in the 1990s, but only to work a shipment of Pu-238 purchased from the Russians. Processed through the ion exchanges in the HB-Line, this work was directly funded by NASA. Eventually what was left of this work was transferred to the Advanced Test Reactor (ATR) in Idaho.[73] For a while, SRS stored some Pu-238, but that supply is now at Idaho Falls.[74]

"ATOMS FOR PEACE" PROGRAMS

When World War II ended, the United States was the world's sole nuclear power. In the first year or so after the war, the United States made some attempts to internationalize this knowledge, namely through the United Nations Atomic Energy Commission, established in 1946. Even though the United States, the Soviet Union, Britain, Canada, and some others, were members of this commission, it achieved very little and was disbanded in 1952.[75] It became one of the many casualties of the Cold War, which began in earnest in the late 1940s, and continued without let-up until Stalin's death in March of 1953.

Commemorative Stamp and Postage Envelope on First Day of Issue, July 28, 1955. AEC's Atoms for Peace Program launched in the support of the development of atomic energy for peaceful applications.

Later that year, as Soviet leaders vied for position in the wake of Stalin's death, there was a brief pause in the worst of the Cold War, and world leaders had breathing room to take stock of the international situation. This was the background to President Eisenhower's remarkable "Atoms for Peace" speech to the United Nations General Assembly on December 8, 1953. This speech set into play formal U.S. nuclear cooperation with friendly nations, and launched the U.S. civilian nuclear industry.

The relatively short speech recognized the potential for a new day in U.S./Soviet relations—one in which the outstanding disagreements in Europe and Korea could be resolved peacefully. As he stated, the stakes were high. Eisenhower laid out in plain terms the capability of existing nuclear weapons to destroy the world, in words that everyone listening could understand:

> Today, the United States stockpile of atomic weapons, which, of course, increases daily, exceeds by many times the total equivalent of the total of all bombs and all shells that came from every plane and every gun in every theater of… the Second World War.[76]

He recognized too that the U.S. no longer had a monopoly on such weapons, and that the Soviet Union was also adding to its arsenal daily.

Rather than despairing at this turn of events, Eisenhower proposed to begin a new discussion about atomic energy. Rather than dwell on its destructive potential, he chose to highlight its great potential for peaceful uses, particularly in the realm of power generation. He dared those in attendance to dream of a world "where fear of the atom would disappear."

Eisenhower offered a number of proposals. He challenged members of the nuclear community to surrender a portion of their stockpile to an international atomic energy control organization that he called the "international atomic energy agency." The United States, he said, would lead the way on this. Eisenhower promised to submit legislation to Congress that would amend the 1946 Atomic Energy Act to allow for the peaceful distribution of U.S. atomic materials and know-how.[77]

Eisenhower did as he promised, and in 1954 Congress amended the Atomic Energy Act to allow for international cooperation in atomic research.[78] The United Nations did its part by establishing the International Atomic Energy Agency in 1955.[79] The main result of this new tack, both domestically and internationally, was to inaugurate the development of atomic power reactors that would make electricity.

This began the first mad scramble to create civilian power reactors, both in the United States and in many other parts of the world.[80] This development had repercussions at Savannah River. It led to a wide range of atomic energy research, beginning with the thorium programs and leading to power reactor research conducted for the AEC. The best-known research program at Savannah River was the Heavy Water Component Test Reactor (HWCTR), built in the late 1950s and operated until the early 1960s. When nuclear materials from experimental research reactors and test reactors from around the world came back to Savannah River, they were reprocessed at the Receiving Basin for Off-Site Fuels, or RBOF, located just west of 221-H. At Savannah River, H Area became the home for much of this research.

Thorium Programs

One of the first programs to benefit from the Atoms for Peace Speech were the various projects to increase the national and international supply of fissionable material. In the 1940s and early 1950s, uranium was commonly believed to be in very limited supply. This led to a tremendous interest in thorium, a relatively common element

that could be irradiated in a reactor to make U-233, a fissionable material capable of running a reactor.[81] This fed into the dream of "breeder" reactors that could make as much fissionable material as they burned up during reactor operation. Any of these options would help solve the problem posed by the dearth of uranium.

Thorium research was at the forefront of these issues in the early and middle 1950s. With the coming wave of new civilian power reactors, it became urgent to explore the thorium option. This possibility was checked out at the Experimental Breeder Reactor (EBR-I) in Idaho in the 1950s.[82] Work was also conducted in a number of other places, and one of these was Savannah River.

The first thorium project at Savannah River was considered as early as 1954-55, and was identified as Supplemental Project S8-1015. At that time, thorium was identified by the code name "88," and a two-story pilot plant building, 677-G, was to be built in the CMX-TNX Area for the recovery of thorium in metallic form for irradiation in the reactors. Project S8-1015 was cancelled before the design of the equipment was complete, but Building 677-G was completed anyway. Construction began in March of 1955 and was finished February 1956, with 17 bays of the old Temporary Construction (TC) Building 8300-D re-used in the new building.[83]

At the same time, in 1954-55, another related project, Work Request 25887, was being considered. This was identified as the "Thorex Process," which was the name given to the proposed process for running thorium elements through the canyons. The work request was for a study to determine the cost of converting the Purex process in 221-H to the Thorex process, also known as the "88" separation process. Thorex was very similar to Purex, but special equipment would have been required to process the material, and in the end, it was decided not to implement the program.[84]

During this period, Thorex was still under study throughout the AEC complex. A modification of the basic Purex process, Thorex was developed at KAPL and at Savannah River Laboratory, where the extraction of U-233 from irradiated thorium targets continued to be studied.[85]

Thorium and Thorex was put on the back burner at Savannah River until the mid-1960s. By that time, Purex was isolated to F Area, and it was possible to experiment in 221-H. The processing of thorium in H Canyon was done in support of the breeder reactor program in Idaho. Begun in late 1964, and continued through five campaigns until 1969, the Thorex program required the modification of the HM process in 221-H to separate U-233 from irradiated thorium. Some of the material that came out of this process was used as fuel in an experimental Light Water Breeder Reactor in Shippingport, Pennsylvania.[86]

The Thorex campaigns were successful in creating U-233, but in the end, the results fell flat. U-233 was certainly fissionable, but it contained residual U-232, which was a high gamma ray emitter.[87] The U-233 decay chain also contained radon and thoron, which contributed to the background radiation of any area that processed this material. To this day, H Area has higher ambient radiation level than F Area, and this is largely the result of Thorex.[88]

In the end, what really killed Thorex was the discovery of new sources of uranium. In the 1960s, uranium was found to be not as rare as originally believed. This deflated the urgent need to process thorium, and it was again placed on the back burner at Savannah River.[89]

Thorium programs, however, did not die. There are still people in the nuclear community who believe that commercial reactors should use thorium-based fuels rather than enriched uranium. In fact, thorium-based reactors are operating today in India, where there is a relatively large supply of thorium.[90]

Power Reactors

Thorium did not work out for power reactors, at least not in this country, but that did not stop the development of power reactors, which proliferated in the United States and around the world in the later 1950s and 1960s. Most of these new power reactors were based on uranium enrichment, using enriched uranium as fuel. Enriched uranium also became the industry's bottleneck, since the normal method for enriching uranium was gaseous diffusion. Even as late as 1969, there were only three gaseous diffusion plants in the United States, and these had all been built to serve defense needs. Also, for security reasons, uranium enrichment was a task restricted to the AEC.[91]

Fortunately, the cutback in military production of nuclear materials in the 1960s allowed for the proliferation of enriched uranium power reactors during that same period.[92] As a government report summarized the situation in 1969: "most nations are turning to enriched uranium systems as the most economical for electric power production." This was expected to remain the case until breeder reactors became the norm by the beginning of the 21st century.[93]

Heavy Water Components Test Reactor (HWCTR), 1962. HWCTR was constructed to provide information about the operation of a projected power reactor that used heavy water as its coolant and moderator. Research at the $9 million dollar test reactor was carried out by American and Canadian scientists. On the homefront, fuel data from HWCTR was used in the operation of the Carolinas–Virginia Power Associates demonstration power reactor at Parr, near Columbia, South Carolina. Courtesy of SRS Archives, SRS Negative 7759-2.

In those salad days of the commercial nuclear industry, the AEC asked Savannah River to contribute its expertise and some of its facilities to the development of the industry. The Heavy Water Component Test Reactor (HWCTR), constructed in what is now B Area, was Savannah River's greatest and most notable contribution to this development, but it was not the only one. Much research was

Annular Dissolver. November 12, 1968, DPSPF 13060-41.

done on electrolytic dissolvers in H Area during that same period.

Normal dissolvers used in the Purex or HM processes do their work with boiling nitric acid, which works well with fuel elements clad in aluminum. That is not always the case with other materials. Power reactors, which must run at higher temperatures than those in the production reactors at Savannah River, could not use aluminum at such temperatures. Experiments were soon done with reactor elements clad in stainless steel or zirconium. Much of this experimental work was done at 221-H, and it centered on the use of electrolytic dissolvers capable of stripping these hard metals.[94]

Savannah River Laboratory's Separations Engineering Division designed and made the first electrolytic dissolver. Based on the principle of "stray current corrosion," the dissolver came with two sets of electrodes. When the fuel element, placed in a niobium basket, was positioned in between the electrodes, the electric current would corrode the cladding. An electrolytic dissolver was placed in 221-H in 1969.[95] This allowed commercial reactor elements to be processed in the canyon.[96] This electrolytic dissolver operated at Savannah River in five separate campaigns until 1979, when it ran out of fuel to process.[97]

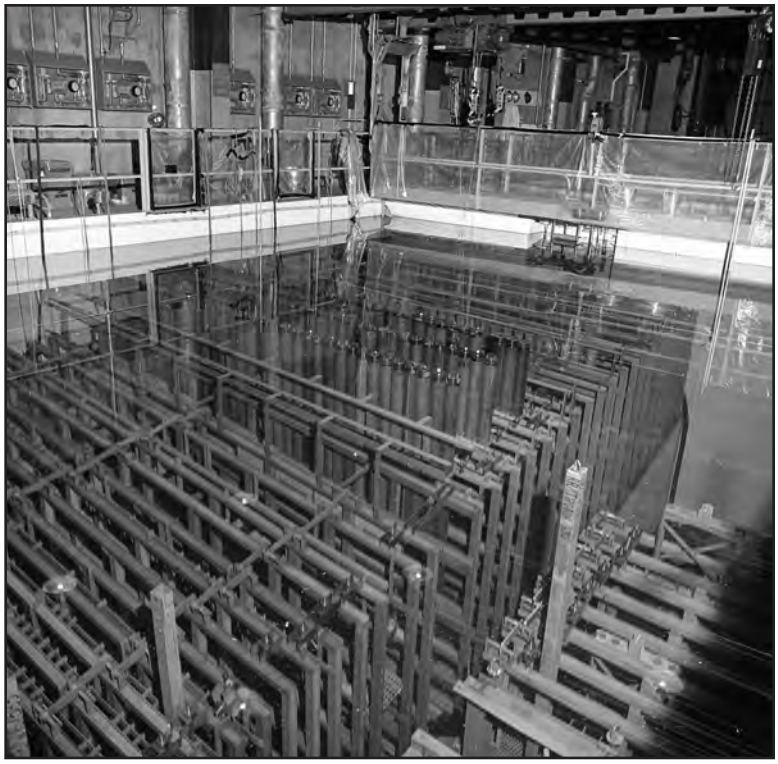
During this same time period, work was also done on annular dissolvers, which could handle unusually shaped reactor elements. These were worked up in the Savannah River Laboratory and tested in TNX and 717-F.

RECEIVING BASIN FOR OFF-SITE FUELS (RBOF)

One of the main ways that Savannah River contributed to the Atoms for Peace programs was with the creation of the Receiving Basin for Off-Site Fuels (RBOF), commonly just referred to as "Rub-off." Atoms for Peace led to small research reactors all over the nation and even in friendly foreign nations, and when this fuel was exhausted, the AEC wanted to make it easy to return the material for re-processing. One of the receiving areas for this fuel was RBOF.[98] RBOF was designed to receive, store, and eventually process spent fuels that came from university reactors, experimental reactors, and other research reactors. This was done to recover any remaining U-235, and prevent nuclear proliferation.[99]

The final scope of work for the construction of RBOF was issued in December of 1960.[100] The site chosen for construction was west of the 221-H Canyon, close to the main west entrance to H Area. The RBOF building itself was assigned the number "244-H." Based on information on file in the SRS Photography Archives, construction of

RBOF (244-H) got underway in 1961 and was completed in 1964. That same year, in 1964, RBOF began receiving spent fuel from off-site.[101]



Irradiated Fuel Tubes on Racks Underwater in 244-H, June 26, 1968, SRS DPSPF 12763-4.

RBOF was designed to perform two main functions: examine returning fuel and store fuel. In order to examine the fuels, there were special tools used to cut open the fuel elements so they could be examined (Orth interview). The fuels were stored in basins, all of which used water as the primary shielding.

The largest of the basins, Basin No. 1, was 60 feet deep. The smaller Basin No. 2 was adjacent to the first one. A traveling bridge served both basins, and it could insert and retrieve fuel rods and other reactor elements as needed. These basins were the core of the facility, but there were other features as well. There was a re-pack basin, disassembly and inspection basins, a motor control center, a main control room, a cask unloading basin and a cask wash pit.[102]

Immediately adjacent to 244-H was a regeneration and decontamination cell facility identified as 245-H. Ion exchange column resin beds were brought into this facility for regeneration and other work.[103] A few other facilities were constructed in the neighborhood of 244-H. The largest of these was 244-1H, built for maintenance and storage. The large metal brace located on the north wall of 244-H was placed there as an afterthought for seismic protection.

When it was completed in 1964, the RBOF facility was state of the art. The first fuels to make use of the facility came from the Savannah River reactors themselves. RBOF disassembled these and sent the critical portions to the High-Level Caves for examination.[104] Soon, however, irradiated materials began coming in from other parts of the country and from abroad.[105]

The return to the AEC of spent fuel from research reactors was almost always written in to the original contracts, so their return usually happened as a matter of course. Other times it was part of the Reduced Enrichment Research and Test Reactor (RERTR) program, whose main mission was to reduce the threat of proliferation by getting research reactors to return highly enriched uranium in return for lower percentage enriched uranium that would pose less of a threat.[106]

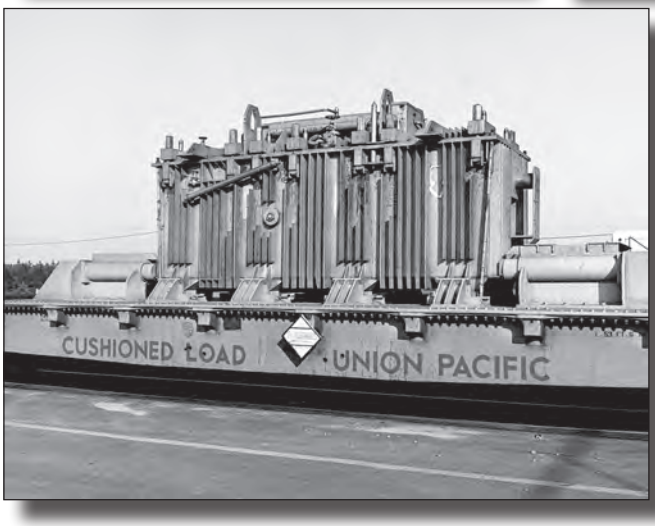
244-H, Receiving Basin for Offsite Fuels, Under Construction. May 29, 1962, SRS Negative 8320-1.

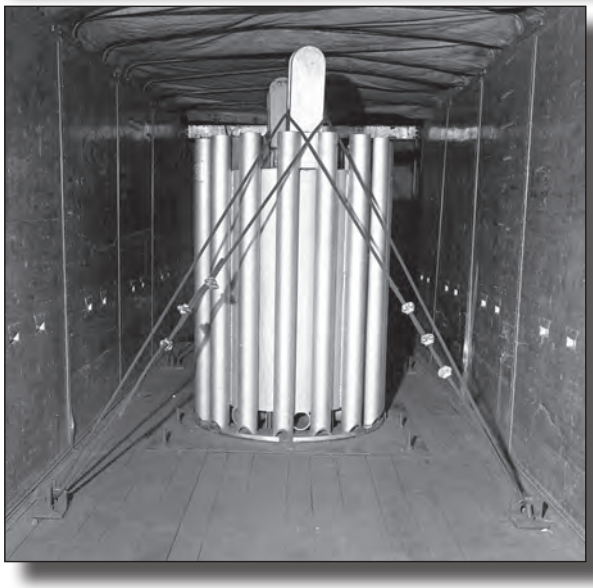
One of the main researchers and project coordinators at RBOF in those early days was Laverne Fernandez, who was otherwise employed at the Savannah River Laboratory. As Perry Holcomb remembered it, many of the international shipments for RBOF came by way of the port of Charleston and then on to Savannah River Plant by rail or by truck.[107] Other fuel came in from Canada, such as the Spent Canadian Reactor Uranium Products or SCRUP that came from Canada's heavy water reactors. The materials that came back were diverse in dimensions, cladding, and the type of fuel cores used. In the end, materials came back from some 30 different reactors in six different countries. Most came from reactors in this country: Hallam, HFIR, Elk River, MIT, HWCTR, and more.[108]

The biggest challenges for RBOF were fuel elements that used stainless steel and zirconium as cladding. Such materials could only be dissolved slowly, even with electrolytic dissolvers.[109] Perhaps the greatest of these

244-H, Receiving Basin for Offsite Fuels, Photographed in 2012.

Fuel Casks





As might be expected, transportation casks to hold the irradiated fuels were a very important part of the RBOF process. The SRS Photography Archive is replete with casks of various sizes and shapes, lashed to railroad cars, bringing material to and from RBOF, (244-H).

problems was the fuel from Hallam, Nebraska. Hallam was an experimental power reactor that operated in the early 1960s. There were problems with this reactor from the beginning, and after it was shut down, the irradiated material was shipped to RBOF for processing in 1965-66. Found to be too difficult for RBOF, the material was transferred to the 221-H Hot Canyon, where it went into the electrolytic dissolver.[110]

Hallam fuel still posed a problem in 1968. A study from that year found that the sodium metal used as a thermal bond between the uranium core and the stainless steel cladding was particularly challenging. It was estimated that electrolytic processing of the sodium-bonded Hallam fuels would require another three years of continuous dissolution. It was proposed that another facility, possibly a new facility, be used to achieve this.[111] Ten years later, it was noted that the de-cladding work was completed by Atomics International of Canoga Park, California; only then were the cores returned to Savannah River for processing.[112]

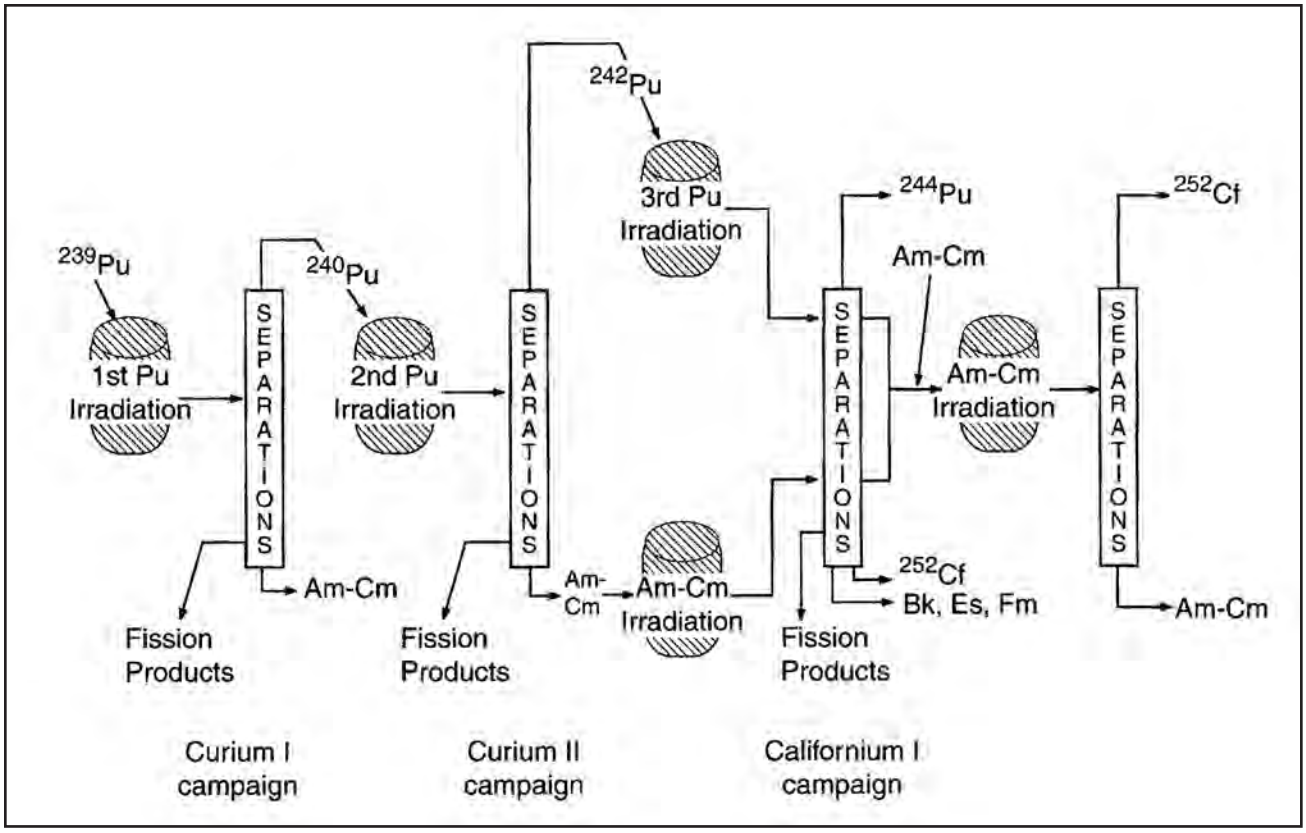
In the end, RBOF was closed down in the wake of the Savannah River reactor closings. Since that time, its mission has been assumed by L Reactor, which now processes spent fuel from U.S. reactors and others from around the world. Even though RBOF had the more modern facilities, L Reactor had other advantages, the greatest of which was its enormous size and greater protection it offered from the threat of terrorist intrusion.[113]

TRANSPLUTONIUM PROGRAMS

Glenn Seaborg, the University of California physicist who was one of the discoverers of plutonium in 1941, was appointed head of the Atomic Energy Commission by President Kennedy in 1961. Seaborg, the first actual scientist to hold this position, remained head of the AEC until 1971. During those 10 years, he had the unprecedented opportunity to conduct scientific experiments on a massive scale, and this is what he did with the Transplutonium Programs that spanned the years of his chairmanship of the Commission.

The goal of the Transplutonium Programs was to create new man-made elements through successive neutron bombardments in a reactor. As Bebbington put it, the process required, "climbing up the steps of the periodic table."[114] The process was not as easy as might be expected. Some of these new elements were first found in the debris from the first thermonuclear explosion in 1952, but duplicating the results in a reactor and processing the materials in the canyons would require great effort. There were a number of requirements: new equipment, improvements to the solvents, and new fuel and targets for the reactors. It would also require close work between the engineers at Savannah River and the scientists brought in to run the programs, many of whom came from the University of California.[115] After irradiation in the reactors, most of the subsequent work would be done in the High Level Caves of the Laboratory and in the F and H canyons. Between the two canyons, most of the work was done in H.

The transplutonium progression was based on steps. The process began with Pu-242, an isotope gleaned from the regular production of Pu-239.[116] Neutron bombardment resulted in the creation of americium-243, the next relatively stable step on the ladder of elements. Another campaign would bump the material up to curium-244. Yet another campaign would bump the Cm-244 to the next stable plateau, which was californium-252. All of this happened in the 1960s, and the late 1960s was the heyday of the transplutonium work. One of the major



The transplutonium elements production program at Savannah River Plant. Source: Harbour, et al., "Development of Chemical Processes and Equipment to Recover Curium-244 and Californium-252," 50 Years of Excellence in Science and Engineering at the Savannah River Site, *2000:158.*

benchmarks of this period was the High Flux campaign, centered around C Reactor, when work was being done on almost all of the new elements, including americium (Am-243), curium (Cm-244), and californium (Cf-252). Californium was the last of the man-made elements created by the program.[117]

The first Transplutonium Program at Savannah River began in 1963, with work at the H Area frames. Special ion exchange equipment was installed to separate plutonium from the newly created americium and curium. The neptunium facility in 235-F made plutonium oxide-aluminum billets, and these were extruded in 321-M. They would then go into the reactors to make curium-244.[118]

In early 1965, curium was as far up the ladder as anybody had gone. The Pu-242 targets had been made with aluminum cladding in the 235-F building, and the final purification work was done in the HB-Line.[119] By 1967, Pu-242 processing as part of the Curium-II campaign, required one shift per day in 235-F and two shifts per day in the B-Line.[120] Otherwise, relatively few changes were required to run the Transplutonium Programs in Separations.[121] A considerable amount of work was done at the High-Level Caves, which served as a sort of pilot plant for the whole process.[122]

By the time the various campaigns were completed in the early 1970s, the basic transplutonium progression of elements had been achieved in the course of three different campaigns, identified as Curium I, Curium II, and Californium I. All were basically steps used to climb the ladder. Curium I saw Pu-239 irradiated in the reactor,

and separated out into fission products, some americium and curium, and a much greater amount of Pu-240. This Pu-240 was irradiated in what was called the second plutonium irradiation. This was separated out into fission products, more americium and curium, but mostly Pu-242. The Pu-242 was put back in the reactor and subjected to what was called the third plutonium irradiation. The accumulation of americium and curium was now enough for this material to go into the reactor as well. When all these were separated, there were fission products, some Pu-244 (which was incidental to the program), some californium, but mostly americium and curium. This americium and curium was fashioned into reactor elements and was further irradiated to create californium.[123] In order for this chain of successive irradiations to work, it was essential that the reactors and the separations canyons work hand in hand.

Tramex Solvent Extraction and Ion Exchange

The Transplutonium Programs required new reactor techniques, such as High Flux, and they also required new procedures in Separations. In Separations, there were two basic techniques used to process the transplutonium materials. The first was the Tramex process, which was a modification of the Purex and HM processes to enable the transplutonium elements to go through solvent extraction. When this ran into problems, the program switched to the ion exchange process. This led to the creation of the rapid ion exchange, perfected at Savannah River.

Tramex was the solvent extraction process developed for the recovery of transplutonium elements during Separations. The first pilot-scale work was done at the Savannah River Laboratory. This featured a two-stage solvent extraction process, with tributyl phosphate (TBP) in the first stage to recover the plutonium and separate a crude actinide-lanthanide mixture. This was followed by the Tramex process itself, developed at Oak Ridge. Tramex used tertiary amines to purify the curium and americium, as well as any californium that was found. As one researcher put it, "the Tramex solvent extraction process consists of three cycles of extraction with a tertiary amine to separate the trivalent actinides from the lanthanides."[124] As recalled by Perry Holcomb, the Tramex process used a tertiary amine in a diluent to extract the transplutonium elements, specifically to separate the americium and curium from the fission products. It did this by the use of organic and aqueous phases, with the aqueous phase comprised of an 11-molar lithium chloride aqueous solution.[125]

The main problem with Tramex was that the aqueous solution required a high level of lithium chloride, which was difficult to control and was highly corrosive to the tanks and piping. This proved such a problem that by the mid to late 1960s, the search was on for an alternative method for transplutonium separation. Interest in this search went all the way up to Glenn Seaborg, chairman of the AEC, but also included Nat Stetson, manager of the Savannah River Operations Office (SROO), Lom Squires, manager of Du Pont's AED, and Clark Ice, director of the SRL. The research chemists who eventually came up with the solution were Bill Hale and John Lowe.[126]

Ion exchange columns, which had been put to such good use in other areas of Separations, were employed in this case as well, with much better results than those obtained with solvent extraction. In particular, a form of high-pressure ion exchange was found to work best. "A combination of high pressure displacement and elution development cation exchange chromatographic processes was able to separate and purify 100-gram quantities of Cm-244 and milligram quantities of Cf-252." This became the key to the success of the curium and californium programs at Savannah River.[127]

The high pressure ion exchange was later renamed "rapid ion exchange" or RIX largely because Du Pont did not like the expression "high-pressure," which made the process seem more dangerous than it really was. Perry Holcomb recalled that Bill Hale and John Lowe basically worked up the process, based on earlier Oak Ridge research, but that Don Hallman and Bill Prout also made significant contributions. Most of these people worked for Bill Prout in the Separations Chemistry Division of the SRL.[128]

The rapid ion exchange, or the "high-pressure displacement development cation exchange chromatographic process," was developed at SRL in 1968-69, specifically for the curium and californium programs. High pressure was required, since this reduced the process time, and reduced the level of solvent degradation caused by the high radiation. The process called for four four-foot tall ion exchange columns with decreasing diameter from four inches to one inch. Each column had Dowex 50W cation exchange resin. This was a finely particulate resin that was suitable for high-pressure cation exchange.[129] The amount of materials recovered was small; the rapid ion exchanges probably processed around three kilograms of curium.[130]

The three main products that resulted from the Transplutonium Programs were americium, curium, and californium. Americium and curium were the first of the three to be made, produced from Pu-242 targets that were exposed to high flux in the C Reactor.[131]

The bulk separation work on curium was done in F Area, with the finishing work done in the High Level Caves. The materials that came from the High Flux Campaign in C Reactor were processed by solvent extraction in H Canyon. After being separated from the other materials, the curium made at Savannah River was usually shipped to Oak Ridge, with most going to the High Flux Isotope Reactor (HFIR).[132]

The Curium II program began in F Canyon and in B-Line, where the Pu-240, Am-243, and Cm-244 was isolated. The recovery of Pu-240 was also done in F Canyon, and it was turned into billets for the curium II program. There was another transplutonium program that was run in H Canyon and the HB-Line, to recover Pu-241, 242, and americium-243 and curium-244. These were made into oxides in the B-Lines. High-quality Pu-242 was sent on to Oak Ridge and the High Flux Isotope Reactor (HFIR).[133]

Californium, the end product of the transplutonium programs, was made in very small quantities. Total production at Savannah River was on the order of around two grams, and this material was separated in the High-Level Caves.[134] It is recorded that the first californium was shipped off site on August 8, 1969.[135]

Working with californium required some new equipment, and one of these was the first neutron detector analysis machine. This device was designed to determine the amount of neutrons emitted from a source. Since californium was a strong neutron emitter, it was made especially for this material. Also known as radiation analyzers, the neutron detector analysis machine was created by Perry Holcomb and Dick Herold. This was used in the 772-F Analytical Lab, and was basically a paraffin block with neutron detectors situated around it.[136]

Uses of Transplutonium Elements

The transplutonium program was largely done as pure science, but it was certainly hoped that uses would soon be found for all of the new elements. This was not an unreasonable assumption, since each of these elements had

unique characteristics. At one point, it was hoped that americium-241 could be used to help located oil wells.[137] While this did not work out as hoped, small amounts of americium are still used today in smoke-detectors.

With its high alpha radiation and high energy output, curium-244 had potential as a heat source, despite its short half-life of around 18 years.[138] Despite the short half-life, it was hoped that there might develop a market for curium, similar to that for Pu-238.[139] Unfortunately, it could not compete with the overall more favorable characteristics of Pu-238, and demand for it never developed.[140]

Even greater hopes were held out for californium-252. A uniquely intense neutron source, californium was thought to have great potential for a variety of medical and industrial uses.[141] Some of the avenues pursued included industrial radiography and "activation analysis" to determine the composition of underground minerals deposits. The idea of using Cf-252 to treat cancer was the most intriguing of all the possibilities. Al Boulogne at SRL made the first californium needle, a small pin that could be inserted directly into a patient's body to fight cancers, particularly cervical cancer. This needle was fashioned from a 12-mcg amount of Cf-252 previously purified by Perry Holcomb.[142] The promise of californium was so great that organizations were set up by both Du Pont and the AEC to market the material. Facilities were also established for processing the material in larger amounts than was possible in the High-Level Caves.[143] This led to the Multipurpose Processing Facility.

MULTIPURPOSE PROCESSING FACILITY (MPPF)

The dream of producing californium in the canyons gave rise to the Multipurpose Processing Facility or MPPF, where californium and other transplutonium elements could be processed in small vessels, like those used for Pu-238. The MPPF was designed to function much like the High-Level Caves in SRL, with manipulators and shielded windows, but with specific features tailored to the production of transplutonium elements. The MPPF would be placed into the canyon itself, specifically the Hot Canyon of F Area. This required cleaning up contamination in two sections of the Hot Canyon, Sections 17 and 18, located at the north end of F Canyon.[144]

Construction of the MPPF began in 1970. The Hot Canyon crane removed the older process equipment, and the area was scrubbed and decontaminated by high-pressure nozzles and chemical solutions.[145] This represented the first manned entry into the Hot Canyon since 221-F went on line in 1954. Concrete walls were cut through selected areas and shielded windows were installed. In the end, eight cells or modules were used to make the MPPF, located in half of Section 17 (17.3 and 17.4) and all of Section 18 (18.1 through 18.4). The equipment installed included the latest cation exchange columns.[146]

According to the Separations monthly report for December 1971, the MPPF was almost complete at that time but was still classed as "under construction." There were two analytical cells, as well as cold feed systems and segregated hot and cold water systems. There was an in-cell crane and a "californium raw-feed evaporator 12-2-2." The latter was not yet installed, but was still being tested at TNX.[147]

The MPPF was completed in 1972, but was almost immediately put on standby in 1973.[148] It remained unused until 1978, when it was started up for basically the first time. Even then, it did not process californium. The

facility was first used to process americium-241, which was made into an oxide and shipped to Oak Ridge for further processing.[149]

As Mal McKibben stated, the MPPF was "never used the way it should have been."[150] It was constructed to facilitate the processing of transplutonium elements, particularly californium, but it was never put to the test, since californium was never made in amounts greater than what could have been handled in the SRL High-Level Caves. In the end, only about two grams of californium were produced in the Savannah River reactors, and none of it was processed at the MPPF.[151]

Despite vigorous marketing campaigns to promote the product, no viable uses were ever found for californium. Californium, usually in the form of needles, was often donated to hospitals and other medical institutions for use in cancer research, but the results were either too inconclusive or the costs too high to allow californium to break into the general market. In the end, the MPPF was used to process about 1.5 kilograms of americium-241, sought by the Isotope Sales Division at Oak Ridge for use as a neutron source to find oil. It ended up being used in very small amounts in home smoke detectors throughout the United States.[152]

Transuranic Waste

The creation of transplutonium elements also led to the creation of the first transuranic waste, which is sometimes identified as TRU waste, for short. Beginning in 1965, transuranic waste was separated from low-level waste (LLW), whenever it was more than 10 nano-curies per gram. At that time, any TRU that was more than 10 n-c/gram was placed into drums and stored on surface pads, covered with soil. Beginning in 1974, TRU waste was further separated, beginning in 1974, if it exhibited a radiation level greater than 100 nano-curies per gram.[153]

HIGH FLUX ISOTOPE REACTOR (HFIR) WORK

The High Flux Isotope Reactor, better known as HFIR, was located at Oak Ridge, but special elements from this reactor were dissolved at Savannah River. This work was done in the late 1960s and early 1970s. The reactor elements that were dissolved had two concentric annular fuel assemblies, with curved fuel plates. Their dissolution required a special HFIR dissolver, designed to take elements that were 30 inches long with a 12-inch outer diameter and 171 fuel plates. For Savannah River, this was a unique type of dissolution.[154]

There were other annular dissolvers later, such as Dissolvers 6.1D and 6.4D. These had large outer annulus sections that measured 10 by 13 feet, and they came with dissolver tanks and condensers.[155]

NAVAL FUELS PROGRAM (247-F)

The Naval Fuels program at Savannah River was a special project. It was not in any way a regular part of the Separations work at the plant, but it was a facility that was constructed in F Area, northeast of 221-F and west of the 217-F storage magazine. The building was assigned the number "247-F." It was a program requested by

the Navy's nuclear chief, Admiral Rickover, who wanted a pilot plant facility for the Navy's nuclear propulsion program. Building 247-F, a 90,000 square foot structure, was built between 1982 and 1985.[156]

Naval fuels are unique in that they are super-enriched, sometimes up to 97 percent U-235. This unusual and expensive fuel is required so that submarines and critical surface vessels like aircraft carriers can operate for long periods of time, using only small reactors. Producing such a concentration of U-235 also has its share of problems, such as the build-up of U-236.[157]

The construction of 247-F must also be seen in light of the nuclear resurgence that took place during the Reagan administration. This was the period when L Reactor, closed since 1968, was refurbished and put back on line. It also played into Reagan's plan for the creation of an 800-ship nuclear navy, expanding the need for nuclear propulsion far beyond what was then done with submarines and aircraft carriers.[158]

The Naval Fuels facility at 247-F did operate for a brief period, but it never really produced any fuel. In the end, it was found to be redundant to other naval fuel pilot plant facilities. First, it was placed on stand-by and then it was shut down in 1989, after naval authorities decided to use another pilot plant located in Tennessee.[159]

CLOSE DOWN OPERATIONS

The 1980s was an unusual decade that began with a nuclear build-up and worries about Soviet expansion in Afghanistan and Africa, and ended with the fall of the Berlin Wall and the liberation of Eastern Europe. This trend continued into the 1990s, with the collapse of the Soviet Union itself. What had started as a nuclear weapons and fuel systems resurgence, ended with a massive nuclear redundancy.

Du Pont's 1987 decision to pull out of the operation of Savannah River, effected in 1989, was totally coincidental to all this, but played into the process nonetheless. The 1988 decision to close the remaining Savannah River reactors was seen as a temporary move at the time, to allow for a new contractor to step into place, but the closures effectively became permanent. The new contractor, Westinghouse, refurbished and briefly started up K Reactor in the early 1990s, but no appreciable materials were made, and the reactor soon closed down for the last time.

The Separations areas were affected by these developments, even if there was a certain lag time. When L Reactor Restart and the Naval Fuels program were on-going, there was some discussion of the need for canyon renovation. Long-range plans for the canyons, compiled in 1984, called for a program of canyon consolidation and improvements over a five-year period. The HM process in H Canyon was to be put with the Purex work in F Canyon. This would allow H Canyon to be shut down for a general overhaul. When that was complete, F would go on stand-by or even be used for some other purpose, and H would carry on the mission.[160]

The end of the Cold War derailed these plans. The closing of the reactors led to a period where both canyons were shut down for various reasons and during various periods throughout the late 1980s and 1990s. Operations in the 1990s were basically to process the backlog of nuclear materials left over from the reactors or from facilities

like RBOF. F Canyon was closed for the last time in 2004. H Canyon is still in operation today, but it is not operating at full capacity. H Canyon is the only remaining Separations facility capable of full-scale nuclear materials production left in operating condition in the entire U.S. nuclear complex.

X. WASTE TANK DEVELOPMENTS, 1950s-1960s

In the 1950s, the ultimate disposition of radioactive waste in F and H areas was given relatively little consideration, especially when compared to the other aspects of the Separations process. The only essential thing was to contain the waste safely. During Project 8980, the original waste tanks were among the last things constructed at the site. Even so, they were important, and they became more important over time. Long after Project 8980 came to a close, the waste tank farm grew tremendously through several construction phases. This growth was crucial because the Separations process created much more waste than anticipated, and because the original goal was simply to contain the waste in a safe manner. Final solutions, even interim solutions, would come later.

The disposal of hazardous waste was a big unsolved problem from the beginning of the nuclear industry. During the Manhattan Project, each individual facility was given broad leeway to deal with their own waste as they saw fit. The problem was not dealt with systematically, and this was still the case when the AEC inherited the nuclear complex in 1947. As Walter Zinn stated in the late 1940s, it was better to put nuclear waste in concrete boxes rather than, "just putting the stuff in the mud."[1] By the early 1950s, the general consensus was that nuclear waste material should be stored in steel containers or tanks.

The worst of the waste, the "fission products," was the zirconium, niobium, ruthenium, cesium-137, and strontium-90. All of these had varying half-lives, in the case of cesium and strontium, around 30 years. It was usually assumed to take 20 half-lives before radioactive materials were considered basically harmless.[2] At Savannah River, there was also a lot of aluminum, which was dissolved with the cladding. This too went to the waste tanks.

The First Four Waste Tanks Built In H Area (foreground), Which Were Type I Tanks. In the background is a grouping of four Type IV tanks built later. May 5, 1961, SRS Negative DPSPF-7457-3.

One of the biggest issues in the construction of the first Savannah River waste tanks, the one that had to be decided at the very beginning of the design process, was the quality of the steel. That the Purex process required nitric acid solutions was a given. The problem was that nitric acid, or any acidic solution, worked best in stainless steel, which was more expensive than regular carbon steel. Given the great size of the waste tanks, and the fact that there would be many more tanks in the future, economy was a vital consideration. On that basis, the decision was made to go with carbon steel, which was the standard at the time.

A nitric acid-based solution cannot sit in a carbon steel tank. That solution would have to be changed to a caustic or alkaline (basic) solution. At Savannah River, this was done by adding sodium hydroxide to the acid. Unfortunately, this led to an even greater volume of waste.[3] Even worse, an alkaline solution, unlike an acidic solution, would cause the heavier materials to precipitate into a sludge that would settle at the bottom of the tanks.[4] This would be the fate of much of the aluminum.

Another issue that had to be decided early was the manner in which the waste stream would go from the canyons to the waste tanks. A diversion box was used to direct this flow, and each set of waste tanks had its own diversion box. Due to radioactive contamination, it was decided to use gravity flow rather than a pump that could not be maintained. The oldest waste tanks and diversion boxes in both F and H areas relied solely on gravity flow. This, for example, was the case with the oldest diversion box in H Area, H-DB1. It was soon discovered that, however difficult to maintain, pumps worked better than gravity. As the number of waste tanks grew, the next generation of diversion boxes was equipped with pumps and pump tanks, as witnessed by H-DB2.[5]

In F Area, excavation for the tanks began in June of 1951, followed by the first concrete pouring two months later. Even so, construction was slow, because the other facilities had priority. The finished tanks were not turned over to Operations until the summer of 1954. H Area began later and finished later: excavations there began in early 1952, with the tanks turned over to Operations in early 1955. F Area originally had eight tanks, while H Area had four. Another four tanks were added to H Area in 1955. Each of these cylindrical tanks was encased in concrete and they were three times wider than they were tall. The tanks also had interior columns to support the tank roof, which was basically flat. The tanks were also set into a saucer designed to catch any leaks. After construction, the tanks were buried to the roofline, and there were risers on the roof to provide access into the tanks.[6]

A slightly different nomenclature was used to identify the waste tanks, depending on the area. "241-F" was used to identify the first eight tanks in F Area. "241-1F" was used to identify the second round of waste tanks that began construction in 1956, with work continuing until at least 1958. These were a new type of tank, marked by domed tank tops, and were constructed immediately west of the original eight tanks. The third batch of waste tanks, constructed even later, was designated "242-F." H Area was a little different. The first four tanks were designated "241-1H." The second batch of four tanks, identical to the first but built to the south, were labeled "241-2H." As waste tanks proliferated on the south sides of both F and H areas, the waste tank complexes became known as "waste tank farms." In the early days, the term "tank farm" was used to identify the 211 tanks on the east side of the canyon buildings; by the late 1950s, it was more common to apply that term to the waste tanks.

From this beginning, with only a handful of tanks, there would eventually be a total of 51 waste tanks constructed over the years in both F and H areas.[7] It was said that Separations were never really finished in 1954-55, and this was particularly true for the waste tanks, which were still under construction when Project 8980 came to a close, with construction on-going for years afterwards.

Even though tank construction would continue for decades, storage in the tanks was considered only "semi-permanent." It was always thought best to put the dangerous fission products in un-leachable concrete, or some other more permanent solution. It was just that in the early 1950s, such a thing did not yet exist or was not financially feasible.[8] Based on proven technology, the waste tank idea was considered the best and it basically worked for over 30 years.

WASTE CATEGORIES

Much of what was done in the waste tank areas was "seat of the pants" progress over the years, and this applied to the way the different waste categories were treated. There were a number of different ways to categorize the waste at Savannah River, and perhaps the easiest categorization is with the radioactivity levels. There were other ways too, as will be seen below.

High Level Waste (HLW), also known by the older term "High-Activity Waste," is the most radioactive of the waste materials, usually with short-lived but deadly fission products. As a result of radioactive decay, these materials are also physically hot, with heat levels that can reach up to five Btu's per hour per gallon. The high level waste generated from Separations was usually sodium nitrate, with some sodium sulfate and sodium carbonate. These contain almost all of the fission products that came from the processed fuel elements. This was the material that was always sent off to the waste tanks.[9]

Low Level Waste (LLW) or "Low-Activity Waste," has much lower level of radioactivity, usually less than one percent as active as high level waste. Even so, it is still too "hot" to be released to the environment. Most low-level waste consisted of compounds like sodium aluminate and sodium nitrate that resulted from the aluminum cladding and from the caustic used to reduce the nitric acid.[10] This material may or may not have gone to the waste tanks, depending on the period of time in question.

Low Level Waste also included most forms of "solid waste," items like contaminated clothing and pieces of equipment. Solid waste was usually put into the burial ground, located between F and H areas.[11] Solid wastes of this sort are not dealt with in the waste tank areas.

Transuranic Waste was in a special category that became more prevalent with the Transplutonium Programs. These are waste materials that are heavier than uranium and have special radioactive properties, even though the radioactive levels are relatively low compared with fission products. They are segregated from the other wastes whenever possible since that have potential value and might be needed in the future.[12]

The high level and low level wastes had different destinations. High Level Wastes always went to the waste tanks, but often low-level waste did too. That was the case at the very beginning of operations, in the early to mid-1950s, when both high and low level waste from the canyons was sent to the tank farms. In the mid-1950s, when it became clear how quickly the waste tanks could fill up, it became common to shunt the low level waste to surface seepage basins located on the edge of the F and H areas. The so-called coating removal materials were counted as low level waste in the early days. Beginning in the mid-1970s, this material was re-designated as high level waste, and sent to the waste tanks. At the same time, seepage basins, which up to that time contained both chemical and low-level radioactive waste, fell out of favor and were closed and later buried. Any material that was not sent directly to the waste tanks, now went to the Effluent Treatment Facility.[13]

In the early 1970s, before the seepage basin closures, it was recorded that the F Area seepage basins could receive 150,000 gallons of low level waste per day when the Purex process was in full operation. Almost half of this material came from the Acid Recovery Unit in 211-F. Other sources included the continuous evaporator in the Warm Canyon, the continuous evaporator and the hydrate evaporators in A-Line, the waste farm evaporator in 242-F, the general-purpose evaporators in 211-F, and the laboratory waste evaporator in Warm Canyon. Each of these had transfer routes to the seepage basins.[14]

Tank waste, whether it was high level waste or low level waste, tended to separate into "solids" and "liquids." Solid is not really the right word, since the heavier materials that settled at the bottom of the tank formed what was usually called "sludge." This generally had the consistency of mud or "peanut butter," as one waste tank operator described it. The major components of this sludge were the various aluminum compounds left over from the dissolution of the cladding.[15]

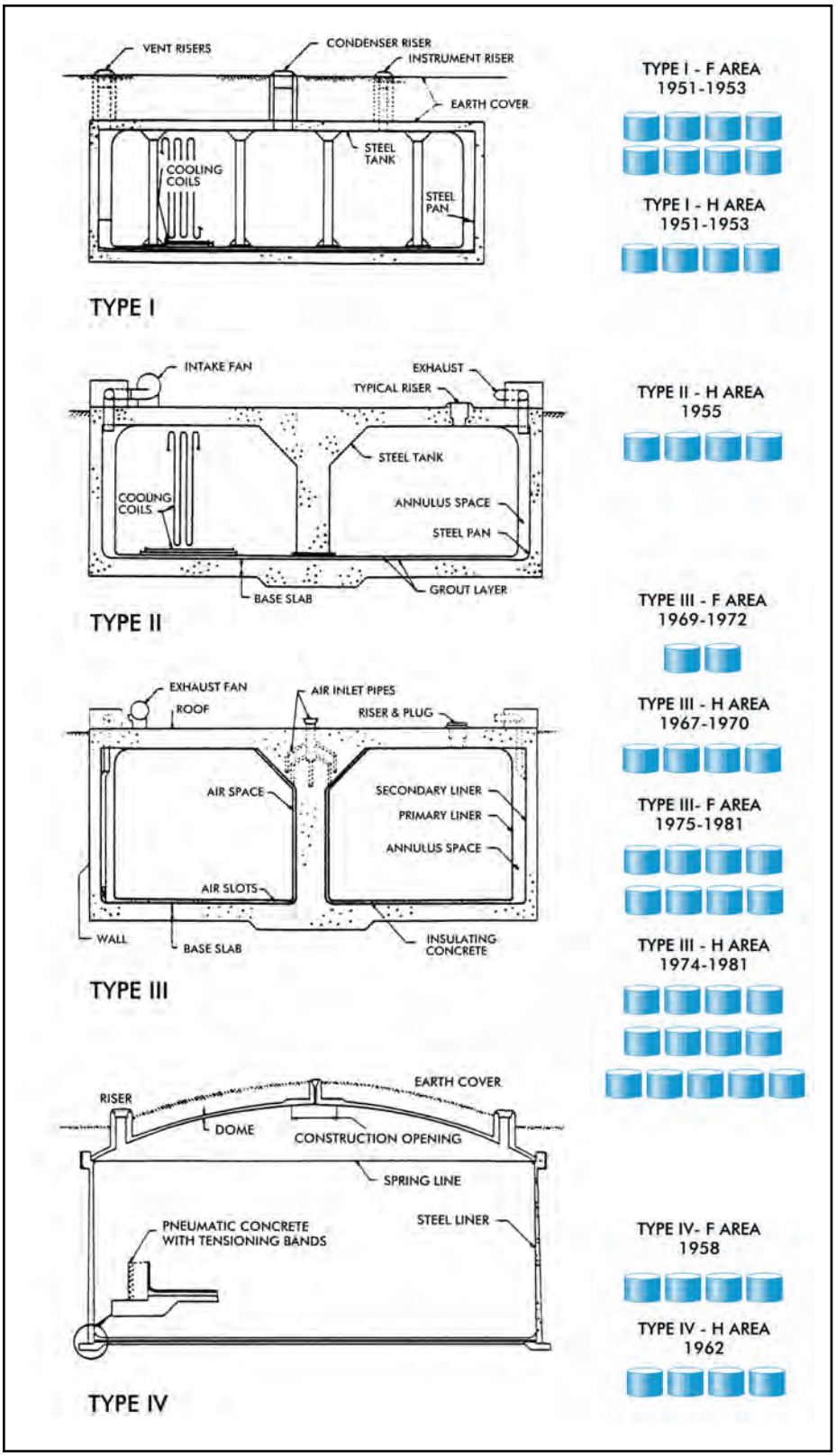
Once the sludge precipitated to the bottom, the remaining liquid was called the supernatant or "supernate."[16] The supernate was mostly comprised of various salt solutions created by adding caustic to the nitric acid solution. For this reason, sometimes the two main ingredients found in the waste tanks are referred to as the sludge and the "salt solution," or salt, for short.[17] Most waste tanks carried a combination of sludge and salt, but the ratios changed over time: the earlier tanks usually had more sludge than supernate; the middle period tanks had a more even mix; while the later tanks were mostly salt solutions.[18]

WASTE TANK DESIGNS

Waste tank construction continued from the 1950s through the 1980s in a series of often overlapping construction programs. There was barely a pause between the end of Project 8980 and the first of the supplemental waste tank construction programs that followed. During this period there were a lot of changes in design and construction. Overall, there was a general evolution from a single-walled tank with a saucer on the bottom, to a single wall only, followed by a double walled tank.[19] Specifically, these changes took place in the progression of four discrete tank designs, labeled Type I to Type IV.[20]

Type I, the earliest waste tank style, was designed by Blaw-Knox and Du Pont and was constructed during Project 8980. Type I was based on the tanks used at Hanford during the Manhattan Project, but made sturdier due to the chance of blast damage and the higher levels of radiation expected at Savannah River. Compared to the later

SRS Waste Tank Types and Chronology



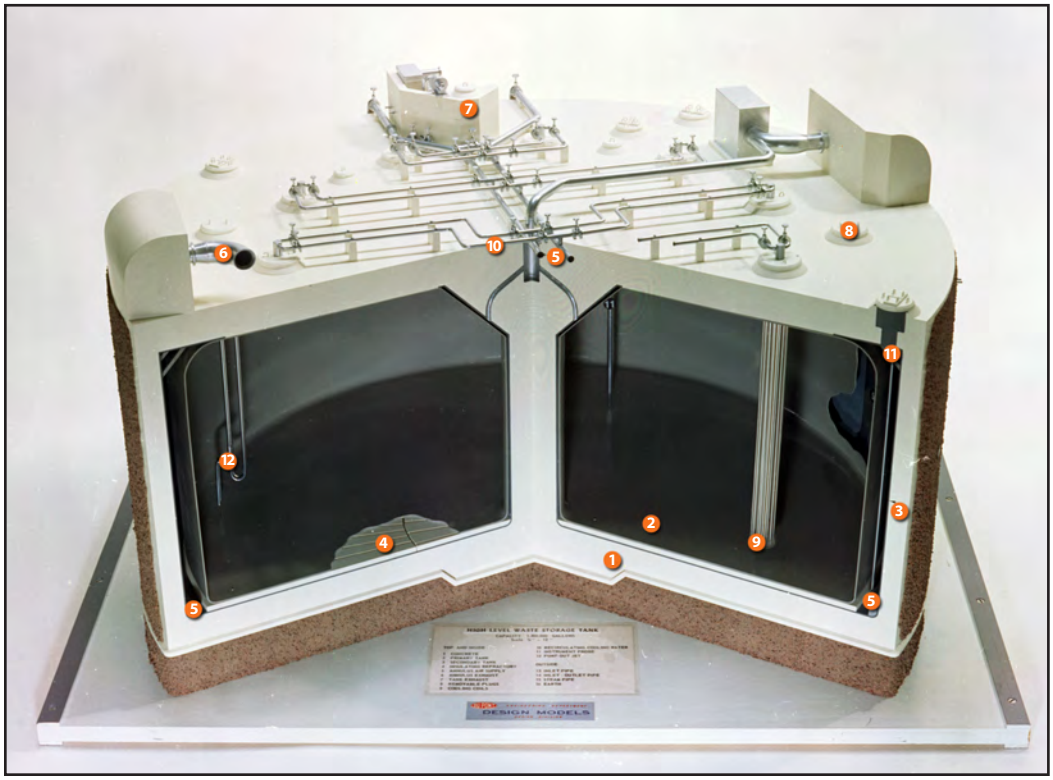
The first liquid waste storage tanks at Savannah River became known as Type I tanks. One of the most critical aspects of construction was the care that had to be taken in making and inspecting the welds of the plates that comprised the tanks. The Pittsburgh Testing Laboratory spent nearly a year and a half x-raying welds to assess quality. Between February 1952 and August 1953, approximately 50,000 feet of welded seams were checked by the laboratory.

Type II liquid-waste storage tanks were constructed in the H Area. The modified design was prompted by construction experience gained building the first tanks, by new data concerning waste behavior from Hanford, and from research at the Savannah River Laboratory.

The Type IV tanks were more economical than Type I and II. They were used to store wastes that generated less heat. These tanks were simpler than the early types, and so were cheaper to design and build. Source: An Evaluation of the Concept of Storing Radioactive Wastes in Bedrock Below the Savannah River Plant Site (Washington, DC: National Academy of Sciences, 1972), 56–57.

241-F, Type I Waste Tanks in Various Stages of Construction. These were the first eight waste tanks built at SRS. The saucer is visible on the tank in the foreground, as well as the one behind it; on the two farther back, it has already been encased in concrete. Photographed February 11, 1953, SRS Negative 2-455-2.

ones, the Type I tank was relatively small. Each could hold 750,000 gallons, and the tank top was supported by a series of internal columns. A steel pan or "saucer," five feet in height, was situated below the tank to catch any leaks, and the saucer was set into concrete. An open annular space was left between the tank and saucer. The tank was made with welded plates, and the welds were checked by photography. After the tanks were finished, earth was filled in around them, right up to and over the top of the tank. Only the risers were visible above ground. The tank roofs themselves were flat, not domed, as would be common later. Eight of these Type I tanks were constructed in F Area; four were built in H Area.[21]



SRS Negative DPSPF-15252-1.

Type III Waste Tank Model

1. *Concrete*
2. *Primary Tank*
3. *Secondary Tank*
4. *Insulating Refractory*
5. *Annulus Air Supply*
6. *Annulus Exhaust*
7. *Tank Exhaust*
8. *Removable Plugs*
9. *Cooling Coils*
10. *Recirculating Cooling Water*
11. *Instrument Probe*
12. *Pump Out Jet*

The interior of a Type 1 tank, either Tank 3 or 4 in F Area, during the construction phase, October 11, 1955, SRS Negative M-4086-2.

Type II waste tanks were designed in 1955 to have one central interior column, rather than many. This was to allow the tank, particularly the base of the tank, to expand and contract with the heat given off by the waste. The tank walls were also made thicker so that they could withstand higher temperatures. This type also retained the five-foot high saucer feature encased in concrete. It was slightly larger than Type I, capable of holding 1.07 million gallons. The second batch of four tanks, put into H Area, were of this type.[22]

Type IV tanks, which were actually constructed before the Type III's, were designed for low-level waste, so it was not expected that they would need any cooling coils. These were single-walled tanks, without the saucer feature. There was no central column; the roof was supported by a dome. These tanks were large, capable of holding 1.3 million gallons. Four were constructed in F Area in 1958, and another four built in H Area in 1962. The ones added to F Area were the first since the original eight, and these four became operational in 1960. The four added to H Area became operational in 1963. Later, after the first leaks were found in some of the early tanks, it was decided that this type was not safe enough, and the single-walled design was dropped from future construction.[23]

Type III tanks, popular from the late 1960s to the 1980s, used a basic tank-in-a-tank design. The outer tank wall was just as tall as the inner tank, eliminating the saucer feature of Type I and II. It also had a capacity of 1.3 million gallons. The inner tank had a central column like Type II, but with more air space and inlet piping than previous types. There were also bent tube evaporators. Some of these bent tube features, located in the center of the tank, resembled an upside-down Christmas tree. Most of the 51 total tanks built at Savannah River were of this type. Some 27 Type III tanks were constructed: 10 in F Area and 17 in H, spanning a period from 1969 to the mid-1980s.[24]

Air Inlet Piping for a Type III Tank, June 6, 1968, SRS Negative DPSPF 12736-4.

At least one major supplemental construction project from the 1950s and 1960s dealt with the waste tanks, and this was Project S8-1030. This was the construction of four new waste tanks in F Area, and they were clearly Type IV, even though not identified as such. The work request was dated to 1955, with the basic work carried out between 1955-59. Each tank had a diameter of 85 feet and was 34 feet, 3 inches high, with a capacity of 1.3 million gallons. The steel tank was surrounded by pre-stressed "shotcrete" cyclindrical shells. "Shotcrete" was described as "pneumatically applied concrete." There was also a spherical reinforced concrete dome roof. These tanks had no cooling coils, and lacked a number of features provided to earlier tanks. They were specifically designed for "low-activity waste."[25]

THE VOLUME PROBLEM, MID-1950s

Waste started flowing to the first waste tanks in 1954, when HLW was sent to Tank 1F and LLW was sent to Tank 7F. Waste began flowing to the tanks in H Area by July of 1955.[26] In those early days, there was relatively little regard for the volume of material that was being sent to the tanks. Liquid waste coming out of the process first went to the receipt tank, also known as the aging tank, where some of the solids settled and short-lived fission products could decay. From the receipt tank, waste continued on to the waste tanks themselves.

This was the extent of remediation in the early days.[27] Many of the nitrates were not recovered from the process and found their way into the tanks, and flushing between campaigns or even between different runs produced a lot of contaminated material that also ended up in the tanks.[28] Some of this material might have been low-level waste, but in the early days, much of this material was also sent to the high-level waste tanks as well.[29]

This soon became a problem. The first HLW tank was already full by June of 1955. This immediately led to a campaign to discover ways to reduce the volume of waste in the tanks. The problem was hit from a number of angles. Studies were done to achieve better control of the chemical compositions used in the solutions. This

alone is believed to have reduced the volume of the waste stream by 22 percent.[30] There were also attempts to reduce the amount of caustic acid used in the dissolving process, so that less would end up in the tanks.[31] Another solution attacked the problem at the tanks themselves; it called for "high-activity waste evaporators."

TANK FARM EVAPORATORS

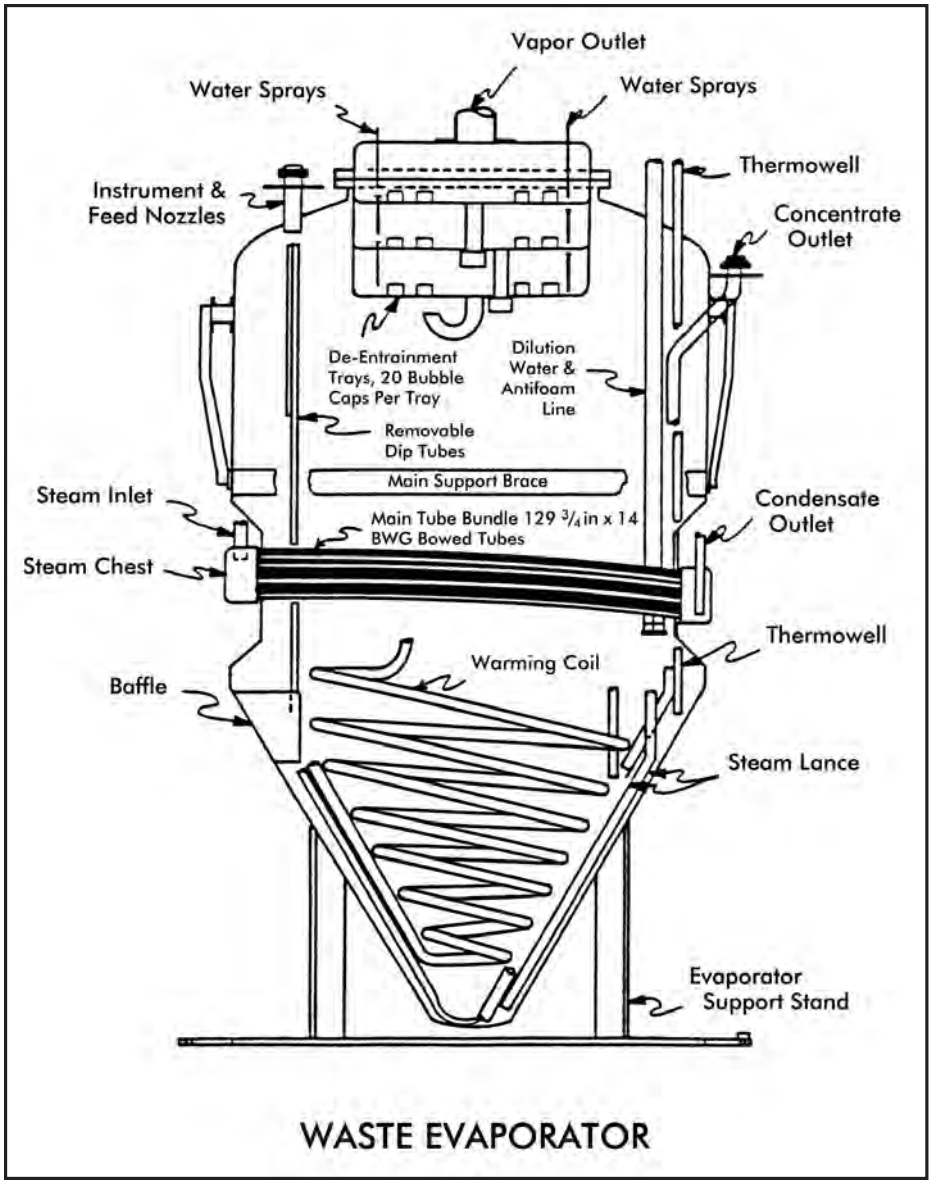
After waste tank volume was recognized as a problem, researchers began to look at the materials already accumulating in the tanks. The waste in the tanks was found to be around 35 percent "solids" (sludge) and 65 percent liquids. It was immediately seen that the percentage of liquids to solids was too high. Studies found that it would be possible to reduce liquids to the point where the solids could comprise 70 percent of the volume in the tanks.[32]

To achieve that result, a number of ideas were entertained. There were schemes to sweep the tank interiors with hot air. Another idea was to boil the waste at a very low rate using hot water. Another was to install a central evaporator, and this was the idea that was eventually chosen in 1955.[33]

Brookhaven National Laboratory and Griscom-Russell Company conducted much of the early research on waste tank evaporators. Much of this work was done in conjunction with additional work on the Purex process. Even then, it was shown to be possible to reduce low level waste, usually a mixture of sodium aluminate, sodium hydroxide and sodium nitrate, by means of evaporation. The process worked with steam coils designed so that any build-up on the coils could flake off naturally. Getting concentrated waste out of the evaporator and back into the tanks was achieved by steam lift. This research continued long after the first evaporators were installed, and much of this was done at Savannah River. By the 1960s, it was learned that all wastes in the tanks could be concentrated by evaporation.[34]

Evaporator being lowered in to 242-F. October 13, 1959, SRS Negative DPSPF 6279-6.

The first SRS project to construct an "external waste evaporation facility" was identified as Project S8-1031. This work was done from 1955 to 1959, with final acceptance from Operation in 1960. These waste evaporators were designed to concentrate radioactive wastes from the canyons before they went into the waste tanks. The first evaporator facility was centrally located around the four tanks that were constructed earlier for Project S8-1030. The new facilities included a single-stage evaporator inside a reinforced concrete shielding structure identified as 242-F. There was also a control house (242-1F), and the requisite process lines and service lines. The ultimate goal was to reduce the liquid



Cross-Section Diagram of an SRS Waste Evaporator. Source: Reed, et al., Savannah River Site at Fifty, 390.

volume in the waste tanks and increase the percentage of the solids, from 35 percent to 70 percent. This would turn the resulting mixture into a thick slurry that would barely move.[35]

The original plans for S8-1031 called for the use of a conventional canyon evaporator for use in the waste tanks. Even with modifications, such as the addition of a jet, it was eventually decided in 1956 to use a different type of evaporator. The new evaporator was purchased from Westinghouse Electric Manufacturing Company. Equipment was also obtained for the removal of the concentrate from the bottom of the evaporator tank, which would be done by "steam lift transfer," using super-heated steam at low pressure.[36]

The first waste evaporator was installed in F Area in 1960, followed by H Area in 1963. At that time, it was expected that the evaporated material would go to the Type IV tanks, but this did not turn out as planned.[37] The first evaporator in H Area was Building 242-H, which was accepted by Operations in March of 1963 and began operation on April 4, working with Purex low-level waste from Tank 21.[38]

Cooling Coils and Evaporation

Although not directly tied to the new evaporators, cooling coils became an important component in the work of the evaporators. Half of the original waste tanks were set up with cooling coils from the beginning. They proved so useful that later, all tanks were equipped with cooling coils.[39] From the beginning, it was known that radioactive waste material in the tanks would be thermally hot, but it was not known how hot. In the 1950s, operators were

surprised to find that waste in the early tanks "boiled," leading to what was called boiling problems.[40] In 1959, it was noted that Tank 241-F-5, then filling with high-level waste, was experiencing wide temperature fluctuations, with "considerable bumping in the sludge layer." The temperature would spike at 111 degrees C., then drop, and then spike again, creating what was called thermal agitation or "bumping."[41]

A Cooling Coil Prior to Installation in a Waste Tank, February 20, 1968, SRS Negative DPSPF 12505-8.

Soon it became essential to control the heat inside the waste tanks. Uncontrolled boiling could not only damage the tank, but also dry out the material to the point there it was no longer sludge but completely solid. At that point, it would be virtually impossible to move the material for future processing.[42]

To improve the performance of the cooling coils, extensive testing was done at TNX, where a test tank was constructed and subjected to experiments to see how various coils reacted to a (non-radioactive) version of sludge situated in the bottom of the tank.[43] Later, cooling coils were placed into all of the waste tanks, even the ones that were originally without it. In those cases, the coils were especially designed so they could be inserted into the tanks through the risers.[44]

Importance of the Evaporators

Within a few years of their first installation in 1960, evaporators were in general use in the waste tank farms.[45] Overall, they reduced the volume of material anywhere from 10 to 33 percent. It has been estimated that without the evaporators, Savannah River might have needed another 85 waste tanks to accommodate the flow.[46] The cost of such a building program would have been prohibitive, and without available waste tanks, work in Separations would have ground to a halt.[47]

Claude Goodlett, who was an expert on waste management at Savannah River, claimed that by 1986, 77 million gallons of waste had been generated by the operation of F and H areas. Evaporators reduced this amount to 32 million gallons, a reduction by over a half. There was even a safety bonus, since waste in a more concentrated form was less likely to leak out of the tanks.[48]

LATER VOLUME REDUCTION WORK

Improvements were made to the waste evaporators for as long as the canyons were in operation. Sometime in the 1960s or early 1970s, the evaporation matrix was changed from alkaline to acidic, after testing revealed better results with acid. As a result, the waste was changed to an alkaline only after the evaporation process, not before.[49] The final waste still had to be alkaline while in the tanks, which were always made with carbon steel.

Work was also done to improve the quality of the ion exchange columns used to remove some of the worst fission products while waste was in the evaporators. In January 1965, it was reported that the resin in the cesium removal column associated with the 242-F evaporator had problems, and this was duly worked on.[50]

Not all of the work done in later years to reduce waste volume had to do with evaporators. Chemical means were also explored and often implemented. Mal McKibben recalled that in the 1970s, he was on a research team that came up with an improvement to the Purex process itself that served to reduce the waste volume sent to the tanks. As he told the story, the Purex process required the separations of plutonium from uranium, traditionally done by adding ferrous sulphamate to the mix. This would change the plutonium atoms from a +4 to a +3 valence, as was needed by the extraction process. The problem was that ferrous sulphamate led to an excess of the sulfates in the waste, a situation that was tolerated since sulphamate was essential to the process itself. McKibben experimented with hydroxalamene nitrate as a substitute for the sulphamate, since it too could reduce plutonium+4 to plutonium+3. It was slower, but also more efficient. This innovation was implemented in the Second Plutonium Cycle and later in the First Cycle. This led to a great improvement in the Purex process, reduced the waste stream to the tanks, and earned McKibben a number of bonuses.[51]

LEAKS AND LEAK MONITORING

Shortly after the waste tanks began filling, there was a rash of four leaks, all in the H Area tank farm. The first occurred in the summer of 1957, when a Type I tank, the first to be filled in H Area began to leak. By that fall, 16,000 gallons had leaked into the saucer that lay underneath the tank. In May of 1959, there was a second leak in a Type II tank, and in July of that same year, a third leak in another Type I tank. The fourth leak began in November of 1959 in a Type II tank, and it became a serious problem by 1960.[52] In that year, some 25 gallons of radioactive salt solution spilled over the top of the saucer and into the soil.[53] This was the Tank 16 leak, the worst case of a radioactive leak from a Savannah River waste tank.[54]

These leaks, coming so close together, had a number of consequences. Tank Type IV was retired as too potentially dangerous, but there were other long-term consequences. It was apparent then, if not before, that carbon steel tanks were not a long-term solution to dealing with Separations waste. Another more permanent solution would have to be found, and the search for that solution got underway at the Savannah River Laboratory beginning in the 1960s.[55]

In the short term, the problem with the waste tanks themselves would have to be identified and solved. After some testing, it was discovered that the leaks came from stress corrosion cracks. Due to radiological contamination, it was not possible to repair the tank directly. After some trial and error, the leaks were eventually fixed by the deposition of solids in the small cracks, "a process aided by the circulation of heated air in the space between the tank wall and the concrete enclosure to encourage evaporation and the accumulation of solids." This was achieved in 1962, with work continuing into the mid 1960s.[56]

The leaks also led to the decision that all future waste tanks should be stress relieved by heating the steel to 1100 degrees F. during construction.[57] This technique became known as "in-place annealing." It also led to changes in the tank designs. As already mentioned, Type IV, with its single wall, was dropped as too risky. Type III became

Periscopes were used to inspect the walls of the waste tanks for leaks. June 30, 1961, SRS Negative DPSPF 7555-1.

the new standard. Here, the saucer concept was dropped in favor of two full walls, one inner and one outer.[58]

Inspection of the waste tanks also became more rigorous. Photographic and later video inspections became frequent, especially for the oldest tanks. Even the viscosity of the sludge was inspected by means of a viscometer. Equipped with a paddle at the end of a long shaft, this device could determine the viscosity of the sludge by the speed of the rotation, and was used to determine the sludge's vertical profile.[59] Samplers were also designed to pull materials out of the waste tanks for further study. By the 1970s, it was common to use heat exchangers to help control the temperature inside the tanks. Automatic reel tapes were also installed at all of the tanks.[60]

Waste Tank Leak Site. Photograph taken from the annular cavity between the steel outer tank wall and the concrete inner enclosure wall. Date unknown, SRS Negative 23205-1.

LATER DEVELOPMENTS IN THE WASTE TANK FARMS, 1960S-1970S

By January of 1965, there were at least 24 waste tanks constructed in F and H areas. By this point, it was common to number them in the order they became operational, regardless of their area location. In this way, the first eight tanks, located in F Area, were identified as 1F through 8F. The next eight, in H Area, were 9H through 16H. These were followed by 17F through 20F, and 21H through 24H. By this time, it was common to move waste from one tank to another, but only within the same tank farm. There was still no way to move waste between the F and H areas. The monthly report for January 1965 recorded the following transfers: Tanks 6F and 7F received waste from 221-F, while 13H and 15H received waste from 221-H. Tank 18F received material from 7F, and 20F and 24H were receiving material from their respective evaporators. Tank 23H received material from RBOF.[61]

By the mid-1960s, it was not uncommon to move waste materials from one tank to another. This was done by means of tubes and pipes that entered the tanks through the top risers, and with the use of pumps.[62] In the early days, the tanks had been filled by gravity flow, but the use the pumps was now standard, both to fill the tanks and to transfer waste material from one tank to another. Even the sludge could be moved. A. J. Hill, a researcher at Savannah River, developed a sluicing method for getting sludge out of the waste tank, based on sludge removing pump tests that had been done at TNX.[63] Depending on what was required, some tanks were filled with sludge, others were full of saltcake; still others had both.[64]

What could not be done was move waste material from one tank farm to the other, but this changed in 1967. That year saw the construction of the 200 Area Transfer Pipeline between F and H tank farms.[65] Even though the transfer line was completed in 1967, the first actual transfer of materials did not occur until 1974.[66]

The 1970s saw the construction of new waste tanks and the inspection of old ones. As an example, the progress report for December 1971 listed 12 between-tank transfers: five in F Area and seven in H Area. The construction of two new F Area tanks, Nos. 33 and 34 were 80 percent complete, and were expected to be finished around April of 1972. The tank inspection program was working on Tank 22.[67] By the end of the 1970s, it was common to move waste tank materials around, from tank to tank and area to area, depending on what was needed where. This continued through the 1980s, with new waste tanks constructed until the reactors closed down and production temporarily came to a halt in Separations. By that point, there were 51 waste tanks that had been constructed in F and H areas.

An interesting observation about the waste tank farms is how the differences between the two farms changed over time. Initially, it was assumed that F Area would have the greatest number of tanks, since it was the earliest of the separations facilities to operate and was considered the main facility. By contrast, H Area was initially thought of as a back-up facility. At the close of Project 8980, F Area did have more tanks, at least technically. H Area, however, soon caught up and eventually surpassed F Area. With the division of Separations into an F Area Purex plant and an H Area HM plant, the nature of the waste materials started to diverge. Because the fuel rods were left in the reactors for so long, there were many more fission products from the HM process than from Purex, and this led to more waste tanks in H Area. In the end, though, despite the reduction in volume and the movement of waste materials around the tank farm, the waste materials were still sitting in metal tanks. As was recognized even in the 1950s, this was at best only a semi-permanent solution.

A PROBLEM TO BE SOLVED

Waste tanks performed a critical function in the overall operation of Savannah River, which encompassed manufacturing of elements, irradiating elements in the reactors, separating the irradiated materials in the canyons, and storing the waste.[68] In order to close the circle and not leave a radioactive and contaminated landscape, it was going to be necessary to clean up the materials stored in the waste tanks. This was not a major problem in the 1950s, when the emphasis was on producing the products needed for weapons, mainly plutonium-239. It became more of an issue in the decades that followed, as the weapons mission could afford to slow down, and as the number of waste tanks grew.

This growing concern was reflected in the organization of the plant itself, as Waste Management became a work category in its own right. Slowly at first, but increasingly over time, the Analytical Lab in 772-F began to concern itself with waste issues, in addition to the usual process samples.

By the 1980s, the waste issue had become a large enough problem that Du Pont began sending high-level officials, including its chairman, to Congress with the news that this issue had to be addressed. This is what led to the first real permanent solution to the waste build-up at Savannah River: the Defense Waste Processing Facility, or DWPF.[69] This was the beginning of a new chapter in the story of Savannah River, one devoted to recycling and clean-up of the materials left over from the production phase.

XI. RECYCLING PROGRAMS AND CLEAN-UP

By the 1970s, the nuclear industry nationwide had bifurcated into two parts, production and power, and both had reached something of a plateau. The military mission of producing plutonium-239 and tritium, directly overseen by the Atomic Energy Commission (and its successor organizations), was leveling off after two decades of high production. The numerous kinks in the system had basically been worked out, both at the reactor level and in the separations process. At both major production plants, Hanford and Savannah River, many of the older facilities had already been retired as either obsolete or redundant. On the civilian side of the nuclear industry, the commercial power reactors for electricity had already passed their initial burst of development that began in the 1950s and continued through the following decade. By 1976, there were 62 nuclear power plants at 44 different sites in the United States, producing an estimated eight percent of the country's electricity.[1]

In the United States, stockpiles of spent fuel were accumulating at many of the power facilities, without a clear-cut plan for either disposing of the fuel or re-cycling it. By the mid-1970s, there was a growing concern about the need to recycle nuclear power plant fuel, seen as the only way to bring the nuclear industry to full maturity. Recycling the fuel was also viewed as critical because at that time it was thought that uranium was in short supply around the world. With uranium in short supply, it was only through some sort of breeder reactor program, which could produce fuel while burning it, that the nuclear power industry could survive into the future. This led to a push for recycling spent fuel in order to pave the way for the next generation of commercial reactor fuels.

While the commercial nuclear power industry was concerned about recycling spent fuel, the production people were becoming increasingly concerned about the accumulation of nuclear waste from years of heavy production. This was a particular concern for Savannah River. Nuclear waste had been accumulating in waste tanks for years, and while it had been evaporated and moved around, there had never been a plan for its final disposition. By the 1970s and 1980s, this had become an increasingly important concern. The end of the Cold War in the late 1980s and early 1990s reduced the need for nuclear materials, but it did nothing to halt the search for a final solution to the waste problem. This chapter will explore all of these issues, from recycling of spent fuel in commercial reactors, to the final solution for nuclear waste resulting from nuclear materials production. Both developments would have a direct impact on Savannah River. The chapter will also deal with the closing of many of the Separations facilities in F and H areas of Savannah River.

FIRST ATTEMPT AT FUEL REPROCESSING, 1970s

By the mid-1970s, most power reactors both in the United States and around the world were water-cooled vessels fueled by enriched uranium that had been bumped up to three to four percent U-235 (natural uranium, U-238, has only 0.7 percent of the isotope U-235). A three to four percent mixture was considered "low enriched uranium." Alternatively, weapons-grade enriched uranium can be bumped up to 90 percent or more U-235.[2]

From the beginning, the power reactor industry was directly tied to nuclear production industry under the control of the AEC (which became the ERDA for a brief period in the mid-1970s, before finally morphing into the Department of Energy). Commercial power reactors relied on the AEC to provide them with enriched uranium, prepared at the government's gaseous diffusion plants.[3] This was done as a means of maintaining control over the uranium enrichment program, which was too important to risk falling into the wrong hands.

After receiving low enriched uranium fuel from the AEC, power reactors would normally burn them for three to four years. By the end of that period, the rise of unwanted but unavoidable radioactive by-products would begin to work against the fission process, and they would have to be removed and replaced with new fuel. The old "spent" fuel would then be left with around one percent of U-235 that had not been burned up, and between one and two percent plutonium-239 that had been created while in the reactor, as well as the unwanted fission products. As the plutonium built up in the accumulation of spent fuel, there was growing interest in saving this plutonium, which itself could be burned in the reactors. As Bebbington put it in a 1976 article, "the fissionable material recovered from the spent fuel of three reactors is sufficient to fuel a fourth."[4] This was the ideal of the breeder reactor, which was to use the Pu-239 to make more Pu-239, creating a more stable closed circle of nuclear fuel production.[5]

The problem with this scenario lay in the commercial production of plutonium, which would be an ever-increasing component in a new system of reprocessed and mixed fuel that would be part uranium and part plutonium. Natural uranium or even low enriched uranium cannot be used directly to make a bomb, but plutonium-239 can be used directly. Plutonium, accumulating in civilian power reactors all around the country, would soon be shipped all over the country, and it could slip out of government control. This would create a serious proliferation issue.[6]

By the mid-1970s, this was a growing concern for the industry, and the decision to reprocess fuel or halt the process because of fears of proliferation, was one that would have to be made at the highest levels of the government. Even though spent fuel plants existed in both Britain and France by this time, there was no active spent fuel reprocessing plant in operation in the United States. In the U.S., the nuclear industry was still based on a "once-through" system, where spent fuel would just pile up at the end of the process as waste material.[7]

DEVELOPMENT OF BARNWELL COUNTY INDUSTRIAL PARK

By the mid-1970s, the governmental agency that oversaw the nation's nuclear material production was in transition. In the wake of the 1973 energy crisis, the AEC was reorganized in 1974 into two agencies: Energy Research and Development Administration (ERDA), which took over the AEC's production facilities; and the Nuclear Regulatory Commission (NRC), which oversaw licensing and commercial regulation.[8] Just three years later, ERDA would morph into the Department of Energy (DOE).

Despite the transition, the government was committed to supporting the civilian power industry by means of national laboratories and a series of research reactors, like the Heavy Water Components Test Reactor (HWCTR) constructed at Savannah River. The government kept tabs on the uranium enrichment process, but did not delve further into the process; it did not manufacture fuel elements for the civilian reactors or process its fuels. It was, however committed to the final disposal of all radioactive wastes, even though that final step had not yet been conceived.[9]

The first facility to attempt the recovery of plutonium and unused U-235 was the Nuclear Fuels Services facility in West Valley, New York. In operation from 1966 to 1972, it could process 300 tons of material per year. Even though it closed for a proposed expansion of the facilities, the rising costs of doing business caused the company

to withdraw its application for renewal. Other companies attempted to enter the business, but these too failed.[10] By 1976, there was no commercial facility in the country that was doing this work, but there was one ready to begin. This was a new separations facility located on the western edge of Savannah River in Barnwell County, an area identified as the "Barnwell County Industrial Park."

The cornerstone of the new Barnwell County Industrial Park was the Allied Chemical Corporation plant designed to process plutonium and unspent U-235 from used civilian reactor fuels. Plans for the Allied plant were announced to the public in February of 1968 at the Barnwell County Court House. At that time, it was envisioned that the fuel-processing plant would be equipped to handle 1,500 tons per year. Shortly after, the General Atomic Company joined up with Allied Chemical to form Allied-General Nuclear Services, which would construct and operate the Barnwell plant. Construction of the plant began in 1970-71 and was completed in 1976 at a cost of some $500 million. At that point, the only thing remaining was the final permit from the NRC, after which processing could begin on the accumulation of some 2,500 metric tons of spent fuel.[11]

One of the featured pieces of equipment for the Allied-General plant was a giant multi-stage centrifugal contactor dubbed "Robatel." Designed for the first Purex cycle of the Barnwell plant, it had been created by the French company St. Gobain Techniques Nouvelles.[12] This contactor was much larger than any of the Savannah River centrifugal contactors, and is still on display in the Separations equipment exhibition yard just west of 221-H.

One reason the final NRC ruling on the Barnwell permit was delayed was that the government was torn between two mutually exclusive options: proceed with reprocessing and risk nuclear proliferation; or shut down reprocessing and close off a potential avenue for proliferation. The nuclear industry itself was pushing for reprocessing, but international pressures were pushing the other way. In 1974, India joined the community of nuclear nations by detonating its first atomic bomb, but did so as something of an outlaw. India had refused to sign the Nuclear Nonproliferation Treaty, and now there was concern that nuclear weaponry would spread to another round of nations, like Pakistan, South Korea, Taiwan, even Brazil.[13]

President Ford, in his last days in office, was known to favor nonproliferation over reprocessing, but the final decision was left to his successor, Jimmy Carter, who became president in January of 1977. In early 1977, a government report came out on the issue entitled "Nuclear Power Issues and Choices," with the conclusion that the plutonium re-cycling option should not be pursued by commercial companies. The study also suggested that the government

Announcement of the Allied Chemical Corporation Plant at the Barnwell County Courthouse, February 29, 1968. SRS Negative 12524-12.

should not get involved with the operation of the Barnwell plant, which, it noted, was already in some trouble even though it had not yet opened.[14]

Carter concurred with the report's findings and on April 7, 1977, made the decision to indefinitely postpone the reprocessing of spent nuclear fuel.[15] As for the Allied-General plant, Carter said that, "the plant at Barnwell, South Carolina, will receive neither federal encouragement nor funding for its completion as a reprocessing facility."[16]

Carter's decision in favor of nonproliferation over re-processing, effectively ended the idea of spent fuel recycling, and by extension the breeder reactor program. It certainly added to the woes of the commercial nuclear industry, which was already suffering from higher costs for uranium, regulatory problems, growing environmental concerns, and, most important of all, rising capital costs.[17] Now it would also have to accommodate the long-term storage of spent nuclear fuels, at least until such time as the government determined the final solution of this material.[18] This only contributed to the malaise of the commercial nuclear industry, which had already lost its initial momentum years before the Three Mile Island accident on March 28, 1979.

In the wake of Three Mile Island, the commercial nuclear industry entered the doldrums, a phase that would last for decades. It has only been in recent years, since 2005, that any new U.S. commercial nuclear plants have been planned and constructed since the 1979 accident. The government was willing to reconsider the re-processing decision during the Reagan administration, but by then the commercial nuclear industry no longer had any firms interested in pursuing what was still a risky and potentially costly enterprise. In 1983, the Barnwell Plant and the Clinch River breeder reactor, still under construction and over budget, were closed down permanently.[19] According to an SRS Separations researcher, the abandoned plant at the Barnwell County Industrial Park is currently known as "the wind sock support facility," named after the most obvious piece of equipment left in place.

WASTE BECOMES A MAJOR CONCERN

Carter's decision might have made sense in curtailing the issue of nuclear proliferation, but it did nothing to help with the problem of nuclear waste, and this was a problem found at every nuclear facility across the nation, including Savannah River. By the 1970s, nuclear waste at Savannah River had begun to pile up from many sources and in many forms, including contaminated material from other parts of the world. The many off-site wastes stored at Savannah River included the Naval Core barrels, contaminated soil from Greenland, contaminated Spanish soil, and nuclear waste from other U.S. facilities, like Mound, Shippingport, Bettis Atomic Power Laboratory, Los Alamos National Laboratory (LANL), Knolls Atomic Power Laboratory (KAPL), and even Three Mile Island (TMI).[20]

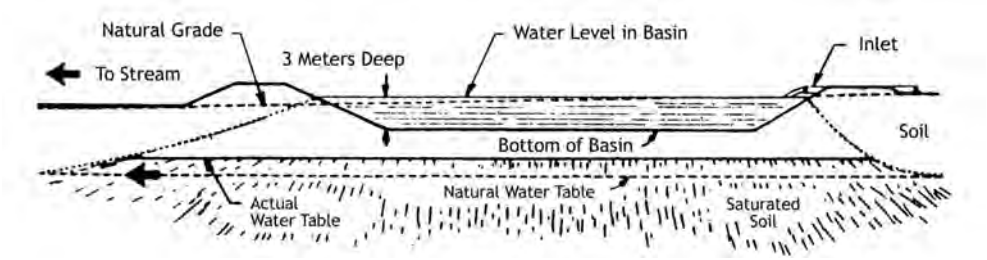
By the late 1970s, waste had grown to such importance at Savannah River that managing it was split off from the rest of Separations, and organized into its own department.[21] Certainly one reason for this administrative change, and growing interest in the disposition of waste in general, was the rise of the environmental movement and the laws that followed this development. This began with the creation of the Environmental Protection Agency (EPA) under Nixon in 1970, followed by a number of other complementary laws in that same decade. One of the most influential for Savannah River was the Resource Conservation and Recovery Act (RCRA), which took effect on October 21, 1976. This law gave the EPA the right to control hazardous materials at every stage of their

development. It also provided a framework for the management of non-hazardous solid wastes. At Savannah River, this ended the era of open dumping of waste materials.[22]

RCRA changed the way solid waste and many low-level wastes (LLW) were treated at Savannah River. In the early days of the plant, hazardous wastes and low-level radioactive waste were simply put into pits or seepage basins, as was customary at other industrial sites. After RCRA, hazardous waste was separated from LLW and was buried as "mixed waste" in Mixed Waste Storage Vaults, often off-site. LLW, for its part, was no longer put in seepage basins.[23]

The closure of the seepage basins was the first major change in the disposition of waste material at Savannah River. Open-air seepage basins had been in use since the 1950s for low-level waste from the Separations areas, the Reactor areas, and even M Area.[24] The design was for the basins to be about 10 feet above the water table, but located far from active streams. The basins were placed in clayey soils that were porous enough for liquid to be absorbed into the ground, but at a rate slow enough so that radioactive materials could decay to safe levels by the time the waste appeared in the nearby stream, a time period that was assumed to be several years.[25]

By the mid-1970s, this process was no longer considered adequate and the seepage basins were phased out around 1975, beginning even before RCRA. The first replacements for the seepage basins were plastic-lined retention basins. Eventually, low-level waste from F and H areas would go to the Effluent Treatment Facility (ETF) that went into operation in 1988 in H Area. This facility treated LLW by eliminating the radioactive contaminants before the material was released to the local stream, which in this case was Upper Three Runs Creek.[26]



Cross-section of a Typical Seepage Basin at SRS. Source: Reed, et al. SRS at Fifty, 393.

Changes also came to the Burial Ground (643-G), located in the open field between F and H areas. Created for

200-F Seepage Basin. February 22, 1965, SRS Negative 10168-2.

the burial of solid low-level waste from the reactor, separations and manufacturing areas, the Burial Ground comprised 76 acres when it was first opened in 1953. It was enlarged to 119 acres in 1972.[27] Everything from aluminum housing tubes, to clothing and contaminated equipment and instruments were placed into 160 trenches, separated by type of contamination, whether it was radioactive or mercury and lead. Low-level wastes were usually placed into plastic or cardboard boxes before going into the trenches. Transuranic wastes went there too, at least until 1965, when these materials were segregated for possible later use.[28]

The TBP solvent from the Separations process was sent to the Burial Ground as well. When TBP was no longer worth saving, it was placed in storage tanks until it was ready to be burned. The burning took place in large open pans.[29] In the month of January 1965, it was recorded that 3,000 gallons of spent solvent was burned at the Burial Ground.[30] This open burning continued, as needed, until the 1970s.[31]

The disposition of the low-level waste, while important, was a relatively small issue compared to the high-level waste that was still stored in the waste tanks. By 1988, when the last of the Savannah River reactors were closed down, there were an estimated 35 million gallons of high-level waste in 51 waste tanks in the 241 areas of F and H. By this time, the waste had largely settled into sludge layers at the bottom of the tanks, above which was the supernate or liquid. The sludge, estimated to be around three million gallons, was the most radioactive part. The liquid supernate was generally less radioactive. Made up largely of sodium nitrate (NaNO3) and sodium nitrite (NaNO2), the supernate was basically considered salt waste.[32] Whether sludge or supernate, this waste material had been evaporated and moved around, but otherwise was the same as when it first went into the tanks, only now somewhat less radioactive due to the passage of time.

The search for a permanent way to store and a permanent place to store high-level waste, began as early as the 1960s. One of the earliest ideas was bedrock storage underneath the Savannah River Plant. This idea was eventually dropped as too dangerous to the massive Tuscaloosa Aquifer.[33] Shipment off-site was considered as well, including one plan to put the waste in an abandoned sulfur mine in Louisiana.[34] Even deep-sea burial was considered.[35] In the end, in the 1970s, the decision was made to go with the process of vitrification as a way to permanently immobilize the radioactive sludge.[36] This was just one of a raft of programs designed to deal with high-level waste. After the basic requirements of vitrification were worked out, the other programs quickly fell into place. This new way forward was the Defense Waste Processing Facility, or DWPF.

THE DEFENSE WASTE PROCESSING FACILITY (DWPF)

By the 1970s, the waste in the waste tanks had stabilized into two basic physical conditions. The heavier materials had settled to the bottom to form a sludge that generally had the consistency of mud or peanut butter. The rest of the material in the tank was in a liquid form called supernate. The insoluble solids that formed the sludge contained 60 percent or more of all radioactive materials in the waste and almost all of the longer-lived radioactive material.[37] The liquid supernate contained mostly salt solutions, but was still too radioactive to be released to the environment.[38] Both the sludge and the supernate would have to be treated in any permanent clean-up program, and the most critical, and the most difficult, would be the sludge. Dealing with the sludge was the basis of the work at the Defense Waste Processing Facility, or DWPF.

The idea for something like the DWPF began to grow in the 1960s and early 1970s. At that time, the basic idea was to stabilize the solid waste in a matrix that would be un-leachable and permanent, and glass was always in the forefront of consideration for this process. In the end, the advantages of mixing waste with liquid glass, a process known as vitrification, outshone the other possibilities. Vitrification bonds down to the atomic level, which effectively stabilizes the waste. It is also versatile. All manner of waste can be vitrified, whether dry or wet. The melters are relatively easy to transport, and the final glass matrix is environmentally stable, more so than cement.[39]

The first vitrification test for the DWPF prototype was done at Savannah River Laboratory in 1972. This work was supported by Pacific Northwest Laboratory.[40] Although there are some obvious similarities between the SRL vitrification and the French method of vitrification, it is believed by most sources that the method used at DWPF was established in this country, not borrowed from the French.[41]

By the mid-1970s, Du Pont began to plan construction of the nation's first vitrification plant, which would be built at Savannah River. Different forms and chemical compositions for the glass were considered during this period, but by 1979, borosilicate glass was selected as the best available material, following closely the developments that were taking place in France. The processes needed to put this material to use were worked out at Savannah River Laboratory and at the testing facilities at TNX.

A View of the Melter in 717-F, Prior to Installation in the DWPF, 2012.

Additional facilities were added to TNX specifically for the testing of DWPF prototypes, and this was done as early as 1978. The first calciners and prototypical glass melters were installed about this time, and testing was done on the different designs. The first DWPF pilot melter was started up in August of 1980, and soon "several half-scale pilot melters were tested at TNX, using simulated waste."[42] The first large-scale glass melter was done there in 1982.[43]

In 1982, both Du Pont and the Department of Energy formally endorsed the borosilicate glass process. That same year, the Nuclear Waste Policy Act required that all U.S. high-level waste eventually be sent to a federal repository for permanent storage.[44] The time was clearly right for the DWPF, which was to be sited on the eastern edge of H Area, in an area now set aside as S Area. The DWPF groundbreaking ceremony was held in November of 1983. Designed by Bechtel and built by Morrison Knudsen, construction continued through the 1980s. Completion was expected in 1989, with start up scheduled for 1990. As a result of delays, start up of Radioactive Operations did not occur until March of 1996. At that time, the first canister of high-level waste was produced and sent to the Glass Waste Storage Building.[45]

The DWPF was constructed during a difficult time. Du Pont announced that it would not renew its contract at Savannah River in early 1987, and left as scheduled two years later. Westinghouse stepped in to run the site in 1989. By the time Du Pont left, 80 to 90 percent of the design work for the DWPF had been completed, and about half of the construction work. For DWPF, construction changed with Du Pont's departure. Mal McKibben, who was one of the project managers for DWPF at the time, recalled that under Du Pont, the lead engineer was authorized to make any changes directly with the vendor, as required by changes in the plans. When Westinghouse took over, the construction moved more slowly. Not only was there a greater involvement by DOE, but now the company of Stone and Webster was employed to oversee all construction changes and they were paid by the hour. As a result, construction dragged to a crawl and went into cost overruns.[46]

By the time the DWPF was operational in the mid-1990s, it was set up to process the waste tank sludge as well as the most radioactive portion of the supernate, usually the cesium and strontium. Before going to the DWPF, the sludge was pre-treated at the Extended Sludge Processing Facility, where it was washed to remove excess sodium and aluminum for better glass quality. Once at the DWPF, the sludge and the most radioactive material from the salt solution was mixed with ground borosilicate, called glass frit, then the whole batch is sent to the melter at 2100 degrees F. The molten mix is then poured into stainless steel canisters two feet in diameter, ten feet high, and three-eighths of an inch thick. When the glass hardens, it stabilizes the radioactive materials in place in such a way that they are immobilized for centuries. The canisters then go to storage in underground concrete vaults that are part of the Engineered Glass Waste Storage Building. There they await final shipment to a permanent geological repository.[47]

The glass canisters, commonly referred to as "glass logs," are stored in S Area. Storage at Savannah River was originally thought to be a temporary solution. For many years, the permanent geological repository was to be at Yucca Mountain in Nevada. In recent years, however, due to political considerations within the state of Nevada, that outcome appears to be unlikely.[48] In fact, it is possible that glass logs will be stored at Savannah River for the foreseeable future.

After a slow start, the DWPF has turned into a success story. By the year 2000, it has been estimated that the facility filled over 1,100 canisters from the waste tanks at Savannah River.[49] Many more have been prepared since that time. Working with the DWPF, clean up crews at the tank farms have been able to close the first of the waste tanks, beginning in 1997. There is even a plaque that commemorates that achievement, which is now located in the SRS Curation Facility, after having been donated to the Cold War Historic Preservation Program in 2013. Enhanced Chemical Cleaning (ECC) in the F Area tank farm was an important part of that work.[50]

Closure Plaque for Tank 20F. 2012

SALTSTONE DISPOSAL AND OTHER WASTE

The salt solution is handled differently from the sludge. After some treatment, this material, which only contains low levels of radioactivity, is immobilized in cement grout and buried in vaults located in Z Area. S Area is largely devoted to the work of the DWPF, but Z area, located immediately northeast of S Area, is where much of the supernate or salt solution is processed (other waste materials, usually solid, are processed in E Area, located between F and H areas). The plant that processes most of the salt solution is known as the Saltstone Disposal Facility, or SDF.[51]

For a period of time, the cesium and other fission products that were in the supernate or salt solution, were pulled out separately and sent to the DWPF for inclusion into the glass logs. This was done with In-Tank Precipitation, a break-through process that used sodium tetraphenyl borate to precipitate cesium within the existing waste tanks. This process was first successfully carried out in 1983 and was adopted as the main way to extract cesium for inclusion into the vitrification process. This led to the creation of the In-Tank Precipitation Facility (ITPF), which carried out this pre-treatment process for the DWPF. It was placed into operation in 1995, but because of high benzene levels, the operation was discontinued the following year. Vitrification has continued since that time by working around that step of the process.[52]

Another means of removing the cesium and other fission products from the salt solution is found in the Salt Waste Processing Facility (SWPF), located in S Area south of the DWPF building.[53] While the main portion of this facility is still under construction as of 2012, the pilot plant has been in operation for a few years. The purpose of the SWP facility is to pull the fission products out of the salt solution and put that material on a path toward vitrification.

After the removal of the fission products, which would eventually go to the DWPF and be treated with the sludge, the rest of the salt solution or supernate could be down-graded to low-level waste. This allowed it to go to the Saltstone Disposal Facility (SDF), which became operational in 1990. The SDF, located in Z Area is not to be

Aerial of Z Area Showing Multisectional Saltstone Facility, 1989. SRS Negative 89-2080-4.

confused with the SWPF in S Area. At the Saltstone Disposal Facility, the supernate is evaporated to a solid form referred to as "saltcake." Mixed with cement, fly ash, and furnace slag, this material was made into a grout and pumped into concrete vaults that were divided into cells. The material was then known as "saltcrete." The final touch required capping with clean grout and a layer of clay earth. These low level waste Disposal Vaults are also located in Z Area.[54]

Modern E Area, located between F and H areas, includes the location of the old Burial Ground, 643-G, as well as the more recent Solid Waste Management Facility. As the name implies, this facility handles contaminated solid waste, but it also serves as a storage facility for trans-uranium (TRU) waste, material that has a very slow decay rate. Beginning in the 1970s, this TRU material was stored in drums placed in the Burial Ground, but this material was retrieved in the 1990s and placed into 55-gallon drums suitable for transport. This material now usually ends up in the WIPP facility in New Mexico.[55]

Another waste facility that began operation in the 1990s was the Consolidated Incineration Facility (CIF). Located in H Area but adjacent to S Area, it was designed to burn hazardous and low-level radioactive waste and mixed wastes, for an estimated four million pounds of waste per year. Construction of this facility began in 1993 and it became operational in 1997.[56] It closed down three years later after it had achieved its goal.

Waste management is one of the main active operations still carried out at Savannah River. It deals with the legacy waste left over from decades of plutonium production, as well as waste produced for heat sources and the special products created for the Transplutonium Programs. This sort of work might not have the glamour and appeal of reactor operation and production during the early days of Savannah River operation, but it is just as

important, in its own way. Permanently dealing with the nuclear waste effectively closes the circle of nuclear production first begun on the site in the 1950s.

END OF THE COLD WAR AND IMPACT TO SEPARATIONS

The Cold War came to a close remarkably quickly, given its intensity and duration. Even as late as the early 1980s, it was simply inconceivable that the Soviet Union would fall into terminal decline, much less collapse, by the end of that same decade. In the early 1980s, the Soviets were involved in Afghanistan, sub-Saharan Africa, and Vietnam, not to mention Eastern Europe, which had been under Soviet domination since the end of World War II. Under Reagan, there had been a U.S. nuclear resurgence to meet this situation. At Savannah River that led to the L Reactor Restart program, and the general ramping up of the plant itself. From most people's perspective, it looked like business as usual, and more of it.

In 1985, Mikhail Gorbachev became General Secretary of the Communist Party, the Soviet leadership post created by Stalin, and a series of reforms began the very next year. Gorbachev's liberalization under perestroika and glasnost, unexpected in the West, began the slow unraveling of the Soviet Union. The oppression that kept the Communist Party in power both at home and abroad began to lessen, and the system began to totter. The fall of the Berlin Wall in November of 1989 was a hallmark of the change that swept through Eastern Europe, as the Soviet system there collapsed. Finally in August of 1991, the failure of a hard-liner coup in Moscow led to the dissolution of the Soviet Union, which collapsed into its 15 constituent republics, the largest of which was Russia.

The end of the Cold War meant that a lot of nuclear material was now unnecessary, particularly highly enriched uranium (HEU) and plutonium-239. Agreements made with Gorbachev and his successors in Russia allowed both superpowers to reduce their nuclear stockpiles. This contributed to the push to clean up the nuclear facilities, and this work was approached from at least three different perspectives. First, there was the clean up of the waste stored in the waste tanks, a process that would have proceeded anyway, regardless of the Cold War. This was the work of the DWPF and associated facilities. Second, there was the general clean up of the nuclear facilities themselves, many of which were unnecessary now that the Cold War had ended. This sort of work is represented by the Deactivation and Decommissioning (D & D) program that got under way in the 1990s and continues to this day. Third, there were plans to reduce the nuclear stockpile, particularly the HEU and plutonium. The most prominent of the stockpile reduction plans is the MOX project, under construction right now.

Bob Romine, speaking of the early days of the Savannah River Plant, said that, "everything we did had never been done before."[57] This comment is just as true for the post-Cold War period that began in the 1990s, when site closure was approached from different perspectives and a variety of different missions. This was the nature of the dramatic changes that began in the 1990s and that are still taking place at Savannah River.

In the 1990s, work at the canyons was on-again, off-again, often because it was unclear just what would happen to the nuclear weapons programs. The fate of the reactors was simpler. All were shut down in 1988. Despite the K Reactor Re-Start program in the early 1990s, K Reactor was never started back up, except as a demonstration.

The cooling tower constructed for K during that time period, was never used. By the end of the 1990s, it was clear that none of the Savannah River reactors would ever be used again—at least not as they were originally intended.

The story of the separations areas is more complicated and more current, if only because separations were closer to the clean-up side of the cycle. In 1992, President George H. W. Bush declared an end to the Cold War, and for a period of time, almost everything in the canyons came to a halt. The tritium facilities were still in operation, since tritium has such a short half-life, and there was still the production of Pu-238 for the Cassini Mission, but Purex in F Canyon came to an abrupt halt. For a three-year period, there was at best only minimal processing in that part of separations. Nobody lost their jobs during that time, but everything was basically frozen in place—even the solutions were left unfinished in the canyons.[58]

The final fate of F Canyon was already under consideration in the early 1990s. Canyon consolidation was discussed as early as 1991, with plans to close down F Canyon and move all remaining operations to H Canyon, after the existing inventory of materials had been processed from the canyon pools and from RBOF. F Canyon was selected for closure because the FB Line could not process Pu-238, which was still needed for space missions. Alternatively, the HB Line could not only handle the Pu-238 work, but also could accommodate alternate feeds of Pu-238 and Pu-239.[59]

One of the first F Canyon Restart plans was dated to September of 1993. It called for producing plutonium nitrate solution for the FB Line, fed from the current F Canyon inventory.[60] In 1994, an internal report came out that recommended finishing the processing that had been stopped in mid-stream in 1992.[61] In the meantime, the F Canyon dissolver was used to process various materials that would then go on to other locations or to a waste or re-processing facility. These materials included plutonium scrap, Rocky Flats Scrub Alloy (RFSA), Taiwan Research Reactor fuel (TRR), and the remaining Mark 31A targets.[62]

This transition period highlighted a new trend. When the canyons started back up, as they would fitfully do later in the 1990s, they would not be the finishing plant for nuclear weapons materials. There was still some production of special products, particularly heat sources for NASA, but even this would drop off. Increasingly, the canyons would serve other processes, performing intermediate steps for the DWPF or the blend-down campaigns. Eventually F was not needed for this work at all and would close for the last time in 2004.[63] Of course, work never ceased in the clean-up program for the waste tank farms, and this work was concentrated in F Area.[64]

The most traditional of the three main clean-up activities was the clean up of the waste tanks. This was basically the transfer of sludge and supernate to facilities like the DWPF and the Saltstone Disposal Facility. In July 1997, Tank 20 in the F Canyon Waste Tank Farm was the first in the nation to be cleaned out. The empty tank was filled with grout, stabilizing any residual material, and capped with cement for the final last few feet. This record event was commemorated by a plaque located at the site of the underground tank. Tank 17 was closed in December 1997. Tanks 18 and 19 were closed in October 2012. [65]

Other waste tanks have been converted into holding tanks for waste material before transfer to the DWPF. This was the fate of Tanks 40 and 51, both located in F Area.[66] Tank 50 serves a similar purpose for the saltstone facility.[67] This is all part of the plan to meet the target date of 2028 for cleaning up all of the Savannah River waste tanks.[68]

Another of the general clean up programs active at Savannah River Site is the Deactivation and Decommissioning program, and the Separations areas have been subject to this clean up just like the rest of the site. Begun in the 1990s, Deactivation and Decommissioning, known as "D & D" for short is the program for closing down and removing many of the old facilities on the site and throughout the rest of the DOE complex. D Area has been heavily impacted by the program, as has M Area. HWCTR is now gone, the older tritium facilities are gone, the old storage magazine (217-F) is gone, and the Naval Fuels facility (247-F), built in the 1980s in F Area, is gone too.[69] Other structures have gone down in more recent years, foremost of which would have to be the massive cooling tower built for K Reactor in the early 1990s, demolished on May 24, 2010.

Separations has also helped other DOE facilities close down. During the Rocky Flats clean up program in the late 1980s and 1990s, there was a molten salt extraction problem. Molten salt had been used to remove by-product americium-241 from plutonium, which left a molten salt residue. Clean up required that this residue be removed. Researchers from Rocky Flats and Savannah River worked up the solution. They produced an aluminum alloy to contain americium and plutonium and separate out the salt, which could then be buried. Much of this work was done in F Canyon before it was closed down.[70]

BLEND DOWN AND MOX

A more difficult and controversial part of the clean-up of the nuclear weapons program would have to be the "Blend Down" mission. This deals with cleaning up and disposing of the nuclear materials themselves. The goal of this mission, which is still underway, is to reduce the amounts of HEU and plutonium-239, which would decrease the likelihood of nuclear proliferation and theft by terrorists.

The Blend Down mission is part of a worldwide drive to eliminate highly enriched uranium (HEU) from the world's nuclear inventory. HEU, one of the nuclear bomb materials, is relatively easy to work with and difficult to detect, traits that would make it ideal for terrorists seeking accessible bomb material. To eliminate HEU, the United States has a program to bring as much of the material as possible back to this country, where it can be processed as spent fuel. H Canyon and the HB-Line both have roles to play in this mission.[71]

Savannah River and DOE work closely with the Tennessee Valley Authority (TVA) as part of the HEU blend down. The arrangement is part of the DOE's "weapons to plowshares" program. SRS receives natural uranium from TVA, and that material is then mixed with HEU to reduce the enrichment levels to below bomb-quality. TVA then takes this material to run through its reactors as fuel. This saves SRS money, since the material would otherwise have to be buried, and it provides TVA with energy.[72]

Getting rid of excess Pu-239 is also part of these nuclear materials reduction programs, but here the issue is trickier. This material is more difficult to work with and is more radioactive than HEU. For these reasons, it is less desirable to the commercial companies that run the nation's power reactors. For them, the traditional fuel for power reactors has always been enriched uranium. Even so, DOE wants to dispose of some 12.8 tons of plutonium, often as a result of treaty obligations, so a number of different methods have been used to reduce the amount. Some small amounts go to the WIPP facility in New Mexico to be buried with the salt; some is inserted

into the process at the DWPF and buried in glass logs. Most of the material, though, will go to MOX, the Mixed Oxide facility that is currently under construction in F Area.[73]

The Mixed Oxide facility, generally known as MOX, is a program of the National Nuclear Security Administration (NNSA), which is part of the Department of Energy. The main mission of the NNSA is to help secure the nuclear weapons materials both in this country and around the world. The mission of the MOX facility is to take most of the nation's excess plutonium, some 7.8 tons, and blend it with uranium for use in commercial power reactors. MOX will be a disposition program that will take fissile material, prepare it for use in power reactors, burn it up, and then dispose of it as spent fuel.[74] The contract for the MOX building was let in 1999 and construction began in 2007. Construction is still going on today.

H CANYON TODAY

H Canyon eventually resumed processing spent fuels in 1997. It also began working with the blend-down program that was already underway throughout the DOE complex.[75] Today, H Canyon is sometimes under-used, but DOE would like to keep it open; the facility is the last of its kind in the entire DOE complex.[76] Currently the canyon is beginning to process the spent fuels that have come to Savannah River from other reactors all around the world. These include university research reactors, test reactors, and material from the Advanced Test Reactor (ATR) in Idaho. Foreign reactor material is particularly welcome, if only to keep the material out of the hands of potential terrorists. All of this material is currently kept in L Area prior to processing in the canyon.

The canyon still has a function, since spent fuel, even after many years, still requires work in a shielded facility.[77] As a recent pamphlet put it, the mission of H Canyon and the HB-Line is to stabilize and dispose of nuclear material "for timely de-inventory of facilities throughout the DOE complex." As it noted, H Canyon is the only large-scale facility still capable of handling radiochemical separations. Excess plutonium from Hanford and Savannah River might be processed for use in the MOX facility, to be blended into a mixture of 5 percent plutonium and 95 percent uranium for use in power reactors. The plutonium that cannot be used by MOX might go to the DWPF to be turned into glass logs.[78]

H Canyon is also active in the Blend Down program to reduce the levels of highly enriched uranium (HEU). By 2010, H Canyon had already processed 21.5 metric tons of HEU, turning it into 280.7 metric tons of low enriched uranium (LEU). This LEU is then shipped to the TVA to be used as fuel in their power reactors.

XII. PERSONNEL PERSPECTIVES

The following chapter contains excerpts from twelve oral history interviews that were conducted for this thematic study focusing on Separations. The full text of these interviews can be found in Appendix B.

DR. EDWARD ALBENESIUS

I interviewed with the Du Pont Company, a campus interview, and they described [SRS] as one of the possible [job] sites... I was taken with that because I really wanted to work in South Carolina or somewhere in the South... I'm glad I chose that.

I was hired to work with Health Physics Department in their Background Survey Program, examining the site for actual radioactivity, to give you a baseline what was the contamination like before there was any contamination. Then I was transferred to Savannah River Lab to work as a research supervisor in Analytical Chemistry Division which was supporting the research that affected the separations process changes, mixer-settler operation and solvent extraction, ion exchange, and the like. We also supported some reactor programs, but chemistry... was heavily slanted toward the research for the separations processes. ...I became manager of that division... And then as the waste management started to become a significant program out there... I got involved in that... the group that I had was concerned with what do you with the glass once you make it, what the repository interaction is and so forth, we had some really great people working in that like Plotnik and others. Looking at the whole program through the furrow of the poor old analytical chemist supporting the research projects that embraced all of this work... we were definitely sophisticated, well-trained, well-equipped technical people supporting the guys who were actually doing separations work.

The plant was designed to be a manufacturer of both tritium and plutonium, so the two processes were there. I mean, they had to be there... and they had to be ready to be operated on a massive scale and were. Actual weapons assembly never occurred at Savannah River. It was always a well-characterized, perfectly describable material packaged in such a way that the next people could do whatever it is to configure it to weapons.

The driver of increasing production [at SRS] really comes from what the Reactor people did. I mean, the reactors were originally designed to be power-level X and they ended up, by modifications in the fuel element design, 3X or maybe even more. So all of that meant that the design basis for the site was so much plutonium and so much tritium and actually then you were dealing with a production potential of three times. The separations canyons were already designed with the capacity that it could adapt to a fantastic change and it was not the limiting thing... if you wanted to change the process, increase it, you might very well rip out what you have and put in new tanks, new piping, new this, and they did that. So the canyon was an extremely versatile instrument.

The hot canyon… first of all you have a fuel element coming out and it's solid… you stick it in a dissolver and you put in nitric acid and you might put in a few other things, but you put in nitric acid and basically dissolve it after you remove the cladding… the cladding material is then removed chemically and it's gone to a different piece of waste. Now you have this irradiated uranium-plutonium solution in nitric acid, and you adjust that chemically to where the plutonium and the uranium are both in the right valence and the right concentration of acid, and you introduce them into the mixer-settlers. That's the solvent extraction. When it goes through the hot canyonís, mixer-settlers, what comes out the end is now a stream that, you know, just in round numbers - high 90s, maybe 95, maybe 99% - of the radioactivity is removed. It's in the aqueous waste, comes out the hot canyon. Now what the warm canyon is going to do it's going to refine that then it's going to dissolve and separate the things that you want, namely the plutonium, and throw out the waste stream which now is a dilute fission product waste stream, and then you're going to allow that to rejoin the really hot waste stream. But you have a warm canyon, which is easier to maintain and so forth. It's still remote though, it's still remote.

Initially the H Canyon also ran a plutonium process and then eventually more locked in on sticking strictly to the enriched uranium recovery, but it was designed to do either one and did do either one, whereas the F Canyon, I think, never messed with the enriched uranium, just exclusively plutonium production. … This was a commercial Du Pont traditionóyou tried real hard to never run a process that you hadn't run in a semi-works, small scaleó not necessarily making the most expensive product in bulk but doing everything that duplicates the process on a smaller scale so that when you go to where you cannot make a mistake you have pre-tested it.

[At TNX] they were allowed to have natural uranium… but they tried real hard and did a pretty good job of keeping any extraneous activity out. They did a lot of the high-level waste work down there, all simulated, all simulated. The original DWPF furnaces were all run full-scale down there but not with radioactivity. And of course the radioactivity in the high-level waste is really the middle section of the periodic table. I mean, it's iron and cobalt and strontium and cesium and a whole bunch of junk that is just everyday. Chemists look at that and say, Well isn't that nice? Yeah, we know all about that. So you can simulate the process perfectly.

[The canyon] was a magic facility, it really was, and it was operated with shielded cranes with operators up there behind great shield walls and so forth. And they could turn things on a dime, they could make connections, they could disconnect, put new piping in, they could take old piping out, they could take new tanks in, old tanks out. I mean, they could do anything.

There were always ongoing process development ideas that were aimed at minimizing the waste, but it was also an article of faith that the important thing was that you got all the product out and you got it out in high purity and you didn't spill any of it. You knew what you were going to do with the waste… they were going to put it in these great big tanks… the incentive to reduce the waste was not anything like as high as incentives to improve the quality of what came out the good end. You're stuck with the fact that it's a high-salt, high-solid content stuff that's coming out. It's very hard to reduce that to a vanishing point, matter of fact you can't.

There were programs to what to do with the high-level waste dating back into the late fifties… the early ones were naïve in that you said, "Well what we're talking about is geologic storage, and what we need to do is to make

sure that the geology is going to tolerate whatever we give it." That whole concept of the waste management long term changed to where you said, "Well, you can't really expect geology to do all that. You're going to have to do a whole lot better on the front end and make sure that the waste you put in is also going to meet these kind of rigorous criteria." There was a humongously important feeling in the Du Pont complex that they really wanted to solve that problem before they walked out, and they did.

[Du Pont was a] great company to work for, and I'm glad I had the opportunity, felt like people like me walked out of a very simple uneducated background, got an education, hit the postwar period and rode the wave, fascinating things to do, and we had one right here, fascinating, big-scale fascinating, great stuff.

CHUCK GOERGEN

I went to work for Du Pont in 1974, and that was when there was a recession. And sales went down and I was in research, which was determined by a percentage of sales. And so they said they weren't going to lay anybody off but they were going to reallocate people, and they asked me to come down and look at an opportunity here, and that's how I got here [SRS].

At the start of the plant, the reactors worked on a single matrix charge of natural uranium with heavy water that can go critical, and so the fuel for the reactor was also the target material. And so the plutonium was produced within that target, within the fuel, then that was transferred to both F and H Canyons, which were essentially duplicates of each other. And in 1959 they went into a shutdown, and with the flexibility of the reactor design they determined that if you had a high enriched uranium fuel driver that you could surround that with various target materials, so instead of just making plutonium you could make all kinds of different products, cobalt-60, curium, Pu-238, higher Plutonium isotopes. And at that time F Area was reconfigured and they installed jumbo equipment, and that's how FB line became JB Line for jumbo buttons, and that's how that terminology began. So JB Line was expanded and built up onto the roof.

Purex process provides several advantages. It has a high DF, decontamination factor. So you start out with a small amount of Plutonium and a large amount of uranium and you wind up with Plutonium with a very small amount of uranium, so the ability to separate the plutonium and uranium to get very pure and then also the recovery percentage. The efficiency of the process is very good so your losses to waste are very minimal and you can recover those losses. So when plutonium was very, very valuable - losses of a couple of grams were significant cost-wise when you're trying to get every gram you could.

The legend goesóthat when the site started up they had their own PAX phone, which is an internal exchange that you could call between areas, but even then you weren't allowed to say plutonium or uranium, and so they called it Element A and Element B. So Element A went to A line, Element B went to B line.

...if you go inside [the sand filters] it looks pretty much like the inside of a parking garage with a sand floor instead. Air comes over and goes through laterals and then filters up through coarse gravel to finer and finer and then at the top it's sand. And if you go inside, you go inside in a plastic suit, primarily for acid fumes not for contamination, because the air from there is swept off by fans and then it goes up the stack. So radioactive discharges are pretty low...

And sand filters are great. The advantage of a sand filter is that it doesn't get occluded by smoke. So if you have a fire, if you've got a HEPA filter and you're drawing through that all those smoke particles can plug up a filter and you can lose filtration. And also HEPAs can burn. So you've got to have some kind of fire suppression on those where you don't have to have that on a sand filter. Sand doesn't burn too well.

And so in the process what you do is after you strip away your product from the solvent you go into washers and you wash it with sodium carbonate and then you wash it with a weak acid, then you recirculate it ... one of the things that the Analytical Lab would do is pull samples of aqueous section of the washer to see how much degraded fission products were building up in there. When it got to a certain level they'd change out the wash.

...the solvent in H Area hasn't been changed out since the late seventies. They used to do wholesale solvent change outs, but the efficiency of the washing is good enough and you run at a low concentration and flows so that the solvent quality is maintained. We had to do some filtering sometimes... but as your n-dodecane evaporates and your TBP degrades, we just go and squirt in a little bit of TBP and recirculate and then sample that and then the Analytical Lab goes and confirms that concentration. And that's a criticality safety. And I'm proud to say that Savannah River has never had a criticality accident, whereas Hanford and Idaho and Los Alamos have had those...

When you went and drained a tank ñ okay, how do you get a bathtub ring? you drain the stuff away and so you think you got rid of it all but there's some that clings to the side, so we talked about "cling-ons" like a bathtub ring... we ensured that we never got the tank up that high that would redissolve or resuspend cling-ons.

As part of the Atoms for Peace Program where we set up all these little research reactors all over the world ówhere everybody would forgo reprocessing to make plutonium and keep down the spread of plutonium. RBOF was the Receiving Basin for Off-site Fuels. And so all those domestic research reactors and foreign research reactors andó you know, we process material from Japan and Germany and just about all these different countries, was received in RBOF. And they've got a deep pool which I think goes down to 60 feet... I think it's 60 feet where you can lower a cask all the way down and then pull a fuel element out and still have it under enough water shielding.

The secret to the canyons' success is their flexibility, and Du Pont did not design to minimum essential.

... a lot of plants, modern plants, ...you hard-pipe them like in Japan and the UK and France. And one of the problems is... They had a design error over in the UK and this pipe vibrated.... and they changed the bracing on the tank and didn't account for the vibration. Well eventually it vibrated enough that it broke right where it entered the tank... they don't have a way to repair it... And that's where the canyon longevity is. There's nothing that I have not been able to fix, repair, or replace in the canyon. People say, "Oh that building, it's almost sixty years old." And I said, "How old's the Boulder Dam, and it's still curing."

...a certain size tank can fit in the .1 or .3 module in any section of the canyon on either side, and the jumpers connect to a certain nozzle on a certain tank to a certain wall nozzle in any of those sections. So being able to re-pipe essentially... it looks like a spaghetti factory but you could pipe anything up to anything.

The key equipment for the canyon is the cranes... everything is lifted and assembled and disassembled with single point lifts, and we actually replaced the cranes with new remotely controlled cranes while the canyon continued to operate.

One of our primary missions now is disposition of nuclear materials. ...there's a drive worldwide to eliminate high enriched uranium because it's a pretty high threat for terrorism.

[About the introduction of computers in to the Separations process] So that was certainly time-saving from doing hand analysis. When I used to count the waste they used to have to do hand analysis of the data which would print out on a teletype and then I'd go and plot the peaks on graph paper and correct for the background and sum the area under the peaks, very tedious.

So software control and configuration control and testing out on test beds and simulators is a big part of how we control the process now. ...as many process engineers that we have, there's almost as many distributed control engineers to convert what they want it to do into computer code to drive that.

In September I think it was '92 Bush declared the end of the Cold War, and so at that everybody said, Oh peace dividend. Shut everything down. We don't need any more weapons. And so essentially everything came to a screaming halt...but essentially everything was frozen in the pipeline where it was. And plutonium in time is bad...plutonium solution will change, so will uranium if it's in contact with solvent it's not static, it will continue to change. And so that was a Defense Board recommendation...which said... it's unsafe to just leave this stuff sit there. You need to have a process or a plan to get rid of it all, to stabilize it, and so that's our stabilization mission.

[About working at SRS] ...contrast to my job in Du Pont ...up there I was using infrared spectrometers that were at least twenty years old... And when I came down here they were using ultramodern equipment ...this site was on a lot of the cutting edge of technical things, and so being technically challenged and working with the latest stuff, it was great.

...the modernization of the U.S.'s nuclear stockpile started happening in the late seventies, and that's where they went to safer systems, fireproof pits, ensuring one-point safe and just improving the overall safety and reliability of the stockpile ...all of a sudden under Reagan there was this great input of people ...

We have a program called Human Performance ImprovementóHow could I screw up today, essentially is what you ask. What are the error precursors? I've never done this before, or I've done it so much I'm not paying attention, I'm not focused. I'd self-check myself, or I ask somebody say, Hey check this over for me before I take this step because once I take the step I can't undo it...

Never underestimate stupidity. You say nobody'd be stupid enough to do tható Guess what? And it's the same, like I don't like the term common sense because I don't like the denominator. I like the term good sense, and there's a big difference between good sense and common sense.

Back then when it was the Cold War we had an enemy and there was a race... being able to protect the nation was a priority. And so when you had an incident we would study it and implement corrective actions and then go on. We had an injury out here...that happened I think in June and they still haven't restarted that operation. So we investigate things much more in detail because there's no threat now to be expedient because we need the production.

I've never been bored here. I've had different jobs every couple years and yeah just working in the Separations Areas primarily. There's always been a breadth of activities that you never get bored.

When you had four reactors running and one went down you still had the other three. If F Canyon went down there was no other place to have that throughput for plutonium. H Canyon, unless you went and changed out all the equipment to put in jumbo mixer-settlers and all that, you couldn't make that up, so the canyons were single-failure type modes of risk. We had enough confidence that we could fix, repair, or replace anything, and you may be down a couple months but you can get back in operation.

PERRY HOLCOMB

When I was in the latter stages of my graduate work at the University of Virginia I started interviewing and Du Pont was one of the outfits that interviewed me... I visited three Du Pont sites, Savannah River being one of them. And a former friend of mine who was in graduate school with me at the University of Virginia, LeVerne Fernandez, was already at work here and so he was my host. And from the work that was going on here and from Dr. Fernandez's glowing assessment of what was going on here, his work, I decided to come to work here... and I'm glad I did.

...my first real experience with Separations was when the preliminaries for the forthcoming curium program were underway... The curium was to be used for studies as isotopic generators using the heat that was emitted from the curium. Curium has an 18-year half-life and so therefore it has a very high amount of heat given off per gram... The predecessor to DOE at the time wanted us to study that really asó for use in thermionic generators, power generators for probes that might be sent to places like Mars... we were studying this back in the late 1960s so really we were ahead of the game... although curium did not work out as expected and so NASA now and has been relying on plutonium-238-powered thermionic generators for their probes like the Cassini probe. The plutonium-238 for that was made here at Savannah River Site.

Those reactors were actually neutron factories so enriched uranium was used there. So H Area was the separations purification area for the enriched uranium…which went back into Savannah River Reactors and the F Area was the production area for plutonium which went onto other sites in the DOE weapons complex.

Plutonium-238 is reallyó it's nasty stuff to work with, has a very high specific activity and it seems to escape everywhere. It's hard to contain, it's hard to work with. It seems to have, I'd like to call it, a mind of its own, whereas plutonium-239 with its longer, much longer half-life and lower radioactivity is easy to work with.

I was on the CAB [Savannah River Site Citizens Advisory Board] when FB Line was officially closed… we were the first ones in there… the first outside people in the old FB Line following its official closure. And they showed us where the work took place, they showed us the glove-boxes, they showed us the vaults. It was a very interesting experience because I had been in FB Line when I was out here actually in Separations Technology. …it was a very funny experience for me to see FB Line closed down and not operating and to seeó the most outstanding thing for me to see was that those big steel doors to those vaults were wide open and there was nothing in there.

I had a very interesting experience in that I was asked to obtain some californium so that Al Boulogne may make the first needle that was used in the medical application of californium-252. And he made that needle in the Savannah River Laboratory from the californium that I had separated from a HEPA filter obtained from the University of California-Berkeley… I purified something like 12 mg of californium, which Al then took and made the first Californium needle that went out for medical use.

What happened was that the Purex process was so unwieldy that…John Lowe and Bill Hale developed a process called the "high-pressure ion exchange" except Du Pont didn't like the words "high-pressure" and so it was renamedó what was it namedó it was renamed "rapid ion exchange."

772 was the support laboratory for the Separations, both 221-H and 221-F. It was a large facility. It did both process support and it also did analytical development. They had an Analytical Development Group out there. I had the Separations Technology Laboratory. … our relationship with Separations was that we provided process support, primarily firefighting. When problems happened in 221-F, or in FB Line, or in 221-H, or in HB Line the Sep Tech Lab was called in to help with those to do analyses, to do tests, to come up with solutions for problems.

In January of 1993 I was transferred to the Environmental Restoration Division, which was brand new… It was really interesting working with them because we were in the forefront of the cleanup and I was their radiochemist, because in the cleanup work we had radioactive materials and so I helped them with analysis of thoseó how much was there, where they were, what to do with them. And so I really enjoyed that work and I worked in Environmental Restoration until I retired on July 1st of 1996.

In the initial design of the Savannah River Plant, the original FB Line had limited throughput capacities and as the Cold War grew warmer then the government decided we need more material, we need more weapons. And FB Line right there was the bottleneck, and so they made FB Line JB Line, jumbo B Line, by increasing its throughput… So JB Line was the early designation given to the revamped higher-production capacity FB Line.

The thing that really impressed me about Du Pont was I think it always had in mind that this place was being run with taxpayers' money. I think Du Pont not only was conscious about safety, which was number one... And secondly to me I always got the impression that even though monies were available, Du Pont was trying to be thrifty with them because they knew where they came from.

The world supply of uranium-235, enriched uranium, was in either one of two places, Russia or the United States. Well, the politics of Russia would never allow them to send out materials to other countries but the United States said, "Yeah we'd like to see other countries develop their nuclear engineering capabilities." So they lent the uranium-235 to these other countries, which had to return the spent fuel back to the United States. That spent fuel came in generally at Charleston. It was trucked to, or railroadedó I've forgotten which, maybe bothó to the Savannah River Plant that took it and stored it in RBOF, Receiving Basin for Offsite Fuels.

The high-level caves is where we took material which had high-gamma radiation. That's where materials were studied, that's where chemistry was done.

I was in Analytical Chemistry at the time when the first computer came to Analytical Chemistry. It was a Commodore 64. ...upstairs in there in the A wing, in 773-A in Savannah River Lab, they had these big stacks of frames which had the tape, the old tape computers and the punch cards... I remember that was given a designation, I've forgotten what it was, but oh they were so proud of that. They were so proud of that computer. Probably that whole outfit is miniscule compared to what you have in today's desktop computer.

When I was in Analytical Chemistry... There was no quantitative means for analyzing neutrons on this site. ...they had health physics machines that they could set up. They were big round black balls in fact which were detectors which could analyze and maybe give you some dose rates...let's say I have a tube of material which contains californium-252 which is heavy neutron emitter. There's no way I could take a tube of that and actually analyze how many neutrons were coming from it. Dick Harold and I built the first neutron analysis outfit, machine, whatever you want to call it, and it consisted of a big paraffin block... it had neutron detectors around the periphery. You'd put the material in the center, you'd put the paraffin block closure on top of it, and then you would count the number of neutrons that these particular neutron detectors saw. ...If I take that same material and put it in this neutron counter I know how much californium-252 is here, I know how many neutrons should be coming from it. So I could standardize my machine. So we made the first analytical neutron detector for Savannah River...

Well, back during the times of production it was, "Do what you have to do to make what we want." That was sort of the governmental position and that was the position that Du Pont took because the government wanted that plutonium.

It wasn't Westinghouse that said, "Okay production is going to cease, we're going into a cleanup mode." It was the Department of Energy that said that and Westinghouse just carried out the wishes of the Department of Energy. So the site, because of the better relations with Russia and the need to actually decrease the number of warheads that the United States had, there was no longer a need for the Savannah River Site reactors or their aging facilities to process what comes out of them.

The californium work was so interesting because I was involved with Berkeley. And visiting out there and seeing what they did and seeing their heavy ion line accelerator where these elements were actually made for the first time, that was exciting to me.

The work I did my last four-and-a-half years for Environmental Restoration was especially interesting because I almost thought of myself as a professor among students... ...I saw that adversarial, combative relationship between our regulator and the Environmental Restoration Division become one of cooperation, and the reason was is that we were both self-educating each other in what we needed. ...I can remember having the regulators come over and I talked to them for two days giving a slide presentation on the environmental radioactivity at the Savannah River Site and then as they became educated we grew to a cooperative effort, from adversity to cooperation.

We had a lot of problems with some of the regulations which were outlandish... We were talking about levels which involved background, and we had background studies at the Savannah River Site that were conducted even before the first operation occurred here. We had analysis of soils. There are two types of radioactivityó primordial, made by God, and anthropogenic, made by man. We had both here at Savannah River Site, so we had to educate the regulators in just what background was.

I came here on June 30th in 1960. I was going to work on July ?ó I've forgotten...but I got a call from personnel. My wife and my five-month-old son and I were staying at a motel there in Clearwater... And I got a call from personnel...and they said, "If you come to work today you can get the July the Fourth Holiday plus. If you come to work before July the 1st you will get one week's vacation between now and the end of 1960." I said, "I'll be there." ...they didn't have to make that call. I think it shows how Du Pont cared not only for its employees but it cared for its employees that were coming to work for them. I always had the feeling that Du Pont cared for me and for my well being and I was glad to work for Du Pont, I was glad to work for Westinghouse. I enjoyed both.

It was fun because we never had a dull moment. We were always trying to run it correctly. When problems occurred we solved them. Sometimes it was an individual effort, sometimes it was a team effort, sometimes Separations would call in Savannah River Lab with which we had a working relationship. We had support from them. It wasó I enjoyed my work here. If I had to do it all over again I'd do it.

ALBERT A. KISHBAUGH

At the time Du Pont was looking for recruits... that would be willing to take on a job building andóactually designing, building, and running the Savannah River Plant and they needed a lot of engineers. ...another reason that I jumped on it was because I had already had my pre-induction physical for going into the service and they could guarantee me that they could keep me out of the service with this job. That was an incentive I couldn't turn down and so that was the secondary reason why I went with them. The job itself

sounded interesting but when I found out I wouldn't have to go into service right away that was what made it easy for me to decide to go with Du Pont.

I started at Knolls Atomic Power Lab...I went up there while the plant was being designed and built. And then I went down to the Savannah River Lab and I worked in the Savannah River Lab...first as a design research engineer and then a senior research engineer, then a research supervisor. And that was up until 1972 at which time they transferred me up to Wilmington, Delaware, where I continued to work on...things that were being done at the Savannah River Plant but I reported to the management up there... And I worked there until 1989 and then I went with Bechtel Corporation because in '89...Westinghouse-Bechtel took over the contract and Bechtel wanted me to work for them...so I ended my career then in 1992 working for Bechtel.

The other thing that we were heavily into was tritium. That's where the site got its name "Hydrogen Bomb Plant" because that was the ingredient that made an atomic bomb into a hydrogen bomb, and we were the site that was going to recover the tritium from the reactors and make it into reservoirs which went into the bombs.

That was one of the features we did in the design of our facilities here at SRP. We made them very versatile, easy to convert into other processes without having to make a lot of equipment changes. We used the same equipment and everything. And that worked very well.

...along with the two canyon buildings, we have a building called a mock-up building [717-F]. And this consists of four of those modules I had mentioned to you that were in the canyon buildings. And they were actual duplicates of the modules in the canyons....all the equipment that went into the canyon buildings had to go through this mock-up building to make sure all the jumpers and nozzles all came together where they were supposed to and they were in perfect fittings, that none of the nozzles were out of line and all that. And so that was an extremely important building.

[Knolls Atomic Power Lab] was a facility that was operated by General Electric... they were demonstrating some of the processes that were going to be used at the Savannah River Plant, some of the equipment but mainly the process or processes. And they were doing that because we had no place to do it down at Savannah River; the place was just being built. And so there was no place even for us to work because the Savannah River Lab wasn't even finished yet. ...And all that work was being done to make sure that the equipment that was being built at this time, being designed and built, was going to work. We didn't have time to wait until the lab was built and then start checking this stuff out; we had to know this stuff because it was already being built, that when it went into the plant site it was going to do what we expected it to do.

...when we transfer solutions in the canyons we can't use pumps because they fail or quit working or don't work properly. ...So all of our liquid transfers were done with these so-called steam jets...the steam comes in one pipe through a nozzle and discharges in the other pipe, and then there's a "T" to those two pipes which is a suction pipe that sucks the liquid up out of the tank that you're going to transfer it from. And when it gets up there and hits the steam then that condenses that steam and that makes it even more of a suction and it levels outó evens out real quick like and all of a sudden you make a nice transfer, no moving parts, just simply using steam.

…just the construction force for the plant site was at 38,582 people. Now you can imagine what these highways were like, to and from the plant with 38,000 people, just construction people. So when I came down in '54, here's these two four-lane highways, one from the Augusta area in North Augusta and one from Aiken, jammed with traffic. You'd get out on that highway and you're bumper-to-bumper. And not only that, these jokers are trying to see how many cars they could pass before they got to work and have a contest in their carpool. Everybody was in a carpool. …the way they helped that out…was they went to shifts, different shifts for different groups. Construction would work from ten to six, operations from eight to four, things like that, so you weren't all on the highway at the same time.

[The canyon] was very impressive. I enjoyed going over there before it went up. Once it went up nobody went in that canyon again.

MAL MCKIBBEN

The Du Pont interviewer visited Emory University every year and talked to the chemistry graduates and graduate school graduates. And the year he came I was a senior, although at that time I was planning on going to graduate school, the dean, the chairman of our chemistry department, asked me to interview with the guy because he didn't have enough people to talk to him. So I did. And they offered me an opportunity to come down here and interview at Savannah River because I had been working on nuclear stuff at Emory with a contractor out of Oak Ridge, and so I already knew what an alpha particle was and a beta particle and that sort of thing.

[Separations and Separations Technology] were kind of like a married couple. We were chained together. They couldn't do anything without our permission and we couldn't do anything without their permission. So we had to work together. And we wrote the procedures, we wrote up incident reports, and we reviewed and approved all procedures or any procedure changes or any tests, that sort of thing. So Sep Tech was very much a viable partner with Separations Department and we got along most of the time very well.

…the original process was in F Area and that was the Purex process. …221-F, where the Purex process existed was the first Purex plant built in the world. …the Purex process is the only process used worldwide today to separate uranium and plutonium from spent fuel, and the guys who developed that have a right to be very proud.

…the control room was all on the fourth level and it was one long continuous control room from dissolving to the final product…when we first started up F Areaó the control room was divided into three parts I thinkó at least two, maybe three. And the people who did dissolving didn't know what went on down at the other end of the canyon. …security was extremely important…

...in spite of all our best [security] efforts the Russians built a plant just like ours almost right after we did. ...they built Tomsk, ... it was a very cheap copy of what we built in 221-F.

...when the plant was built in the fifties the state was segregated, and by law. So Du Pont had to by law design it and build it as a segregated facility. What that meant was we had black places to eat, we had black restrooms and so forth. But before we started it up Du Pont decided they weren't going to operate it that way, and so it was probably the first big place in South Carolina that was fully integrated, and that was quite a thing.

Centrifugal contactors were a wonderful thing. SRL development, our construction people built them, and quite honestly when the people were building their Separations facility over here in Barnwell, the Allied General Nuclear Services, they wanted to build some centrifugal contactors. So they took our drawings and they went to a number of vendors and said, can you make these? Every one of them said, no. The specifications are too tight, we can't make those. But our construction people made them. And they worked like a charm...

We ran two Thorex campaigns to get uranium-233 and thorium recovered from irradiated thorium. There are still a lot of people who think that our commercial reactors ought to use thorium rather than enriched uranium. The Indian government in India is in fact doing that. They have the world's largest supply of thorium and they want to use it, in the ground over there. The Thorex process was a messy process, and we had thorium showing up in streams there for a long time after the Thorex process was run.

And it looks like now that Idaho Falls is going to be making Pu-238 in the future. DOE has made that decision. We have sent all of our neptunium which we had been storing and keeping to Idaho Falls and... if they can get the money to do itó they'll be irradiating and making Pu-238, purifying that and making heat sources.

[About RBOF]...a cask could be unloaded under water. You take the fuel out, hang it up under water so that the amount of radiation reaching the surface was controllable and not large.... that's where we put the spent fuel that would come back to the United States from research reactors around the world.

Now 235-F... believe it or not it was originally built to make weapons and then DOE decided they didn't want to make weapons here.

In order to [switch to a computerized control system] we had to change all the instrumentation which was pneumatic to digital electronic. All of our tank volumes, flows, everything was pneumatic tubes... So we got rid of all those, put in electronics, and then we had a signal that could be used for distributed control or computer control. And it was a major improvement because it eliminated potential for operator errors for one thing. It would take action if a certain limit was exceeded. ...it alarmed to notify the control room people but it didn't wait on them to do something, so it was a significant improvement.

Honestly, we weren't concerned about waste [in the early days]... you don't ask your septic tank if you can flush.

...we put in television instead of using optics for the operator to look what was going on. We replaced some cranes...which were originally mostly carbon steel and were corrodingó with stainless steel. That was a major change both in F and H that improved the quality of the cranes including the optics and the controls. ...The thing that Du Pont did which other sites did not because Du Pont had the contract that allowed them to do it, when something needed improving we improved it. ...Du Pont always wanted to upgrade things, make them modern, make them work, improve the quality...

Now when we turned it over to Westinghouse Savannah River Company they named [another] company... to be our technical overseer. They had to approve every design change no matter how trivial. They had to approve the cost of it and the need for it. Stone & Webster was the company. ... they got paid by the hour basically, they wanted to drag everything out... It really jacked up the price like you wouldn't believe...

[About the importance of Separations to the whole process] It was not just important, it was essential. We made the products. Now Reactor people think they're the center of the site. I said, no you're just a hot feed prep for us.

An interesting asideó almost none of the people who are contractors to DOE today around the country are chemical companies. They are construction companies or they're design companies. Originally in the Manhattan Project and early on in the Cold War all the contractors were chemical companies because it was chemical processes.

At Hanford they had an explosion, which I was on the committee to investigate, of hydroxylamine nitrate and nitric acid. ...there was nobody there, nobody either on the contractor's side or on DOE's side who understood the chemistry of hydroxylamine nitrate and understood that if you boil it down with nitric acid it'll explode. There was nobody there, not a single person, who knew that.

But [DOE] just came to the idea that chemical engineers were as good as chemists and they're not. They're different. That's a different education. Chemists understand what happensó not only what happens but why and what are the reactions and the side reactions. Chemical engineers just know that if you do this, this is the result, but without understanding why. And it's a problem.

A lot of companies that do chemical work have made the mistake of assuming that a lawyer or an accountant could head the company. They become good CEOs of law firms and accounting firms; they are not good CEOs for chemical firms.

...I think it's in Bebbington's book talks about Crawford Greenewalt speaking to the Atomic Energy Commission before he accepted the contract. And he told them, now guys we'll do this and here's the terms. And we're going to send our best people down there. That's going to cost us. But if we send down some of our best people, senior managers, to do this some of those people are going to be making more money than you guys make. If you're not happy with that tell me now and we won't do this contract.

Du Pont was a helluva good company to work for. … at that timeó just one exampleó they plotted out early on what my career path should look like and everybody elseó to prepare him for where we think he's going, he needs this job and he needs this job and he needs this job. They don't do that today. …We were part of the management team. Even when I was a relatively young chemist, skinny and black headed we had congressmen come visit. I was invited to meet with them. Technical people were invited to participate. Not today, no, no way. We were considered part of the team. Not today. It's very sad.

…when Du Pont left after getting one dollar for the life of the contract nobody in the federal government said thank you, nobody. Du Pont did it as a government service, patriotism, and nobody said thank you. That really, really irritated me… Strom Thurman told the president of Du Pont thank you but that was just between him andóit was not an official government thank you.

VINCENT MINARDI

…when I got here in '78… there were about $350 million worth of project upgrades for FB Line. That included modifications to the HVAC system, the plutonium precipitators, the mechanical line which was the line that took the product and finished it and packaged it… There was project work going on every place. …the old precipitators that produced the plutoniumóthey were just about at the end of their useful life when I got here, so one of the major projects was the replacement of those cabinets and all of the equipment in it with new, up-to-date, modern equipment.

New Special Recovery was a major project built on top of the canyon and adjacent to FB line, never started up … It did not ever go operational, basically because the Cold War ended.

…initially back in the fifties the FB Line produced a smaller metal button of plutonium-239, and that was upgradedóand I can't tell you exactly when the JB Line, which was the jumbo button line, replaced the original FB Line, but that'sóit was always called FB Line but the JB kind of stuck because it was the jumbo button line.

[About budgetary concerns]…typical, the DOE funding didn't match the need. There was always an issue of balancing need versus funding available. It was an annual process. Basically we would build what was considered to be a five-year plan that was revised every year and an annual budget that was based on whatever Congress chose to appropriate and what part of that appropriation was for Separations versus the rest of the site.

[Separationís] budget was 350 to 400 million out of a billion-and-a-half [for the whole site] per year. …it was probably about a third for reactor production, but the reactors really didn't stay operational very long after the Cold War; they pretty much went out of business. And the other largest section of the budget was for waste, waste management.

[Speaking about RBOFís budget] Twenty-five, thirty million [yearly] I'm going to think, somewhere in that neighborhood, one really big operation.

so the crane rode above the cell covers and when equipment needed to be repaired or fixed the crane would actually lift the cell cover, move it on top of another cell cover so that that cell was open, and the crane would do whatever mechanical work needed to be done. The crane was used to take the plutonium target, which was manufactured in the reactor, transport it via rail to the canyon in a cask. The canyon cranes would unload the casks and load those into the canyon dissolvers. So they would have to remove the cell cover off of the dissolvers and extract the old targets, whatever was left of them, and load the new ones in for dissolution. And that's typically the same operation in both canyons.

...every year every president prepares a Strategic Arms Commitment along with the Department of Defense and they agree on how many nuclear weapons they were going to have in the stockpile. And when I got here the stockpile was increasing. And there wasn't anything that said it was not going to continue to increase because the Russians were building nuclear weapons and we were building nuclear weapons until Reagan decided to outspend them, which is what he did, and that was what ended the Cold War. I mean, basically his decision to outspend them, build more weapons than they could even imagine building.

There was a period of time when F Canyon was shut down and there was a restart effort for F Canyon, FB Line was shut down and there was a restart effort for FB Line. H Canyon and HB Line continued to operate because they had a longer-term mission. Then they restarted and eventually they finished their mission and were shut down some time in early 2000.

Separations was the mission. Pure tritium, pure plutonium, enriched uranium was the mission of Savannah River Site. That was what it was built for.

...the whole site at that time was on the front end of the Cold War. ...M Area which they manufactured canyon fuel and targets for the reactors...and that fed the reactor and the reactors fed the canyons and the canyons fed the B Lines and the B Line fed Rocky Flats. So it was all part of the Cold War. Producing 239 was the Cold War.

Every day was a challenge. And interesting. Had a lot of interesting stuff going on, so there was never a dull moment, never a dull day. Lots of great people ...that had been here long before I got here and retired while I was here and operating staff were just good people, hardworking, knew what the rules were, how to handle radiation exposure and monitor themselves. So for the most part it wasó people-wise it was a really good place to work. And from a technical standpoint it was extremely challenging, being an engineer, kind of fun.

FB Line was probablyó operating staff was probably close to 125 to 150 operators, and then you had a supervisory staff, engineering staff, equal. ...Between the management, engineering, QA, RadCon, it was probably between 250 to 300 people total, maybe 350 people at one time. ...That's just the FB Line. ...That does not include the canyon. ... Whole of Separations was probably 1,500 employees, 1,500, 1,600 in the late eighties, early nineties.

Well when I first got here, before Westinghouse came in, there were about 10,000 to 12,000 employees, and for every person that worked in the canyon or directly in Separations there were... support personnel... So if the Separations Department at that time was 1,500 people, 3,000 people on the site were associated with support and Separations in one way, shape, or form or another which would have included the labs, the lab personnel, the RadCon personnel, site engineering, site maintenance, SRTC which is now SRNL.

Now when Westinghouse came in, the site population went to almost 25,000. ... One of the things that was different between the Du Pont and Westinghouse was there was a Du Pont engineering staff offsite that supported Savannah River Site. So when I say there were 10,000 to 12,000 that was 10,000 to 12,000 onsite employees but there were other employees within Du Pont that were dedicated to the support of this site but on an as-needed basis. So we would buy that service, engineering service from corporate Du Pont. ... whereas Westinghouse had it in-house with Bechtel. ... that was not all of it. Some of it was just Westinghouse way of doing business was different. ...And then you had K Reactor going on and the upgrades. And so there was a bunch of other stuff going on at the time that caused that major shift.

[as to why Du Pont left] DOE wanted more involvement in the budgetary process and the funding and what was allocated to the site and how it was spent and where the money went, whereas under Du Pont, [Du Pont] said, Here's the bill. ... [the government] Never saved anything with the new arrangement. It cost them more money. The bottom line is it cost them more money to run the site.

if you look at the Department of Energy side under Du Pont versus under Westinghouse it probably quadrupled the number of employees... So total dollars were going up because DOE was insisting on having more personnel, more oversight, more input in the operation and in order to do that, their side had to grow. And as their side grew... that forced some of the growth that you saw on the Westinghouse side over and above just bringing the engineering and the other stuff in here. The more people you had on the Department of Energy side requesting stuff, asking for stuff, managing stuff, the more people on the Westinghouse side it took to support them and give them what they needed and provide the information and the documentation and etc. that was required. I mean, instead of asking ten questions a week you get twenty-five or thirty. It takes two or three times more people to answer those questionsó

...the people that were here when I got here, although many of them were not college educated and had come up through the ranks from operators to managing those facilities, were just super people. They knew their business, they knew their equipment, they understood what its limitations were, they understood the safety aspects of running those facilities. They took no chances. They did it right.

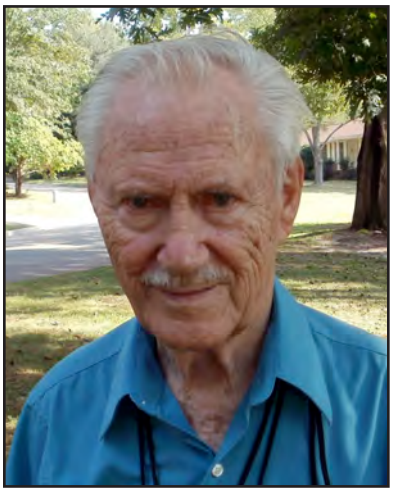
...those people just grew with the plant, grew with the knowledge of the plant, had been here from day one when it started operating and were operators on the floor and they knew the processes inside out, had an unbelievable amount of knowledge of the capabilities and what was required to make it all happen.

...the people that had spent their entire lives working here at SRS from the fifties through the eighties, people that had a forty-year career out here and were up in the management chain were just phenomenal people considering the technology that was here and the processes that they were running, and the safety aspects of running these processes was just kind of mind boggling.

…that's the human-interest story at Savannah River Site, that these people were dedicated to supporting the needs of the government. Very little was spoken outside of the site as to what they did. People…in the surrounding areas had hardly any idea for a long, long time as to what was going on here. People on the outside had no idea. At Savannah River Site they do something out there, we don't know what, and the people who worked here never talked about it. That was part of the security philosophy of the site. They never took their work home, they never talked about their job and what they were doing and where it was going and where the products were…

DONALD ORTH

The man who was to be the first technical director flew out to Berkeley when the plant was announced and asked all of the graduate students to please finish and get up because he would offer us a job...That's when we first heard what was going on, and I went ahead and completed my degree work and actually signed on for Du Pont on April the 13th of 1951.



[Purex] was conceived by Oak Ridge at Oak Ridge National Laboratory during the period after the Manhattan Project, and it was the first application of tributyl phosphate as a solvent in a system that contacted aqueous nitrate solutions of metals with the solvent which would extract into the solvent, and then by reversing the chemistry one could back extract out of the solvent, so it's just a series of such operationsó extract, back extract, extract, then back extract, then one could pull out specific elementsó uranium and plutonium, neptunium, thorium, whatever it was you were trying to do. All of those things were used as parts of the basic process, the same equipment being convertible by just adjusting the chemistry.

772 [Analytical Laboratory]. That was adjoining the canyon building in F Area. …And it was very valuable to have it there because then when something went wrong in the plant or something unusual you could immediately run over to the laboratory right there and get some analyses, which was a faster way than if you had to launch a research program on analytical material involving Savannah River Laboratory.

The original [waste tanks were] a steel tank sitting in a steel saucer. The saucer only went up so far on the wall. And so what happened when leaks occurred they could tell leak occurred, but some of the first contaminations that reached the ground were when a leak occurred that filled up the saucer and overflowed out into the ground next to it. They were not serious leaks in the sense of quantities of material …but of course politically it's a disaster if stuff leaked out of the tanks and got in there. …once that problem was realized that if you have an opening on the edges of the tank and your stuff can overflow that's not going to be desirable, that's when then later tanks were built with a liner all the way up to the top so that they were a double-wall tank, really a double-wall tank.

The laboratory was essential to the success of the project as a whole, but the problems occasionally occurred when it simply was not able to get the proper attention out of the laboratory, who were trying to run as the equivalent of a national lab which they finally did after forty years... Parts of the laboratory were very cooperative all the time and very valuable, other parts were more interested in basic research than in helping the plant.

highly enriched fuels... started coming back in as any number of universities shut down their own little reactors. After Three Mile Island and things like that, all kind of people got nervous, We don't want any reactors here. So little cities would end up taking a vote and saying they want the college either shut down the reactor or go away... And so anyway that's what the RBOF was... storing of research reactor fuels and examination of our fuels.

...at one end of 235 they built cells because there was a business to make some of the actual heat units that would go into the satelliteó well not satellitesó these were some of our long-range throw-them-out-and-see-what's-in-the-rest-of-the-universe things. We built a facility to make these little spheres but again a certain amount of politics got in here. ... Los Alamos was doing the job and they did not really want the competitionó I don't blame them mind youó and one thing led to another and we never started really up our own facility to make these little spheres of hot plutonium-238.

Everything the crane did was either a vertical screw or a horizontal screw...The canyons have been completely gutted using just vertical and horizontal screws on occasion. And they call them Hanford connectors because they were invented for the bismuth phosphate process at Hanford. So if you hear Hanford connectors it doesn't mean you're out at Hanford somewhere...

that mock-up facility again was a tremendous value. In fact, the place could not have been built without the mock-up. First thing you had to do is build a mock-up before you build anything else... You built it with the mock-up, and then you checked it out with the mock-up, and then you hauled it over and put it in the canyon... I don't think we ever had a failure that was due to the fact that somebody built something wrong using the mock-up.

The first crude little computers came in and were used just to monitor some flow rates...then got into the stage of semi-controlling them rather than just telling you what's happening...that was a gradual procedure, which took a number of years to end up with what I'll call any kind of computerized controls.

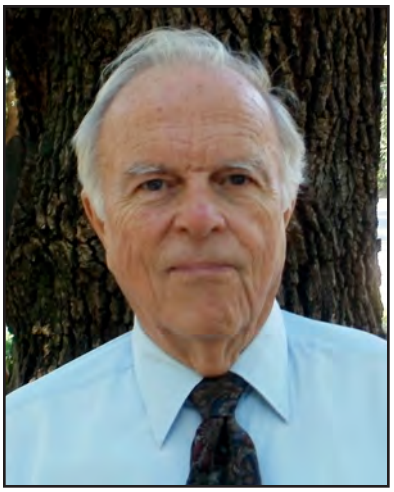
[In the 1980s] they converted the cranes from strictly visual observation to electronic observation...

When the Reactor people would stand up and say, We made this and we made that. We said, No you just made a bunch of highly radioactive material in a big gunk you can't use.

I came right out of school...with a job already in hand... and I reported to Argonne National Lab for several months... [then] I was sent to Oak Ridge to work on the business of concentrating plutonium. And then like the other people in that group when facilities down here got built, as soon as they got a couple of shacks or something for us to live in they transferred us down here.

WILLIAM LEE POE

I interviewed Du Pont and thought it would be an interesting short-time career. [laughs] It turned out to be a full career...Prior to that I spent a year in Oak Ridge at the Oak Ridge National Laboratory doing power plant work for the Purex Process that we were going to use in 200 Area. I was transferred from there to Dana, Indiana, and helped produce heavy water for the reactors down here. Came down and started working in 400 Area, the heavy water production facility here at SRS, and continued that work on producing heavy water for about ten months and then I went to the 200 Area and worked in 200 Area for most of my career.



The Purex Process was to take the uranium slugs that had been irradiated and dissolve themólater on, tubular elements, and dissolve them and separate the uranium from the plutonium and the fission products recovering the uranium and plutonium and putting the fission products in the waste tanks.

the canyon itself is a very flexible thing. You can change the process and use the same building, you can add processes if you have enough space and we hadó we built it with some extra space put in because we didnít know what weíd have to do.

the hot canyon and the warm canyon are the same. They justóthe difference is in the thickness of concrete shielding around them... more for the hot canyon, of course.

they had a 717-Building [717-F] which was a mock-up shop that had two modules in it so you could construct your jumpers and then go down and see that they would fit before you put them in the canyonó terrible thing to put one that doesnít fit in the canyon and then find out it doesnít work... You canít fix it then because itís contaminated.

There are four modules in a section and a module will hold a tank. And so there were eighteen of them, and they were all the same when you go from one to the other except for external piping... we made several modifications in terms of the tanks. They originally were cylindrical tanks and when they wanted to increase the capacity of the canyon they put in bi-cell tanks... looked like a figure-eight tank...you lifted out the two at once but they gave you much more capacity...

The first thing you came into was a dissolving section where you dissolved the uranium, plutonium, and fission products... And then you went through a process called the head-end process which was a centrifugation... hat allowed you to separate undissolved stuff from dissolved stuff. And then you went to first cycle... In first cycle there are two steps. One step is a ...separation of the plutonium solutions from the fission products and uranium, and thatís then sent over to the warm canyon and run through a second plutonium cycle which is another solvent extraction process to purify further the plutonium solution concentrated. And then the material is put in holding tanks and finally sent to the B Lines where itís processed further and decontaminated and reduced to metal... And the remaining uranium solution is also sent to the warm canyon to a second uranium cycle and concentrated there in the second uranium cycle...and then...made into a metal in A Line.

the route to the waste tanks was underground waste headers buried outside of the building fed by gravity to the tank farm, so the canyon had to be higher elevation than the tanks in the tank farm.

I remember going in…during startup, going in the canyon and climbing down and looking in the centrifuges when it had uranium solution running through them, and there was some hands-on evaluation to verify that it was doing what we thought it was doing. [laughs] Itís hard to know what itís doing when your only access to whatís going on down there is from the periscopes on the cranes.

The canyon…is a long, 12-foot wide, if I remember correctly, by 100-and-some-feet long, so itís just a long thing.

We talked long and hard about when we got ready to build the DWPF of how we were going to transfer the waste from F Tank Farm over to H, and we did that by pump. Thatís the first pumps. We had never used pumps for waste before.

most of the motive forces in the canyons were jets… if you look at your hose pipe, your hose nozzles, you can think of them as jets… what you do is you increase the pressure by reducing the size of the hole… And what it does is it allows you to transfer without having anything with mechanical equipment in the canyon that has to be maintained.

[772-F] had all kinds of analytical capability. If we needed something really special weíd send up to SRL, but most all the analysis were done in the F Area lab.

We burned solvent that was badly degraded in the burial ground for years, but that was a small quantity… And boy when you burned it, it sure did smoke, golly.

[uranium-233] went to Oak Ridge, and interestingly enough when I was in Oak Ridge…mid-eighties, I went out and saw the stuff was still sitting there…nobody had ever done anything with it. It was sitting in the pilot plant. And they had drilled a hole in the concrete shielding and stored it in there, because I saw some of the papers that I had filled out to ship it.

235-F was initially made to make bombs…But it was never used [for that purpose]…so we used it for processing neptunium from the H Canyon.

Now the glass logs…it was molten borosilicate glass cast into stainless steel canisters, and these things were… twenty feet tall… They were originally planned to go to Yucca Mountain but… theyíve decided that wasnít safe and have no outgo for that, so that material will stay here in South Carolina… We looked at Yucca Mountain for twenty years and decided that was the right thing to do and the best thing to do, and then all of a sudden this new guy comes in he says, No good, weíre not going to do it.

[There was a leak incident] where the gang valve corridor valve leaked, it had a suck-back and brought high-level waste into the personnel area of the sample tunnel and then we had to clean that up. And that was one of those times where you say, Okay youíve got ten seconds to go down there, so hurry, donít walk slowly [laughs] because youíve got to get in and out. But they had it pretty well orchestrated so that they could get the job done.

JOHN PORTER

I was at Vanderbilt, graduating from Vanderbilt at the time soó I was very much interested in the nuclear industry. In fact, my thesis work had involved some work with uranium so I was mainly interested working either at Oak Ridge or at Savannah River. And it was a pretty tough choice but actually in the final analysis I decided [laughs] Iíd rather come back and live closer to home, so I think thatís mainly why I came back to Savannah River.

I think there were always good openings in the laboratory for new Ph.D.ís because they did need to have people to continue to work on the processes and try to improve them, so there was alwaysó except for just a very few occasions over the life of the plant, there was almost always some hiring going on in the laboratory.

[Day-to-day] was definitely not routine because I was doing research work and so I had a lot of freedom to do the job the way I thought it should be done. I was assigned a problemó improve this process or develop a new process so I had to go in the laboratory and do that. And so you formulate an experimental plan and then you go do it, so every day is probably a little different than the previous day. Next month you may be working on something entirely different.

Well I think there always was [competition]...Everybody had their own problems that they were working on so it wasnít two or three of you assigned different laboratories to do the same thing...everybodyís ambitious, looking for a supervisory job so everybodyís trying to do a good job. There was a lot of cooperation also but I think there was a lot of friendly competition.

my earliest major programs was the neptunium-237, Pu-238 program, and as you know that was initiated in the laboratory...It subsequently moved to the plant but initially they irradiated the targets in the reactors then sent the targets to the high-level caves to be dissolved and then processed to isolate the products...itís somewhat of a stretch of those facilities to do that kind of thing but it worked out pretty well. So I was working on the purification process for both the neptunium and the plutonium, worked on that for several years... And I got one patent out of it. It was a process to reduce the neutron emission from plutonium-238 oxide...

in the early years there was very little patenting done foró probably again for security reasons and theó you know, there was not a lot of publications in the early years either because of security reasons.

A lot of Du Pont reports and internal reports were always written, but outside publications often because of security justó it just couldnít be done. And I think for a long time DOE discouraged it, actually discouraged publications and I think Du Pont just kind of went along with that. I think DOE also considered it a lot of trouble... It has to go through all the clearance and process and all this kind of stuff and it doesnít happen fast... in more recent years things have become very open, perhaps too open, but it got to the point where by the eighties I would say, publication was certainly encouraged by all parties concerned...

There was always competition between the various disciplines...whether youíre working in Reactors or working in Tritium or working in Separations. There was always a competition for resources. ...I think every group is perhaps inclined to think that they are the most important, and so you get into a bit of a rivalry here. And it was interesting

to watch as management changed foró youíd have periods of time where managers, the top-level management in the lab, would be out of the Reactors, they would be the physicists. So the physicist was sort of in charge and the physicist wouldóthe chemist would think that the physicists were getting more resources or that kind of thing and thenó so the next phase comes in and hereís a chemistry person heading the laboratory and all of a sudden all the physicists [laughs] areó have their nose out of joint because suddenly they think the chemists are getting preferential treatment. So it was kind of interesting to watch the cycles as they went through there, but the way the management changed, it was each dog had its day.

[Moving to Works Technical in 1975] was a very big change in terms of responsibility, in terms of the scope of the job. In the laboratory I have no idea about the numbers of people that I might have been managing... it was probably, I donít know, about thirty, forty, fifty, maybe a hundred people... but when I moved to plant, now weíre talking hundreds of people. ...At that time I think Separations included Heavy Water, Tritium, Waste Management. It was very broad oversight over a lot of different activities... I was dealing then with day-to-day problems. It was not developing a process for something we wanted to do next week or improve a process in general but it was, Whatís the problem today?

The matter of separate QA programs did not really come along untiló I wonít quote a date, but in general when the quality movement began to take place in this countryó if youíd have talked about the quality movements back in the fifties, people would not have known what you were talking about...

[F Area Lab] would occasionally have some special programs, like the NURE Program...Natural Uranium Resource Evaluation... there was that period of time when DOE decided they needed to define the uranium resources within the United States... It was operated out of several laboratories, not just Savannah River, but they divided the country up into north, east, south, west, whatever, and this laboratory got this segment and that laboratory got that segment. And what they did they went out and in, Ím going to say like, in each square mile of their section they would take soil samples...and theyíd bring back and analyze them. And just think about doing this for the entire country. And they analyzed it not only for uranium but for quite a list of other elementsóiron, manganese, zinc, vanadium, you name it, probably twenty elementsó really an interesting program. Savannah River did such a good job on the program that eventually the work was taken away from the other laboratories and given to Savannah River. ...Unfortunately before it was all over, DOE kind of lost interest.

for many years there was no separate environmental program here onsite. It was again one of those things that it was embedded in whatever we did. And also the environmental regulations did not start coming along until when the sixties or... So we had to set up environmental programs to define...how weíre going to manage our waste which is the main focus of all of that, and where we had legacy such as stuff already in the ground, what are we going to have to do about it?

You can find a lot of things to criticize about this site, say well youíve got contamination here, there and yon and so on and so forth which is all very true. At the time it occurred it was within all regulations that existed. So you can pick almost any industry you want to. You can pick the paper industry or a mineral industry, a gasoline industry, petroleum industry and can bring up a lot of accusations and identify a lot of problems that have resulted from the practices that they engaged in at earlier times... It would have been better had that not been done that way but it was legal, it was within all regulations, people were not intentionally insulting the environment.

many people donít want to acknowledge the fact or they would rather forget it, but perhaps the fact that this plant came online as rapidly as it did saved us from being a part of Russia... It was a matter of the national defense. And a lot of people who are living today did not live at the time. They were not living during World War II or not living during the early days of the Cold War. They donít know what it was all about. They donít know the fear that was in the hearts and minds of some people in this country...

DR. WILLIAM E. PROUT

...in about November of 1951 Du Pont came to University of Texas and offered me a job to come to Aiken South Carolina... since Savannah River Laboratory had not been built yet in November of 1951 I was sent to Knolls Atomic Power Laboratory in Schenectady, New York. Knolls Atomic Power Laboratory was called KAPL. The people who were at KAPL were the first people who came to the Savannah River Plant.

the thing we developed at KAPL, or they developed, was the tributyl phosphate process, which was the separation of plutonium and uranium and we gave it the nickname of Purex: plutonium uranium extraction. That's what Purex means.

I first got radiated with cold uranium because I had the uranium in a flask and I was going to feed it with a pump to the mixer-settlers and I stuck that suction tube down too far and I imploded the cask all over my hand with uranium. [laughs] That was my first contact. And I went down and set the radiation machine off and took a shower.

...one of the things I did early in the game was - I knew we were going to put in seepage basins. ...the material in this part of the country is two types of clay, well actually, three types of clay. The red clay in Georgia is attapulgite or montmorillonite, and the white clay in South Carolina is...kaolin. And I went down to...the West Virginia kaolin company down there and I found out some things about kaolin. ...I did find out that kaolin clay and the red clays of Georgia would absorb some of the radioactive materials. So we lined the seepage basins with these.

in about 1970 we had twenty years of telegrams from this plant, 200-H Area had a series of telegrams for twenty years and F Area had it for twenty years. This made a total of forty years of telegrams to Wilmington about incidents and we started to categorize those and put them in the computer. And lo and behold we could tell you what would happen when certain things occurred...

They had seventy-five pounds of eosin crystals [fluorescent red dye] [at TNX] one time... I said, John what'd you do with that eosin? He said, I took it out there towards the Savannah River and I just emptied it in the backwash. I said, What do you think happened? He says, That thing turned blood red. I said, What'd you do? I got in the car and went down to 302, it goes across the Savannah River, and he said, Here come that red stuff down the river. I said, Was that the end of it? He said, No I visited a fellow over inó down below Barnwell, there's a little

town down there. I forgot the name of it now. He says, I went through his backyard one day and he had his boat there and that thing was blood red all over the boat. And he said, I know what he did. See, it was against the law to come out of the Savannah River and come fishing. And he said that fellow said, I thought it was Moses turning the river red. He said, It just turned red.

ROBERT CARL ROMINE

When I was in construction we worked in…H Area and we couldn't get the place built. They finally closed it down for a year-and-a-half. They had so many design changes coming through from F Area to H Area that they just said, Stop. And I think it was about eighteen months construction stopped on H Area until they finally could finalize the prints for the place. By that time I was out of there and in the laboratory...

...the laboratory was the only place that they would hire people from high school. Everyone else had to be twenty-one...We had a lot of women, a lot of young men right out of high school hire into the laboratory, eighteen, nineteen, twenty years old and I was twenty-three or four years old, married with a child.

we had more Ph.D. chemists out here than anyplace in the United States, I think.

...they needed someone from the lab to come up and weigh those buttons,...they had people that were doing this already but I guess they thought they needed someone from the laboratory. That was a decision made back then by upper supervision. So I'd go up there and weigh those buttons before they canned them up... They had a little glove-box there that was inert gas inside and just a scale. And I would weigh them and they had little safety sign up there and a bucket of sand and this thing said, If they ever start burning pour the sand on it... you'd pick those things up and you would see sparks fly off them but there was a possibility I guess they maybe could burn.

They'd can [the plutonium buttons] up into a can... about the size of a tuna fish can... they'd put one button at a time in these cans. And then we had containers that you put them in that kept them separated so you didn't put one on top of the other because that would have been a little dicey to do that.

...about our lunch. We'd all gather around the table there, the fine group of us and we'd play a card game called "Dammit" for lunch. And we all brought our lunch with us. So we'd eat our lunch and play cards at lunchtime, which this is the atmosphere that we had there.

Francis Gilmore Du Pont Rust came to work with us down there. He was a graduate from Georgia Tech. ...looking at his badge we'd say, Hey Frank what's that "D" stand for. He said, Du Pont. We just laughed... so one day Frank came into work and he's all dressed up carrying a briefcase, coat and tie on and all that. Frank what's going on? He said, The family's having a portrait taken up in D.C. and I've got to go up and get my picture taken.

[we said] yeah Frank go ahead. We'll see you, the whole group of us. And so about six months later the Du Pont magazine came out and it had a whole group picture on the front, must have been 120 of them, and there's Frank standing there. Well you know how we felt then.

so I asked Frank one time... Tell us why you're working? We know you're a wealthy man... And he said, Well the family sort of required that people from the family go to school and work for at least fifteen years with the company. Then he said after that we can either stay or we could go. And he stayed exactly fifteen years and moved to California ...He raises Appaloosa horses... But he did his bit for the company.

Bill Prout] came in one day and he said, We've got to go up to the C Wing. We've got a little stuff we want to do up there. I said, Okay let's go. ...we went up there to the mini banks and the mini mixer-settlers and we ran a couple programs... Bill knew more about it than I did. I just did the work in the lab. But he said, We'll go up there and stay six months. Well, we went up and stayed seven months and he went back to the B Wing and I stayed up there fourteen years running those mini banks and the mixer-settlers...

...the same time when I was working down there [in 773] they sent up some californium to us and they wanted to see it. So I'm in there, in a glove-box, and the plant manager and a whole bunch of people standing behind me and I was like this, you know, sort of shaking. And they wanted to see it and so I poured it out there. And they had a little vial. At that point I think it had a camel-hair brush. I'm doing this, brushing it around. All I had to do was sneeze and all that stuff would have gone up in the air. [laughter] Even though I'm outside the glove-box.

...in the mini cells we ran that place very efficiently because we could have had major accidents up there and things like that but we never did. And as far as I know we never got anyone with an uptake or with an over-exposure.

We received the samples in stainless steel "doorstops" as we called them ...when those samples came in were really high and they were hot. ...And so one day we had a doorstop come out and some way the vial got lifted out and broke or something. Anyway, there was a spot on the floor about the size of a 50-cent piece. And the HP went in and read it and I think you know it was 3 or 4R. Well 3 or 4R radiation that's the most we'd ever heard of... So they said, We've got to clean this thing up. The first way they do it you'd go in and take a Kotex is what we used back in those days, just a cotton pad, and put it down on it and soak it up... Well HP said, You can go in and spend say twenty or thirty seconds and that's all. And we were all dressed out. So we line up a bunch of people. We got supervision and everybody in there and they're running in and out. So I said, I got this thing beat. They said, What? I'm going to get on the end of the line and they'll get it all cleaned up...and I won't have to go in there. Well they had two of us left and HP said, Well let's go in and check and see what happened. I said, Yeah please do. I don't want to go in there. They came back and said, well it's down to a certain reading. Well how long can you stay in there now and work on cleaning? They said, Two hours. So I'm in there two hours scrubbing that floor with Kotex. I never volunteered again from the end of the line. ...that was in F Area where I did that, that little bit of cleanup.

...if they had a problem in the plant we could reduplicate it real easy in those mixer-settlers. ...you know how big those things were in the plant compared to what we were using and the whole 16 cells were only about a foot-

and-a-half, foot long, a little over that, the mixer-settlers, about that thick with two rows on each side going back and forth. It really did work well.

[Describing the mini-cells] ...it would just be a block, say an inch-and-a-half, say two inches thick and about a foot-and-a-half long and about six to eight inches high,ó just a block of metal. Then they would drill holes in it, two rows of holes up each side with holes going back and forth from one cell to the otheróyou put something in one end and it would slowly work its way up going back and forth through those cells like it does in F Area clear back up to the other end. ...they were designed to just do exactly the same thingóand had little electric motors on top that were in the stirrersó that was the design of the mixer-settler itself. ...And we had a glass front on it and we would polish the glass in front so that see we could see each cell. The cell had three sides and a hole in it, you know, and the top was open and the mixer came down in. But we're looking at it and we had this glass that we fitted over the front of it, and we could put it on there so that it would completely seal so it didn't leak from cell to cell. ... And that way see when we're running a cell we could see in both sides of it, if you picture what I'm saying. The cell was there but we could look in and see the whole cell, all the liquid inside, so we could watch the levels change and all that, and that's how we ran it.

I don't believe there was ever a flow sheet run in F or H Area that we didn't run first in our mini cells. ... we were a miniature 200-F Area.

That was a different type of work that we did in 773 because up there weó they'd give us a problem and we'd work on it, and it wasn't something we had to give them an answer in five minutes tható with plant support over in the lab there it was.

As you started at one end the liquids say are both clear, top and bottom. You had a hard time when you look in to see the oil or whatever it was sitting on top of an aqueous solution. It'd be clear. But you could see it. You could see aqueous and organic solution. When you look at it you could tell which is on top and which is on the bottom. And so then you could follow that and just see how it was working all the way down to the end because each cell would turnówould be a different color. If you're going after blue like plutonium it'd just work down until at the end it was solid blue

...aqueous is a solution like water and organic is oil, see so theó one floats on top of the other. ...Oil and vinegar... It's the same type of thing. So then when you mix them togetheróagitate it and mix the two together you're going to get some separation from the oil into the aqueous and the aqueous into the organic. And you do that in sixteen stages too, you separate out what you wanted. And you did that by using the specific type of chemicals and solutions that were used in there in the aqueous and the organic solution.

The way we worked... [the chemists would] come in and give us a flow sheet to run. They'd design it upstairs on paper. They'd come down and hand it to me and I'd run it. And a lot of times I'd make runs and I wouldn't know why I was doing it. I'd just say, It did this or it did this. At the end after we sampled the whole run... I'd take them into Analytical and then they would give them back. And see a lot of those things I did I didn't really know why I was doing them.

A lot of times sometimes those mini banks would sit blank there for a month or so, nobody ever used them. We didn'tó we weren't using them constantly all the time.

If we get a sample in a uranium doorstop delivered to us, we had to all dress out, salt mask, coveralls and the wholeówhatever, open the door underneath the cell and it had sort of like a forklift dolly only it was a little dolly we had that was made to lift up these door stops. And those things weighedó I think the uranium one weighed 110 pounds, something like that. We had two little knobs coming out on it that the forklift would go under and pick it up, out of where it was and then we could put it in underneath the cell. All this you're doing with radiation control there to watch that nothing was spilled, nothing was gotten out or whatever, and it was the assault mask and all that. That was a tough job to do. And sometimesó it was just time consuming really. The rest of the time we're working in a lab coat.

...the last three years I worked it was the hardest physical work I did because we were running a boat up and down the Savannah River, we were in and out, picking water samples and all over. It was hard physical work.

We did our job and got it done and we did it well. I know we did because we won the Cold War.

Du Pont took care of me health wise, everything else...I never went home with the job. ...I would have been dead if I'd have been a doctor, lawyer, Indian Chief, with a heart attack years ago. But I've never had any worries like that.

There was so much work that Du Pont had done out here at this plant that had nothing to do with making a bomb, really. And so much knowledge was gained...

MAJOR THOMPSON

...my advisor in graduate school was a consultant for Du Pont at the time and one of the places he visited on a regular basis was Savannah River, and knowing that I was from the South initially and wanted to go back South he recommended I come here. I interviewed a number of places and decided that this was the place where I thought I could learn more things and do more things and so I came here.

My main expertise has been in solvent extraction in support of both the Purex process in F Canyon and the modified HM process for H Canyon. ...the flow sheet that is now being operated in H Canyon I developed in the mid-70s for the specific purpose of doing low-enriched fuels as well as the high-enriched fuels.

772 is right by the F Canyon and from F Canyon they had a "tunnel" that they could transfer samples. They had sample trucks to transfer from H... And so they transferred it by trucks that were shielded so that more contaminated samples could be done.

[772-1F] was actually a cell facility. Their older cell [in 772-F] was built and started operating in '53, '54 ...it just needed to be replaced because of all the handling of that high-activity material.

the waste here and at Hanford, if I recall, were both done in somewhat similar ways in that you took it and you evaporated it as far as you could without having solids come out and then you neutralized it with sodium hydroxide and then that slurry was sent to the waste tanks and it was stored as sodium hydroxide solution and you had to maintain certain chemical characteristics such as theó and there are specifications for it, but in essence the tanks themselves they started out to be what is called single-shell, in other words a tank. And the tanks have always been built here with sort of what is called an annular space and then a catch pan at the bottom that is steel.

at the time there was so much stainless being required for building the canyon and other facilities, reactors and things like that, the story is it would have used up the entire stainless steel output for the country if they had built the waste tanks that way, and so they opted to build them out of carbon steel. That is what required going to a caustic solution rather than an acid solution...

The object of this in hot canyon is to get rid of the fission product waste here and to separate uranium and your plutonium and these then goó these go to the warm canyon side for further purification.

They had a quarter-scale waste tank out [at TNX] where they could test new pumps and slurry pumps to get the slurries moving and things like that and study the characteristics of that. Also they had an area where they didóinitially where they did reactor-type studies. So Du Pont would never have built a plant without TNX and without it operating.

The [centrifugal] contactor itself was 25 cm in diameter and that's about 10 inches, 2.5 cm, 4 cm per inch, so it was just under 10 inches.

So what you'd do is when you mixed you'd get an emulsion, like vinegar and oil you shake it up. ...with the centrifugal contactor you're speeding the separation of that. And so you separate them out and it comes in as emulsion at the bottom... And so at the top this portion would be say organic and this portion would be aqueous. So against the wall the aqueous can flow out over the weir and against the center it can flow out and go into a separate weir that then takes it to the next.

What [the "do-bads"] would do is might hold fission products such as zirconium or ruthenium in the solvent and that increased the degradation due to radiation because it couldn't get it out. Radiation in this can produce all sorts of things.

they didn't know that it was and so it was a do-bad... You had to find out what it was before you could...correct it and explain it, and that was one of the things that the lab would do.

the operations differed in the products that they were making. ...in F Canyon the main product of course was the plutonium for weapons. In H Canyon the products were different. When I came the products were the enriched uranium... And the other product that we recovered then was neptunium.

the only thing about the Pu-238 is that at one time when we were talking about that at one time in the eighties we did build and transfer and make the actual encapsulated heat sources here, and that was in the eighties for a short period of time. But Pu-238 is a nasty rascal to handle and the facility got so contaminated, had so many contamination incidents, that they switchedówe switched production from Mound to here and then it went to Los Alamos.

[RBOF] was just a small building on the right and as you drove up toward the main H gate it was a very small facility and it was built...to receive offsite fuels such as the fuel from the high-flux isotope reactor at Oak Ridge.

The Atomic Energy Commission...well, Seaborg was the head of it for a long time and Seaborg had vision and it was an agency and it was highly thought of and so typically funding for new programs was much more readily available. Once we went to a cabinet department things started to drop off, and DOE has just turned so political...

The original cranes were, the cab was on this side of the canyon wall, this is the hot side. The crane's over here. He's got a periscope. That's what he's looking through. That's how he's got to do it.... you have to use impact wrenches because the crane's not going to be able to do anything except operate an impact wrench. So if you've got something that you've got to get off you've got to have specialized tools to do that, and so you have specialized connectors, you have things that can be operated by specialized tools.... it takes someone very skilled at that to do it.

As a matter of fact for many years, probably end of the eighties, early eighties, one of the main solvent quality things was a shake test and a timing for the separation time. You just shook up solvent with a nitric acid concentration and timed how many seconds it took for it to separate. If it took too long then you had to do something about the solvent. And the lab found that interfacial tension could be measured and it was a good indicator of the solvent separation time and so that was changed.

It was not uncommon on either mixer-settlers or the centrifugal contactors to have to change motors. They'd fail and you'd have to change them.

221-H is in use. ... it is processing residual highly enriched uranium for blend downó and that is one of the biggest things that has been happening is they went from processing to recycle it, to processing to dilute it down for use in TVA reactors, which is called the uranium blend-down program. And that has been highly successful.

But that canyon is scheduled to continue operating on miscellaneous spent nuclear fuels like from foreign reactors and research reactors here, HFIR, things such as that until about 2019. But the main thing that they will be doing isó at the moment anyway, is to blend-down.

you could not have gotten weapons-grade plutonium if you didn't have Separations...the whole purpose of the site was to get plutonium for weapons...you can't do that without Separations....it is totally essential to doing the job for which the plant was built.

I think there are three important parts. You've got the reactoró and you can't separate them. You've got the reactors, because they've got to be there to irradiate the material. You've got the Separations which does the separations, gets your plutonium out, and allows you also to recycle your uranium, the enriched uranium, and you have the waste because you've got to handle the waste. So those are the three essential operations. You might as well forget building the plant if you don't have those three.

Now the people at Idaho they went to calcining their waste, in other words converting it toó it really came out as more of a granular solid, and they stored it in stainless steel what they call bins underground. That's a far safer way of doing it and in essence it could probably be left there forever.... Whereas our storing it as liquid means that you have a chance for leaks and leaks could potentially get into the environment. Now we've done the protections. Actually Hanford started out just putting some of the stuff in what they call cribs. Those are just trenches in the ground.

Now the lab had a case where after we had done the curium processing in the cells we needed to clean all that out, because curium and any very high alpha activity it is what is called it crawls, and it can crawl up a wall, up a pipe... And we had to clean it out... I actually spent an hour...in a suit hung in a bucket inside the top of a cell spraying down the walls with a high-pressure water stream.... I was one of the ones that had longer time in there because the radiation dose was already down...

...fairly early in the late sixties we made the biggestólargest amount, a gram of curium metal, which nobody's ever made another gram. I mean there's not a whole bunch around. We had a lot more around then. And so it was an accomplishment to get that amount separated and then be able to make a metal and do measurements that gave us information on the vapor pressure of curium metal

I'm mainly a consultant now and I can pass on information to other people that don't have that background... when I feel as though I can stop contributing something that is useful I'll leave. I won't work anymore.

XIII. CLOSING REMARKS

Separations have been a vital part of the Savannah River operation since the beginning of the plant in the early 1950s. The reactors may have irradiated the raw materials and turned them into fissionable and other useful isotopes, but only separations could isolate these elements and purify them into a useful form. The materials created in the reactors had to be cleaned-up, with valuable materials going one way, and waste by-products going another. Without separations, there could be no final product—no nuclear weapons, no NASA heat sources, no transplutonium elements. The whole process was highly radioactive, which made the work expensive, difficult, and potentially dangerous.

A plant like Savannah River – with reactors, canyons, and all that went with them – would never have been built had it not been for the urgency of the Cold War. This lengthy and multi-faceted conflict kept the place alive. There were other programs at Savannah River besides the military missions, but they were always secondary to national defense. When the Cold War ended, most of the other programs died too. Almost all activity since that time has centered around the clean up of the site. This still left an important mission for separations, since "clean up" was a part of what the canyons did even during the Cold War. So long as there are nuclear materials to be processed, there will always be a need for at least some separations facilities.

Someone once said that working at Savannah River was like being on the "front line of the Cold War." That is a good way to express the value of the contributions made by the individuals who worked at Savannah River, and in particular those who worked in separations. They played a valuable part in what can only be called a war effort. John Porter, talking about the necessity of that war, described those times well:

> Many people don't want to acknowledge the fact, or they would rather forget it, but perhaps the fact that this plant came online as rapidly as it did saved us from being a part of Russia.... It was a matter of national defense. And a lot of people who are living today did not live at that time. They were not living during World War II or... the early days of the Cold War. They don't know what it was all about. They don't know the fear that was in the hearts and minds of... many people in this country. They don't understand it. It's incomprehensible to them that it was necessary to build a place like this.[82]

In addition to the Cold War defense work, the people at Savannah River Site made contributions to nuclear science through the Transplutonium Programs and the many NASA missions, particularly the manufacture of Pu-238 as a heat source. They even helped define the parameters of the civilian nuclear power industry.

In recent years, separations workers have also been in the forefront of efforts to clean up the waste left behind as a result of these projects. Clean-up was an after-thought in the early days. Even now it is not glamorous, but it is essential if we are to close the circle on the production of nuclear materials. That work is not yet finished. In the future, separations workers will continue to provide the expertise necessary to make our nuclear materials as safe and as useful as possible. That is the goal of the DWPF and the Saltstone Disposal Facility. It is the promise of new programs like MOX. So far, the separations performance, both production and clean-up, has been impressive. If the past has any bearing on the future, this will continue to be the case.

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59. Mal McKibben, oral interview with Mark Swanson, September 16, 2010.
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61. Charles Goergen, oral interview with Mark Swanson, September 13, 2010.
62. Dissolver Study Guide, 11.
63. Michael Lewczyk, personal communication, October 18, 2011.
64. Paul Carroll, personal communication, July 19, 2011.
65. Reed et al., *Savannah River Site at Fifty*, 535; New South Associates, *Savannah River Site History Project Protocol*.
66. Paul Carroll, personal communication, July 19, 2011.
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69. *Ibid.*, 536.
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71. Charles Goergen, oral interview with Mark Swanson, September 13, 2010; Major Thompson, oral interview with Mark Swanson, September 20, 2010.
72. Charles Goergen, oral interview with Mark Swanson, September 13, 2010; Michael Lewczyk, personal communication, Oct. 18, 2011.
73. Charles Goergen, oral interview with Mark Swanson, September 13, 2010.
74. *Ibid.*
75. Charles Goergen, oral interview with Mark Swanson, September 13, 2010.
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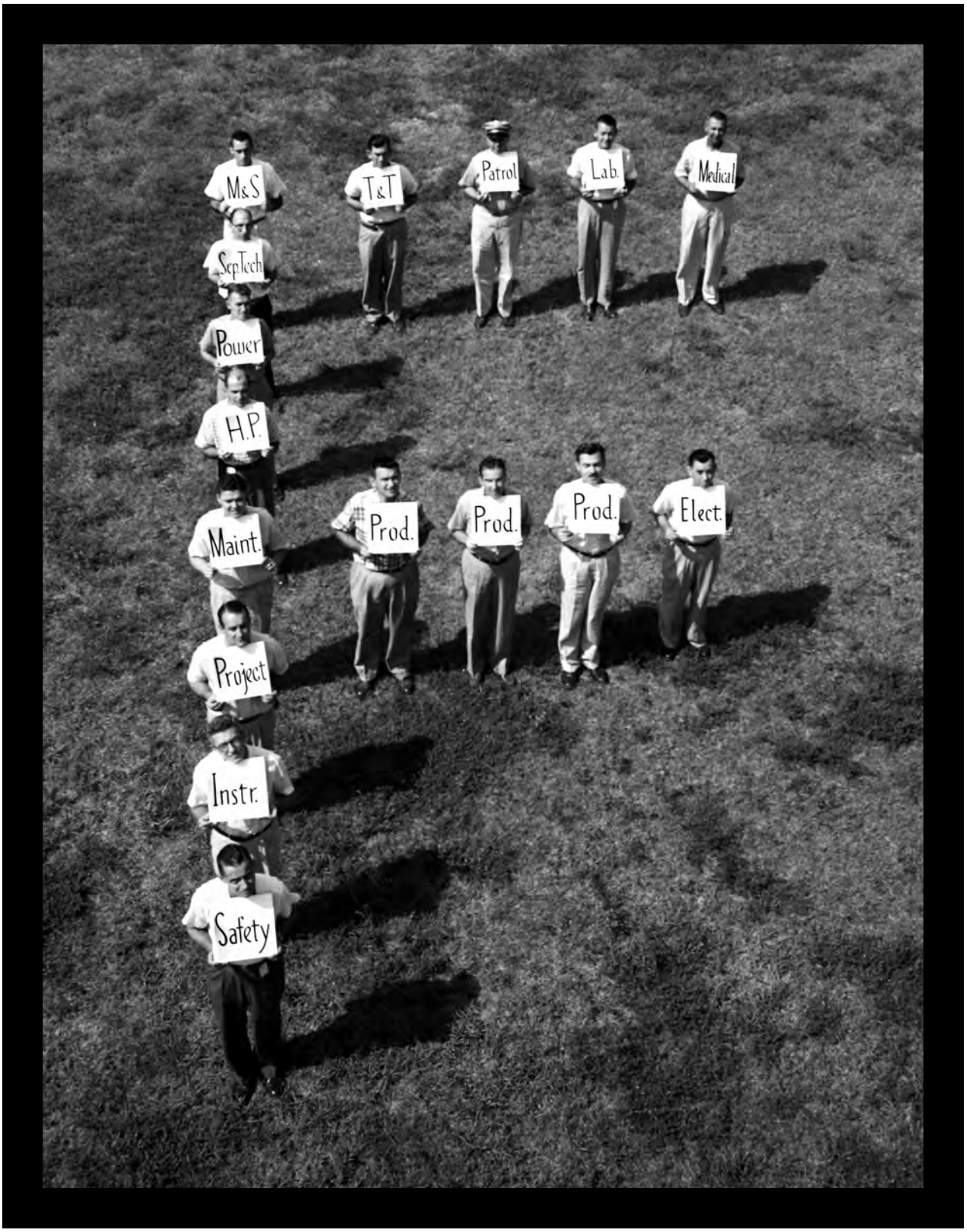
77. Charles Goergen, oral interview with Mark Swanson, September 13, 2010.
78. Savannah River Site Material Stabilization and Disposition Program, 2007 to Present, Highlights (Savannah River Nuclear Solutions, Savannah River Site Public Affairs Pamphlet, August 2010).



F Area Employees: Joe Parrish (Safety), Bob Lovell (Instruments), Tony Carpenito (Projects), Hush Lovelady (Maintenance), Don Nichols (Health Physics), Bill Trollinger (Power), Vic Reilly (Separations Technology), Frank Summers (Methods & Standards), Dallas Poole (Traffic & Tansportation), Troy Walden (Patrol), Bob Foster (Lab), Fred Shepherd (Medical), Paul Ferriter, George Bird and Walt Egan (Production), Jim LeBert (Electrical). Source: Savannah River Plant News, *September 14, 1956:3.*