SAVANNAH RIVER SITE COLD WAR
HISTORIC PROPERTY DOCUMENTATION

Aiken County, South Carolina

300/M AREA
FUEL & TARGET FABRICATION

NEW SOUTH ASSOCIATES
PROVIDING PERSPECTIVES ON THE PAST

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NARRATIVE AND PHOTOGRAPHY

300/M AREA – FUEL AND TARGET FABRICATION

Aiken County, South Carolina

Report submitted to:

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ABSTRACT

This documentation was prepared in accordance with a Memorandum of Agreement (MOA) signed by the Department of Energy–Savannah River (DOE-SR) and the South Carolina Historic Preservation Office (SHPO) dated February 27, 2003, as well as the Consolidated MOA of August 2004. The MOA stipulated that a thematic study and photographic documentation be produced that told the story of 300/M Area's genesis, its operational history, and its closure. New South Associates prepared the narrative and Westinghouse Savannah River Company (WSRC) completed the photographic documentation. M Area is the site of Savannah River Plant's fuel and target fabrication facilities operated from 1955 through the end of the Cold War, producing fuel elements to be irradiated in the Site's heavy-water moderated and cooled reactors. This effort called upon the expertise of scientists, engineers, and operations personnel. Over time, the physical characteristics of the fuel elements changed in size and configuration allowing greater area for heat transfer that was needed for increased reactor powers. These changes were accompanied by further changes in cladding technology. With the shutdown of the plant's reactors by 1988 and the end of the Cold War, fuel element production ceased. Deactivation and decontamination of the M Area facilities began in the 1990s. The photographic documentation and oral history were completed between 2003 and 2005 and the research and compilation of the narrative history were completed in 2005.

ACKNOWLEDGEMENTS

Foremost, oral history provided by Messrs. Fred Rhode, Norman Brady, Sherwood Bridges, Charles Mettlen, and Dave Honkenen was instrumental in developing this narrative. Each of these men, all veterans of 300/M Area and its operations, provided a personal and detailed perspective on the work that was completed in M Area. When we first saw the facilities they were devoid of activity and had been cleaned out with little remaining installed equipment. They gave the buildings life.

The authors owe Mr. Walt Joseph a debt of gratitude. He gamely organized the fuel and target production data that is a critical section of the report.

Mr. James Wiedekehr with WSRC helped organize the large format photography showing how the portion of the 313-M process equipment that was intact worked. He is also the informal curator of 300/M Area artifacts, providing safe storage to models and equipment that told the area's story.

Mr. Tom Feske of WSRC contributed to the documentation effort, coordinating and assisting with the field work. The irrepressible Linda Perry assisted with the photographic fieldwork and the gathering of drawings. We really appreciate her hard work. Steve Ashe, Bruce Boulineau, Byron Williams, and Wes Simon, the talented and lively WSRC Site Photo Services team, did a great job on the documentation photography and I wish to thank each for their part. Thanks to John Knox and William Gregory, DOE-SR, and Adam King, SRARP, for shepherding the documentation through the review process.

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ACRONYM LIST

ACHP	ADVISORY COUNCIL ON HISTORIC PRESERVATION
AMCP	ASSISTANT MANGER 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	DECOMMISSION AND DEMOLITION
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
HABS	HISTORIC AMERICAN BUILDING 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 NATIONAL NUCLEAR SECURITY ADMINISTRATION-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 & SMITH
WIND	WEATHER INFORMATION AND DISPLAY SYSTEM
WSRC	WESTINGHOUSE SAVANNAH RIVER COMPANY

I. INTRODUCTION

This documentation was prepared in accordance with a Memorandum of Agreement (MOA) signed by the Department of Energy–Savannah River (DOE-SR) and the South Carolina State Historic Preservation Office (SHPO) dated February 27, 2003 and a Consolidated MOA dated August 2004. The agreements stipulated that a thematic study and photographic documentation be produced that told the story of M Area's genesis, its operational history, and its closure. M Area, also known as the 300 Area, was the site of the Savannah River's fuel and target fabrication facilities constructed as part of the Savannah River Site (SRS) between 1950 and 1955 and expanded in the late 1950s. It operated until the end of the Cold War. SRS was known as the Savannah River Plant (SRP) until 1989. The impetus for the study was the imminent decommissioning of manufacturing buildings 313-M, 320-M, and 321-M. These facilities are considered eligible for listing on the National Register of Historic Places as contributing resources to a proposed SRS Cold War Historic District.

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; the Augusta, Georgia metropolitan area lies 15 miles to the northwest. The cities of Jackson and New Ellenton are located on the Site's northern perimeter. SRS is considered to be part of the 18-county Central Savannah River Area (CSRA) adjoining the Savannah River in both South Carolina and Georgia.

SRS GEOGRAPHY

SRS's role within the DOE weapons complex was the manufacture of plutonium-239 and tritium, raw materials needed for the production of nuclear and thermonuclear weapons. The weapons produced in this complex were the foundation of our nation's military and foreign policy between 1942 and 1992. [1] 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. Today there are sixteen building areas on the SRS. Those building areas directly involved with fissile production materials – reactor areas R, P, L, K, and C and chemical separations areas F and H – are clustered at the site's center within a deliberate arc-like arrangement with 2.5-mile intervals between building areas. Recently created areas for waste management, E, S, and Z are also within the site's interior. Pilot plant activities (T Area) and the heavy water production area (D Area) were situated by the river and west of the process area. Building Areas A/M, which are integrated together, are located at the site's northwestern perimeter; A was the site's administration center while M Area, the focus of this report, was the fuel and target fabrication area. Area B and Area N, known earlier as Central Shops, fall roughly within the core process area. G Area refers to facilities not

300/M Area's Historic Buildings

313-M

320-M

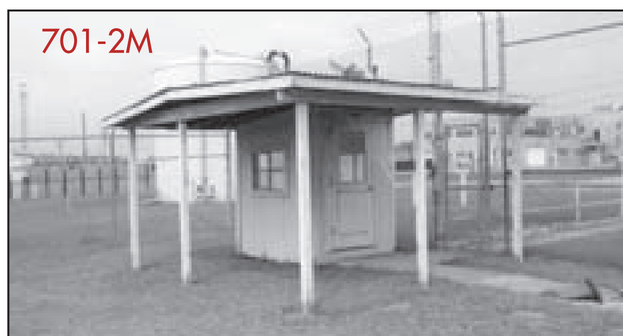
322-M

321-M


305-M

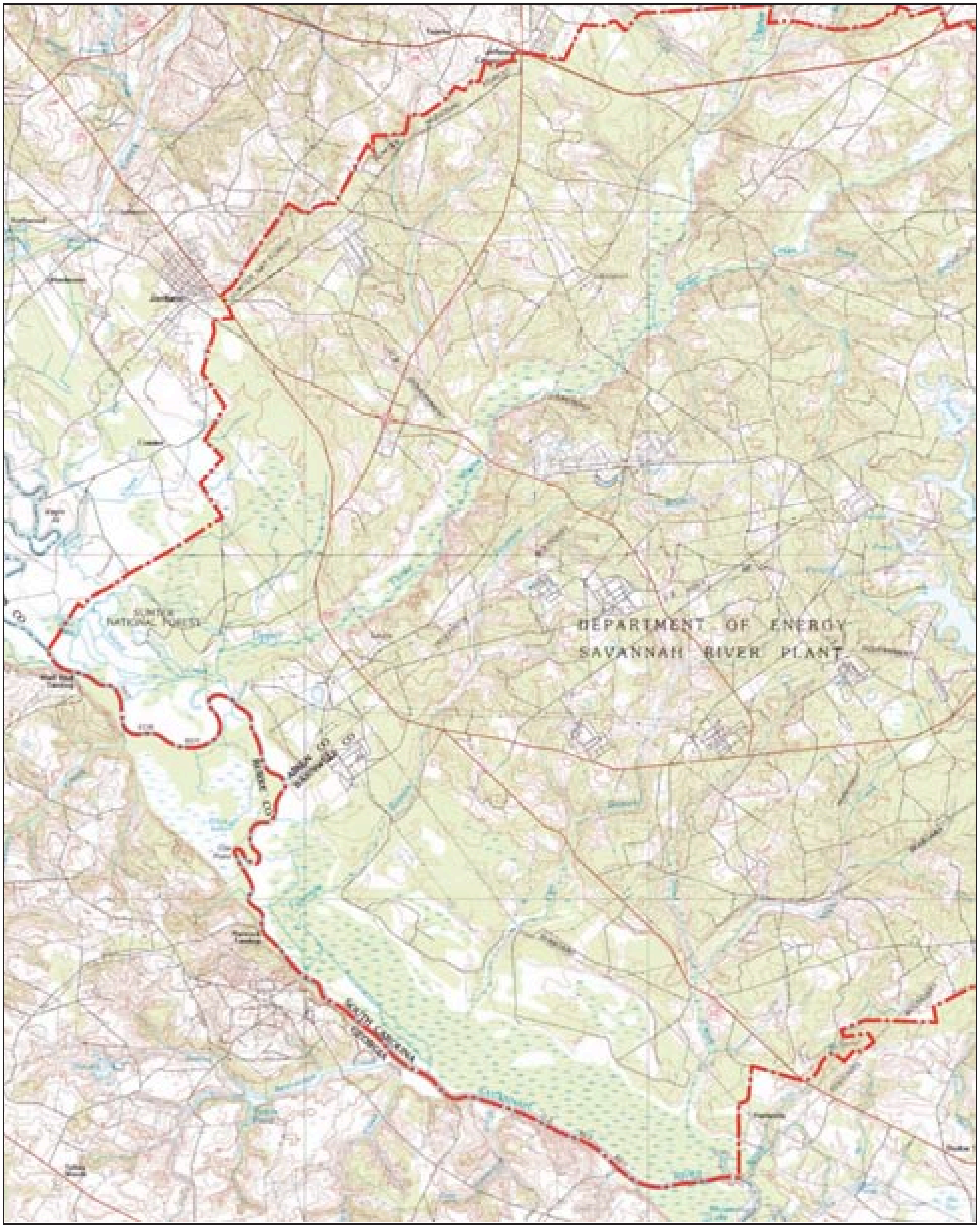

704-A


701-1M

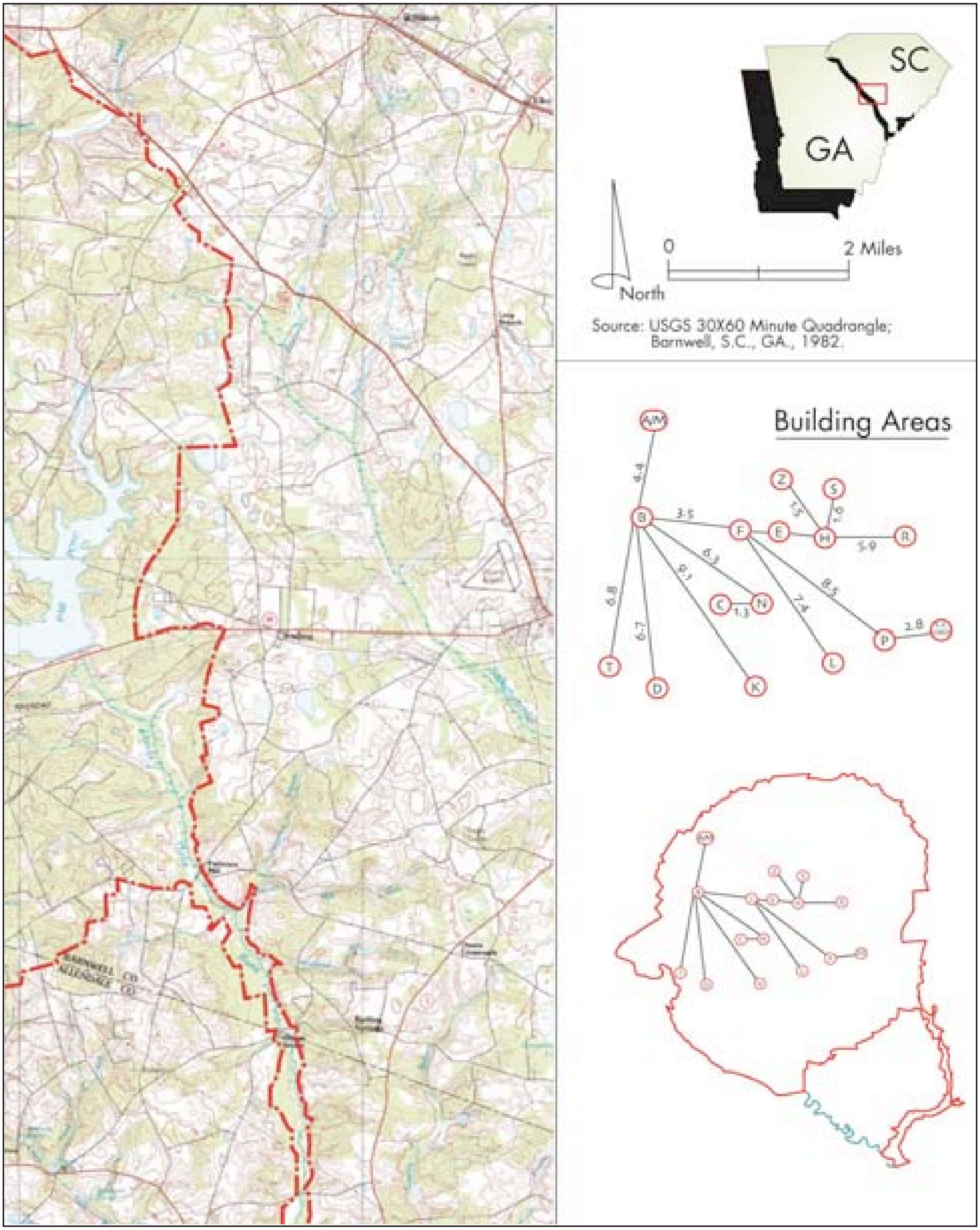

701-2M


701-3M


710-M


DEPARTMENT OF ENERGY
SAVANNAH RIVER PLANT
SUMTER
NATIONAL FOREST
SOUTH CAROLINA
GEORGIA

SRS Location Map



within the aforementioned areas. Finally, the site's infrastructure includes a road system, a railroad system (under demolition), and on site utilities that furnish the site's energy needs.

SRS COLD WAR HISTORIC DISTRICT AND ITS SIGNIFICANCE

The SRS 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 Criterion 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 Criterion 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 Criterion C is usually applied to an architect or architectural firm, it is appropriate here. Du Pont brought its 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 SRP.

The historic district is also considered eligible under Criterion 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 special 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 Criterion C.

SRS's historic district may also fulfill National Register Criterion 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 within 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 the likes of which few regions in the nation would ever experience, changed the housing stock and appearance of the towns these atomic immigrants would move to, changed the make-up 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 the SRS within their first thoughts and words. The SRS was extremely significant regionally as well as nationally and at the state level.

DOCUMENT ORGANIZATION

The MOAs stipulated that a written narrative should be developed based on primary sources to the greatest extent possible, including but not limited to oral history, archival history, and drawings. A companion documentation mitigation strategy was further stipulated - capturing the buildings and its interior process areas using large format photography when intact interiors were present and 35 mm black and white photography for exterior photographic documentation and for interiors that had compromised historic integrity. New South Associates was responsible for the historical research, oral history and the compilation of a narrative. WSRC was responsible for the photographic documentation, its archival processing, and its compilation. New South's HABS photographer completed the large format photography for installed equipment in 313-M, WSRC's photographers completed the remaining photography.

This narrative provides an overview of the historic processes carried out in M Area, followed by specific building descriptions and photographic documentation. It is a section within a developing portfolio of similar studies that address the historic production mission of the Savannah River Site during the Cold War and its role during the Atoms for Peace Program.

After this introduction, there are six chapters. Chapter II provides a historic context for the Site's Cold War history from a national and local perspective. The remaining chapters deal exclusively with the history of fuel and traget fabrication at SRP. Chapter III gives a short history of fuel and target development prior to 1950 in the production complex. The following chapter deals with the construction phase and focuses upon the 300/M Area buildings. Chapter V describes the original equipment installed in the buildings. An operational history is presented in Chapter VI and conclusions are given in Chapter VI.

For clarity, the 300 Area will be referred to as the 300/M Area in this document. Two main facilities that have received building number changes will be referred to by their historic number designations in the overview. 305-M and 777-M were renumbered after their production mission ended to 305-A and 777-10A, respectively, in recognition of their new uses for research, development, and administrative functions.

II. SAVANNAH RIVER SITE COLD WAR CONTEXT

The 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 nuclear science.

COLD WAR DEFENSE MISSION

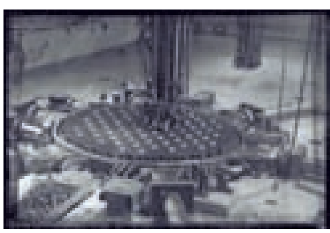
The defense mission of the SRP, as it was known prior to 1988, was an integral part of the AEC program to create weapons-grade plutonium and tritium for incorporation into fission and fusion bombs, known respectively as atomic and hydrogen bombs. The defense mission of SRP, and for that matter, the AEC, 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.

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

Plant Processes

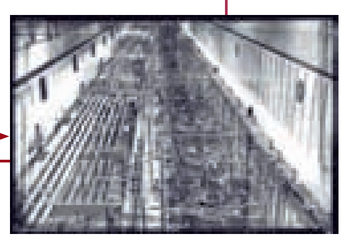
Fuel and Target Fabrication

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).

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]

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

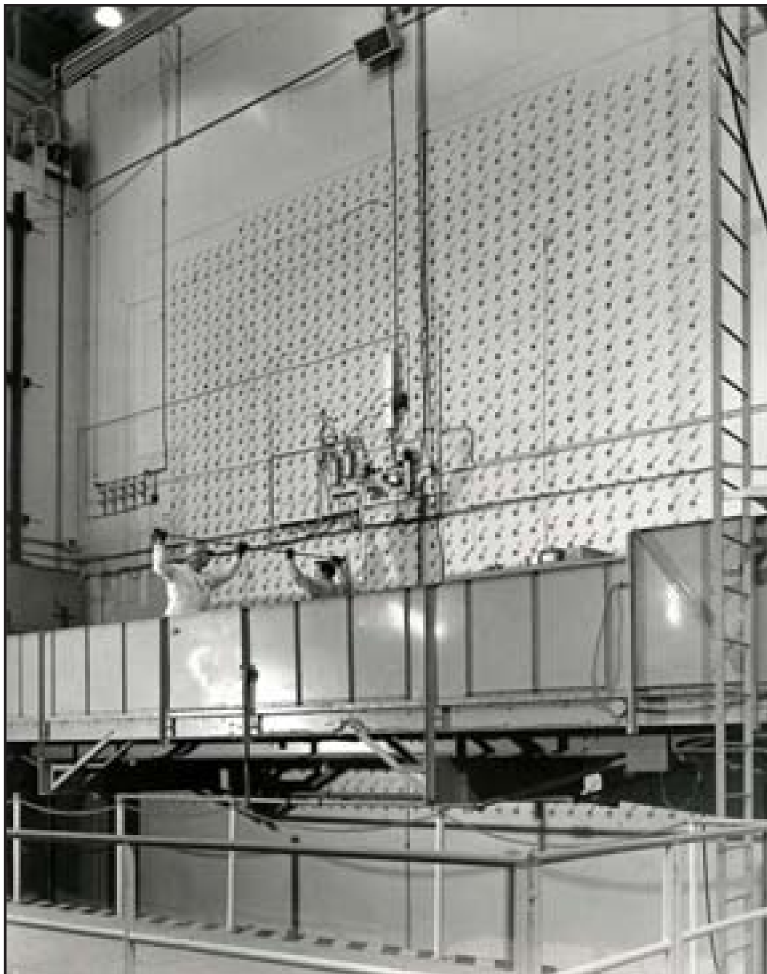
The last half of 1942 saw the groundwork laid for the development of the Manhattan Project. Groves and others selected the methods and sites to be used to produce the bomb. For both speed and economy, Groves wanted to concentrate on one single method for bomb production, but science would not oblige.[6] 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.

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



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

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 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]

To do so in a field of endeavor in which they were not expert, Du Pont was to depend heavily upon the Metallurgical Laboratory of the University of Chicago for 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]

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.

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.

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.

Mike Shot. Courtesy of the Los Alamos National Laboratory

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 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.

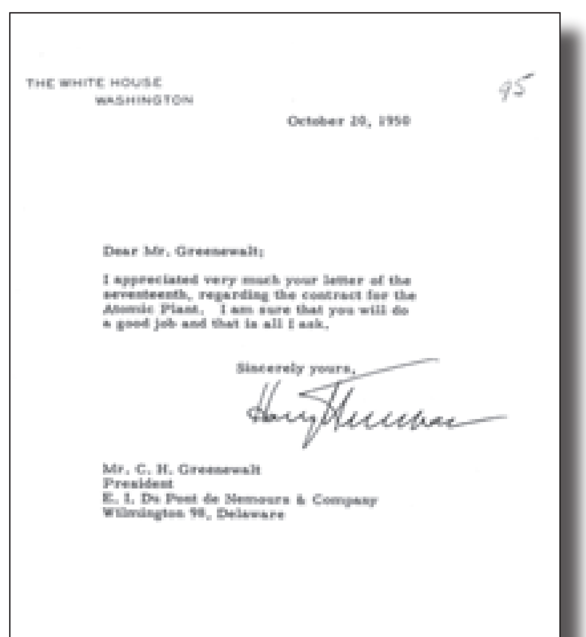
Enlarging the stockpile was the first response to the Soviet bomb. The second was the decision to produce a hydrogen bomb, a weapon many times more powerful than the uranium and plutonium devices dropped on Japan at the end of World War II. On January 31, 1950, Truman signed a presidential directive 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]


THE WHITE HOUSE
WASHINGTON

95

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

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]

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]

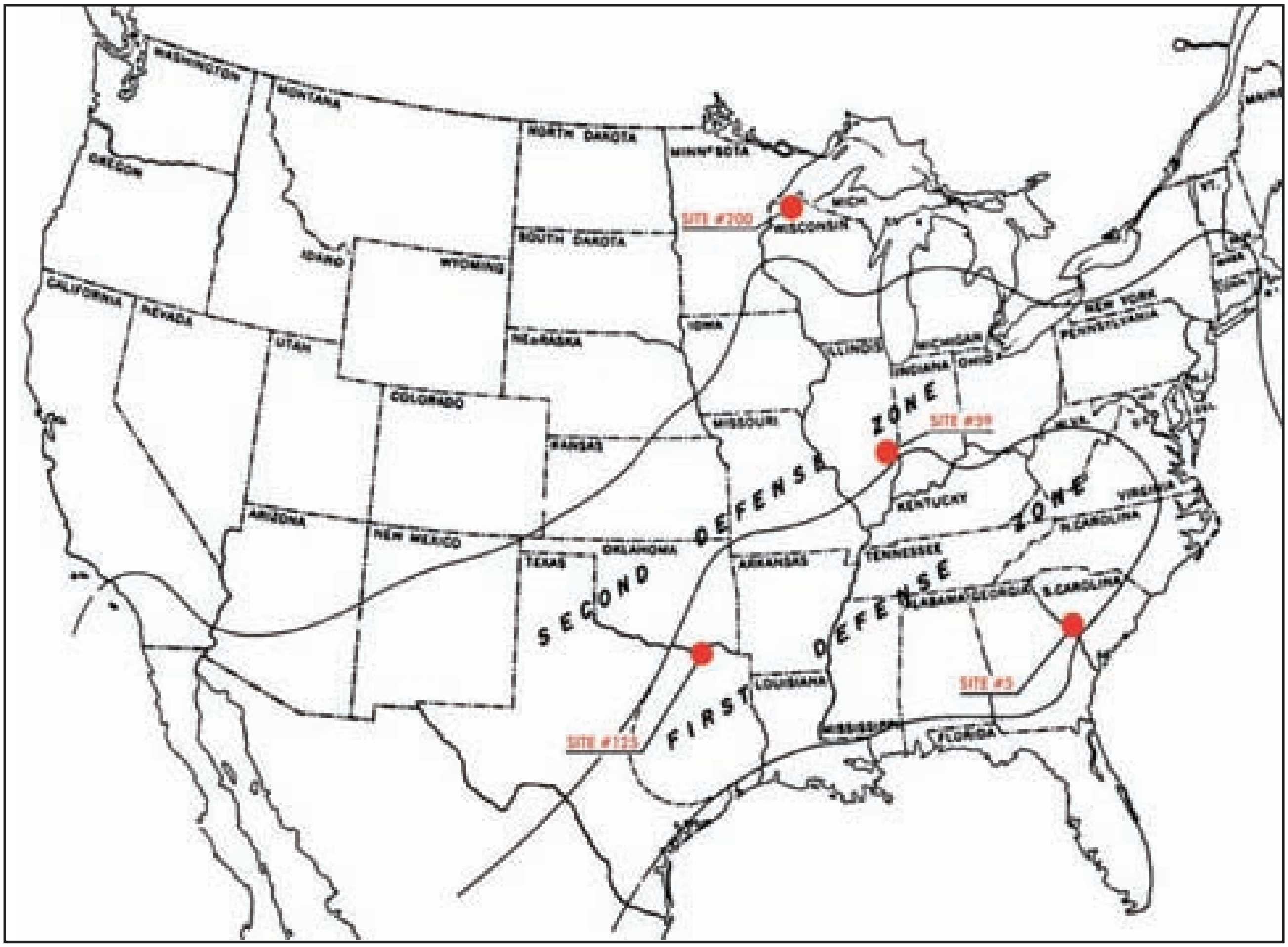
The AEC had first contacted the COE and asked them to prepare a list of sites including government-owned lands that might be suitable. This preliminary data was reviewed in the Cincinnati Corps Office of the Great Lakes Division but was found lacking in definition. The following methodology was agreed 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.

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.



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

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 Augusta Chronicle
$260,000,000 H-bomb material facilities will be constructed in S. C. near Augusta
Allies facing 'new war'
Plant means big boom for Augusta

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.

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.

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

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.

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.

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

Site Layout

SRP was originally organized into nine manufacturing areas, a central administration area, and two "service"-building 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, a cloverleaf that was the first 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.

Each area was given a number and a unique letter designation (Table 1). 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.

1956 Basic Information Map- General Areas.

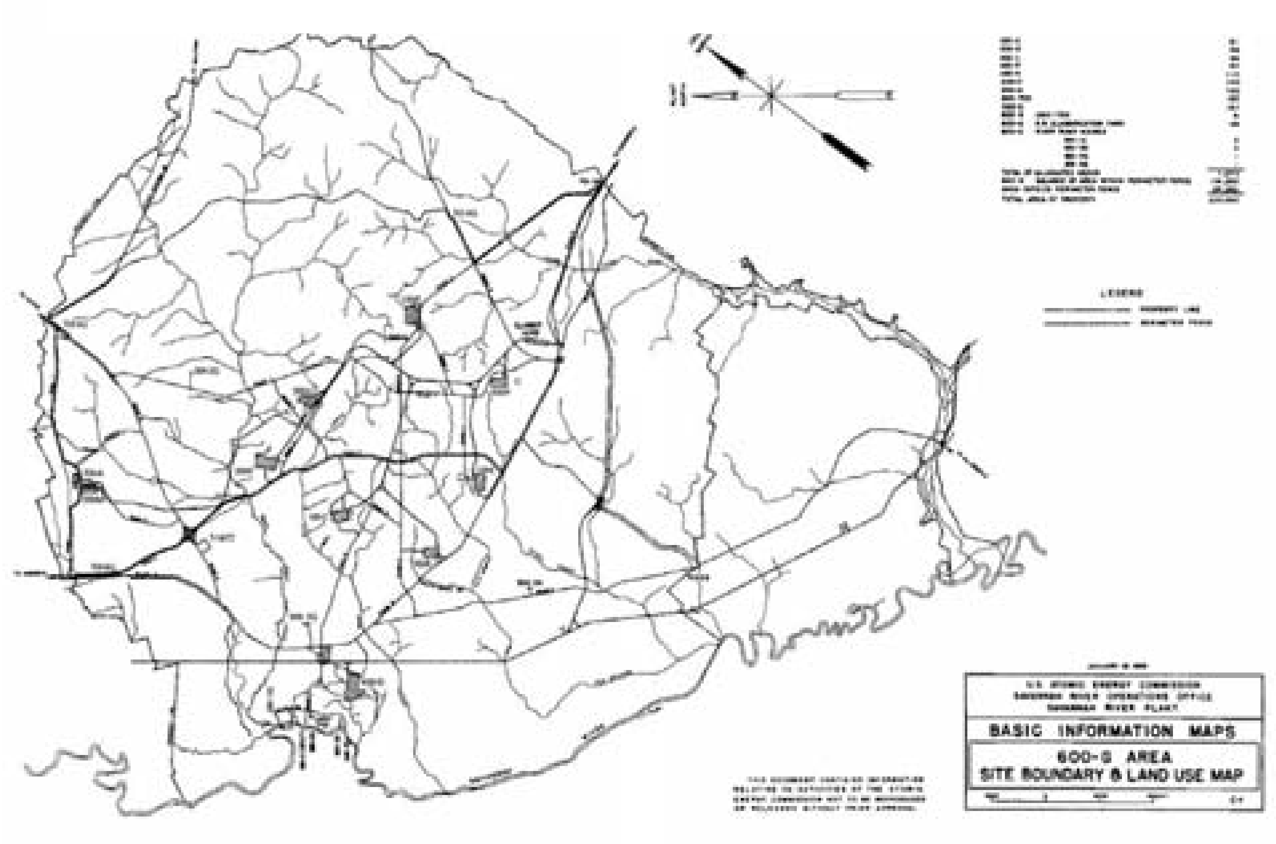


Table 1. Area Nomenclature

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

Each 100 area, 100-R, 100-P, 100-L, 100-K, and 100-C, was situated within the manufacturing core in the central part of the site, aligned in an arc. After considerable discussion, 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 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.

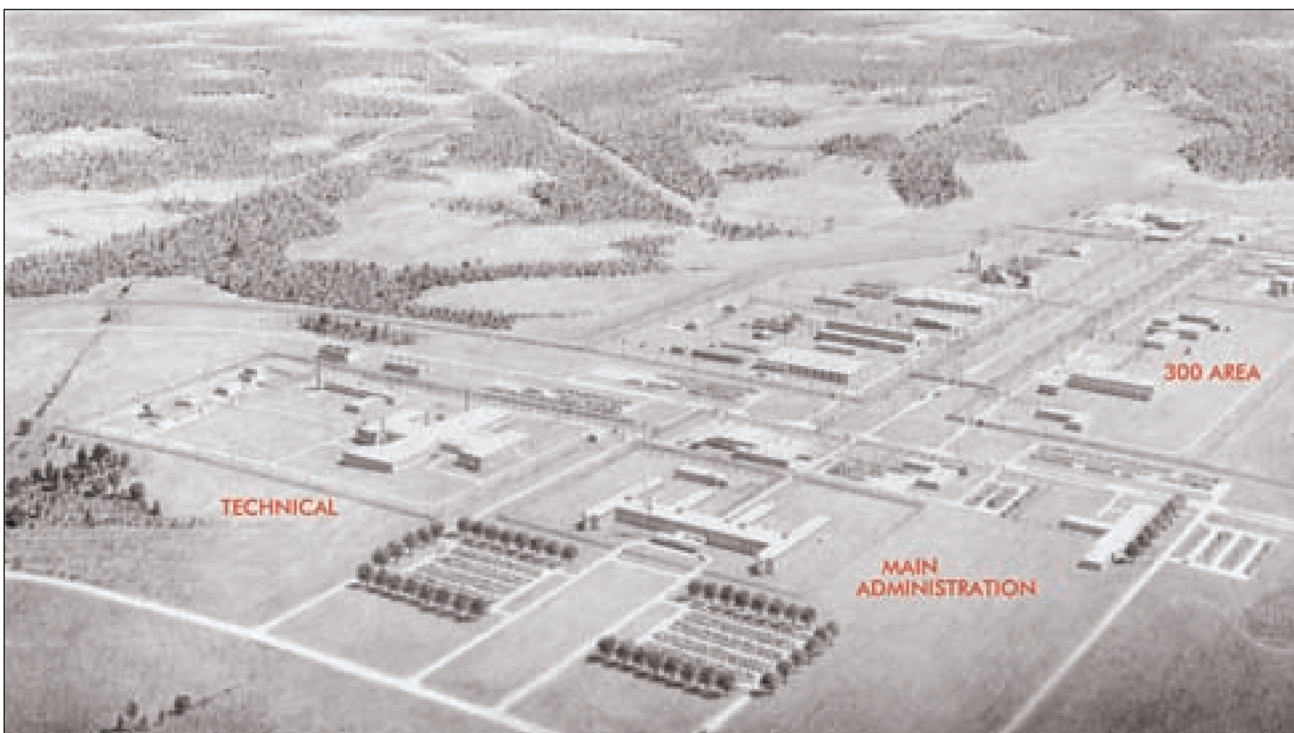
Nine coal-burning powerhouses located in the building areas supplied steam to the process areas and the overall site. The large pipes that carried the steam are above ground, arching over roadways where necessary and paralleling the road system. Outside the manufacturing and service building areas, general 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 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 aboveground 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 appealing 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.



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

Table 2. 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. This 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]

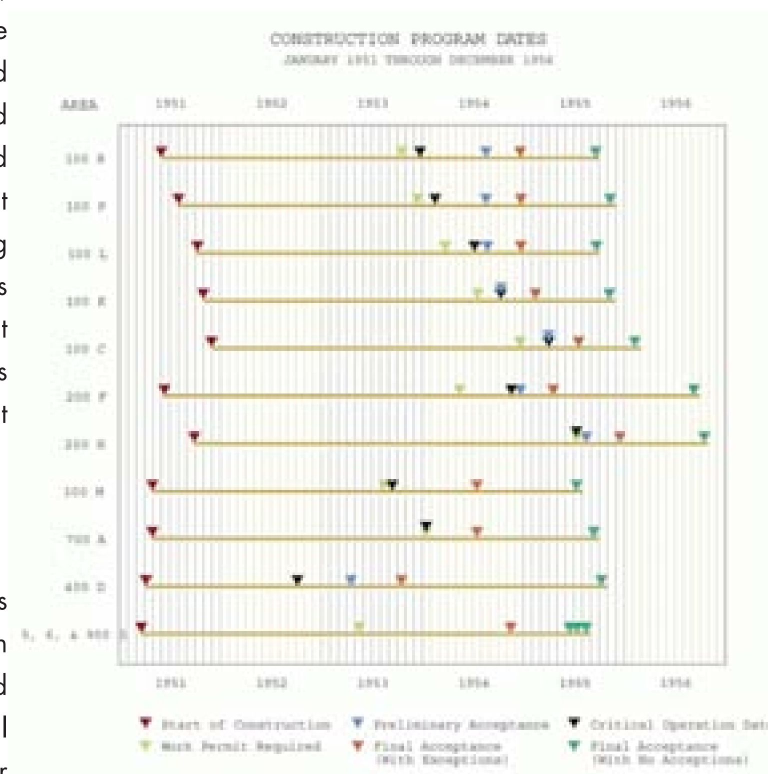
New York Shipbuilding - This firm was responsible for fabricating the five reactor vessels that were transported by barge to the South Carolina site. Known as the NYX Program, this effort produced the cover plate of the reactor vessels known as the "plenum" (a laminated steel plate 19 feet in diameter, 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 the standards of a later generation of nuclear engineers, 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 3. 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 (the 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, 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 the 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] This report provides a more detailed account of SRP's 300/M Area's genesis and operations history in the following chapters.

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 brought to criticality in December. 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 in 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 how the reactors operated and to the reactors themselves. 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, and tritium was produced as essentially a byproduct 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

Operations at the Savannah River Plant included two main types of separations: combined plutonium and 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 a building in the F Area, which started operating in October 1955, where the slugs were melted, instead of dissolved, to release the gaseous tritium. After melting, the tritium was purified by a process known as thermal diffusion. Tritium extraction was moved to its current location in H Area a few years later.[75]

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. Modifications to the H Canyon by applying lessons from early operations in F Canyon allowed H Area operations to see a throughput of seven tons per day.[76]

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.[77] 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.[78] 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.

The first tritium facility was located in Building 232-F. A 232 building was also constructed in the H Area, but it was not completed during the initial phase of construction. The H Area tritium building was outfitted for production in 1956, and by the end of the year two lines were operating. Tritium was originally shipped elsewhere for placement in the reservoirs, but by 1957 this was completed in Building 234-H. In August of the following year, tritium began being recycled in this facility as well. Tritium processing capacity in the H Area facilities was doubled in 1958, 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.[79]

Waste Management

In general, the waste facilities at Savannah River were modeled on those at Hanford but modified somewhat since the radioactivity of the high-level wastes 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 the F Area, and four in the 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]

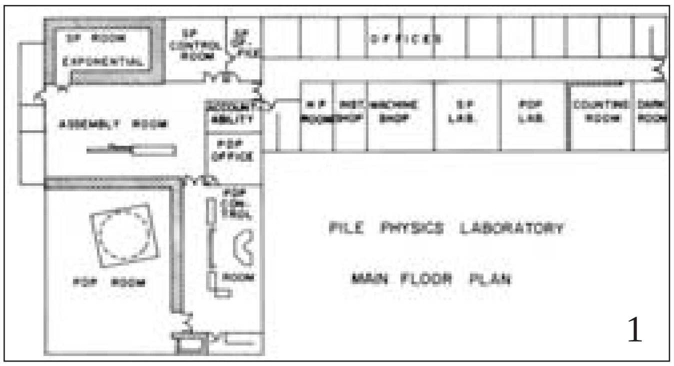
Four single-wall tanks for low-heat high-level wastes were constructed in the F Area in 1958, and four in the H Area in 1962. These tanks have caused numerous problems due to leakage through fine cracks caused by the reactions of the solutions stored there with the materials in the tank walls. However, 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 TRU solid wastes were buried in designated sections of the burial ground early on but, by the early 1980s, they were being stored on concrete pads in containers that allowed for later retrieval.[83]

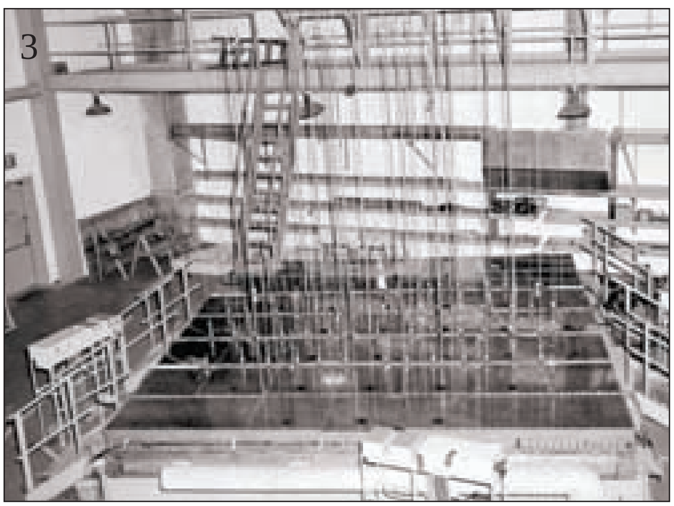
Research, Development, and Testing

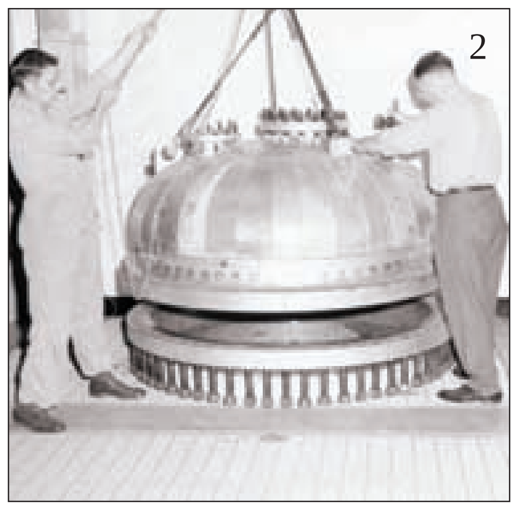
The scientists and researchers at the Savannah River Laboratory (SRL) were responsible for research and improvements in process design in support of SRP's operations. From the beginning, it was noted that neither heavy-water moderated reactors, nor the Purex process, had ever been operated on an industrial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

Savannah River's Test Reactors



1. Pile Physics Laboratory floor plan. This facility housed three test reactors used by SRL researchers. The reactors were placed under the high-hat area of the building. Courtesy of SRS Archives, negative DPSTF-83. 2. Pressurized Subcritical Experiment (SE) test reactor in Pile Physics Laboratory that was used to measure nuclear parameters at high pressures and high temperatures. When built, it was the first of its kind. Courtesy of SRS Archives. The Standard Pile (SP) was designed and constructed by the General Electric Company and was similar to the Thermal Test Reactor at Knolls Atomic Power Laboratory. (Not shown). 3. Fuel elements were placed in the Process Development Pile (PDP), a zero-power test reactor used for physics research. Courtesy of SRS Archives, negatives DPSTF 1-2613, 1-2536. 4. PDP control room. Courtesy of SRS Archives, negative DPSPF-8929-13.





People, Research and Development

5. Graphite Test Pile control room in 305-M. Courtesy of SRS Archives, negative 2023. 6. Face of Graphite Test Pile, Courtesy of SRS Archives, negative 38887-1. 7. Interior of Heavy Water Components Test Reactor. Courtesy of SRS Archives, negative DPSTF-6027. 8. Aerial of Heavy Water Components Test Reactor (HWCTR). This test reactor facility was decommissioned in 1997. Courtesy of SRS Archives, negative 7885-G.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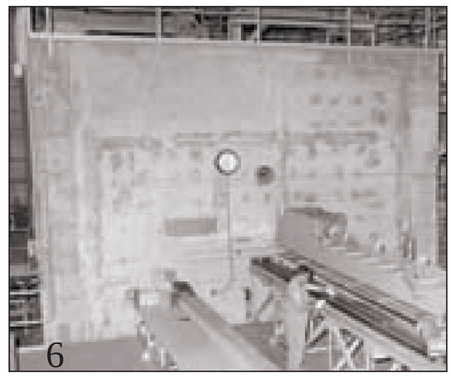
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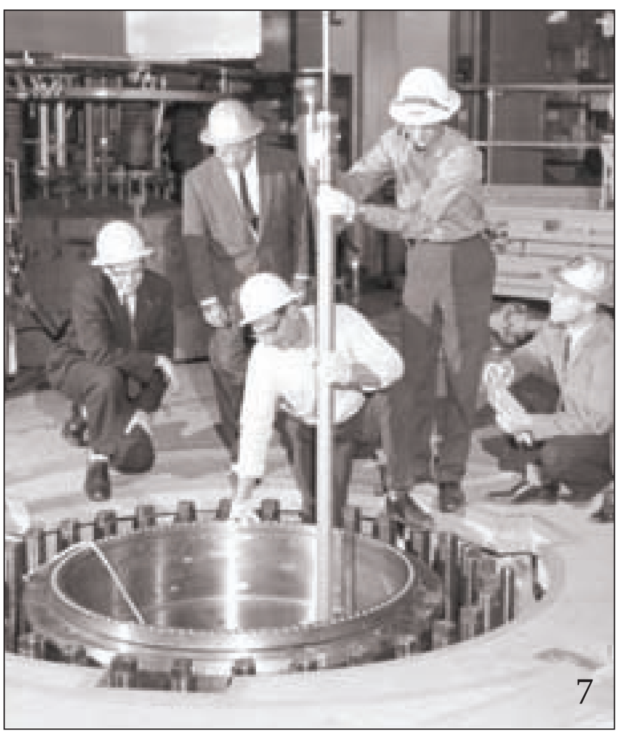
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the versatility of the reactors called for the development of new fuel and target elements. The need to explore the safety and process issues involved called for the installation of laboratory facilities that were fully equipped to allow research and 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 conduct 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.

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.

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.

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.

"When we started using these reactors down here, the commercial nuclear business hadn't been invented yet. We had five reactors going—and commercial power reactors were just a gleam in the scientist's eye. So everything we did was pioneering—there was no real road map for us."

- Gerry Merz

Source: "Reacting to Change," *The Augusta Chronicle*, November 6, 2000.

(Above) Aerial View of P Reactor, 1989. Courtesy of SRS Archives, negative 89-2074-7

(Right) Detailed Aerial View of P Reactor.

(Below) At the close of the decade all five of Savannah River's reactors were shut down. P Reactor had earned the designation of "World's Safest Production Reactor" with its impeccable safety record spanning almost three decades.

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.

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

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]

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

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 form a national and complex-wide perspective to provide background for the narrative that follows. The next chapters deal specifically with the history of one of the processes mentioned, fuel and target fabrication at SRP, beginning with the evolution of the technology.

III. FIRST EXPLORATIONS

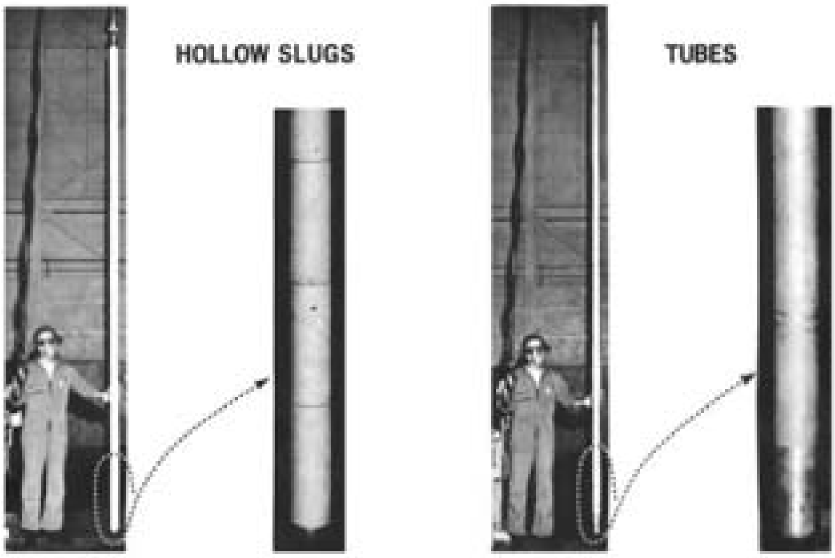
Two basic forms of materials for irradiation in reactors were fabricated during the Cold War – solid slugs (rods) and tubes. Both were fabricated at SRP. As the name suggests, slugs were cylindrical columns of uranium. Both slugs and tubes were combined into assemblies or groupings for insertion into the reactor. Slugs were placed side by side and tubes were nested inside each other. The SRP operations personnel produced slugs and tubes that converted uranium, other elements and alloys to metal then produced the shape desired for the reactor assemblies. The basic fuel at Savannah River was uranium-235. Uranium-238, that would be converted into plutonium, and lithium-6 for tritium production were the basic targets.

Savannah River's reactors primarily made plutonium and tritium. To do so, they required a combination of fissionable material to provide the neutrons or the "fuel," and fertile material to serve as "targets." Combinations of fuels and targets, known as fuel assemblies, were produced in the 300/M Area by foundry and machine shop operations using uranium feed material. Simply said, fuel assemblies are engineered groups of fuels and targets that contain materials capable of fission. Savannah River scientists would develop more than 83 fuel assemblies by 1972 in pursuit of high-performance fuel elements particularly over the first twenty years of operation.[1] Despite that number, only a select few became plant workhorses capable of producing the neutrons needed to irradiate the target materials that would then be transformed into plutonium, tritium or special isotopes in the plant's production reactors. The technological basis that allowed the creation of those "workhorse assemblies" derived from a World War II context. This chapter explores that context to ground the discussion of the later Cold War technology.

EVOLUTION OF A TECHNOLOGY

Solid Slugs

When SRP's R reactor went critical in 1953, it was charged with fuels and targets that echoed Hanford's technology. Cylinders of aluminum-clad natural uranium metal about 1" in diameter and 8" in length were placed end to end in a quatrefoil, a tube about 14' long containing four interior columns in which the slugs were inserted. Hundreds of quatrefoil assemblies, placed vertically in the reactor vessel and held in place by a lattice or grid, compelled heavy water past the slugs. Antiquated but adequate, this technology would be replaced by fuel assemblies designed by SRP's scientists and engineers to successfully function at higher power levels. Between 1950 and 1975, research and development occurred that led from solid slugs to hollow slugs to large diameter tubes as fuel and target design strove to achieve higher performance values and in particular



Hollow Slugs and Tubes

Reactor assemblies are circular in crosssection, about 4 inches in diameter, and about 14 feet long. The example on the left is a fuel assembly consisting of several tubes nested in concentric circles. The one on the right consists of a column of slugs stacked in an internal aluminum housing tube weighing several hundred pounds.

greater heat transfer surface which translated into higher reactor power levels. The starting place for this evolution is the Manhattan Project and Hanford.

Accounts of developing technologies with shared objectives often in competition with each other occurring within a secret context in a time of world conflict make for compelling history. While certain processes should and do hold central stage in Manhattan Project history such as pile or reactor design or chemical separation processes, the beginning place is uranium and its conversion from ore for use as a nuclear fuel. Finding the threads of that part of the storyline is challenging. When Savannah River began operation, it received uranium feed materials from Fernald where the purification of uranium was the first step of many involved with preparing uranium for use as a nuclear fuel. Uranium feed material is purified and formed uranium metal that has been machined to exact specifications. The antecedent processes involved in the purification and the conversion of the oxide into uranium metal were incrementally developed at disparate locations both in academic and corporate environments in the early 1940s as was the engineering involved with slug manufacture and reactor design. During the Manhattan Project era, gaseous diffusion was chosen as a method for this separation. The process required the construction of enormous structures in which gaseous uranium was driven at specific temperatures through miles of filters that gradually collected uranium-235 atoms in increasing concentrations. Referred to as "uranium enrichment," Oak Ridge possessed the first plant and plants at Fernald, Ohio, and Paducah, Kentucky, later followed.

Reactor Assemblies for Irradiation in SRP Reactors and Reactor Profile Showing Reactor Vessel.

BASIC CONCEPTS

A nuclear bomb requires fissionable material, and production reactors make fissionable materials from "fertile" materials through nuclear bombardment. The three basic fertile materials are thorium-232, uranium-238, and plutonium-240. The first two are found in nature; the third is artificial. Thorium can be bombarded to produce uranium-233, uranium-238 can be bombarded to make plutonium-239, and plutonium-240 will yield plutonium-241. Lithium-6 is a fertile material used for the production of tritium.

Not all uranium atoms are the same. When uranium is mined, it consists of heavy atoms (about 99.3 percent of the mass), middleweight atoms (0.7 percent) and lightweight atoms (< 0.01 percent). These are the different "isotopes" of uranium, which means that while they all contain 92 protons in the atom's center (which is what makes it uranium), the heaviest atoms contain 146 neutrons, the middleweight atoms contain 143 neutrons, and the lightweight have just 142 neutrons. To refer to these isotopes, scientists add the number of protons and neutrons together and then attach that total on the back of the name: uranium-234, uranium-235, and uranium-238.

As a rule, fissionable material is limited to uranium-233, uranium-235, plutonium-239, and plutonium-241. Of this group, only uranium-235 exists in nature and it is difficult to isolate. Ninety-nine percent of the atoms in uranium possess an atomic weight of 238; the remaining 1 percent has a weight of 235. This small percentage needs to be isolated in sufficient quantities to generate a chain reaction.

Tritium is a critical component in the construction of thermonuclear weapons. An isotope of hydrogen that appears rarely in nature, it had to be produced through irradiation of lithium in nuclear production reactors. The isotopes of hydrogen are protium, deuterium, and tritium. The nuclei of these isotopes contain one proton and either zero (protium), one (deuterium) or two (tritium) protons. All three of the isotopes exist in nature, but most of the existing tritium has been prepared artificially through nuclear reactions such as:

$$_{3}Li^{6} + {}_{0}n^{1} = {}_{1}H^{3} + {}_{2}He^{4}.$$

This reaction, which depicts the lithium isotope of mass six absorbing a neutron (mass one) and decaying into tritium (mass three) and helium (mass four) atoms, was the basis for tritium production at SRP. Tritium produced at SRP was mixed with deuterium for use in a nuclear weapon. Such tritium-deuterium mixtures are used to boost the yield of nuclear weapons through thermonuclear reaction that can produce over four million times as great as the amount of energy released by chemical reactions. Tritium must be handled carefully at all stages of its production and use as it undergoes radioactive decay by emission of a Beta particle (an electron) and conversion to a helium atom of mass three.

Source: M. R. (Mac) Louthan, Jr. "Aluminum-Lithium Technology and Savannah River's Contribution to Understanding Hydrogen Effects in Metal," in Proceedings of the Symposium *50 Years of Excellence in Science and Engineering at the Savannah Rover Site*. Prepared for the US Department of Energy under Contract No. DE-AC09-96SR18500, Westinghouse Savannah River Company, 2000, 31-32.

Enriching uranium increases the amount of "middle-weight" uranium atoms. The fuel for nuclear reactors has to have a higher concentration of uranium-235 than exists in natural uranium ore. This is because uranium-235 is the key ingredient that starts a nuclear reactor and keeps it going. Normally, the amount of the uranium-235 isotope is enriched from 0.7 percent of the uranium mass up to about 5 percent.[2]

Highly enriched uranium, defined as having more than 20 percent uranium-235 and typically more than 90 percent, is used in nuclear weapons. Low-enriched uranium, consisting of less than 20 percent uranium-235, is used as fuel for nuclear reactors. Uranium-238, which is removed during the enrichment process, is referred to as depleted uranium. Depleted uranium is used to make plutonium. The uranium-235 in the nuclear fuel of a production reactor provides the chain reaction while the uranium-238 in the fuel captures neutrons to produce plutonium. Irradiated materials rich in the isotope plutonium-239 are considered "weapons grade" and they are later separated chemically from other materials for use.

EMERGING TECHNOLOGY - PURIFICATION AND CONVERSION TO URANIUM METAL

In its pure form, uranium is a heavy silver-colored metal. Described as malleable and softer than steel, it is more dense than lead and vulnerable to surface oxidation and water particularly at high temperatures.[3] Uranium possesses several chemical forms but it is most commonly found as an oxide typically in pitchblende. This is the chemical form most often used for nuclear fuel. A bright yellow granular solid material known as "yellow cake," uranium oxide was chemically processed from uranium ore.

The process begins at the earth's crust from which uranium mineral ore is extracted. By definition, the mineral has to have the physical and chemical attributes that distinguish uranium and must be found in sufficient concentrations that it can be profitably extracted either solely or with other minerals. Uranium is the major component (between 50 and 80 percent) in pitchblende and uraninite and to a lesser extent in carnotite, torbernite, tyuyamunite, autunite, uranophane, and brannerite. Typically, minerals that contain uranium possess only a small amount and the degree of purity varies. Thus identifying promising ore deposits is challenging. Once identified, the ores and the concentrates are sampled and tested to assay purity and to identify the other accessory minerals present within the ore.

Uranium processing at Fernald involved a series of unified manufacturing plants that housed related processes in an assembly-line fashion. Fernald's predecessor "plants" during the Manhattan Project were geographically distant and of all shapes and sizes. A rooftop in New Jersey served as a laboratory as did a small corporate lab in Massachusetts that specialized in producing powdered metal alloys, and the Bureau of Standards in Washington. Early experiments in these locations on uranium materials were fruitful but the techniques involved could not be used confidently to produce a uranium powder that would not ignite when exposed to air or pure ingots of uranium. As a consequence, scientific attention turned to uranium oxide as a first step toward developing a process to convert uranium into uranium metal.[4]

In January 1942, uranium oxide was available in storage in New York and also for purchase at the Eldorado Gold Mines on the north shore of Lake Ontario and its mines near the Arctic Circle.[5] The available supply of raw material at that point was commercial grade black uranium oxide that was in sore need of purification if it was to be used in the endeavor at hand. And tons, specifically 250 tons, of oxide were needed annually to operate a plant producing one kilogram of uranium-235 per day.

How to purify uranium oxide was solved through existing chemical knowledge and experiments completed at the National Bureau of Standards which showed that the crude oxide dissolved in nitric acid formed uranyl nitrate which could then be dissolved in ether with all the impurities left behind. The uranium would be recovered, concentrated, and then reduced to uranium dioxide. The problem was producing uranium dioxide on an industrial scale. Mallinckrodt Chemical Company in St. Louis met this challenge by the summer of 1942 producing what was needed to produce uranium metal or hexafluoride used for uranium enrichment.[6]

Making uranium metal was another story. Only a small amount of uranium metal meeting nuclear requirements was produced in the United States prior to 1941. Westinghouse Electric and Manufacturing Company's Lamp Division had produced this using an experimental technique that required a photochemical reaction of the uranium oxide with potassium fluoride produced by sunlight. To accomplish this, their operations were situated on the company's roof in Bloomfield, New Jersey. They were successful in slowly and expensively producing uranium metal with good purity but only in grams. Tons were needed.[7]

A second source of metal was available through a process credited to Peter P. Alexander of Metal Hydrides Company. While pounds of uranium metal were produced by reacting uranium oxide with calcium hydride using this method, it delivered highly impure pyrophoric powder. One source notes that it was so capable of igniting that special precautions were used to remove the powder from the reduction furnaces and that refrigeration was necessary as the powder would become red hot even when packed in metal cans.[8] The melting and casting of the powder was equally problematic. Enter Frank A. Spedding of the Iowa State College in Ames and the Ames Project where a branch of the Metallurgical Laboratory was established.

The Ames group developed a cost effective process for producing pure uranium that could be cast into large ingots. The process, known since 1926 and which produced metal initially in solid form rather than powder, needed calcium metal and good-quality tetrafluoride to work. As tetrafluoride was under production at two Manhattan Project plants and high-purity calcium was made at Metal Hydrides, the needed ingredients were now available and the Ames Project staff made use of them producing a ton a month of uranium metal by September 1942 at the Ames laboratory.[9] They would later substitute magnesium reduction for calcium for more effective conversion and to lower costs. Successful, the Ames group produced "biscuits" of uranium metal, weighing between 40 and 125 pounds which were then melted and cast into ingots about four inches in diameter and 13 inches long.[10] Industrial scale development followed their success. By the close of 1942, contracts had been let for uranium metal production to Mallinckrodt Chemical Works, the Union Carbide Corporation, and the Du Pont Company using the process technology worked out above at Ames.[11]

SLUG DEVELOPMENT

While the production of uranium metal was developing, pile or reactor design was on the fast track. The general shape of the uranium fuel to be inserted into the piles under development began with a consideration of layers, then lumps, then "pipes." Foremost, the uranium needed protection in the pile from corrosion from the surrounding reactor coolant and conversely, the coolant needed to be safe from contamination. Reactor design at the Met Lab in Chicago at this juncture called for a cylinder of graphite with horizontal aluminum tubes containing the fuel running parallel to the axis. The uranium slugs were to be sealed in aluminum cans with a small enough diameter that they could be surrounded by cooling water the flow of which was controlled on the exterior of the reactor.

An atomic energy history aptly notes that if Fermi and Seaborg were the discoverers of the new world of nuclear energy, engineers working with the Technical Division at the Metallurgical Laboratory in Chicago were its first explorers.[12] The engineers were required to meet the overall project requirements – creating complex machinery and equipment that would prove reliable under extreme operation conditions on a large scale – as well as challenges such as overcoming corrosion, fabricating metals, purifying metals, building special equipment, tools etc. Added to this responsibility was a unique challenge to "know the effect of radiation on corrosion rates, on the properties of metals, on chemical reactions, on instruments and other equipment, and on man.[13]

Given the ground that needed to be covered, engineering for the fabrication of uranium metal into slugs, the canning of slugs, and the design of aluminum tubes was parceled out to a wide ranging committee of institutions and companies including: Iowa State College, the Battelle Memorial Institute, the Bureau of Mines, the Grasseli Chemicals Department of Du Pont, Westinghouse, and the University of Wisconsin. Richard L. Doan, chief administrator of the Metallurgical Project, headed the committee. While this committee worked, construction on the X-10 project proceeded at Oak Ridge. Du Pont was the designer/builder of an air-cooled experimental pile, the chemical separations pilot plant, and supporting laboratory facilities (see previous chapter for illustration). Construction began in 1943 just as the Hanford site was selected.

The possible methods for protecting the uranium slugs were to spray, coat, dip, or can the slugs. The experimental pile under construction at Oak Ridge was air-cooled which gave everyone some breathing room and a number of technological courses of inquiry were put into play. Grasseli Chemicals in Cleveland was assigned research on the hot-dip approach. Aluminum Company of America (ALCOA) worked on canning. The latter had more promise even though rigorous testing showed that no more than 50 percent manufactured were considered satisfactory for use. Specifically, the weld between the can and the end cap was predominantly responsible for the failure and engineers at the Met Lab were consulted to correct the welding issue. At this point there was no bond between the slug and the can. The air-cooled technology used at Oak Ridge in the X-10 that allowed for the use of unbonded slugs gave the engineers some time but the startup of Hanford's full- scale production reactors was imminent and sufficient slugs were needed.

Considered a crisis by all involved, parallel lines of research developed but the approach that involved the use of an aluminum-silicon alloy (Al-Si) as the bonding agent between the slug and its can and the inclusion of a zinc bond in a special canning technique caught Du Pont's Crawford Greenewalt's attention. While he recognized the problems inherent in bonding, he felt the advantages were worth the trouble. Specifically, the bond on the slug would further heat transfer and it would also safeguard the uranium from corrosion and swelling if the can did leak. The completion of the construction of the 300 Area at Hanford, which included slug fabrication facilities, a low-power pile, technical laboratory, instrument shops and a semiworks, allowed Du Pont to begin experimental canning operations.

> The development line consisted of little more than a series of open tanks in which scores of operators dipped clusters of machined slugs. Starting with a series of degreasing and pickling baths to remove dirt and oxidation, the slugs were successfully dipped into molten bronze, tin and Al-Si. Since the temperature, composition, and duration of each dip were extremely critical, the operators had great difficulty in achieving uniform results or detecting faulty slugs. After the final dip, the slugs were forced into the aluminum cans with hydraulic presses, a tricky process which produced a large number of rejects. The next step involved end trimming and the complicated task of arc welding the aluminum can in an argon atmosphere. Completely a manual operation, the welding step required weeks of training to achieve reasonable results. When the end had been faced and machined, the slugs were subjected to a series of tests to detect weld failures, pinholes, or lack of bond uniformity.[14]

Hanford's 300/M Area work force could produce three to four slugs a day working double shifts. A two-week yield of 36 substandard slugs did not assuage the doubts of all involved that knew tens of thousands were needed to charge the first production reactor. Du Pont could either lower standards or order an emergency charge of unbonded slugs which many scientists already advocated using. Neither path was taken. Du Pont essentially stayed the course. As experience grew and with the addition of personnel and dipping lines, slug production accelerated using the method described above and Hanford employees were able to meet the needed number of slugs to charge the first reactor and play its historic role in ending World War II. Hanford has completed a history of its 300 Area detailing its operations that shows workers conditions, significant events, etc.[15]

The development of equipment and machinery to achieve the same products in the 1950s at SRP is a different story with an eastern seaboard setting, Du Pont as the storyteller, and a host of other firms eager to participate in the atomic energy field playing major roles. Eight years later at the onset of the Cold War, the preparation of uranium feed materials would begin at a new location and in a different technological environment. While fuel element technology at startup would mimic Hanford technology, it changed by the late 1950s as production requirements, costs and performance needs changed.

SRP MANAGEMENT STRUCTURE - AEC AND DU PONT

SRP, a product of the AEC expansion in response to the Cold War, would be shaped by the Hanford experience. But other factors such as the presence of a growing AEC weapons complex as well as advances in reactor technology made for critical changes. The AEC's primary purpose was the development and production of nuclear and thermonuclear weapons, and as its secondary purpose the promotion of peaceful uses of atomic energy. The government arm of that effort was extended to Savannah River in the form of the Savannah River Operations Office, the AEC's operations office that had jurisdiction over Savannah River.

The overall goals of the AEC and the weapons and peaceful programs related to nuclear energy in the United States were established in Washington at the AEC headquarters. The AEC headquarters staff could be divided into two groups: program directors in charge of the various commission projects and management directors in charge of administration. The general manager, through assistant general managers and the commission division directors, carried out policies. The major divisions within the commission were Production, Research, Reactor Development, Contracts, Construction, Safety, Raw Materials, Isotope Development, Nuclear Education and Training, Biology and Medicine, Licensing and Regulation, and International Affairs. The policies, programs, and oversight functions of the headquarters were carried out through the major field offices, called "operations offices." Each operations office was a complete organizational unit with responsibility for the business and technical aspects of the programs under its jurisdiction. These operations offices—originally located at Los Alamos, Oak Ridge, New York, Chicago, and Hanford—were given authority to hire and fire their own personnel and to set their own means of meeting commission objectives.[16]

The Savannah River Operations Office was established in early 1951. The field office was ultimately under the authority of the AEC's director of production, the local focus of responsibility being the manager of operations. This operations manager was charged with overseeing the production of fissionable and special materials, as well as fabricated items (such as the plutonium warhead pits originally planned to be produced at Savannah River); oversight of engineering and construction program administration; supervision of the Dana Area Office in Indiana; and the approval of purchases and contracts, with the further approval of the director of production for those valued over five million dollars. The operations office geographical area of responsibility included not only the Savannah River production facility, but also general assignments for Atomic Energy Commission programs in South Carolina, North Carolina, Georgia, Florida, Alabama, and in the Former Panama Canal Zone. These responsibilities primarily included monitoring and coordinating with off-plant persons and organizations in issues related to atomic energy and radiation control and research, and providing public information.

DU PONT MANAGEMENT AND DEPARTMENTS

Initial Du Pont management of its operations at Savannah River was derived from its commercial operations and its recent wartime experiences. As stated in the contract covering Du Pont's involvement at Savannah River, the company had very nearly full control of site management. Du Pont took the stance that the functions of the AEC, and its oversight arm of the Savannah River Operations Office, as far as the operation of the plant was concerned, were limited to setting production goals; coordinating efforts in the national complex; ensuring the quality, safety, and accountability of products and operations; and auditing expenditures.

Du Pont management extended from the company headquarters in Wilmington, Delaware, through the Atomic Energy Division of the Explosives Department, established as soon as Du Pont agreed to take on the Savannah River project. Construction was managed under two departments, the Explosives and the Engineering departments, with the assistance of auxiliary departments such as Legal and Purchasing. The Explosives Department had primary responsibility—it defined the scope of work and developed process specifications—and Engineering acted as the architect–engineer. The Design Division of the Engineering Department handled all in-house design work; all final designs had to be approved by the Explosives Department, whether those designs were developed in-house or subcontracted. Once plans were approved, Engineering's Construction Division took on the construction. Completed facilities were turned over to the Explosives Department for operation.

The Construction Division, under the direction of the Du Pont Engineering Department, was formed during operations. This division, based in Central Shops, was responsible for changes and improvements to the facilities and for new construction. Their ranks included field project managers, engineers, and superintendents for most of the major crafts groups such as ironworkers, pipe fitters, layout, electrical, sheet metal, and carpentry. Employee relation's superintendents were part of the force, as was a physician, cost and evaluation personnel and individuals with expertise in instrumentation. Construction also had resident subcontractors who were specialists in piping, electrical work, insulation and testing and inspection of completed works.

The head of the Atomic Energy Division was ultimately responsible for the company's management of Savannah River. Under the division head were three managers over functionally divided Technical (originally Research), Manufacturing (originally Production), and Control divisions. The Technical Division during the design and construction phase was responsible for development of the operations facilities and their equipment. Wilmington's Manufacturing Division was responsible for the operation, maintenance, and security of Savannah River overall; for assuring that design, construction, and modifications were carried out effectively and as necessary; and for safety and quality in general. The most important section of the Manufacturing Division was Process. The Process Section coordinated work with Du Pont's Engineering Department, analyzed Technical Division information and prepared it for use in production, worked closely with the Works Technical and Works Engineering at Savannah River to overcome problems and make improvements, and helped with the budgeting and coordination of major activities. The Process Section also acted as liaison between South Carolina operations and the Atomic Energy Commission and its other contractors concerning engineering and process matters.

Under the Savannah River Plant organization, the Works Technical Department served very important functions assuring continued safe and efficient operations. There was a department for each major manufacturing activity at Savannah River, and departments for overall concerns such as the Health Physics, Analytical, and Equipment Engineering Divisions of the Works Technical Department. Works Technical provided guidance for operations, initiated and followed facility improvement tests, evaluated results, and very importantly served as the channel through which production requested assistance from the laboratory and worked with the laboratory to translate research and development efforts there to plant operations. Works Technical also prepared Test Authorizations and Reactor Startup Authorizations, which were formal notifications granting permission to begin operations activities according to normal practices or deviating from normal practices. Of great importance to the site in all areas was the Health Physics Department, which was responsible for monitoring contamination and potential contamination both within the site boundaries and in the wider region.

The Production Departments, as the name implies, were responsible for operations in the various plant areas in accordance with the technical standards developed by the Wilmington Technical Division.

Works Engineering embraced the following departments: the Power Department, the Maintenance Department, and the Project Department. The Wilmington Technical Division was responsible for new products and processes, of information between the laboratory, other AEC sites, and the sections in the Manufacturing Division. The Technical Division also served as a channel for communications between field operations and Du Pont's Wilmington auxiliary departments and the Executive Committee.

At Savannah River, the laboratory organization was initially divided into three broad functional divisions associated with general physics, the reactors, and separations. In general, the laboratory was responsible for most development work, the testing of process modifications, maintaining the plant's technical standards, and approving test authorizations. The Physics Section dealt with broad theoretical, experimental, and criticality data, including the assessment of new reactor loadings. The Engineering and Materials Section developed and evaluated designs and fabrication techniques for reactor assemblies and their constituent components. Separations and Services operated the laboratory facilities and made improvements to chemical separations processes and equipment.[17]

SUMMARY

Du Pont, the builder/operator of the Manhattan Project plants at Oak Ridge and at Hanford, re-entered the atomic energy field to design, build, and operate the new plant in South Carolina. Once again, the Wilmington firm was immersed in how best to fabricate feed materials that best suited the newly defined production needs of the country and that represented best practice in the industry in terms of efficiency and cost effectiveness. With alacrity, Du Pont sent future operations personnel to Argonne and Oak Ridge National Laboratories and in addition sent a small group to Hanford for a six-week stint to observe the canning process.[18]

Du Pont also entered into sub contracts with firms that complemented their core skills, added to their expertise, and their labor force. Voorhees Walker Foley and Smith (VWF&S), an architectural and engineering firm, subcontracted with Du Pont for building design and area layout. They created the building envelopes that housed the nuclear processes, defined the building areas, and the site's overall layout and context. The establishment and construction of 300/M is the focus of the following chapter.

IV. 300/M CONSTRUCTION

New York based Voorhees, Walker, Foley & Smith (VWF&S) was chosen as the plant's architectural and engineering firm for its experience in industrial architecture particularly laboratory design and possibly for its work in the early 1940s when they renovated Columbia University's laboratories for atomic energy research. Perry Coke Smith was the firm's lead architect on the SRP project.[1]

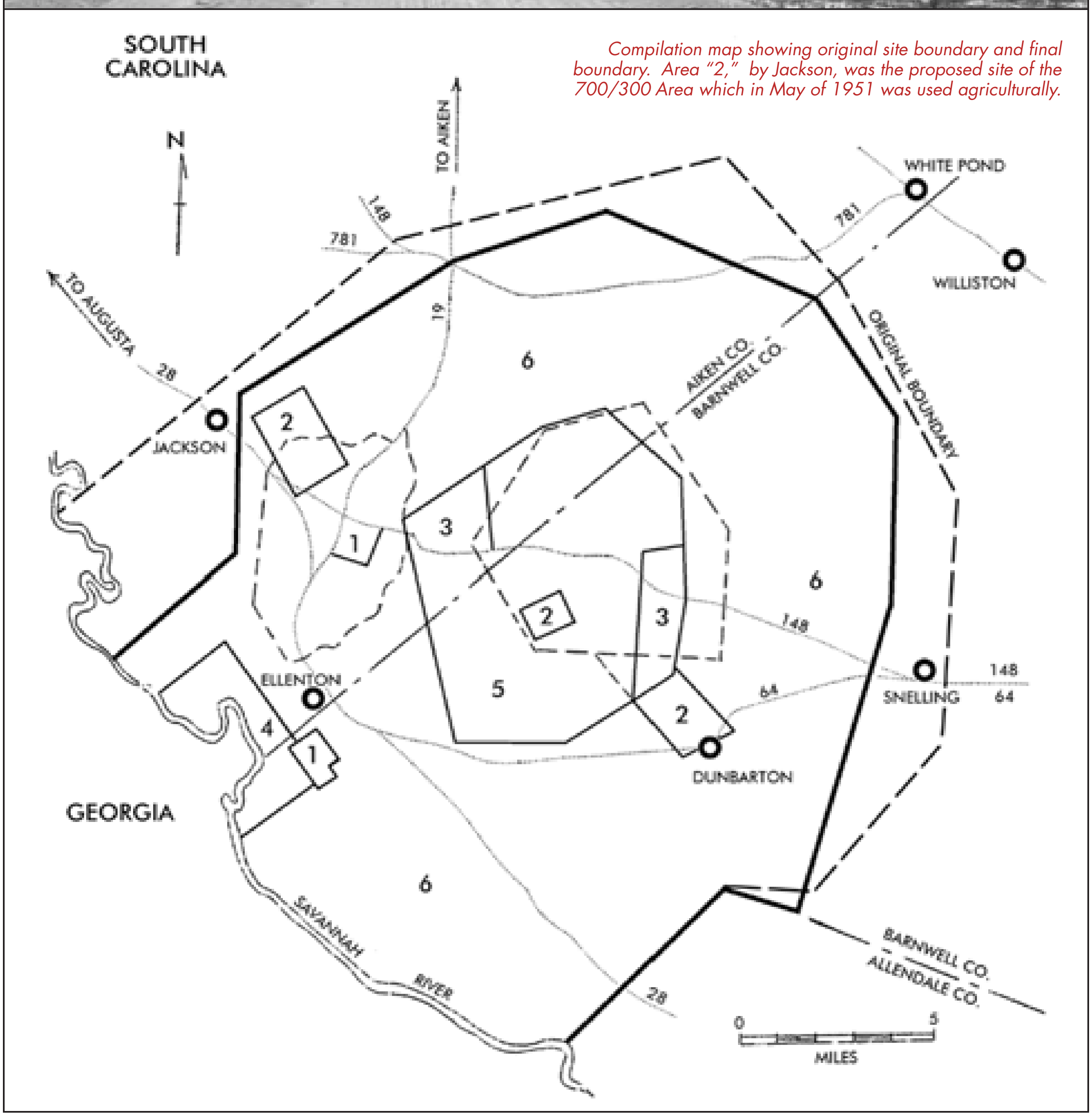
300-M AREA DESIGN AND LAYOUT

> Dutcher and McCullin visited J. Tinker's office to discuss 300-700 area layout. After explaining reasons for our layout as shown, in detail, Tinker gave final approval in the presence of Swertsfeger, of A.E.D. and Petrescu of Design. We are now ready to do some real work in this area.[2]

Prior to this triumphant entry in A.J. McCullin's work diary placed on March 13, 1951, Du Pont's civil engineers and Voorhees, Walker, Foley, and Smith civil engineers had worked hard but unsuccessfully to identify a location for the future fuel and target fabrication area. Early discussions on plant layout indicate that the 300-M Area was first conceived as a separate building area complete with its own powerhouse and service buildings. However, economics prevailed and the 300 and 700 areas were conceptually united so as to take financial advantage of mutual power and service facilities and to afford the new fuel and target fabrication facilities some proximity to the main laboratory that was to be part of the 700 area. McCullin's diary shows that the conceptual joining of the two areas was established in early December of 1950, shortly after the plant announcement. Working out the many concerns to make this a reality, however, took three additional months of effort.

Beginning logic placed the 700-A Area at the intersection of Highway 19 from Aiken and then Highway 781 from Augusta. This corresponds to the current entry to SRS at Highway 19 at Barricade 2. This locale changed when design criteria, specifically that the joined areas should be equidistant from Augusta and Aiken to accommodate the workforce, particularly the administrative jobholders, was invoked. Safety, a second design criteria for the location of the area, necessitated the establishment of certain safety distances. 305-M, a major facility within the area, would house a graphite test pile or reactor. Reactor safety distances required that the 300-M Area be located 5 miles distant from the nearest reactor area and that the test reactor in M Area be located 2 miles from the plant boundary.[3] Other layout concerns proved challenging. For example, the future location of the joined areas at the proposed plant's northern reaches was tied to property acquisition and the stabilization of the plant's boundary was still fluid in early 1951. This further complicated the layout task.

A draft general layout was completed by the end of February for 300-M Area. The Site Boundary Layout, Savannah River Plant Map 3304 completed in January 1951 shows the proposed building area location .5 miles east and parallel to then Highway 147 (later renumbered Highway 125) and approximately 1.25 miles from the site boundary. McCullin's work diary indicates that the proposed site plan shown in the 1951 map was not



Compilation map showing original site boundary and final boundary. Area "2," by Jackson, was the proposed site of the 700/300 Area which in May of 1951 was used agriculturally.

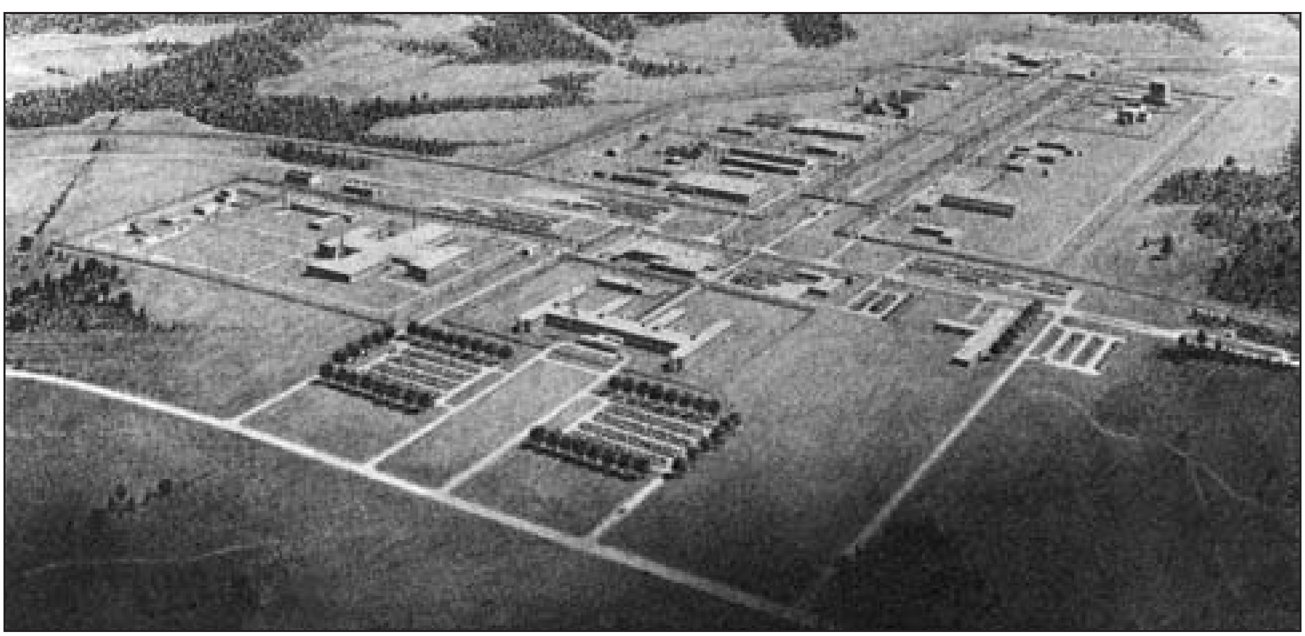
considered acceptable by Du Pont management. A new layout was needed and it was to be "…started from scratch without regard to natural features such as trees, etc."[4] Du Pont's Design group had a week to complete it. The reference to trees is ambiguous but the work diary indicates that a new layout was achieved within a week and that the civil engineers moved the proposed location for 300-M Area .5 mile east from the original location to where 300-M Area stands today. Underscoring the importance and timeliness of the selection, Robert Mason, Du Pont Field Construction Manager, gave his imprimatur to the area location, calling to advise that he had made a personal field inspection of the selected area and that he approved.[5]

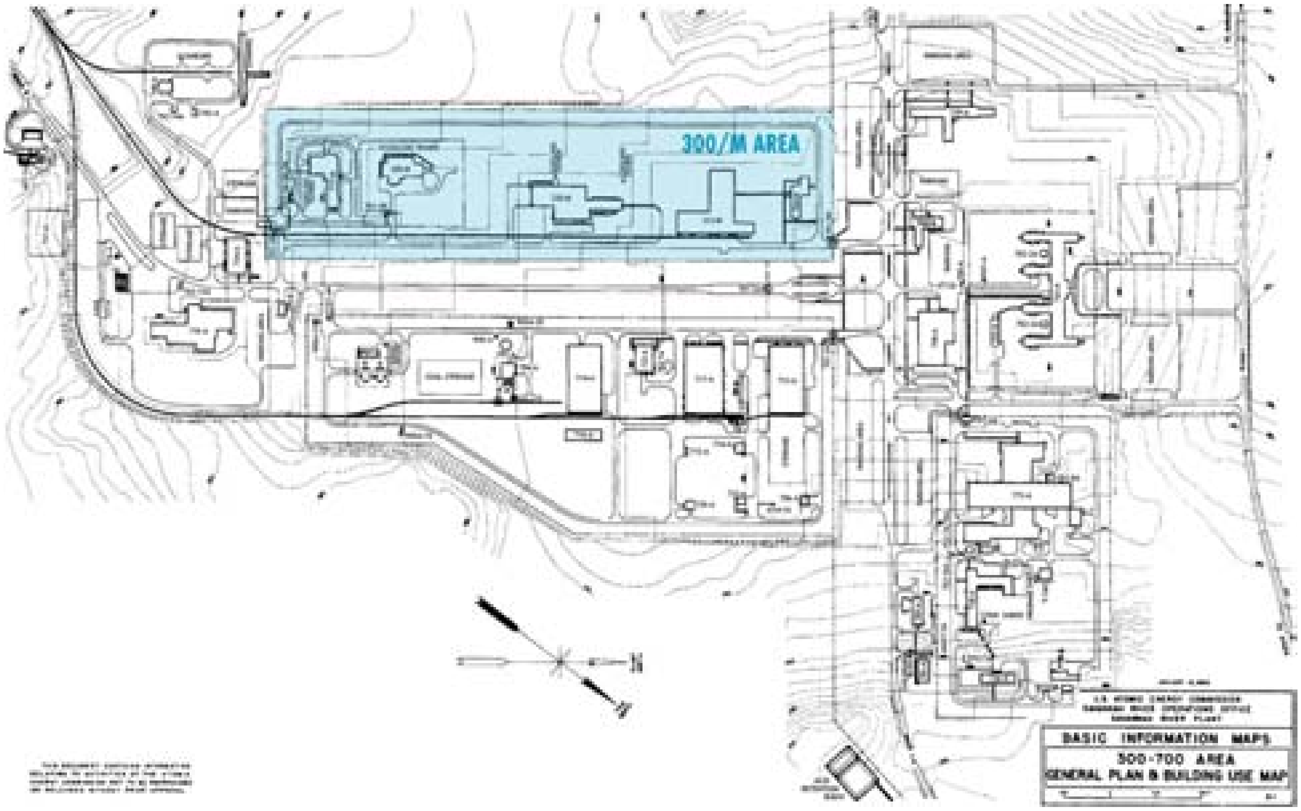
The new location was an agricultural field south of Green Pond Church on a 145-acre tract acquired from Evan Williams and the adjacent Williamson tract.[6] Photographs taken prior to the start of construction show no buildings present on the section of the parcel chosen for the building area but an unimproved road and fencing is shown and groves of trees. It appears that the proposed site was leveled and that all vegetation was removed with the exception of an oak tree which still stands today as a reminder of the area's rural non-industrial background.

The site selected for the 300-700 Area is one mile south of the northern perimeter, in the northwest section of the site. The closest process facility, F Area, lies within 4.5 miles of it. These distances indicate that the preferred safety distances were not fully met in the layout but came close, particularly with the process building safety distance parameter. The halving of the 2-mile preferred distance to the perimeter was possibly predicated on acquisition concerns and the need to establish this important area simultaneous with the determination of a site boundary.

The whole 300/700-Area layout has a crisp almost military layout. It is roughly U-shaped with the main administration building commanding the entire building area. Road D bisects the 700/300-Area, leads to the center of the site, and terminates at the back of the main administration building. 300-M Area, which constitutes

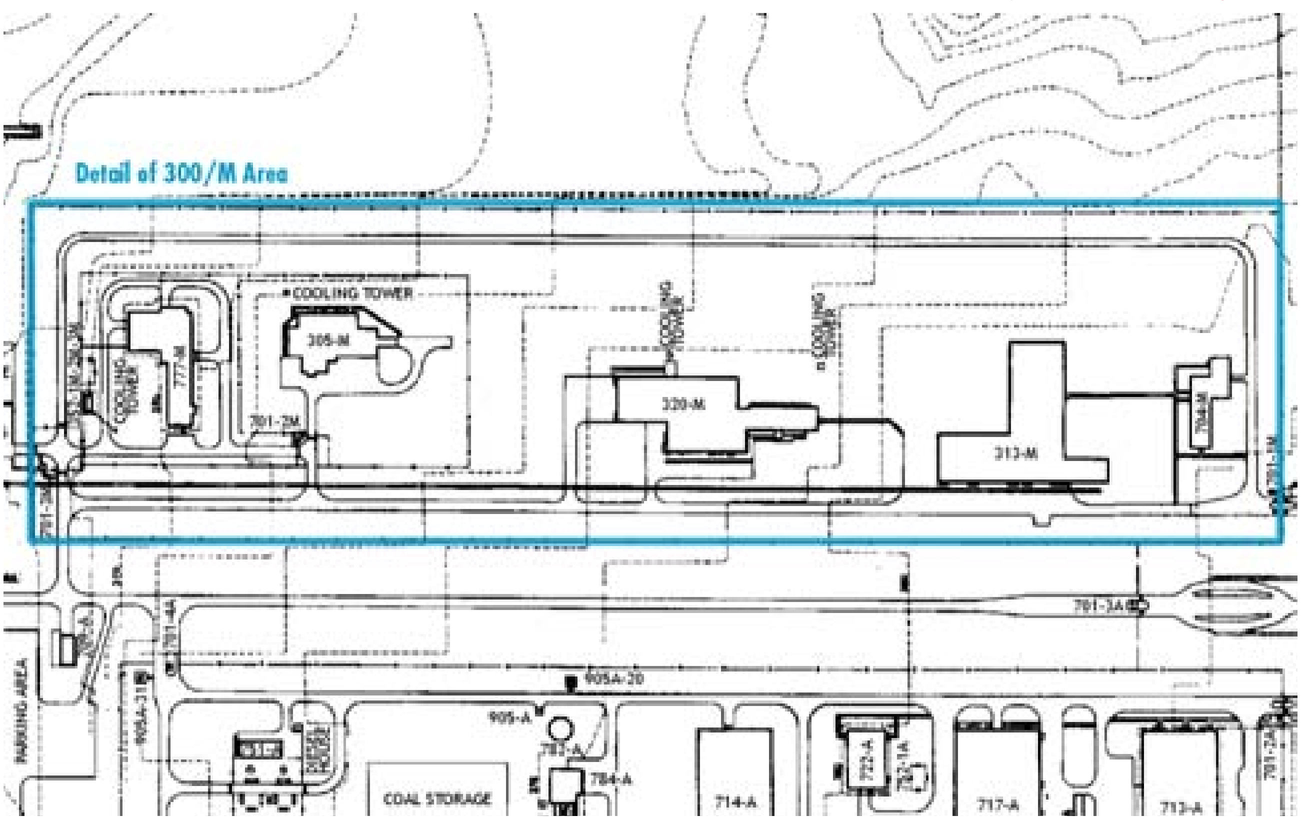
Plan for 700/300 Area, No. 30, Voorhees, Walker, Foley, and Smith. Architects and Engineers, 101 Park Avenue, New York. The 300/M Area is shown below in the upper right hand corner of the architectural plan.





300/700 Area Map, January 1956.

Detail Showing 300/M Area, January 1956.



the western leg of the "U," is rectangular and is oriented on a north-south axis using plant north. Road A-1 bounds it on the north and Road D is its eastern boundary. The opposing frontages on Roads A-1 and D contain 700 Area buildings. 300/M Area was connected to the plant railway system. Two thousand six hundred and forty linear feet of standard gauge track were laid on a straight line parallel to Road D east of the M Area facilities. No electrical power was generated in 300-M Area instead three secondary substations supplied power from the plant's electrical network. A-Area's boiler house, located on Road D across from 305-M, supplied steam for use in the manufacturing processes and for heating. Underground water lines delivered and distributed water through separate systems for domestic, fire protection, and process water use to 300-M Area.

The buildings in 300-M area were laid out in linear fashion from north to south in the following order: 701-1M, 704-M, 313-M, 320-M, 305-M, 701-2M, 777-M, and 352-1M. M Area was originally designed with eight facilities, four of which, 313-M, 320-M, 305-A and 777-M, were process facilities. An office and change house known as 704-M was situated to the front of the area for worker's convenience and a substation was built on the southern perimeter of the building area. Two gatehouses, one on the northeast corner (701-1M) and the second on the southeast corner (701-2M), controlled access to M Area that was surrounded by a nine-foot high chain link perimeter fence. By 1954, smaller support buildings such as 710-1M, a lithium storage building, were added.

Major change occurred between 1955 and 1957 when a fourth manufacturing building (321-M) designed to produce a new fuel type was added to 300-M Area.[7] A laboratory (322-M) for process control and for method development, a substantial addition to 320-M to produce targets associated with the new fuel type, and ancillary structures including a Tank Farm (312-M), air compressor house (319-M), and some other service facilities were also part of the 300-M Area expansion. The majority of the new construction, including the laboratory and the manufacturing building, was placed west of 320-M, an expansion pattern that would hold true for later area changes. Buildings closest to Road D are first generation facilities while newer constructions lie to the west in a "second block" of development. The new laboratory was placed conveniently between the two manufacturing buildings, 320-M and 321-M and support structures close to the main buildings.

The initial layout of the buildings did not reflect a work sequence in production as much as a workflow. Operations in 313-M and 320-M produced separate products and the products of both were tested in 305-M. When 321-M was built and placed into operation, it also produced a separate product. Internal area subdivisions recognized that flow. M Area was subdivided into three internal areas. The northern area contained 701-1M, 704-M, 313-M and 320-M. Later 321-M and 322-M joined that group. Buildings 305-M, a graphite pile, and 777-M, Physics Laboratory, were each fenced separately, reflecting their separate missions and the interlocked need to maintain a safe and secure barrier for these important facilities.

As noted, Building 305-A was integral to the area's quality control functions from the plant's inception through 1975. Its graphite pile was used to test reactor fuel and target elements. Conversely, 777-M's location in M Area was a matter of convenience. The Physics Laboratory was not truly associated with fuel and target fabrication. It was an adjunct facility that operated as an experimental component of the production reactors and was part of the Savannah River Plant Laboratory. Building 701-3M, a third gatehouse, was added for the convenience of workers in 777-M in 1954. As 777-M was not integral to the 300-M Area mission, it will not be treated in the this document but will be treated as a research and development resource as it was manned by Savannah River Laboratory personnel and is more appropriately thought of as a research and design facility.

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.[8] Standardization of design for the primary 300/M area facilities was not necessary as only one fuel and target fabrication area was needed. However support facilities such as area guardhouses and administration buildings would follow standardized plans for those building types.

BLASTPROOF CONSTRUCTION

Meetings between Du Pont, the AEC and other subconsultants were ongoing in November and December of 1950. Drexel Institute of Technology's 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.

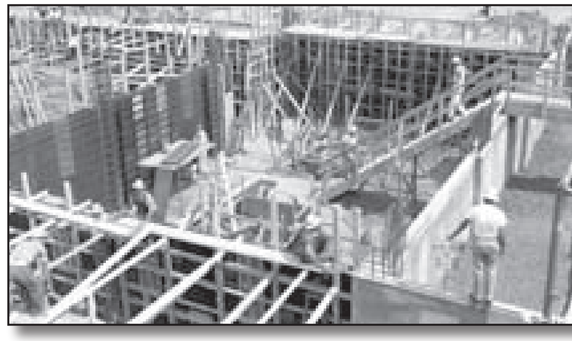
Class I buildings were described as massive, reinforced concrete, monolithic structures with a static live load of 1000 lbs per square foot.[9] Their exterior walls and roof were to be poured, reinforced concrete with a supporting frame of reinforced concrete or structural steel. Critical process buildings 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 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 made of asbestos-reinforced cement.[11] As an exterior sheathing it reduced the load bearing factor considerably from 120 to 20 pounds per square foot when compared

Photographic Sequence Showing the Construction of 313-M in 1951.



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 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.

300/M Area's process facilities were predominantly Class II buildings and its support structures were of Class III construction. Only 305-M had a section that was constructed as a Class I wing.

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 and that data were 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 a gatehouse 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 building's 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 were labeled 784-A and 785-A. The numerical nomenclature for the 300/M Area is fairly straightforward with process buildings assigned a number in the 300s and support building numbered by type such as 700 for administration buildings and security buildings.

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.[13]

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.[14]

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."[15] 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 VWF&S, a leader in industrial design for laboratories. VWF&S had an impressive number of projects in the atomic energy field, such as the Murray Hill Bell Telephone Building, a cyclotron building at Columbia University, and other facilities at Argonne National Laboratory. Its credits in 1954 included laboratories and factory facilities for NY Telephone, Ford, GE, IBM, R.H. Macy, Proctor & Gamble, General Foods and others.

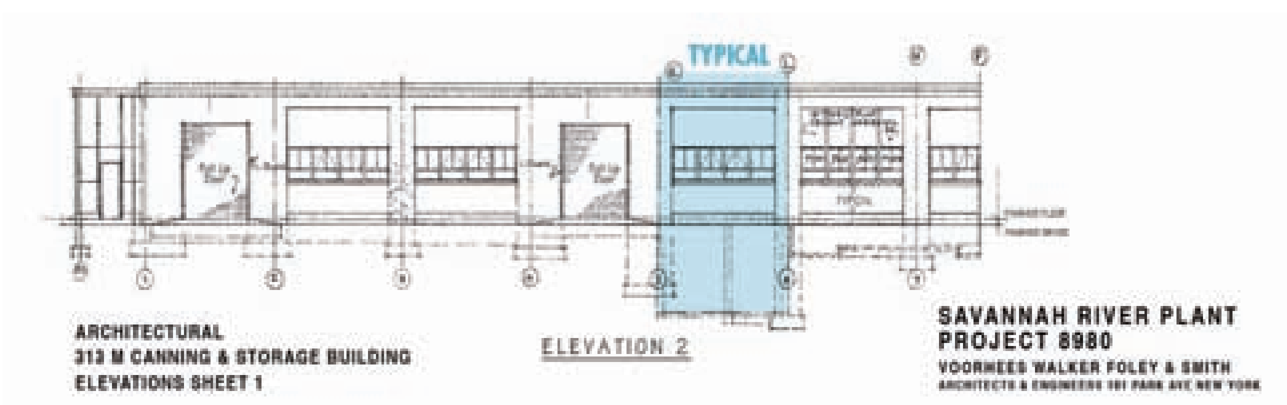
The firm was also responsible for the site plan and design of Du Pont's Experimental Station in Wilmington, Delaware, described as a "campus of six modern laboratory establishments" and an additional campus for Du Pont's rural headquarters at Milford Crossroads near Newark, Delaware. The laboratory complex was designed using the flexible-modular concept: "VWF&S studied the particular requirements of each of the six participating (Du Pont) departments, then 'added 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."[16]

For Du Pont's rural headquarters project, VWF&S, 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, VWF&S was an easy choice as Project 8980's subcontractor for architectural and engineering.

The first generation of buildings at SRP was simply designed using the functional ethic described above. 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 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 aboveground so that massive pipes parallel roads or arch over them. Economically motivated, this design feature has strong visual impact.

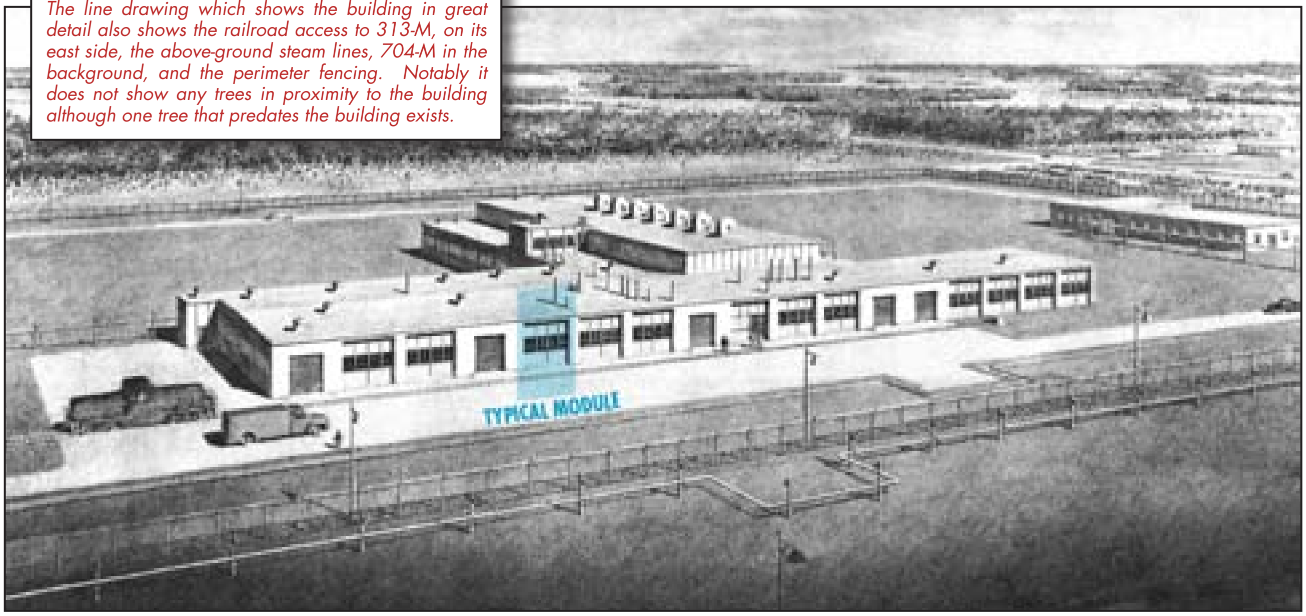
As-built drawings show that the architects developed "typical modules" for each building's elevations when possible. Using structural columns, reinforced concrete, and Transite™ panels in which windows could be placed as their main vocabulary, the architects repeated the typical exterior module as many 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, particularly within the 300/M Area building stock. 300/M Area buildings are also good examples of overall industrial flexible design. Each were constructed to allow subsequent expansion as it was recognized during planning that the Hanford fuel and target fabrication technology was adequate and necessary for start up given the urgent schedule ahead but that changes would need to occur to accommodate the new Savannah River technological environment and to provide sufficient expansion space should future product requirements require that option.

Typical Building Module, 313-M – Canning Building Elevation



Architectural, 313 – M - Canning and Storage Building Sheet I, W155410, Savannah River Plant, Project 8980, Voorhees Walker Foley & Smith, Architects and Engineers

The line drawing which shows the building in great detail also shows the railroad access to 313-M, on its east side, the above-ground steam lines, 704-M in the background, and the perimeter fencing. Notably it does not show any trees in proximity to the building although one tree that predates the building exists.



313-M Canning Building, Birds Eye View Line Drawing, Voorhees Walker Foley & Smith.

Flexible design dictated that the new buildings should be constructed to take whatever the future forecasted. Boxlike, color neutral, and functional in style, the 300/Area buildings may have appeared to be expedient building envelopes but their construction history shows they were anything but. The 300/M Area designers were partially successfully in achieving their flexible design goals in establishing the original industrial area. However, in 1955, a major manufacturing facility would be added to the 300/M Area as well as support buildings and structures to further operations. Despite their efforts to produce fully flexibly designed facilities, the production of a new fuel type, Mark VI; fuller knowledge of what was needed on the basis of production experience; some relaxation of the urgent schedule as the startup deadlines had been met, and the Du Pont desire for better technology were all involved with the M area expansion between 1956-1958. Even the most devoted architect to flexible design could not have envisioned the spatial needs of equipment needed for the next generation of fuel assemblies.

300/M AREA BUILDINGS

The following treats the construction of the buildings in 300/M Area, their architectural description as-built, and the design criteria employed in their construction. Start up, development of process equipment, and the early operations history will be handled in the following chapter. 300/M Area was first built out between 1951 and 1955 as part of Du Pont's Project 8980. The first section deals with those buildings. In 1955, additional manufacturing facilities were added to produce a new fuel type, the Mark VI, and to round out the complement of original facilities. The second section describes the facilities constructed between 1956 and 1958 as part of Project S8-1044.

PROJECT 8980 – 1951-1955

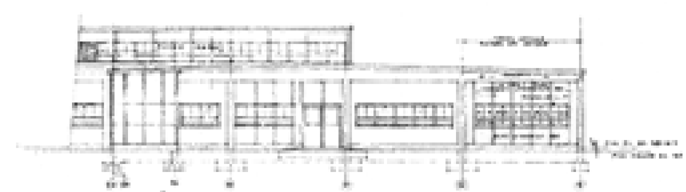
313-M Canning Building

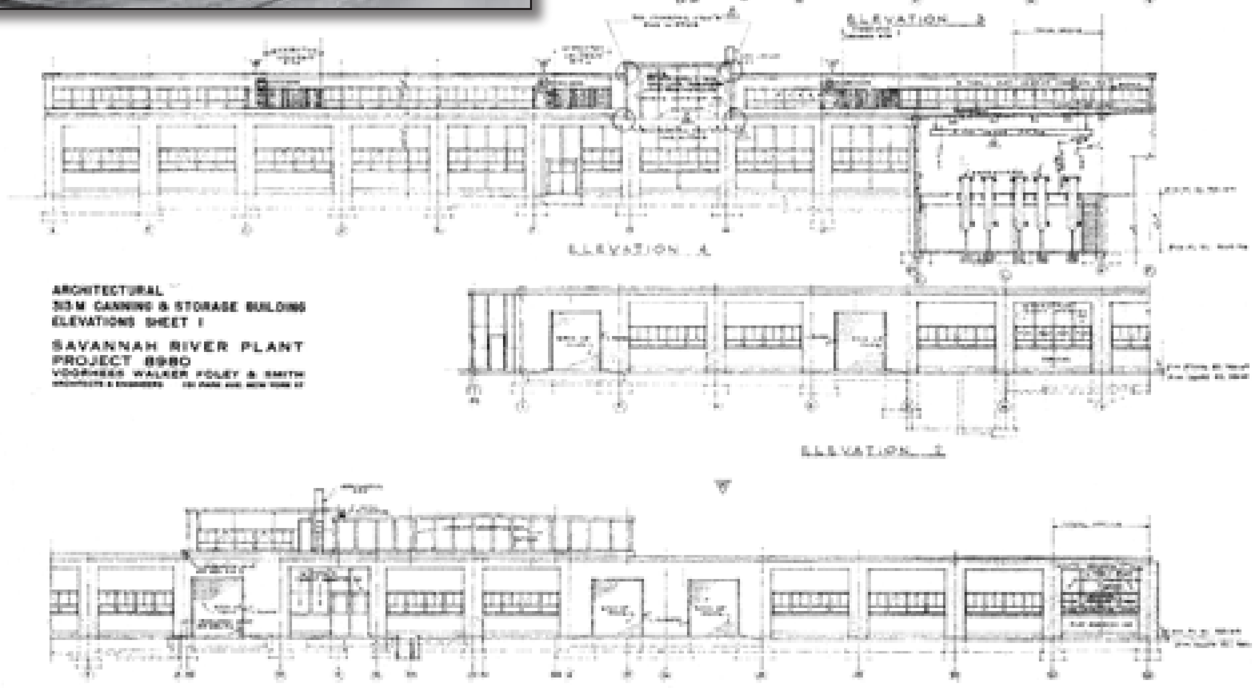
Building 313-M was designed by VWF&S to house the process equipment involved in the preparation of uranium fuel slugs. Its ample size was based on design criteria that all related facilities should be under one roof, thus eliminating the need for small support buildings. This criterion stemmed from lessons learned at Hanford. Crafted to allow the extension of the building in three directions should future process changes warrant such an expansion, it was a prime example of flexible design.[17]

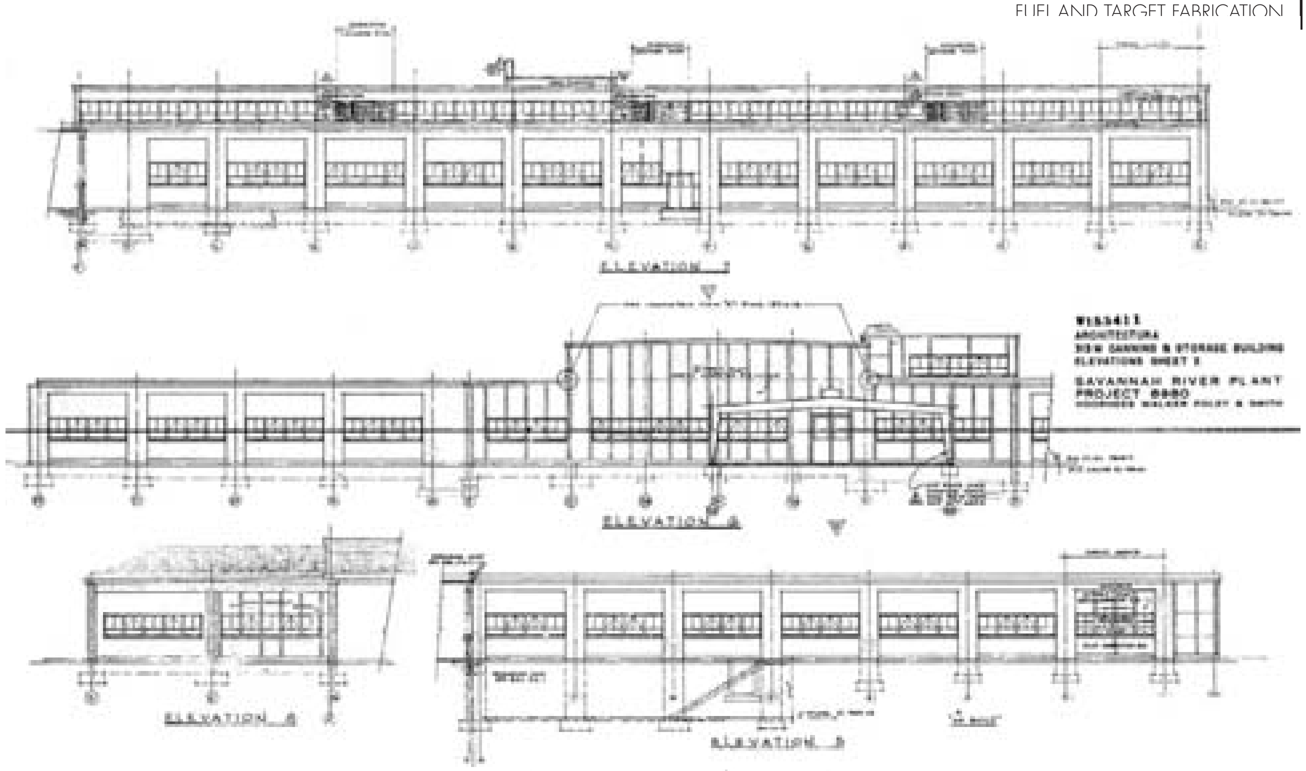
The large T-shaped building's construction began on June 3, 1951. It was the first building under construction in the 300/M Area and it would be occupied by Operations on September 29, 1952, sixteen months after ground was broken. Du Pont's photographers provide progress photographs as the T-shaped single story facility took shape.

The building had reinforced concrete spread-footing foundations, a reinforced concrete and structural steel frame, and a flat concrete roof. A long clerestory supported by steel trusses ran along the central wing's roofline. Seven exhaust fans were situated on the clerestory roof.

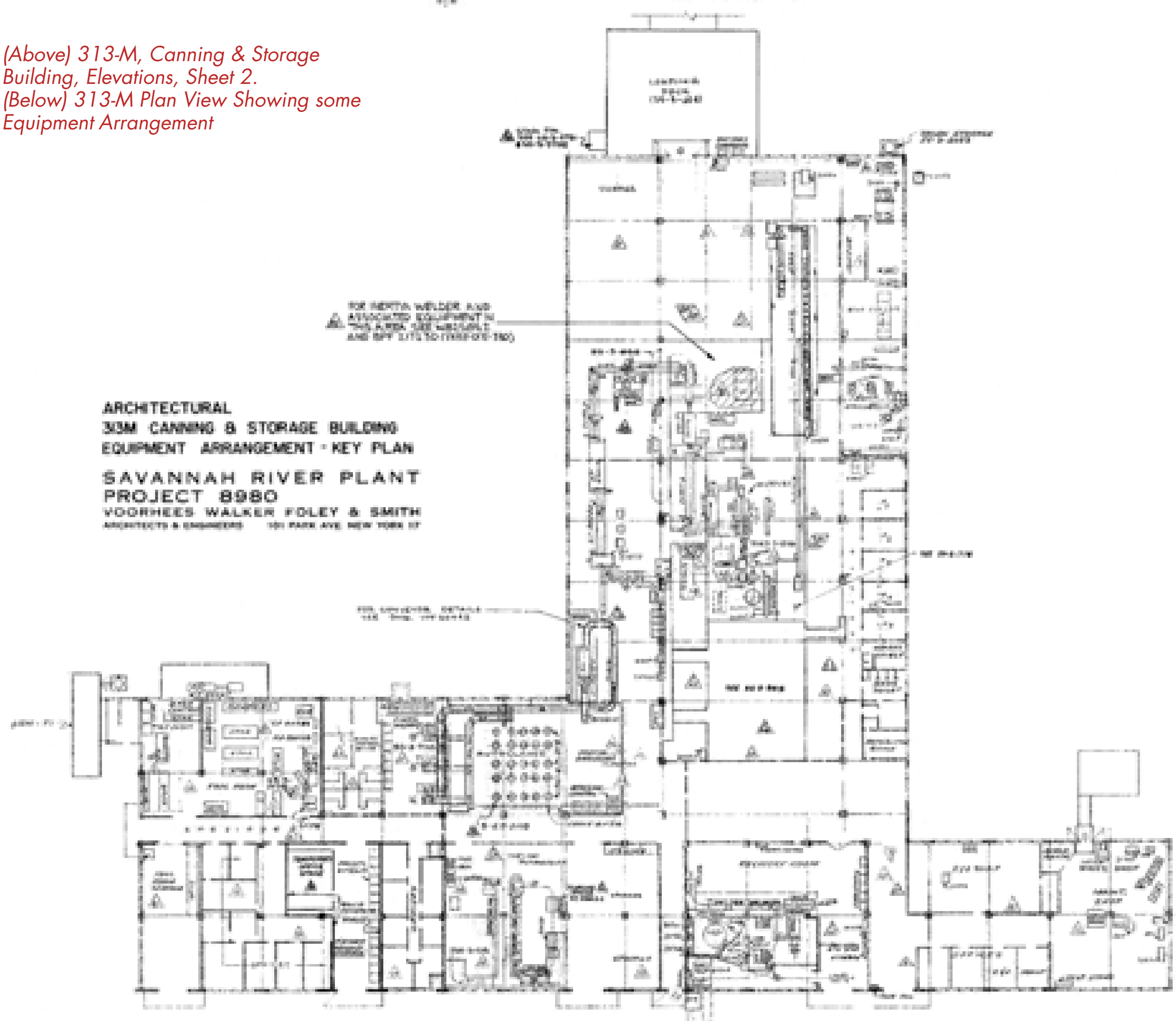
313-M's Elevations







(Above) 313-M, Canning & Storage Building, Elevations, Sheet 2.
(Below) 313-M Plan View Showing some Equipment Arrangement



The building's exterior walls were composed of a repeated "module" featuring a slightly inset Transite™ panel on steel girts with a band of four commercial fixed and projecting windows between two framing concrete columns. This "typical module" was repeated on each elevation except the south side where there were five windows in each band. Industrial openings with steel roll up doors were plentiful allowing vehicular egress into the building and the movement of product and machinery. The windows in the clerestory were all fixed. A covered loading dock was located on the building's west side to facilitate raw material storage. The plant railroad right-of-way stretched along the east side of the building and an access road through 300/M Area that paralleled Road D.

The section of the building at the crown of the "T" was 344 feet long and 98 feet wide at the south end and 50 feet wide at the north end. This section was 17 feet high from roof to finished floor. The section that lies east west or the base of the T was 181 feet long on the south side and 229 feet on the north side and 112 feet wide. The section under the clerestory, the pit furnace area, was 25 feet to the top of roof truss and 18 feet to the bottom of the truss. Overall the building contained 53,100 square feet of space.

Designed to handle output from four canning lines, only two operating lines were installed initially. Nine major interior areas were associated with slug canning:

- a receiving and inspection area (1,500 square feet) located by truck apron on east side of building;
- can, cap and sleeve preparation area (3,310 square feet) located on east side of building;
- slug preparation area (located adjacent to canning lines in west section);
- canning area (13,960 square feet) located on west end of building;
- lathe and welding area (2,790 square feet) located adjacent to canning area;
- test and inspection area (2,450 square feet);
- autoclave area (3,500 square feet);
- X-Ray room (1,150 square feet) east of autoclave area; and a
- slug recovery area (2,880 square feet).

Fifty-seven percent of the building's process space was devoted to the canning area. Specific storage areas assigned for essential materials, finished product, raw materials, metal storage, "special" process storage, and H.F. storage cumulatively occupied 8,580 square feet. Finally service areas for offices, tool storage, instrument shop, electrical and utility area, restrooms, and corridors composed the remainder of the building.

Interior detailing was minimal. Concrete floors were in place throughout the building except in the canning and can, cap and sleeve preparation areas where acid-proof brick was laid. A pressed fiberboard wainscot (four feet in height) was added to interior walls in corridors where there was truck traffic. Fluorescent lighting and incandescent lighting was used. Notably the lighting systems in 313-M and 320-M could be blacked out remotely from Building 720-A, Patrol Headquarters.

The addition of the clerestory to the roofline was a major architectural change from Hanford's 313 building that had wall fans to dissipate heat from the furnaces. Positioned over the furnace pit section where the canning operators worked, the clerestory in 313-M was designed to help remove the intense heat that would well above the furnace area. To combat this, air was brought in via six louvered vents in the clerestory. Fans attached to the louvers drew air in and then distributed it through a network of ducts that terminated in flexible nozzles that delivered air to the canning operatives at their stations.

The building was not air-conditioned and the steam plant in A Area supplied heat.

320-M Alloy Building

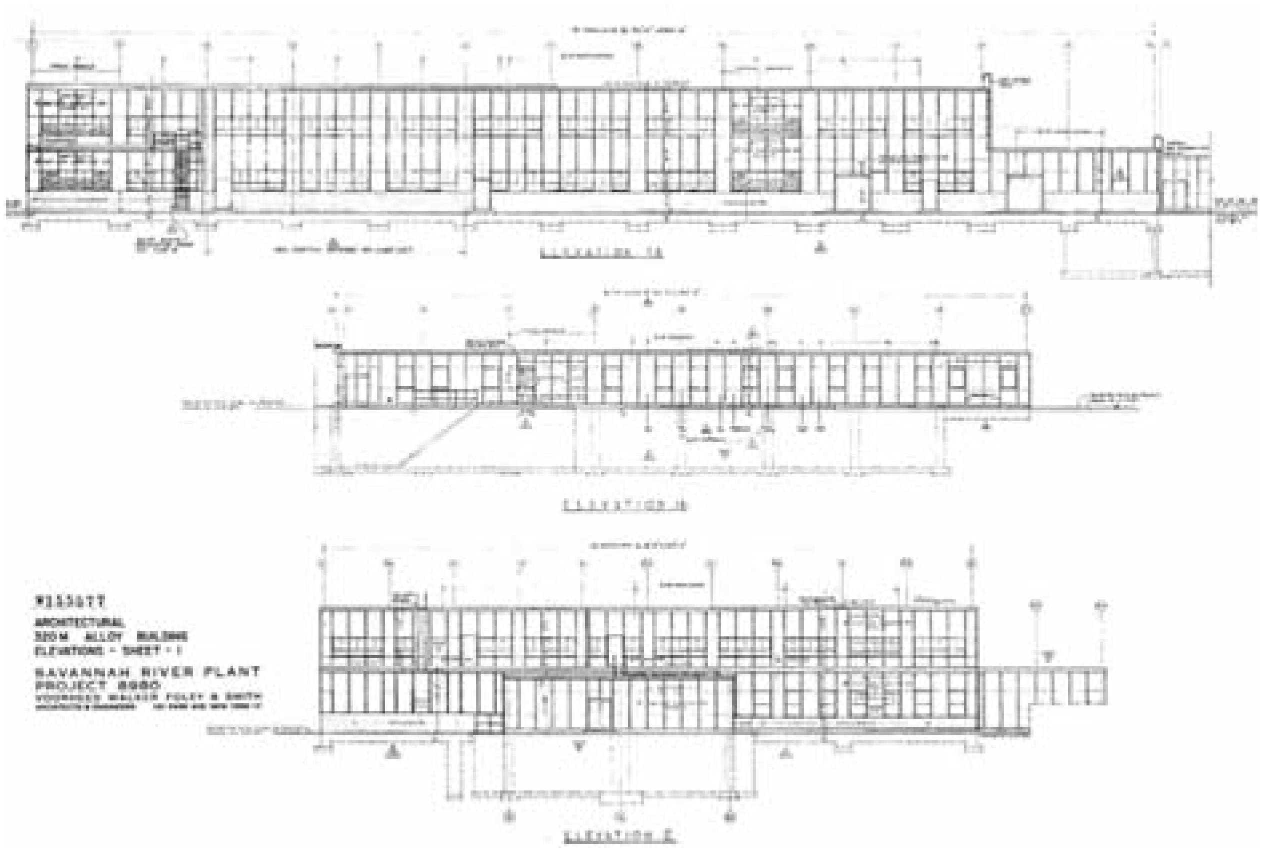
The Alloy Building was a VWF&S design built to house the production of lithium-aluminum alloy control rods and circumferential blanket rods containing lithium that would be needed in SRP's heavy-water cooled and moderated reactors.[18] The lithium-aluminum rods were needed to control the chain reaction in the SRP reactors and to produce tritium by the transmutation of lithium. Like 313-M, this facility was to house all related functions under one roof for economy and efficiency. Initially, plans were made to separate some of the process in a separate building designated as Building 306 but the plans for 320-M were changed to allow for rod assembly equipment and to store the finished product. The facility was expanded between 1956-58 to handle further production needs. This expansion is described in a later section.

The design of the building and its interior equipment is particularly notable as 11 reactor- charging scenarios were

320-M Construction View View to Northeast (1), View to Northwest (2) Workers laying pipes along railroad in 300/M Area

under consideration when this building was under design. In an era of teletypes, it is more than probable that they were flying between Wilmington, New York, Chicago, Washington, and Aiken as all the principals involved in reactor design weighed in on the final design elements that would impact control and blanket rod manufacture.

320-M Alloy Building, Elevations, Sheet 1



Moving ahead with building design and construction as parallel design forces tackled issues with reactor design was a hallmark of the construction and design of the SRP and, in 320-M, Du Pont and its subcontractors created a facility that could be used under all potential reactor design scenarios that were currently under consideration.

Construction began on the building in June 1951, a few weeks after construction had begun on 313-M. However, Operations took partial occupancy on August 15, 1952 over a month before 313-M was partially occupied. Construction-era photography was completed showing the building's location south of 313-M.

320-M is an irregularly-shaped Class II building. It has one and two-story sections as well as a below ground level on the east side that is of Class I construction. The manufacturing or process area is housed under a section that is 262 feet in length and 152 feet wide. It has a second story section 28 feet in height and a single story section 14 feet in height. A single story section on the east side of the building measures 140 feet by 53 feet and 12 feet in height. The building contains 54,742 square feet of space.

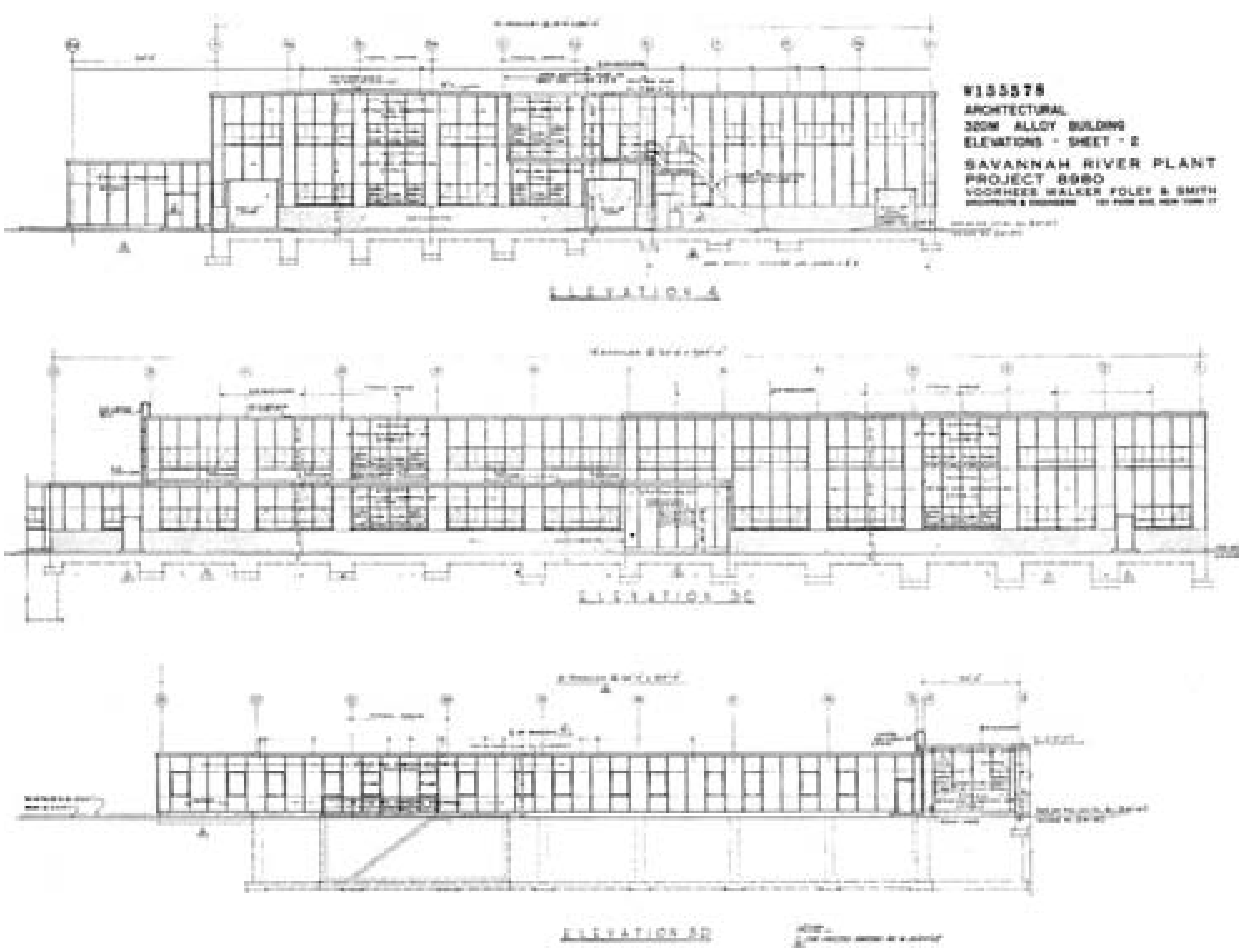
It has a concrete foundation with spread footings, a structural steel frame and a concrete slab roof with multiple drum vents. One section of the process area has a corrugated cement asbestos board roof.

The exterior walls have continuous cast–in-place concrete lower sections (a skirt wall between 3-4-feet in height) and upper modular panels of Transite™ and glass. Each exterior wall module features four upper and lower panels of Transite™ board with two bands of fixed and projecting commercial steel sash windows sitting on top of the raised concrete side walls. The number of modules used on a side was dependent on the needed length. The south elevation has a slightly different module in width but keeps the same elements so that the building keeps its uniform look with its two bands of windows that surround the building. Personnel entries are hollow metal; industrial doors are steel roll-up doors.

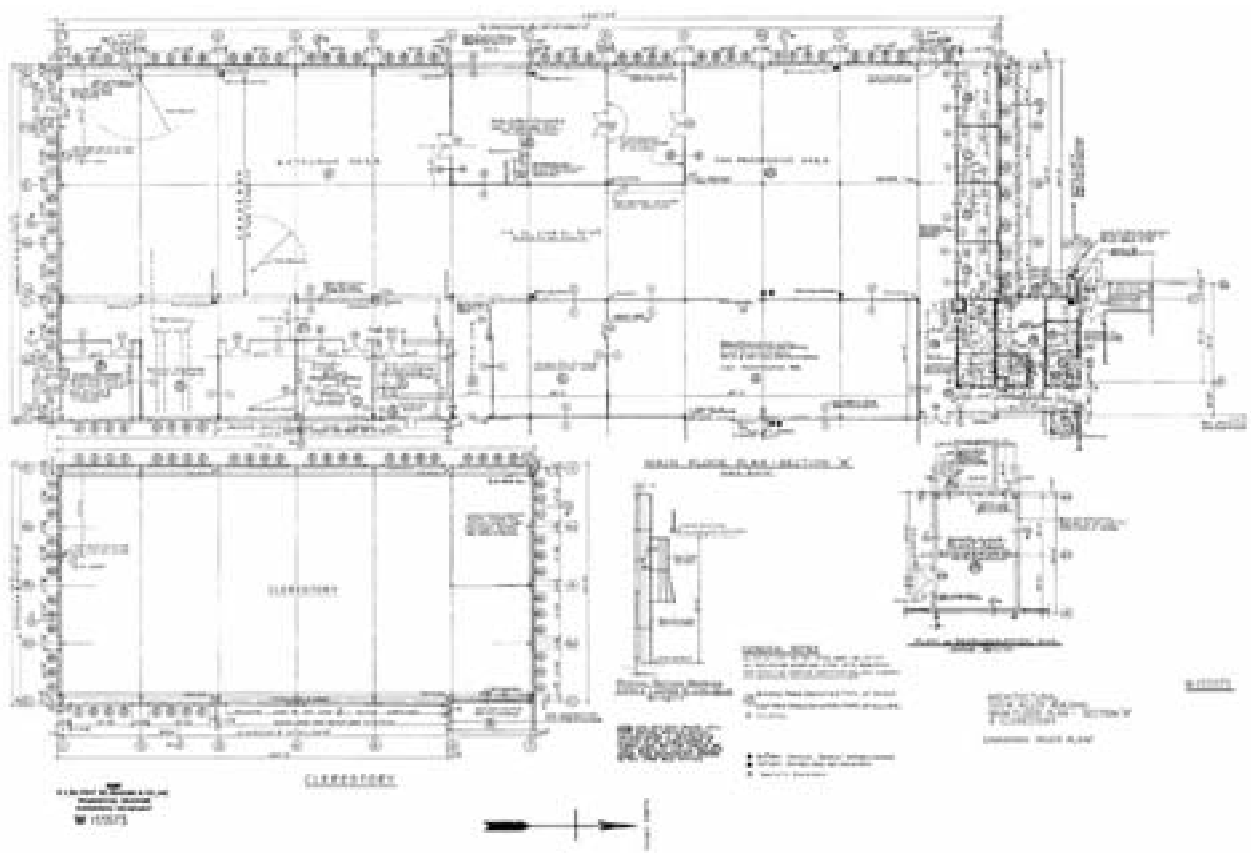
Exterior walls were insulated then protected by a tempered pressed fiberboard wainscot in the process area. The office area, laboratory wing and service area had differing thicknesses of exterior concrete walls that were needed for protection from radiation or from hazardous materials. A Class I construction or blastproof construction underground bomb shelter over 1,000 square feet in size with walls 24″ thick was built into the design to accommodate employees in 313-M and 320-M if an emergency should occur.

There were seven major components within the 320-M production process that took place in 12 interior process areas:

320-M Alloy Building, Elevations, Sheet 2



320-M Alloy Building, Main Floor Plan, Section A



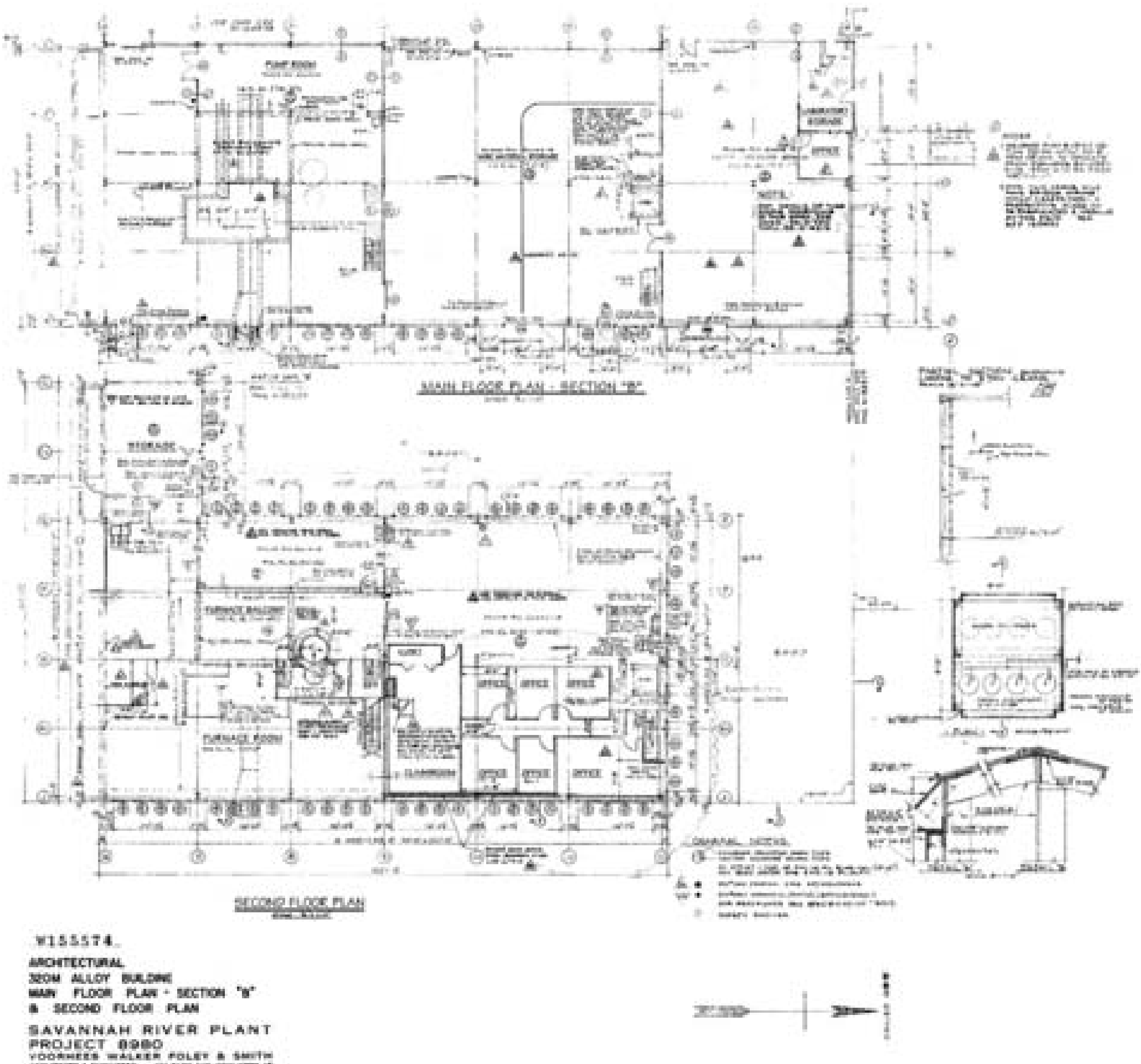
- raw material storage area sufficient to store a six month supply (9,650 square feet);
- furnace room (6,280 square feet);
- X-ray room;
- billet machining room (1,625 square feet);
- billet welding area (included above);
- billet storage area (included above);
- extrusion area (8,600 square feet);
- air-conditioned process room (1,200 square feet);
- can, tube, and rod cleaning areas (included below);
- can processing area (7,900 square feet);

- rod manufacturing area (included above); and
- finished product storage for a three month reserve.

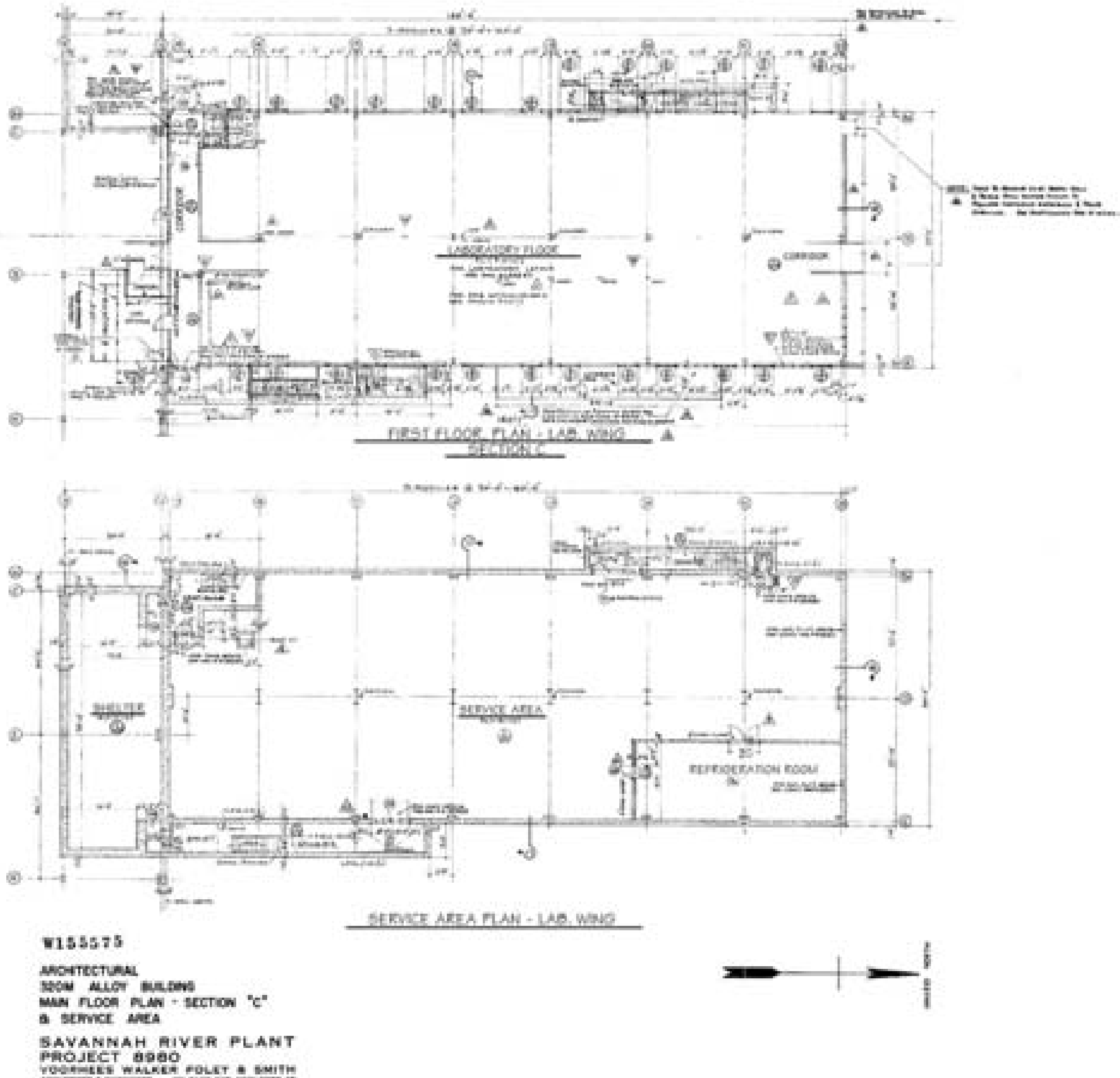
Raw material storage claimed the most space in the building with the extrusion area coming in a close second. In addition to the above, there were other areas incorporated into 320-M: ancillary storage, administrative area, maintenance area, change rooms, laboratory wing, and service area. These areas roughly occupied 27 percent of the building.

As in 313-M, interior architectural details were spare. For the most part the building had an open plan. Interior walls in the process areas had pressed fiberboard at the base covering the lower four feet of the walls and

320-M Alloy Building, Main Floor Plan, Section B



320-M Alloy Building, Elevations, Section C



Transite™ on the upper walls mounted on steel studs. The office area walls had fiberboard, Transite™ and glass. Special areas such as the X-Ray room have 16-inch thick, cast-in-place, reinforced concrete walls. The bomb shelter has 18-inch thick walls and a 24-inch concrete roof. Floors are concrete except on mezzanine and in furnace area that have checker plate flooring and acid proof brick in the can and tubing area. The laboratory floor area was finished in asphalt tile.

Unit heaters supplied heat. Lighting was both fluorescent and incandescent. In contrast to 313-M, a portion of this facility was air-conditioned. This change was predicated on the need to perform some of the machining actions in an inert gas atmosphere using "dry boxes" so that lithium-alloy materials wouldn't be contaminated with the hydrogen that is normally contained in the atmosphere. Research showed that the likelihood of that occurring was greatly reduced by good temperature (75 degrees F) and humidity control (35 percent). Thus the addition of air conditioning was considered an effective substitute for dry boxes. The billet machining operation area and laboratories presented similar concerns so they were air conditioned, and as the office space was adjacent to those, employees housed there benefited from proximity as air conditioning was extended to their domain.

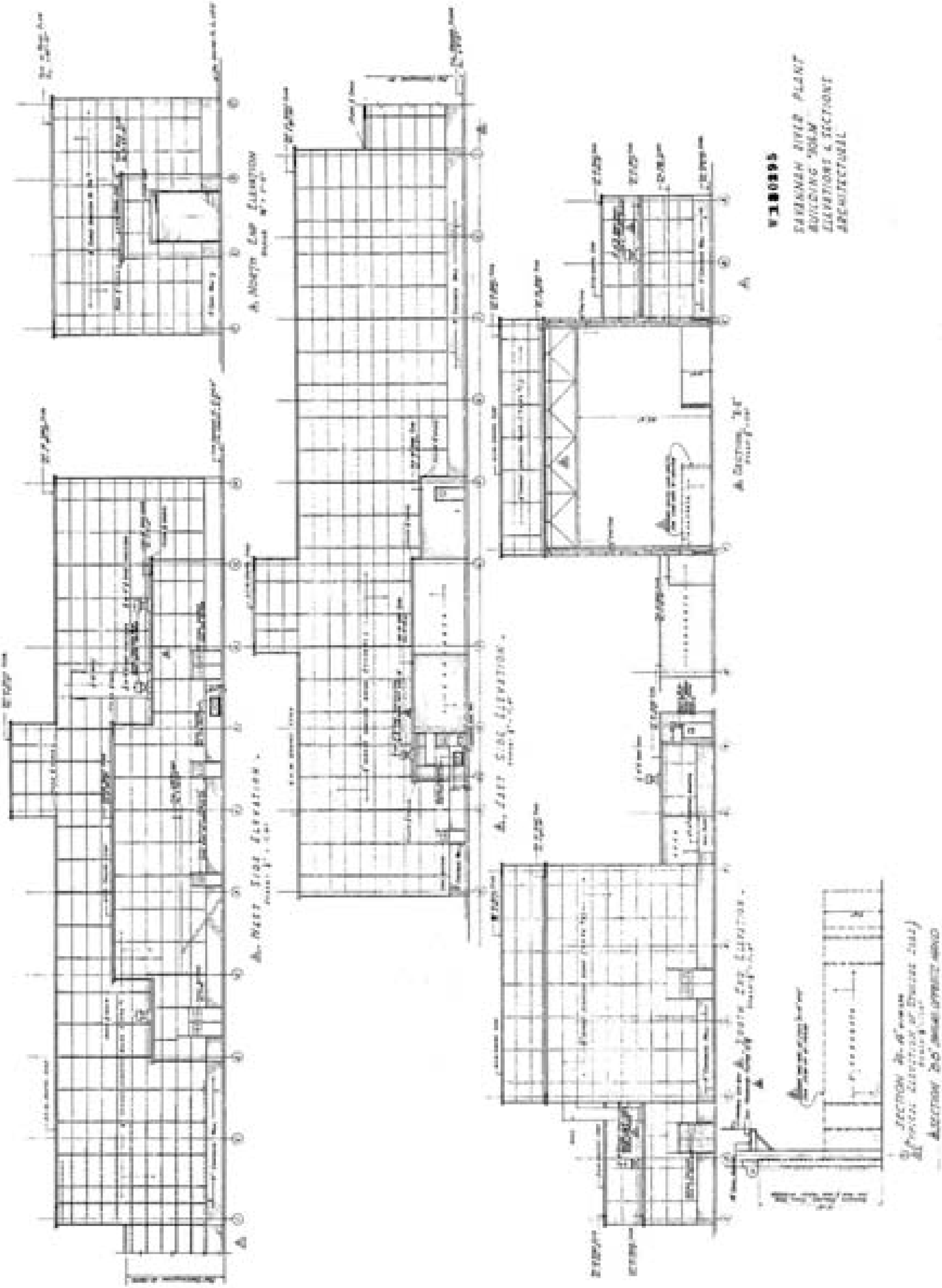
305-M Test Pile

305-M was considered critical to the SRP mission and was needed immediately to assure success at startup. Its purpose was to test bare slugs, canned slugs produced in 313-M and control rods from 320-M to assess their quality for use in the production reactors.[19] Situated directly south of 320-M, the VWF&S-designed facility was devoted to one piece of equipment, a test graphite test pile or reactor. Placed in the center chamber of the building under a tall high hat, the test pile was the centerpiece of the building and all openings and ancillary components were arranged to maximize its performance (see illustration in chapter 11). It went critical for the first time on September 16, 1952.

Construction began on the test pile building on June 18, 1951 and it was partially occupied eighteen months later. The facility was a modified version of a similar graphite pile at Hanford. It differed from the Hanford example in that it was to be a Class II structure and built to be dust-tight using residential construction standards. Also the facility was designed with a laboratory, bomb shelter, ample storage space and most importantly, it had to be in operation in time to test the first slugs and control rods produced in SRP's 300/M Area.

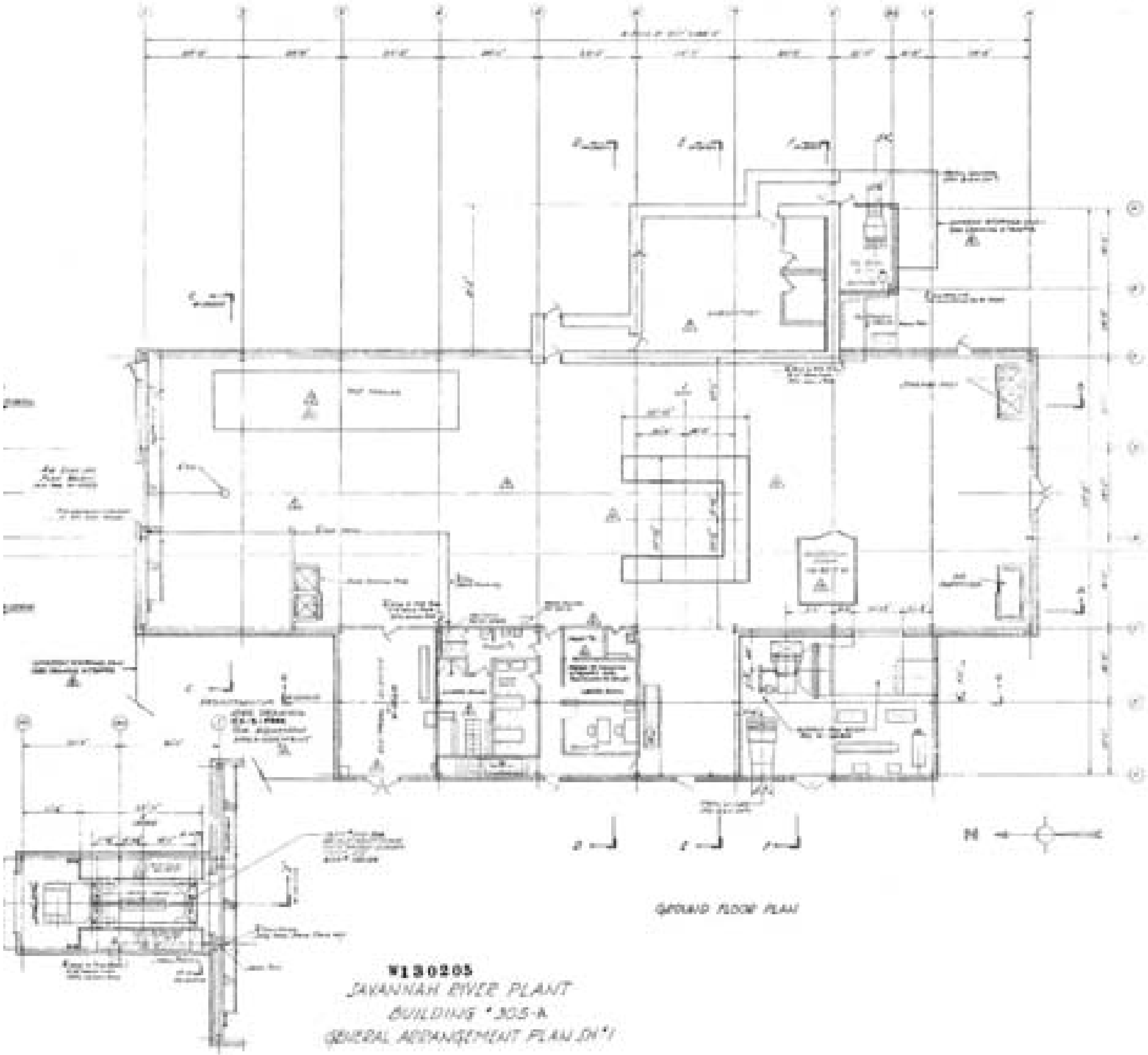
While the building would have some modifications from the Hanford example, lessons learned at Hanford would play a vital part in its construction. A major concern was the need for cleanliness in the building's interior and in the laying of the graphite blocks. No dirt or other materials were allowed that might affect the reactivity of the pile. To avoid this, Du Pont had the air-conditioning installed early on so that construction could proceed in a closed environment, the interior workplace was frequently cleansed, and construction workers were specially outfitted with coveralls and gloves to maintain cleanliness. This parameter and the need to make the schedule for startup appear to have been challenging. The construction history uncharacteristically makes the point that the completion of this facility was due to a close collaboration between the construction force and the operations supervisors on hand.

305-M is largely an open plan, single-story, boxlike building with multiple rooflines and an airlock entry passage on the north end. Like the other 300/M manufacturing buildings of Class II construction, it has reinforced concrete spread-footing foundations, a structural steel frame, and a concrete slab roof. Trusses support the roof slab in the high hat area with steel beams elsewhere. The roughly rectangular main chamber, approximately 183 feet by 5 feet, housed the test reactor, an uncooled, graphite moderated structure that was cubelike in form measuring 25 feet by 25 feet by 21 feet and six inches. A five-foot thick barrier wall surrounded the interior graphite cube.



305-M, Elevations and Sections

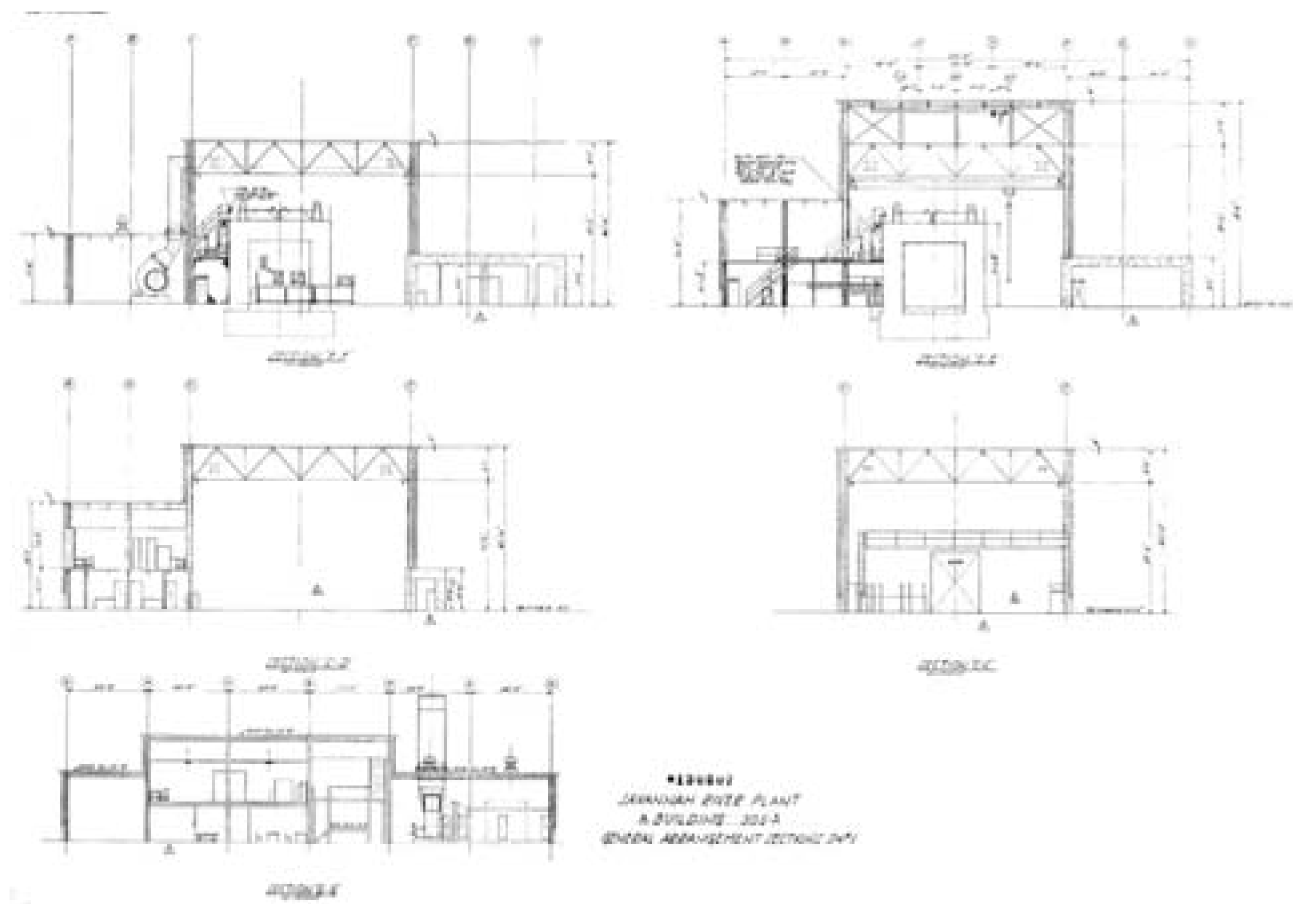
305-M, General Arrangement Plan



The remaining components were located around the main chamber to maximize testing performance. A narrow, linear, office and control room wing on the building's west side measures 122 feet by 30 feet. The control room section is two stories high with the control room on the upper level with fixed Thermopane windows allowing observation of the test pile below it on the main floor. An air lock extension, 40 feet by 21 feet, was placed on the north end of the building as an annex. This was the portal through which the control rods and slugs were brought into the building and through which they left. Large doors, electronically operated, communicated between the airlock and the reactor chamber. The exterior walls in these sections are poured, reinforced concrete to a height of 4 feet 2 inches; the remainder of the exterior walls area covered in Transite. This section contains about 15,128 square feet of space.

The laboratory area and bomb shelter, both mentioned in the design criteria for the building, were resolved into one small section of Class I construction approximately 43 feet by 30 feet, having reinforced concrete spread

305-M, General Arrangement Plan, Sheet 1



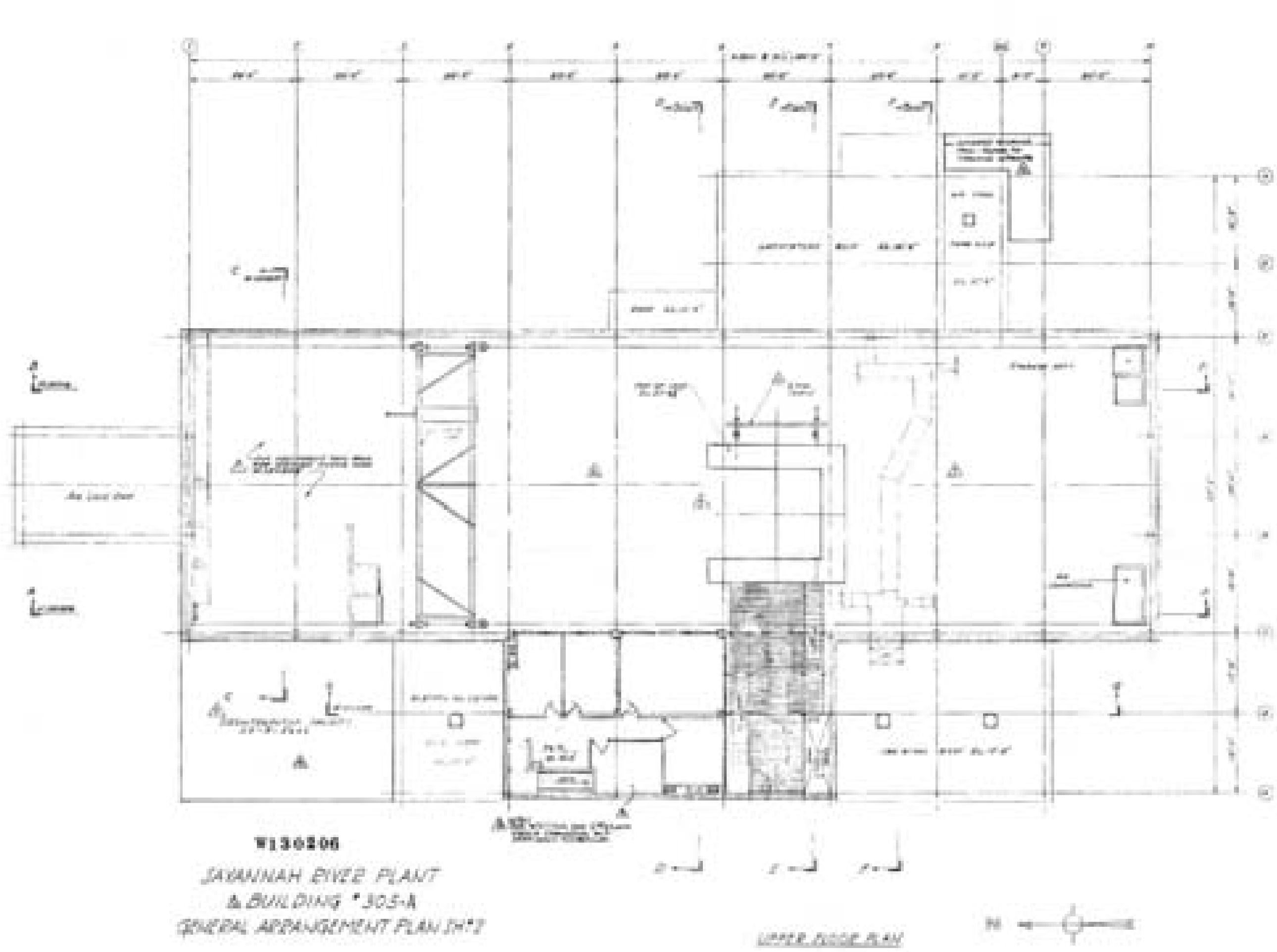
footing foundations, reinforced concrete floors, walls, and roof slab. Only 1,270 square feet were devoted to the laboratory wing.

The building's interior was sparely finished with exposed concrete for walls, floor, and roof. Interior partition walls were flat cement asbestos board on steel studs. The control room had an acoustic tile ceiling and an acoustical "Fiberglas" application over the cement asbestos board, and asphalt tile flooring.

There were eight principal areas within the building:

- Storage and shipment areas specified as separate Hot Assembly Storage and Cold Assembly Storage, room for truck parking space between, and airlock (3,125 square feet);
- Test Pile, Charging and Control Rod Area (8,375 square feet);
- Control Room (1,135 square feet);

305-M, General Arrangement Plan, Sheet 2



- Office and Welfare Area (1,315 square feet);
- Electrical Equipment Room (600 square feet);
- Laboratory (1,200 square feet);
- Supply Fan Room (1190 square feet);
- Air Conditioning Room (180 square feet); and
- Cylinder storage platform (145 square feet).

The building was heated by forced air through heating coils and the area powerhouse supplied steam. The facility was air conditioned throughout with the main chamber set for 70 degrees in the winter and 85 degrees in the summer. Lighting again was both fluorescent and incandescent.

701-1M

701-1M, 2M, and 3M Gate Houses

Designed as functional and standardized building types by VWF&S, the gate houses were Class III constructions sharing certain attributes: projecting rooflines, 360 degree visibility, single story, and small size.[20] Ubiquitous and necessary, they allowed security guards protection against the elements as they checked badges on those entering and leaving a building area by foot or by car. In addition, they served as a designated place where health physics personnel could issue and process the badges that were indicators of exposure to radiation.

Construction began on 701-1M, a gatehouse and sentry box, and 701-2M, a sentry box, on October 15, 1951. 701-3M was constructed three years later to accommodate the needs of personnel working in the southern end of 300/M Area.

701-1M, a gatehouse and sentry box, was the 300/M Area's main entrance. Both buildings are one-story, structural steel frame buildings (9 feet in height) on reinforced concrete foundations with reinforced concrete slab roofs and Transite™ panels for exterior cladding. The same is used for the interior wall finish. The gatehouse is 30 feet by 10 feet in plan with a flat roof. It is distinguished by a projecting roofline, steel frame double hung sash windows, and hollow metal and glass doors. North and south elevations have double door entries. The accompanying sentry box, a 4 feet 6inch square building, is set on a concrete island between traffic lanes.

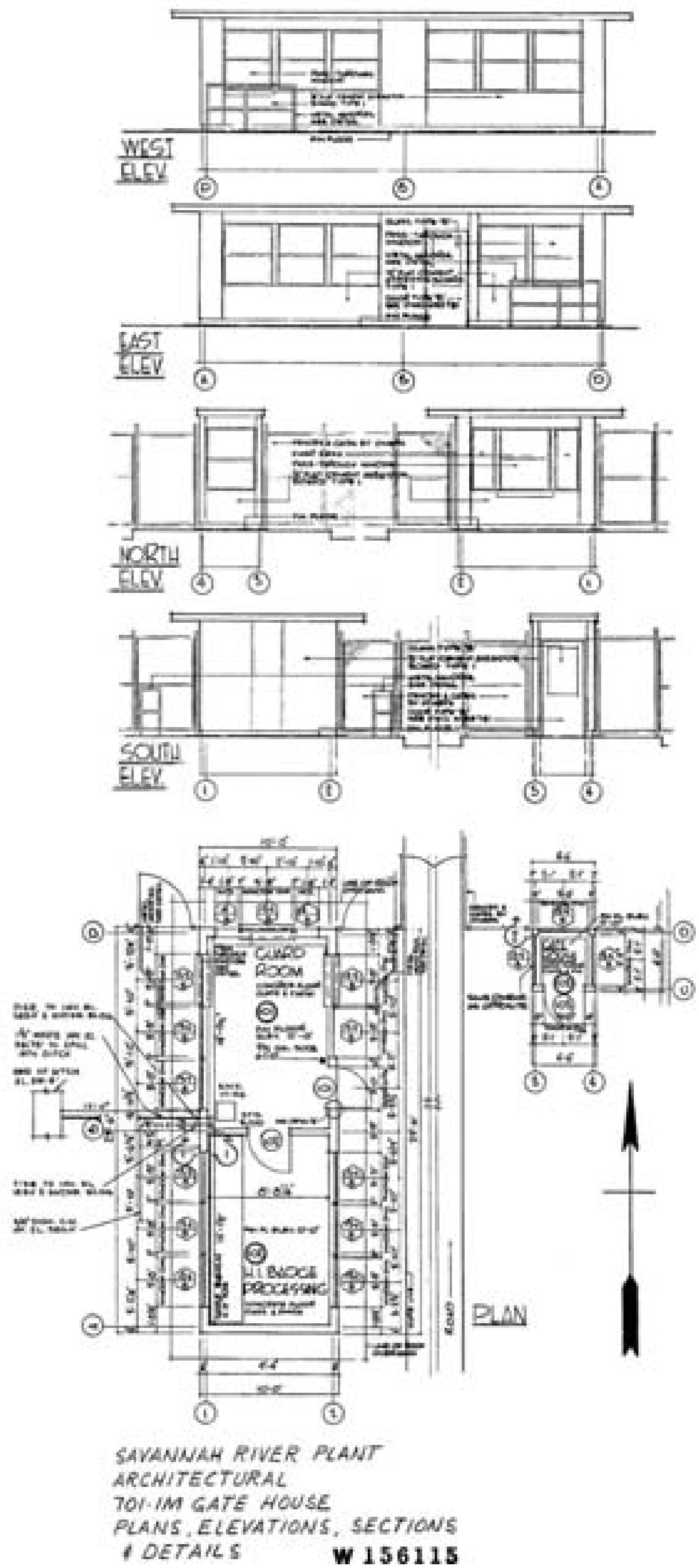
701-2M is a duplicate of the sentry box that formed part of 701-1M except in its building materials. It has a wood frame and built up roofing on wood. Otherwise it rests on a concrete slab and has Transite™ panels for its interior and exterior walls. 701-3M is larger; measuring 13 feet by 15 feet but also possesses a wood frame.

704-M Office and Change House

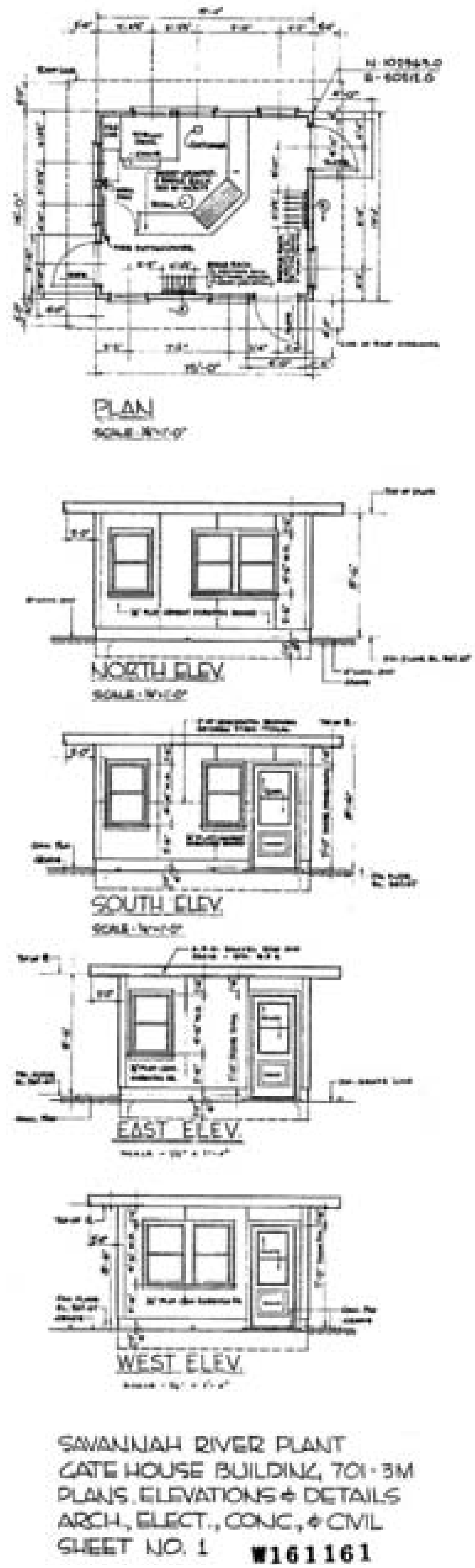
This building functioned as the 300/M Area administrative headquarters with office spaces (five) and conference room, locker rooms and lunchrooms. Designed by VWF&S, construction began on June 21, 1951 and the facility

Views of Building 704-M

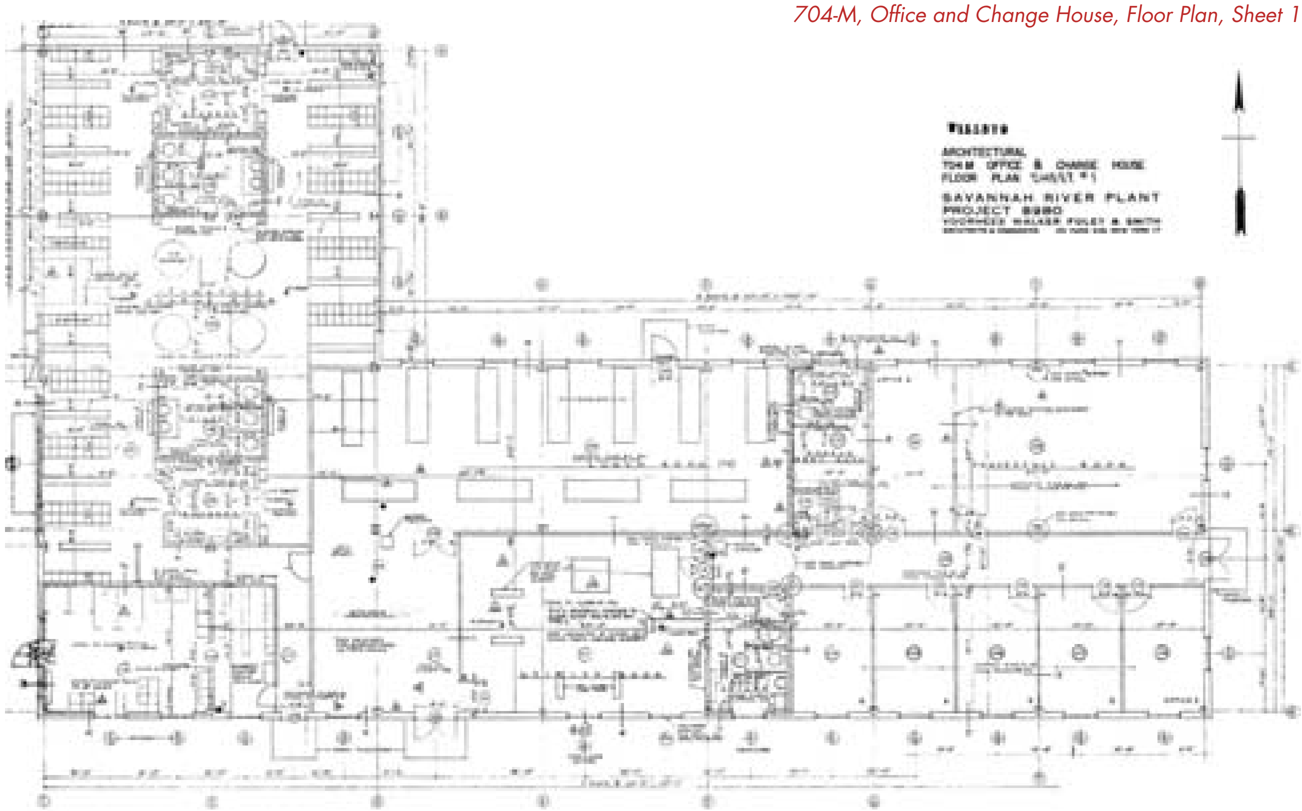
Detail of 701-1M, Gate House Plan and Elevations



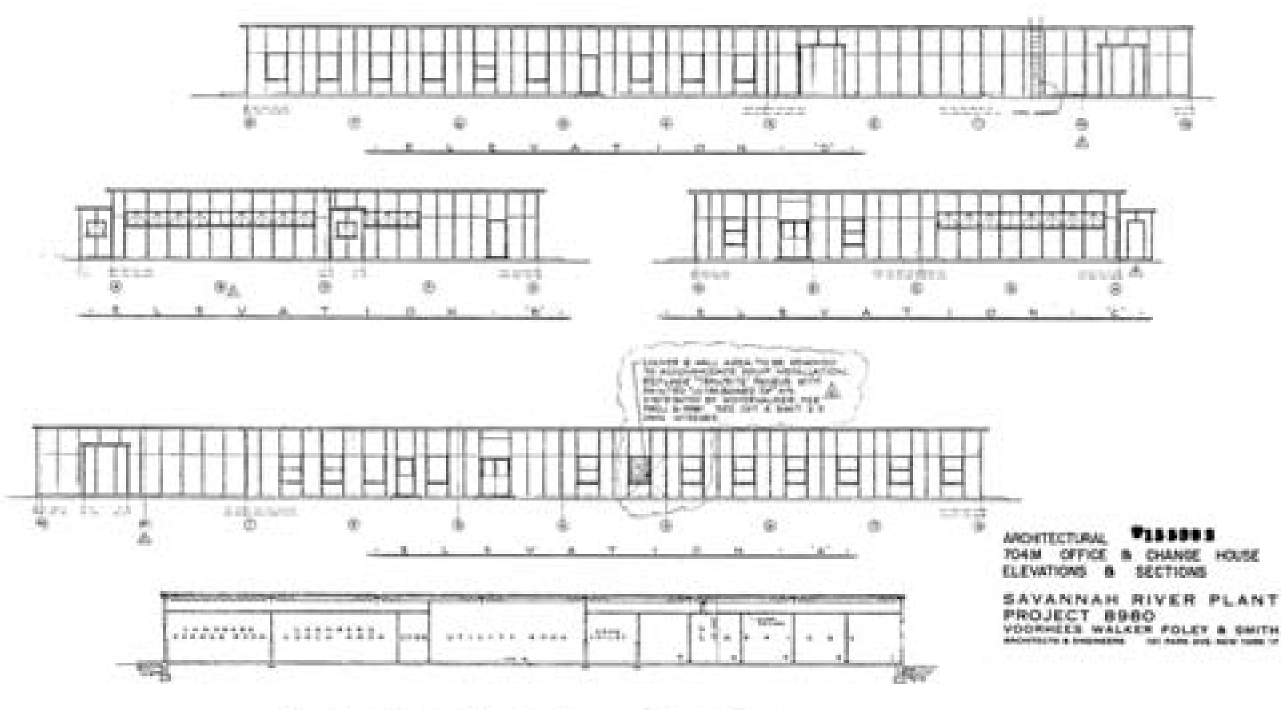
Detail of 701-3M, Gate House Plan and Elevations



704-M, Office and Change House, Floor Plan, Sheet 1



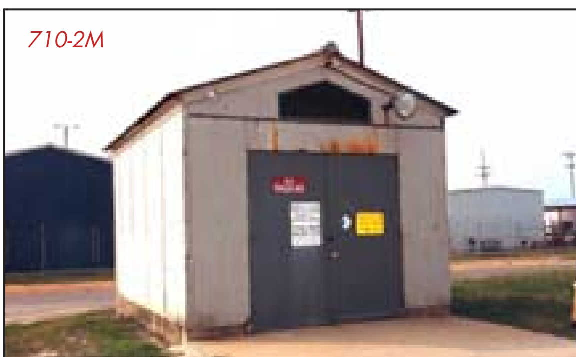
704-M, Office and Change House, Elevations and Sections



was partially occupied ten months later. Considered an expendable facility, this building was not built to sustain a bomb blast rather it was designed for friability, the ability to crumble, allowing its superstructure to remain in place.

It is a single story, Class III, L-shaped building measuring approximately 82 feet by 141 feet. It is a steel frame building with web roof joists, a reinforced concrete foundation with spread footings, and a concrete slab roof over rib lath. Walls both exterior and interior are Transite™ and the building has a suspended ceiling throughout. Built using a repetitive module of Transite™ panels and double hung steel frame windows, the building is functionally designed. The west wing features projecting steel frame windows. Entries are located in the east and west elevations. Interior details were spare with asphalt tile flooring and Transite walls. The doors are hollow metal.

Originally the building had five offices, a conference room, lunch rooms that could seat 96 individuals, locker, shower and toilet facilities to handle 250 employees (divided into office, operators and laborer's facilities), a storage room and an utility room. The operator's lunch and locker room occupied 3,600 square feet while the laborer's lunch and restroom space occupied 720 square feet. Office personnel had their own restrooms. Heat was furnished from radiators in some sections, forced air in others.


710-2M

710-2M Storage Building

This small single story, steel frame and Transite™ building on a concrete slab is a later addition to M Area. It was constructed in 1954 for the dry storage of lithium for use in 320-M. Affording 234 square feet of storage space, the small gable roof facility with corrugated asbestos roofing was situated south of 320-M at some distance for the safe storage of the needed raw material.

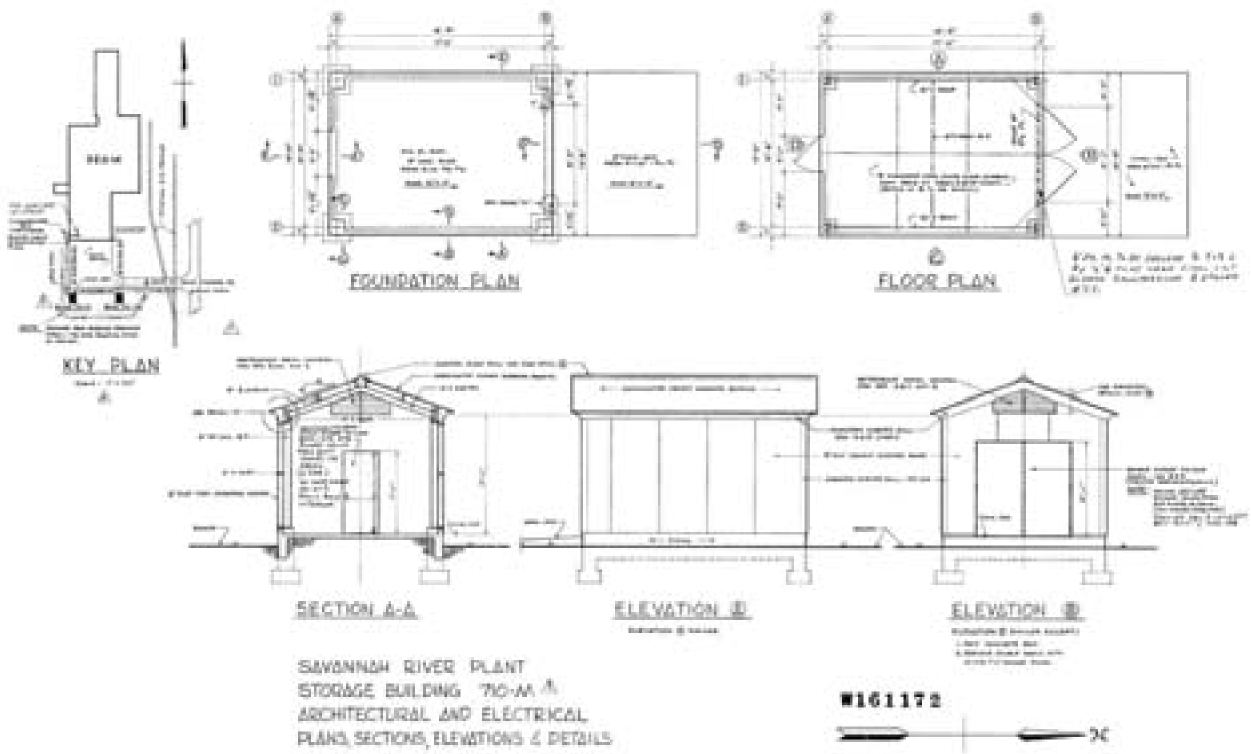
352-M Secondary Substation

Designed by Gibbs & Hill, this substation (not illustrated) reduced the electrical current received from Building 751-A, the Primary Substation, and delivered the proper current to 305-M and 777-M. Two sections of the substation are located on concrete slabs; the third is mounted on a platform. The entire facility, which is situated south of 777-M, is fenced. It was constructed between May 1952 and February 1954.

500-M - Properties

Du Pont designated infrastructure features with numbers. Thus in M Area, the perimeter fence and road lighting ("Fresnel luminaries") was considered Facility 501-M. Astronomical time switches were used and a blackout control system was in place. Electrical distribution lines were designated 503-M and the fire alarm system, which included fire alarm horns, pull boxes, alarm transmitter, etc and was connected to Patrol Headquarters (709-A) was designated 505-M. The Safety Alarm System, 507-M, was installed to provide security warning

710-M, Storage Building, Plan and Elevation



signals and an autocall signaling system for executives and key personnel. Loudspeakers, radio and telephone communications were tied into this system whose central controls were at patrol headquarters.

600-M Area

Standard gauge track laid throughout SRP was designated 601. In M Area, railroad transportation was used for freight items or for objects/materials too bulky to truck in. The rail line in M Area had 2,640 lineal feet of standard gauge track running for the most part parallel to Road D and to the east of the main manufacturing buildings.

Roads were given the building number 603 and pedestrian walkways were designated 604. Fencing which consisted of nine-feet high chain link perimeter fencing with gates was put in place by the Wickwire Spencer Company.

Parking areas were considered 613-M and any site work and general grading was assigned 697-M. The latter included all clearing of the site of trees, stumps and bushes by Green Construction Company.

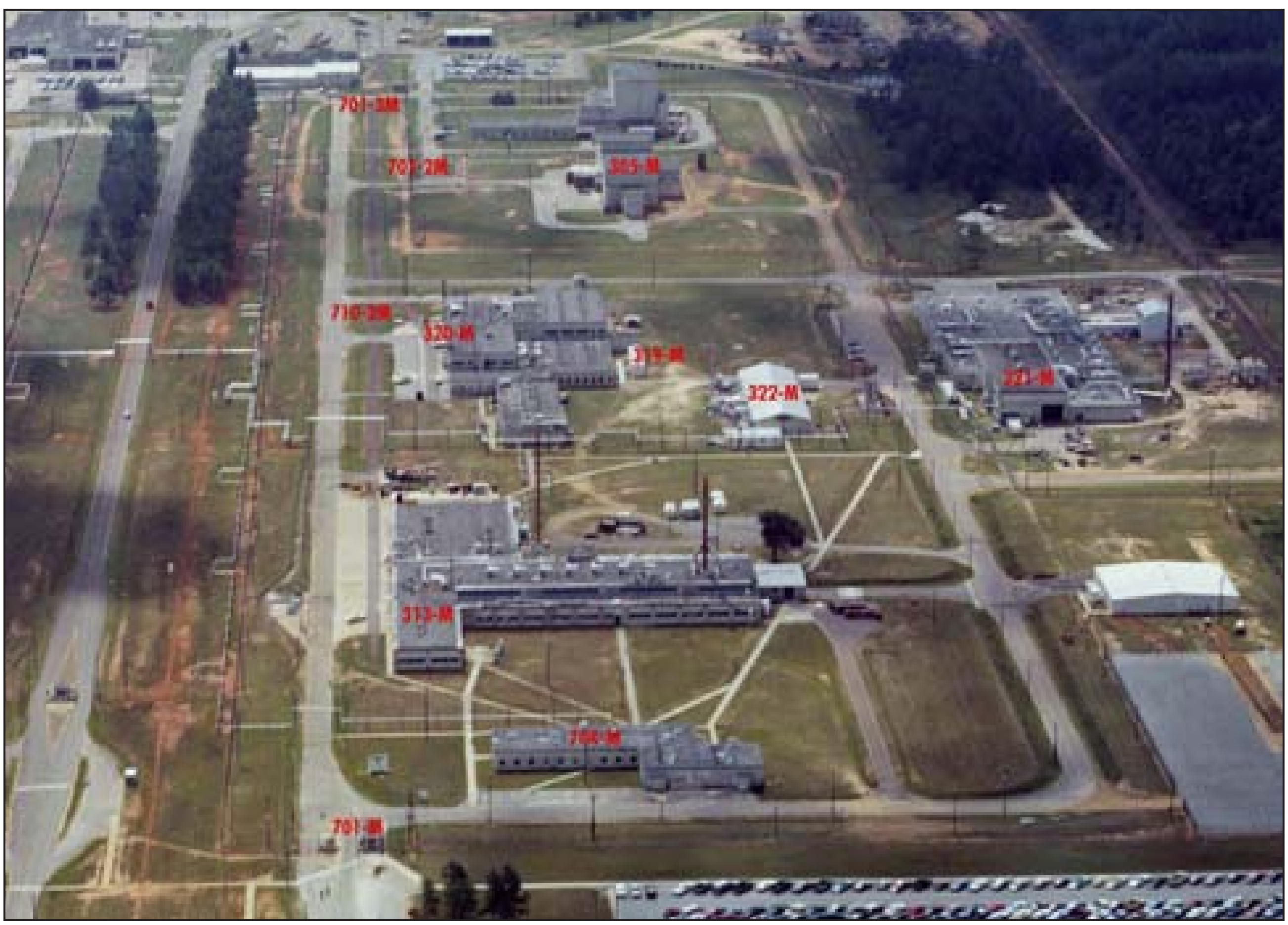
PROJECT S8-1044 – 1956-1958

The first fuel assemblies at SRP consisted of four columns of short aluminum clad cylinders of natural uranium metal placed end to end in 14-foot-long vertical Quatrefoil tubes. These were handily produced in existing facilities at the plant but SRP engineers recognized that these assemblies placed limitations on reactor power levels.[21] Research conducted at SRP showed that fuel types that had a higher surface-to-volume ratio would not limit reactor power levels and higher power levels translated into greater product yields.

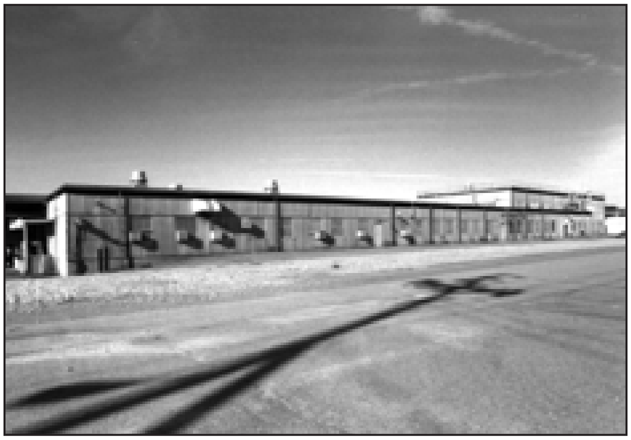
Du Pont had contracted with Nuclear Materials, Inc. as early as 1951 to consult on the manufacture of fuel elements. This firm would develop "coextrusion" a process in which highly enriched uranium metal was formed into a fuel tube that was bonded on both its interior and exterior producing the needed higher surface-to-volume ratio. Referred to as "extended surface elements," experimental work was first completed in 320-M.[22] By early 1955, sufficient study had been accomplished by Savannah River Laboratory personnel and in concert with national laboratories to develop engineering specifications for facilities to produce a new element known as the Mark VI that was composed of a column of target slugs placed within an enriched fuel tube. A second component design candidate, the Mark VI-A featuring two concentric fuel tubes surrounded by a target tube, was also under consideration but laboratory development had not advanced to warrant the design of new production facilities for it.

The new facilities included a manufacturing facility referred to as 321-M, a metallurgical laboratory or 322-M, a tank farm, an air compressor house, a seepage basin, and the extension of services (transportation, power, well, etc) to the new facilities as well as additions to 320-M or the Alloy Building.[23] VWF&S was not involved in

Aerial View of M Area



these construction projects. Both architectural and engineering for the new facilities were handled in-house by Du Pont's Engineering Department's Design Division, Construction Division, and Engineering Service and Research Divisions.[43]



Views of 321-M, Looking Northwest (Left), and Northeast (Right)

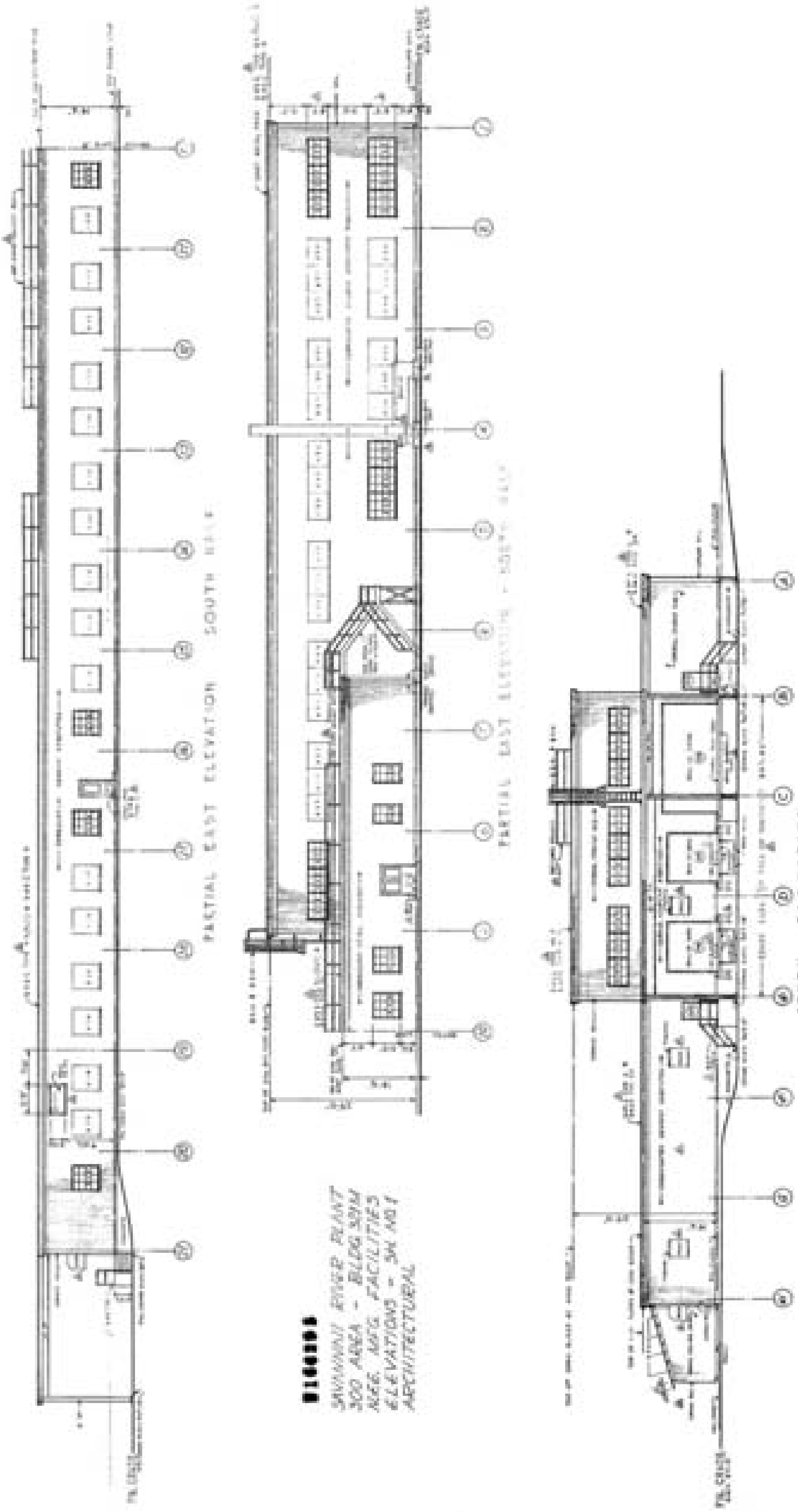
321-M Manufacturing Building

Du Pont's Wilmington Process Section were mainly responsible for designing this facility but SRP Production personnel, Works Technical, and Technical Division personnel all played a part in its creation. Du Pont's Wilmington Process Section designed a building that fit well with the surrounding architecture. Construction began in June 1956 and the building was completed in September 1957. It housed equipment used in fabricating highly enriched tubular fuels and was the focus of the coextrusion program.

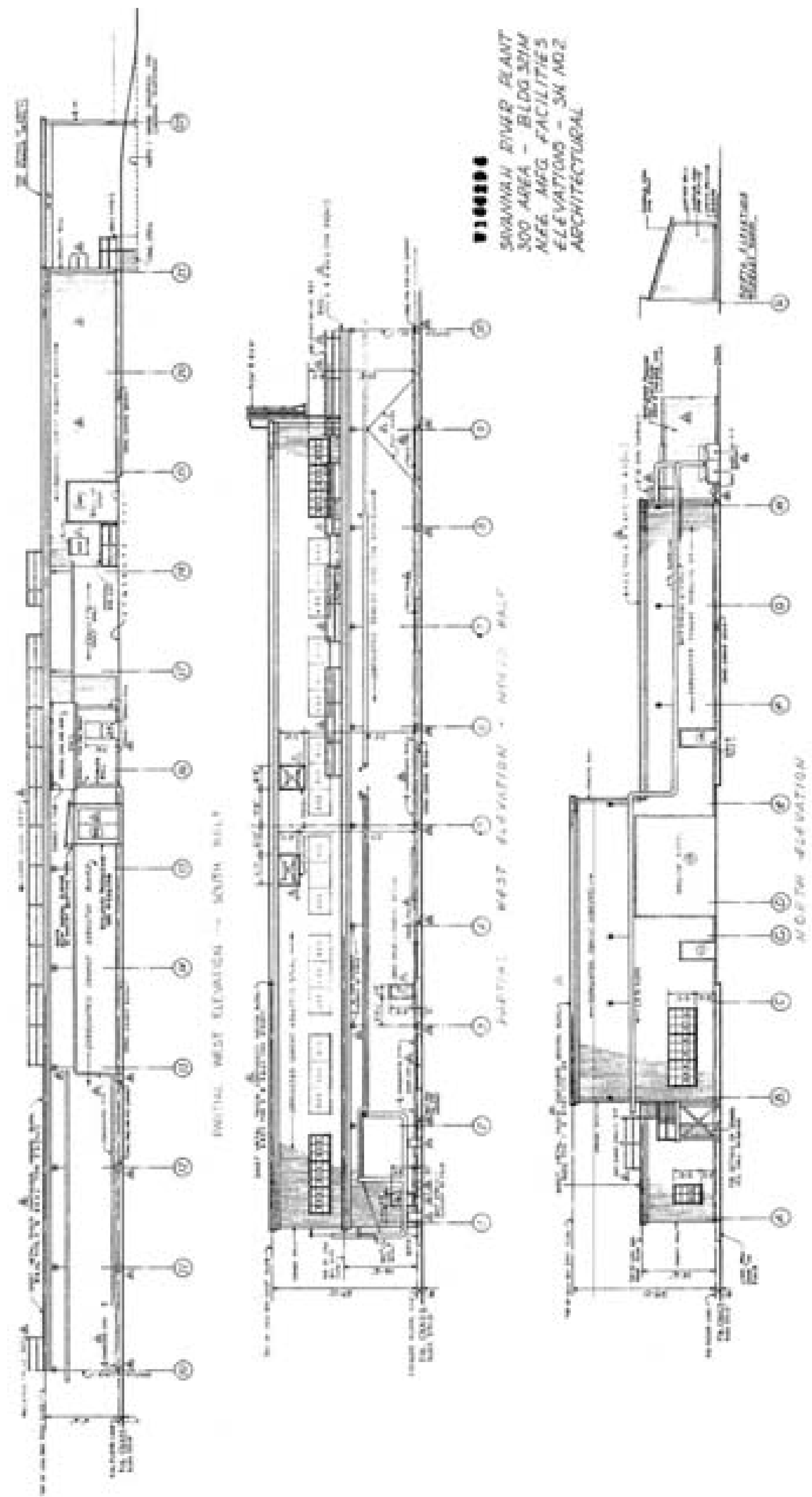
321-M, a Class III building, was sited east of 320-M essentially creating a new "block" of development in 300/M Area. It is a single story, steel frame, roughly rectangular building with a concrete roof slab and Transite™ siding. Overall it measures 400 feet in length and 120 feet in width. The roofline has two heights. The taller section (60 feet by 160 feet) on the north end of the building reaches 30 feet in height. It housed the extrusion press. Shops and offices were situated in a 24 feet by 292 feet bay extension on the east elevation. A covered loading dock was placed on the south end of the building.

Steel sash windows were placed on the east elevation and in the extrusion press area that had two bands of windows. Industrial doors were steel rollup while personnel doors were hollow metal.

Oralloy, a term for enriched uranium processed at Oak Ridge, was the main raw material used in 321-M and its use demanded special attention due to its value and its reactivity. Security, accountability, control of contamination and the prevention of criticality were all mentioned as design parameters for 321-M. A Class I vault was constructed in the storage, receiving and shipping area in which "bird-cage" containers from Oak Ridge could be stored. Intermediate and finished materials produced during processing were kept in a locked storage area.

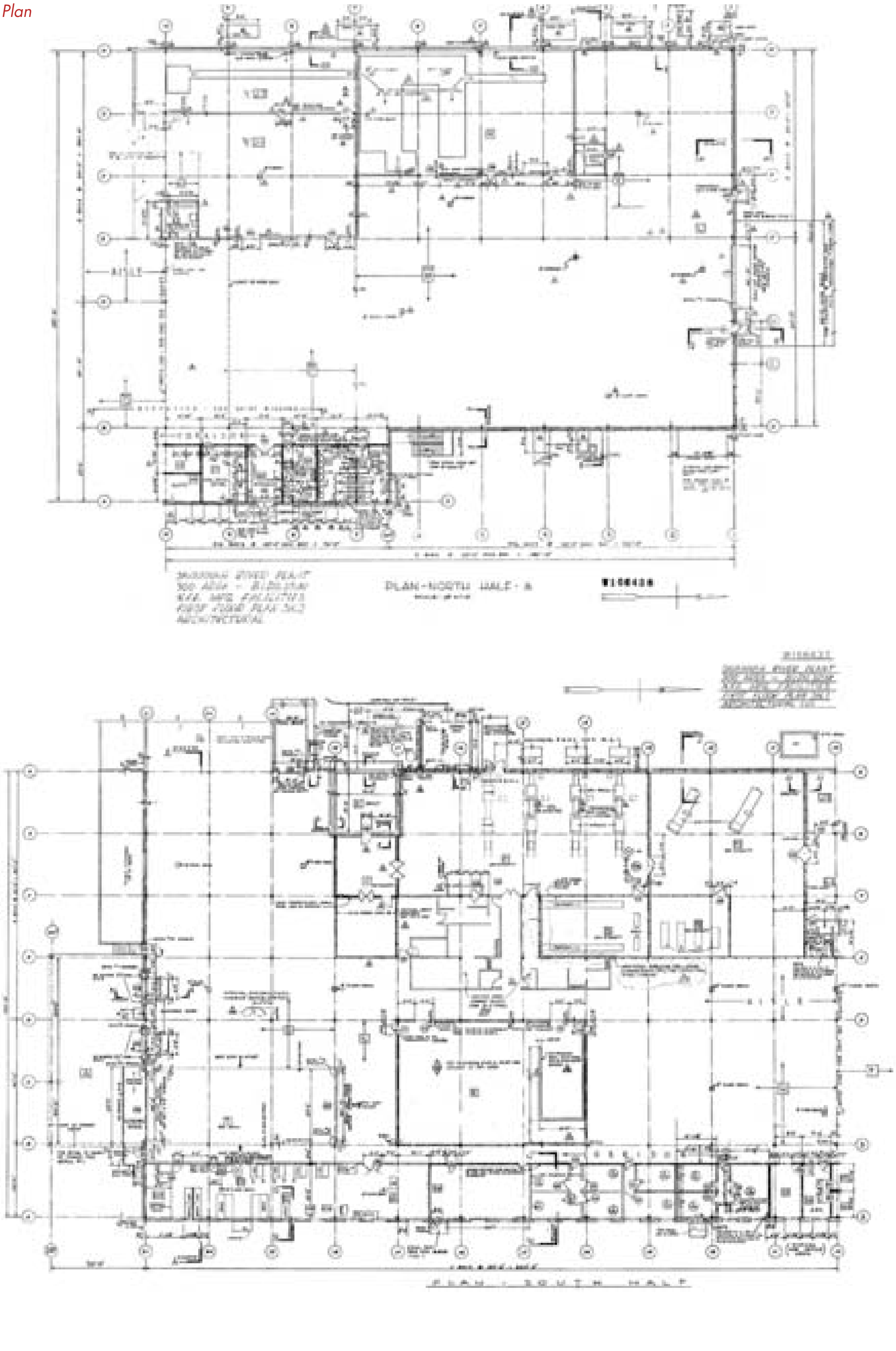


321-M, N.F.E. Mfg. Facilities, Elevations. Sheet No. 1



321-M, N.F.E. Mfg. Facilities, Elevations. Sheet No. 2

321-M, Plan



The main process areas were:

- storage, receiving and shipping;
- melting and casting;
- x-ray inspection;
- extrusion;
- inspection;
- straightening;
- machining;
- cleaning;and
- checked and stored/packaged.

320- M Alloy Building Additions

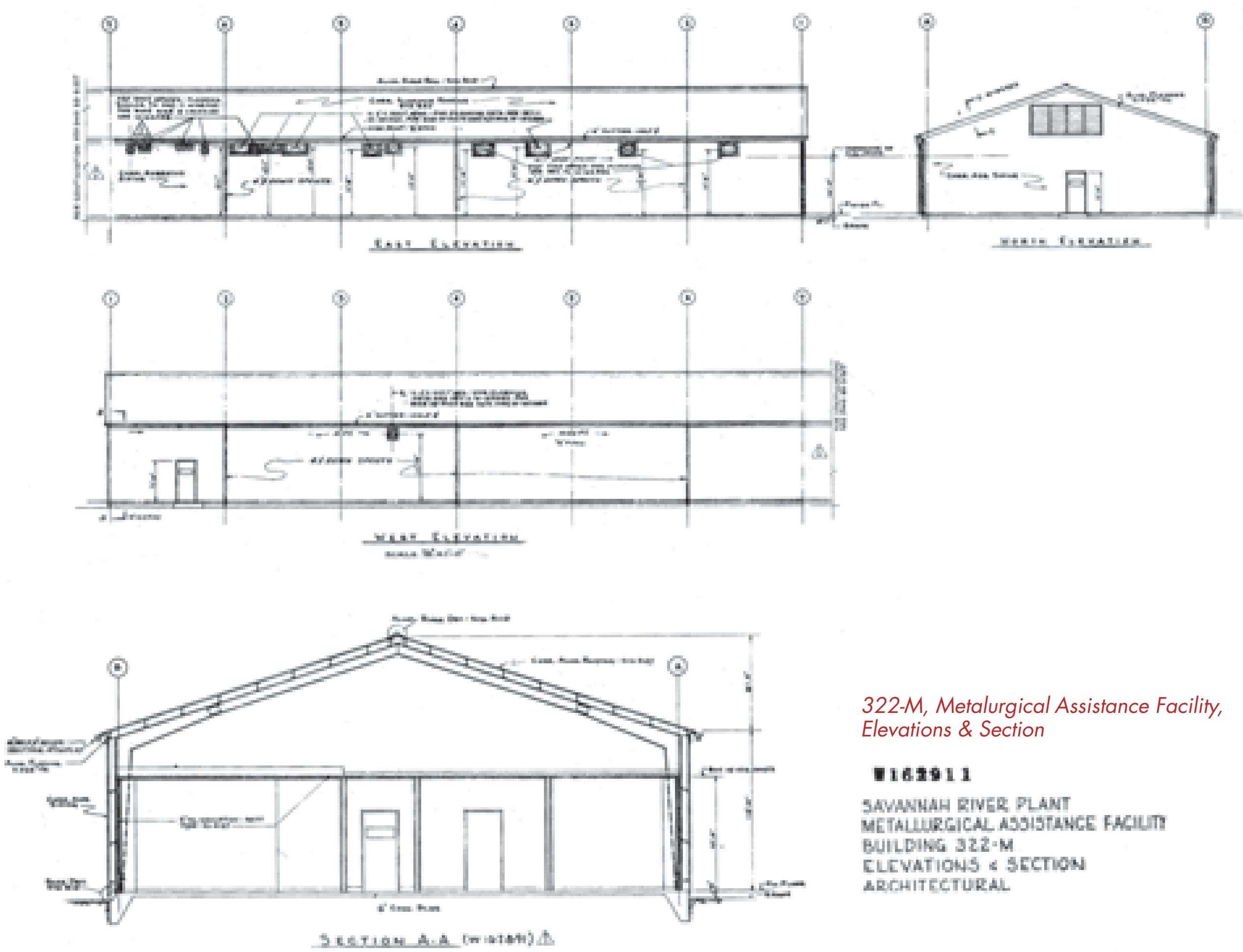
As the equipment needed for production of the Mark VI fuel component was considered similar to the original equipment, Du Pont chose to process all target materials in that building. A 60-feet by 60-feet two-story addition was appended to the south end of the building where the furnace area was located and interior arrangements modified so that:

- the billet lathe area was enlarged by adding the space allotted to the original welding area;
- the welding equipment was then placed in the storage area in the south end of the building;
- the pin machining room extended by a bay;
- five modules were added to raw materials laboratory and a small 53 feet by 20 feet addition was constructed to house a materials laboratory and a lithium laboratory; and
- a second floor area was created via the extension of the original roof over the furnace are extension. The building materials matched those used in the original construction of 320-M.

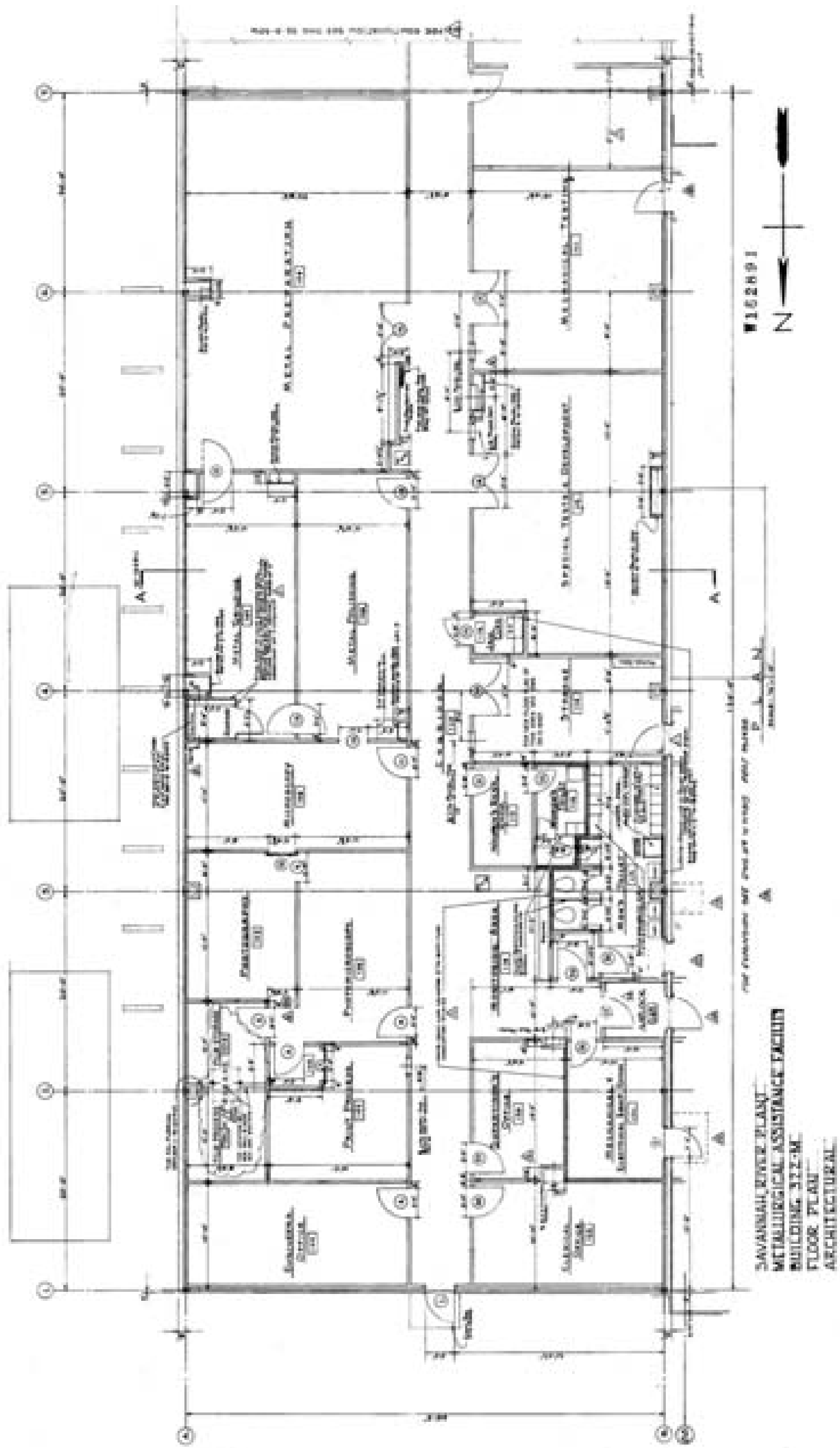
322-M Metallurgical Laboratory

A Class III 5,800-square foot laboratory with a service floor had been on the books for construction but as a cost savings gesture a Butler prefabricated steel structure with a corrugated aluminum gable roof was substituted. The

Historic View of 322-M



322-M, Metalurgical Assistance Facility, Elevations & Section



322-M, Metallurgical Assistance Facility, Floor Plan

120-foot long by 50-foot wide and 14-feet from floor to eaves building placed on a concrete slab was strategically situated between 320-M and 321-M.

It would later be enlarged by adding two gable roof pre-engineered metal buildings produced by INRYCO on its north and west elevations.

View of 319-M

311-M Tank Farm

A small tank farm consisting of a 9-feet by 36 feet stainless steel tank and a similar tank slightly smaller was added west of 321-M and a railroad spur added to access it. Both were bullet-shaped tanks resting horizontally on concrete saddles, an elevated platform between them. The larger tank was for nitric acid and the smaller for trichloroethylene, both were pickling and cleaning solutions used in 300/M area operations.

319-M – Air Compressor House

Situated directly west of 321-M, the compressor equipment housed in this facility supplied air to 321-M. It was a small, one-story, steel-frame, gable roof building.

Other Facilities

Additional roads, utility connections, sanitary sewage disposal facilities were also added to accommodate the expansion. A roughly rectangular earth-embankment type seepage basin was created that was approximately 330 feet long and 220 feet wide. The basin, a focus for environmental remediation in the 1980s, was situated west of 300/M Area. Process wastes (including acid wastes that were neutralized before discharge to the process sewer), steam condensate, and cooling water were sent to the process sewer then to the seepage basin. At that point in time it was believed that the basin would allow the dilution of waste and act as a filter, with slow seepage through underground channels that led to the river.

SUMMARY

Initial construction began in April of 1951 and 300/M Area, as first conceived, was largely completed in 1953. Expansion was swift as the technological base grew. The scientists and engineers at Savannah River Laboratory worked closely with operations personnel to work through initial design challenges and to make advances in fuel and target technology.

The initial push to build out the area was collaborative with VWF&S working with Du Pont to accomplish the civil engineering and building construction involved. However, once operations began and the refinement of processes occurred, Du Pont handled all new construction. The construction period ended and the work began in earnest as operations personnel having achieved startup now settled in began refining the processes.

V. PROCESS EQUIPMENT

Even before bulldozers began prodding 310-square acres of South Carolina's rural agrarian land into a Cold War landscape, a host of American companies and research facilities were engaged in determining the guts of that transformation – the process equipment needed to produce nuclear materials.

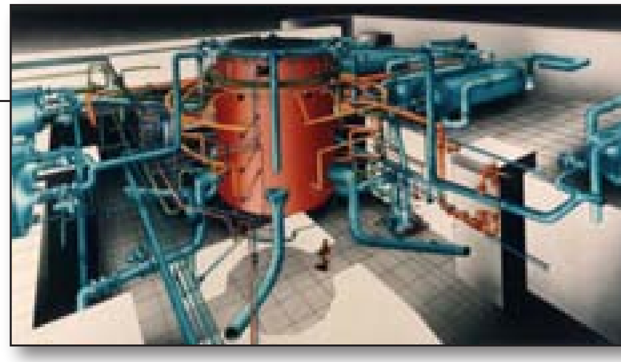
American Machine and Foundry, Argonne National Laboratory, Alcoa, and others responded to a scope of work that was fairly fluid. The Engineering Histories provide details of the whole development process chronicling successes, failures, and attempts that were put on hold either for cost effectiveness or scheduling. The process equipment development was conducted in a flexible design environment that could respond to changes in product requirements from the AEC. This same design environment was marked by openness in that multiple players were involved under the direction of Du Pont. This sense diminishes as the plant nears the end of construction. The newly established Savannah River Laboratory, working at times in concert with the national laboratories, assumed process development authority. Dedicated to solving start up problems, production efficiency and the development of new production processes, the laboratory's scientists and engineers energetically began work in 1953. Their efforts would result in an expansion of 300/M Area and continued change as fuel and target fabrication processes were refined. The development of the processes and the equipment needed to carry them out follows. In a general sense the process equipment discussion is handled by building as each 300/M Area building housed a distinct process or set of processes. In fact, the building number and process were used interchangeably in the historic documents that provide their history.

PROCESS EQUIPMENT DEVELOPMENT

American Machine and Foundry (AM&F) was a major contributor to the 300/M Area process equipment overall as well as work in other process areas and their efforts were described in a separate construction history that encompasses the whole of their work in SRP's construction. While other firms would contribute directly to a specific piece of equipment or to parts of a process or to an approach, AM&F appear to have been more of a prime subcontractor on call to fabricate whatever was needed as well as specific equipment. Their history provides a unique view into how the subcontractor relationship worked within the flexible design environment.

A manufacturer of industrial machinery and the world's leading manufacturer of cigar and cigarette making equipment, AM&F was in the midst of an expansion when Du Pont approached the firm for help with the construction of the Savannah River Plant. AM&F was actively seeking military contracts in 1948 that would advance the diversification of its product base. To date the firm had specialized in a variety of automated equipment such as cigar and cigarette-making equipment, baking equipment, dispensers, drill chuck, saws, industrial mixers and other equipment.[1] The firm's portfolio and expansion plans must have been convincing as Du Pont brought AM&F on board specifically to "design, develop, and manufacture prototype machines and mechanisms and process development" for use in the

REACTOR DESIGN



The Savannah River reactor tanks were cylindrical and, in size, roughly as high as they were wide. The tanks would be filled with heavy water, which would serve as both coolant and moderator. The various fuel and target elements entered the tank from the top, with elements arranged in a triangular pattern, with seven inches between basic lattice positions. There were two sizes for the hundreds of openings or lattice positions that accessed the reactor tank. Known as principal and secondary lattice positions, the former had larger diameters than the latter. The principal lattice positions were to be filled with quatrefoil fuel assemblies, loaded with uranium slugs, and septifoil assemblies that contained control rods; a small group of positions acted as gas ports located along the periphery of the tank. The secondary positions were reserved for safety rods, bismuth irradiation rods, and instrument rods or "thimbles." In later years, source rods, used to provide a neutron source for instrument detection, would occupy some of these positions.

The principal lattice positions were arranged to form two different lattice arrangements within the reactor. The central area, comprising 65 percent of the core, was the "flat zone" or FZ lattice, so named because the radial distribution of the neutron flux was constant or "flat." The outer 35 percent was known as the "buckled zone" or BZ lattice, where neutron flux decreased rapidly with distance from the outer edge of the flat zone. All of these positions were identified by a rectangular system of coordinates, with the x-axis identified as the north–south line, parallel to the long axis of the reactor room.[2]

Heavy water served as both moderator and cooling agent, with 94 tons in the reactor tank, and another 106 tons in the circulating system. In the first reactors, six pumps circulated heavy water through the reactor system. The design called for heavy water to enter the reactor tank from six inlet nozzles spaced around the top of the tank, or water plenum. Heavy water would then leave the tank through another six nozzles placed around the base. The heavy water would be reused after being forced through six heat exchangers, where it would be cooled by light water pumped from the Savannah River at a rate of 67,000 gallons per minute. The decision to install only six heat exchangers in the first reactors was made because of the shortage of heavy water. Provision was made for the addition of another six for a possible total of twelve.

To make a reactor critical, the safety rods had to be withdrawn, after which the control rods were withdrawn sequentially from the septifoil housing in such a way as to control the reaction. Each septifoil was a seven-chambered aluminum tube that contained two cadmium rods, lithium-aluminum rods, and lithium-aluminum rods. The cadmium was a neutron absorber, or reactor "poison." The lithium in the control rods absorbed neutrons to make tritium. In the first year of full operation, the only tritium produced at Savannah River came from the lithium bombarded in the septifoil control rods.

reactor, separations and fuel and target fabrication process areas at the plant. The contract estimate for the work to be completed was $12,731,542.

AM&F employees working on the Du Pont contract were first located at the firm's Brooklyn annex then the New York Authority Bus Terminal. The addition of more project-related tasks led to the establishment of further laboratory spaces for assembly and test areas such as Special Projects Laboratories in Brooklyn and Buffalo. The Brooklyn Special Projects Laboratory, adapted for use from a company warehouse and incorporated a 60-foot high tower, was adapted for use. This facility housed an assembly shop, machine shop, a chemical and metallurgical laboratory and an electrical assembly shop. Interestingly, the engineers were assigned compartmentalized workspace within the laboratory that was divided by the type of process equipment under development. Hence the AM&F lab had "100", "200" and "300" work areas, terms synonymous with reactor, separations and fuel and target production respectively. The number of engineers assigned to these tasks is unknown but about 400 AM&F employees were provided with "Q" clearances so they could work on the Du Pont contract in 1952. The Special Projects Laboratory for 200-300 Area was guarded around the clock and all classified metal materials as well as other items were placed in vault when not in use.

Weekly conferences between AM&F staff and Du Pont's Engineering and Design personnel were key to design development. As noted above, Hanford provided a context for the project. The operations crew sent for training to Hanford would provide information and Du Pont's experience in constructing Hanford was a bonus. However, Du Pont's first brush with the nuclear industry ended after World War II; General Electric assumed the post war operation of the Manhattan era site. When Du Pont returned to the atomic energy field in 1950 to construct SRP, it was able to see what worked and did not at the WW II plant and hopefully better engineer the new process area projected for South Carolina.

Design of SRP's reactors was underway in the fall of 1950 with Du Pont and members of the Argonne Laboratory worked in cooperation. Fuel dimensions were one of the many elements worked out during this time period. The primary question was whether the reactors should be designed for the production of plutonium or tritium. Initial plans called for a concentration on tritium but the AEC also wanted the reactors to produce plutonium. Du Pont engineers reached a compromise that permitted both; they moved the fuel rods closer together, allowing the reactors to reach higher power levels as needed to produce either isotope.[3] Thus the AEC's vacillation between the reactors' primary use as either a plutonium-producer or a tritium-producer led to the development of "versatile" reactors.

The Du Pont engineers decided to concentrate their design efforts on a "pilot pile," essentially a first reactor, that could be used to check the design work needed for the other four reactors to follow. The pilot pile could be used for full-power tests of fuel elements and lattice arrangements. This pilot pile was 105-R. Timing was critical for fuel and target developers as the new 300/M area products, fuels and targets, were needed to charge 105-R as well as the plant's test reactor, a zero power heavy water reactor known as the Process Development Pile, that would be built for 777-M (later known as 777-10A).

This use of flexible design allowed Du Pont and AM&F to move forward on the 300/M Area process equipment while reactor design was underway. Working under Du Pont's direction, AM&F adapted existing industrial tools/equipment for incorporation into the process parameters, developed prototypes, and created flow patterns for actual process work. Historical summaries written by both firms concerning their role in SRP's establishment strongly indicates that AM&F was assigned components of the development of 300/M Area processes, in some case this included an entire process and in other instances just tools or parts of the process equipment needed for a given process. Du Pont's engineers appear to have handled the acquisition of commercially available components that were needed as well as designed or adapted parts of the processes in tandem with AM&F. The extent of the collaboration between the two firms and their individual contributions to the process equipment development and first installation is chronicled in the AM&F narrative, *Savannah River Plant Engineering and Design History* completed in 1954. It is replete with code names for processes, as is Du Pont's later in-house summary for the 300 Area construction in a series with the same title completed in 1957.[4] The following discussion draws on both summaries to provide a balanced view of the development period and the equipment that was first installed to produce fuels and targets.

The AM&F history states that existing equipment at Hanford was evaluated for use at SRP but "it was found that practically nothing was of direct value to the new plant because of obsolescence."[5] This quote refers to the types of targets and control rods needed for SRP's heavy water moderated and cooled production reactors that were considerably different from those fitted out at Hanford and would require process development. The AM&F history provides a step-by-step discussion of target and control rod manufacture as well as a flow plan.[6] In contrast, the initial fuel slug canning process, less well described in the AM&F narrative, was essentially borrowed from Hanford. However, it is clearly stated that time prevented the development of a more improved technology for startup. Hanford's technology, the triple-dip method, worked. But Du Pont was keenly interested at producing a better can assembly program as soon as possible and its Engineering Department Design Division and its subcontractor AM&F sought to modernize components within the equipment that was installed at startup and to establish a path forward toward better process design. AM&F did borrow the services of a Hanford welder to help with the project but their account notes that AM&F was responsible for developing new equipment such as a new can-welding machine. The AM&F can-welding machine superseded its predecessor at Hanford, producing better welds automatically.[7] This advancement was then incorporated into Hanford's operations beginning a pattern of technology transfer between the two nuclear production plants.

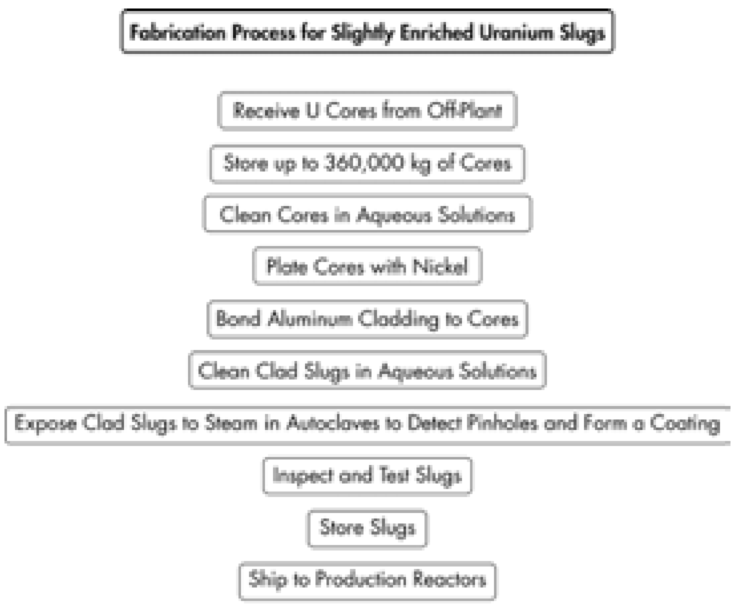
AM&F would design the equipment for future operations in facilities 313-M and 320-M. Appendix A contains a full summary of the tasks completed by AM&F for Du Pont, the quantity of machines produced, and the date completed. The manufacture of fuel, targets and control rods production equipment was in their purview. The major jobs were the development of parts of the "F" or fuel canning line and target production in its entirety. In addition to the fuel and target production lines, they performed economic and mechanical studies to further efficiency within process development and operation. For example, they worked out a chemical pickling process for cleaning fuels that would allow a production rate of 400 fuel slugs per day using commercially available equipment. It some cases it appears that AM&F was responsible for the development and the delivery of machinery for use at Argonne National Laboratory or other testing facilities. In other cases prepared raw material was delivered for use. Clearly, AM&F as well as the other contractors involved responded to an open scope of work. Also, the AM&F job summaries give some sense of how many pieces of equipment were made for delivery or if specifications were the sole deliverable.

While all the listed tasks (Appendix A) were important, the creation of equipment to outfit the major process buildings in the 300/M Area designated as 313-M or Manufacturing Building and 320-M or Alloy Building needs further discussion.

FUEL FABRICATION EQUIPMENT, 313-M

As noted above, the initial process was essentially adapted from the Hanford operation that used the triple dip process with aluminum-silicon bonding of the slug fuel to the can. This design decision was based on schedule. While some of the component parts used at Hanford would be available commercially, others needed to be fabricated. An important first step was the freezing of design data on the dimensions of the fuels and targets that needed to be produced. AM&F received this data from Du Pont and Alcoa in February 1951, two months after they received the work order to proceed.

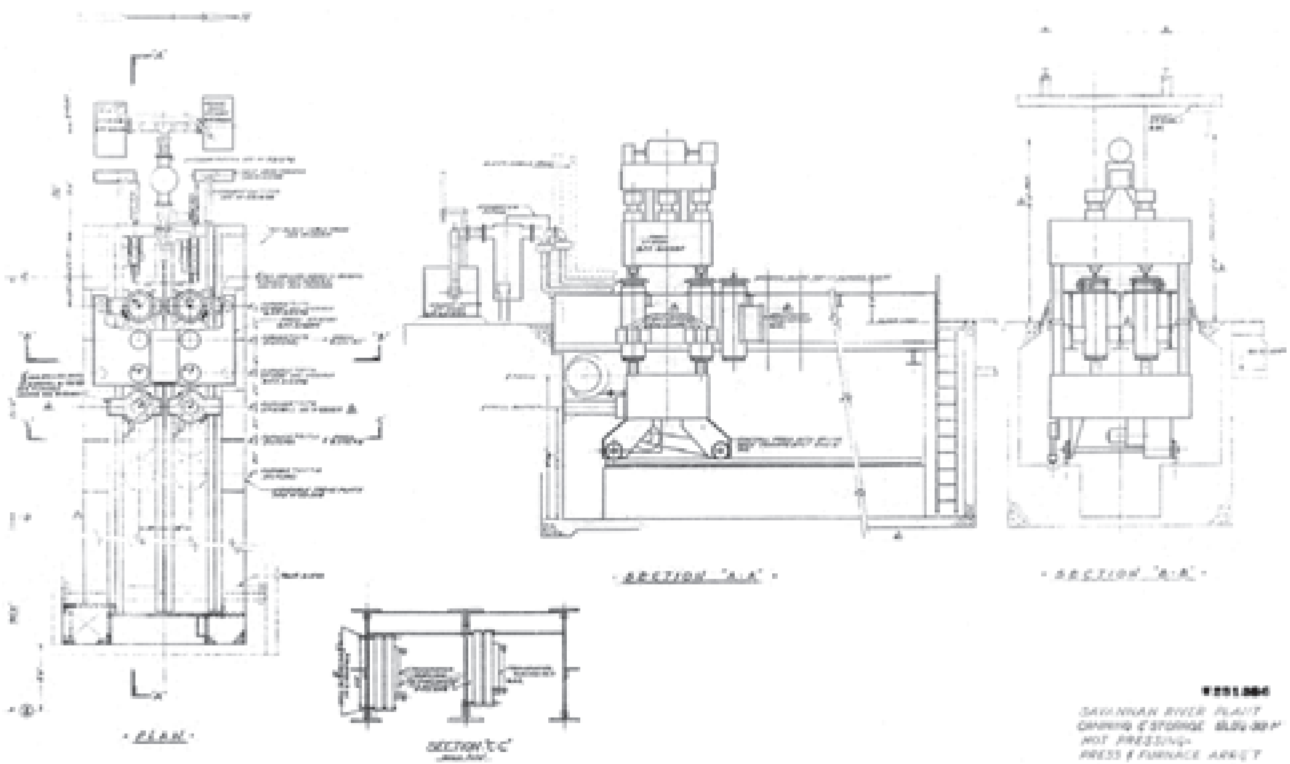
The manufacture of slugs in 1950 referred to the jacketing of a uranium slug with an aluminum can and the finishing of the can to specified dimensions. There were three components involved: a uranium slug and an aluminum cap and can. All three were to be cleansed prior to the canning process during which the slug would be encased

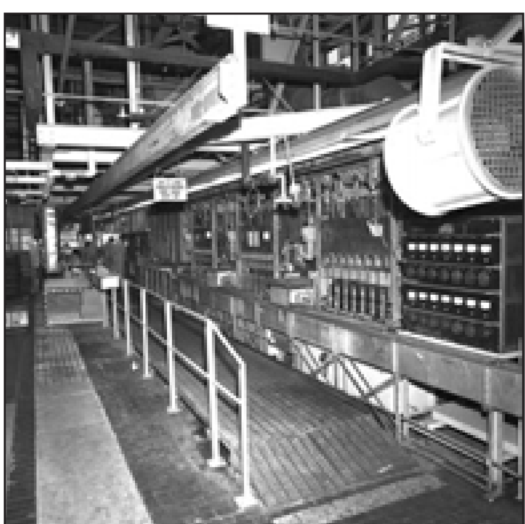


in the can and cap using a molten aluminum-silicon alloy as the bonding agent. After canning was accomplished, the fuels would be machined to size, the cap can seam would be welded and the finished product would then be ready for testing.[8]

The process outlined above required a line of resistance furnaces for the molten metal and tanks for pickling, cleaning, and quenching. The process began with the preparation of the slug, can, cap, and sleeve all of which were purchased. Not all purchased slugs were found to be acceptable; slug warpage remained a continual problem.

The first step involved checking for dimensional accuracy, testing, and cleaning. The slugs were degreased, pickled in nitric acid, rinsed, and then dried. The caps and cans were also degreased, washed, etched, rinsed and dried. New sleeves were degreased, blued (which involved heating until a blue oxide formed), soaped and dried. Used sleeves were also recycled for reuse after they were stripped and cleaned.

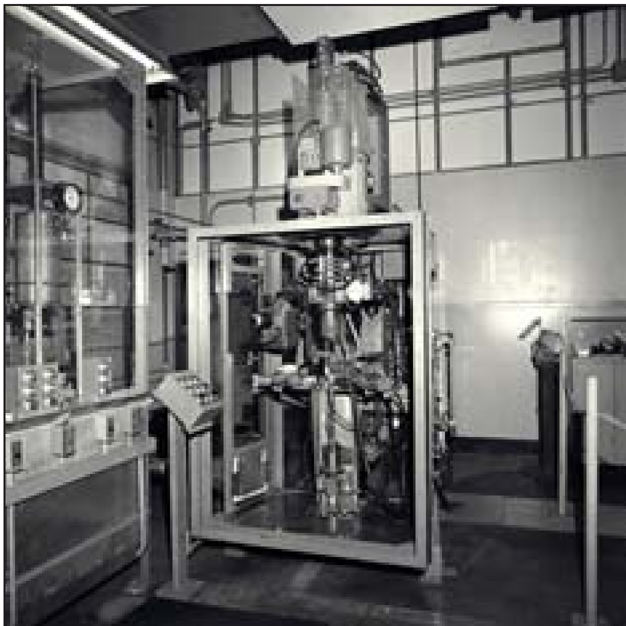


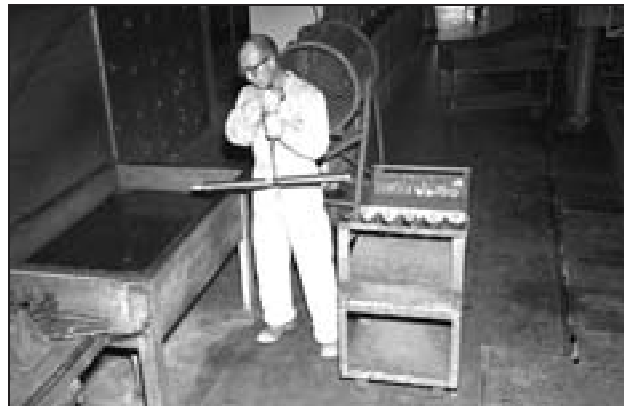


Hot Press Line.

Sixteen heavy-duty resistance furnaces were acquired for the canning line. The canning of slugs was a manual operation that required operators to move from furnace to furnace, dipping slugs into furnace vessels containing bronze, tin and aluminum silicon (Al-Si) alloy. The slugs were first dipped in the bronze bath heated to 730° C. then treated to remove any oxides that might accumulate. The bronzed slugs were then quenched in a tin bath at 600° C. to cool the slugs to canning temperature, to remove copper from the bronze and to promote more successful "wetting" in later dips. A centrifuge then removed the excess tin and the tinned slugs were immersed in a molten aluminum-silicon (Al-Si) bath at 590°-600° and then dipped in a second

Miscellaneous Views Showing Testing and Cleansing Equipment in 313-M.





Al-Si bath. Specially designed baskets were used for dipping, tongs were used to transfer slugs in some parts of the process, and agitators were used to keep the molten baths consistent in their texture.

The second Al-Si dip was more complicated; both slugs and cans were dipped in this bath and the slugs inserted into the cans. The aluminum cans, encased in steel sleeves, were dipped simultaneously with the slugs into the second Al-Si bath and the slugs were inserted into the cans while they were submerged. Canning lifts were used to accomplish this. Preheated aluminum caps in the Al-Si bath were then inserted in the cans by force. The canned slugs were then removed from the bath, quenched with water and then inverted so that the canned slugs would slide out of the sleeves.

The process required handling tools to safely move the slugs through the furnace stations, to agitate the molten metals in the furnaces, and a canning lift assembly to immerse and retrieve submerged slugs from the Al-Si bath. AM&F delivered a variety of tools for these purposes– tongs, basket agitators, baskets, lift assemblies, and centrifuge tongs - that differentiated little from the tool set used at Hanford for the same process except that the length of slugs at Hanford were 4 inches in length rather than the 8 inch long slugs for use at SRP.[9]

Manual and labor intensive, the canning process was described as a line operation. Similar handling tools were required for the bronze furnace that was used prior to tinning the slugs in some examples. Notably the agitator on the tinning furnace was initially operated by a treadle but was shortly replaced by a motor.

After canning, the slug was ready to be faced and welded. Facing involved the preparation of the cap end which was cut and faced to a certain thickness and a V-shaped groove 0.050" deep was machined into the Al-Si bonding layer. A turret lathe was used for this purpose. Can welding was a critical issue and seven machines were developed to weld a fold-over closure on aluminum cans. To do this, AM&F designed an inert arc-welding machine using a water-cooled torch and argon gas that could be operated manually or automatically. The machine welded bonded slugs (1" and 8-7/16"long), target can assemblies (3/4" x 10-1/2"), and 35W5 can assemblies (620" diameter x 6.445" long).

Visual inspection and the testing of the canned slugs was the final step in their fabrication. Canned slugs that did not meet the specifications were discarded and those that did not have a good bond were eliminated using a frost test. The remainder was then treated in an autoclave (a pressurized steam heated vessel used to establish special conditions for chemical reactions) to test for the soundness of the canning and weld. If they swelled slightly they were rejected or if they were off the mark on diameter and warp. X-ray of the cap-can weld also weeded out problem canned slugs. Five percent of the output was sent to 305-A for further testing and then returned to their lot.

AM&F's design involvement also included the completion of drawings that showed development of the Cap Assembly for flat bottom cans. Testing showed that the original cap assembly designed with a steel plug was problematic as the cap assembly would float in the bath and the steel plug came loose from the cap assembly. To rectify this, a steel ball was added to increase the weight of the cap assembly and an aluminum plug replaced the steel plug. This corrected the cap assembly and allowed the machining of the assembled can to proceed in a more standardized fashion to a definite length. The equipment used to assemble the fuel can caps was a hollow cap assembly press that was compact and operator friendly. A lathe was used to remove excess material on the hollow cap, then chamfer and groove the remaining section.

Accountability for nuclear materials was important. Each fuel can assembly was permanently marked; its lot number, canning line number and canning date was to be embossed on the can. Quality control of the product was carried out with inspection tools that included a straightness gauge and test bar.

Table 1 provides a full listing of equipment that was set up in Building 313-M for the start up of operations to can and store uranium slugs and "special" slugs for use in the plant's production reactors as described above. AM&F's contribution to fuel production technology at SRP was significant, including ancillary equipments and tools, weld procedures, and numerous studies. Du Pont Engineering personnel would be responsible for outfitting the future building with the autoclaves, testing equipment, other commercially available units as well as a host of tools, handling equipment, and industrial furnishings needed to complete the process at start up. Most of the major pieces of equipment were installed by the summer of 1952.[10]

Views of Autoclaves at Floor Level (left, top and bottom), an Open Autoclave, and a Detail from a Model Showing Each Autoclave's Subfloor Equipment.

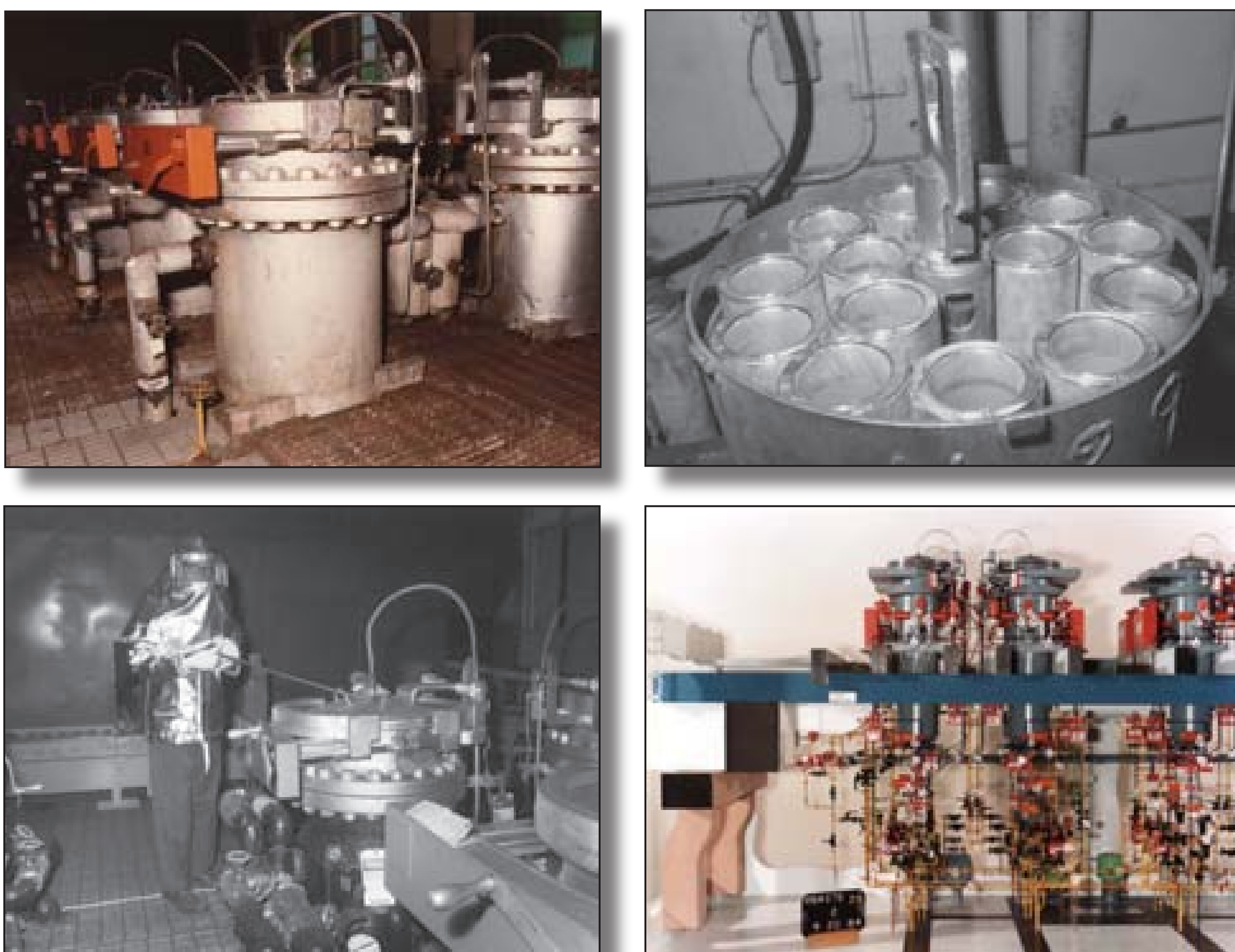


Table 1. Installed Equipment at Startup, 313-M

Building Area	Sub Area	Square Feet Allotted	Equipment
Process and Inspection	Receiving and Inspection	1,504	• Roller conveyor • Scale • Monorail and hoist 1/2 ton capacity • 4000 lb. Fork lift truck • Benches • Miscellaneous inspection gauges • Pallet transporter (2)
	Canning Furnace Area	13,960	• Vapor degreaser • Pickle Tanks (2) • Rinse Tank • Hot Air dryer • 1/2-ton monorail system • 1-ton monorail system • Timers • 1/2 HP pump g.p.m. • Parts trays and racks • Hand Truck • (16) 60 KW electrical resistance furnaces • Control instruments • Centrifuges • Quench tanks • Exhaust fans • Various fixtures, agitators
	Lathe and Weld Area	2,790	• Turret Lathes • 200 Amp. Welders • Welding Machines
	Frost Test and Etch Area	2,449	• Spray Booth • Spray guns and tanks • 1/4 H.P. pump – 5 g.p.m. • Timers • Parts Racks • 1-1/2 H. P. pump – 40 g.p.m. • Monorail and hoist 1/2 ton cap • Constant temperature chamber • 3- KW high frequency induction heater • Vapor Degreaser • Acid etch tank • Hot air dryer • Code stamping press
	Autoclave Area	3,497	• (20) 20″ diameter 300 p.s.i. autoclaves • 3-ton bridge crane • roller conveyors • Parts racks and baskets • Work benches • Duplex sump pump, 3 HP, 200 g.p.m.

Building Area	Sub Area	Square Feet Allotted	Equipment
	Cap, Can and Sleeve Preparation	3,312	• Vapor degreasers • Electrical motor and chuck • Work benches • Monorail and hoists • Cleaning tank with rotary brushes • Caustic tank • (5) Rinse tanks • Soap tank • (2) Hot air dryers • Duponal Tank • (2) Etch tanks • Methanol Tank • 1 1/2 HP pump 40 g.p.m. • Timers • Part racks and baskets • 1/3 HP pumps – 5 g.p.m. • Cap Assembly Press
	Recovery Area	2,880	• Caustic Tank • Caustic Mix Tank • Acid Tank • H.F. Acid Tank • (2) Rinse tanks • Neutralizing tank • Agitators • Filter press • Table scale • Platform scale • Turret lathe • 1/2 HP pump 20 g.p.m. • Monorail and hoist 1/2 ton cap • Trailer disposal tank – 1000 gallons • Timers • Work benches • (6) Pumps • Part racks and baskets
	Special Process Area	1,520	• Arbor Press • Hydraulic Press 15 tons • Sizing and stripping dies • Bubble tester • Vacuum pump 21 c.f.m. • Receiver (vacuum) • Work benches • Turret lathe • Welding machines • 200 amps welder • Code stamping press
Building Services and Miscellaneous	Offices	762	• “conventional office furniture”

Building Area	Sub Area	Square Feet Allotted	Equipment
	Toilet and Smoking areas	632	
	Electrical and utility areas	4,611	• (2) Sub stations • (2) Hot water heaters
	Tool Room	672	• Work benches • Cabinet and shelving • Bench drill press • 10″ bench lathe • Bench grinder • Carbide tool grinder • Miscellaneous small tools
	Instrument Shop	336	• Drying oven • Work benches • Cabinet
	Quality Control and Gauge Crib Area	1,150	• Work benches • Cabinet and shelving • Laboratory Furnaces • Laboratory sink • Stripping equipment • Various inspection tools • Table scales • Hydraulic Press
	X-Ray Area	1,108	• Semi-automatic X-Ray machine • Film developing machine • Film viewers and holders • Work benches • Cyclograph equipment
Storage	Essential Materials	960	• Pallet Rack
	Finished Product	2,880	• Steel pallets • Plastic boxes
	Raw Material	3,216	• Steel Pallets • Plastic trays
	Metal Storage	609	• Drying oven • Flux mixer • Platform scale • Metal cutting saw • Benches and racks
	Special Process Storage	760	• (5) Battery chargers • Crane and hoist – 1 ton • Steel pallet • Plastic trays
	H.F. Storage	154	• None

Building Area	Sub Area	Square Feet Allotted	Equipment
Semiworks		4,800 Located in Canning Furnace Area	• Draw bench – 20,000 lb cap • Salt bath – approx 200 KW • Quench Tank • Vapor degreaser • Pickle tank • Duponal Tank • Rinse Tank • Hot air dryer • Shear 15′ x 3/8″ • Drill Press • Milling Machine • 200 amps welder • 1-ton crane • Work benches • Stretch straightener – 75-ton cap. • 30″ diameter 300 p.s.i. autoclave (in • autoclave area substation (in electrical area)

Source: Engineering Department E.I. Du Pont De Nemours & Co. (Inc.), *Savannah River Plant Engineering and Design History Volume IV #300/700 Areas & General Services and Facilities.* U.S. Contract No. AT(07-2)-1, Du Pont Project 8980, DPE-973, 1957, 4-12.

TARGET AND CONTROL ROD FABRICATION EQUIPMENT, 320-M

As noted, the needs of Savannah River's reactors predicated new technology and AM&F's contribution to developing fabricating equipment and a flow pattern for canning and rod manufacture as well as other parts of the process that suited these needs is significant. Others involved included the National Research Corporation for casting and melting equipment, Argonne National Laboratory for design data, and the U.S. Army Air Force Manufacturing Methods Pilot Plant at Adrian, Michigan for extrusion data. The Aluminum Company of America or Alcoa, producers of aluminum and aluminum alloys since the nineteenth century, was also integral to parts of the process particularly with setting parameters for the successful extrusion of the alloy. Du Pont's Engineering Department had full design responsibility and project coordination.

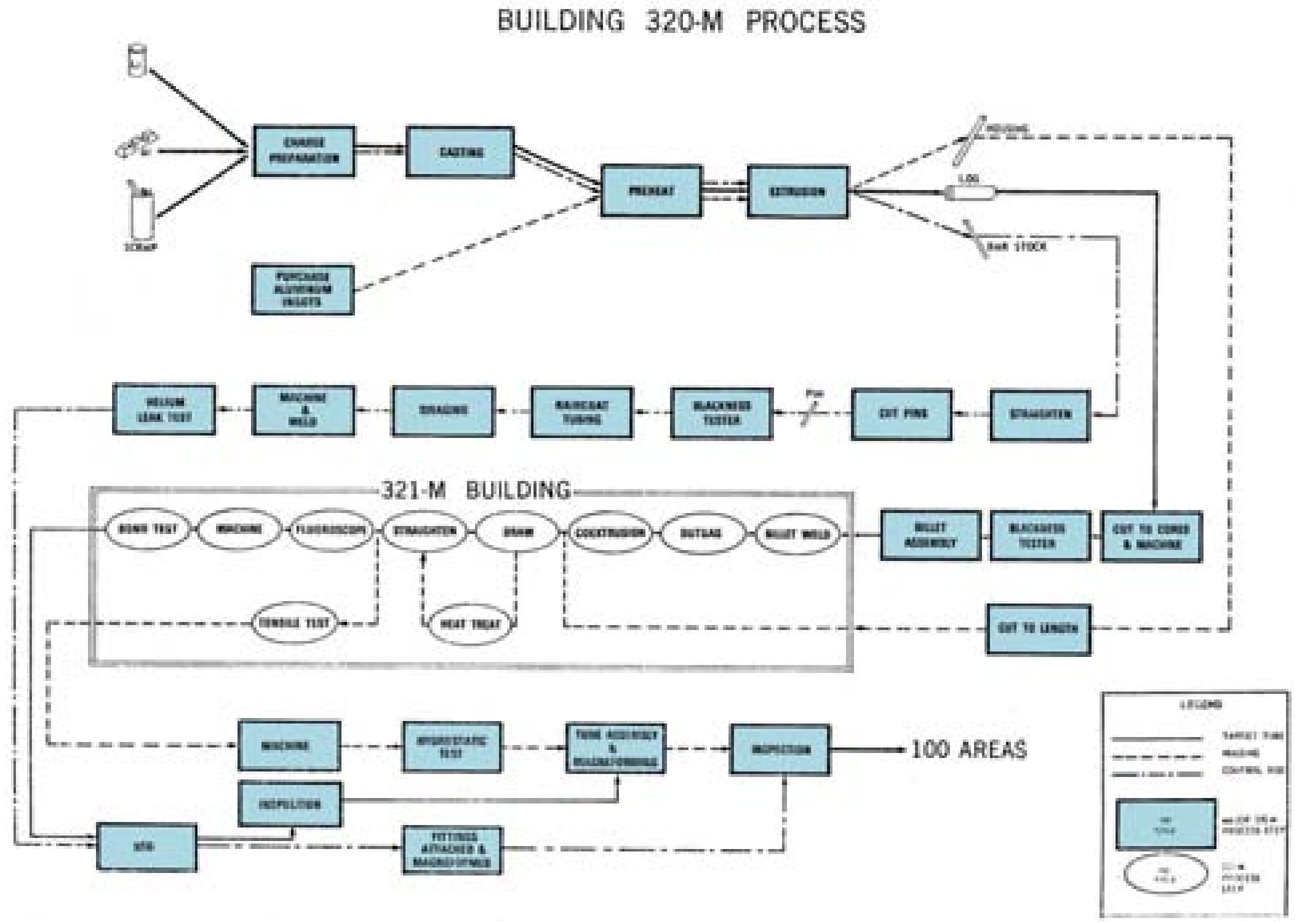
The equipment and process envisioned for future installation in 320-M - the Alloy Building, was designed to produce lithium-aluminum rods for use in the reactors to control the reaction and to produce tritium by the transmutation of lithium. Two types of alloys were needed with different lithium contents. The AEC's product requirements required the fabrication of control rods from 3 1/2 percent alloy for use in either plutonium or tritium-plutonium producing reactors. Control rods and circumferential blanket rods made from 10 percent alloy were to be fabricated for irradiation to increase tritium production.

The AEC's decision in 1952 that SRP should initially produce plutonium in all reactors and apply excess reactivity to tritium production determined the immediate focus of operations in the future 320-M facility.[11] Thus, at startup the fabrication of the 3 1/2 percent alloy rods for plutonium production took precedence but equipment design also took into consideration future need for tritium production. In fact, it was necessary to design "for the production and fabrication of materials having differing characteristics, since it was anticipated that, eventually, the 10 percent lithium-aluminum alloy might ultimately be the primary product of this building."[12] Also the possibility early on in the design phase of converting to the production of other lithium alloys, like magnesium-lithium, was considered and, consequentially, design features were incorporated into the equipment that would allow some exploration of this potential. However, there was a limit to design flexibility. "Where major uncertainties existed in the process, it was resolved among the Operating Section of AED, A.M.&F., and the Design Division to install sufficient equipment to attain start-up capacity only. Future expansion of the initial building and equipment, if necessary, would then be based on experience gained during the start-up operations."[13] This quote establishes the design priorities – having sufficient control and blanket rods for R reactor start-up but also shows that Du Pont was cognizant that further facility and equipment design may be in the offing - a forecast essentially for the future Building 321-M constructed in 1957.

The production process for the control rods entailed seven main steps:

- melting the component metals to form the alloy;
- casting the alloy into billets;
- extruding the billets into rods;
- cutting rods to length and straightening;
- machining the rods into slugs;
- canning the slugs in an unbonded format; and
- assembling the canned slugs in rods by encasing them in aluminum tubes and sealing the tube ends.

Experimental work at Argonne had established that the melting and casting operations had to be conducted in a way that impure gasses, primarily hydrogen, were removed from the raw materials to be charged in furnaces and also to prohibit the same impurities from reentering the alloy billet. To accomplish this, the operations had to be completed using a high vacuum or a combination of vacuum and argon atmosphere. In addition a stream of argon through the charge appeared to degass the melt. Other design considerations involved the selection of



the "tilting pot furnace" over a vertical bottom-pour crucible type and the use of a clay bonded graphite crucible in the furnace.

In addition, a sequential melting process was devised to stave off lithium loss that occurs due to its volatile nature in a molten state. The National Research Corporation (NRC) produced a melting procedure on a bench scale that could be mocked up for production use at SRP. Their procedures for melting were adopted for use at SRP:

- melt and outgas aluminum under high vacuum;
- raise pressure in furnace by adding purified argon;
- make desired lithium addition and melt in;
- pump down to raise vacuum;
- remove hydrogen by bubbling purified argon through the melt;
- raise to a higher vacuum and hold until melt is outgases completely;

- raise pressure by adding purified argon to melt chamber; and
- adjust temperature and pour melt into molds.

With these considerations under control, the following process flow was configured for installation in 320-M. In a general sense, the process equipment for rod manufacture differed from the slug fabrication equipment foremost in size but the use of lithium alloy in 320-M necessitated temperature controlled environments and special storage concerns. These are discussed below.

Aluminum ingots and sealed cans of lithium, the essential raw materials needed, were placed in a receiving area and stored prior to their removal to the furnaces. The ingots, sawed in half, were sized to fit the charging furnace, as were the lithium containers. These raw materials were weighed in bath lots sufficient to yield two billets. The lithium cans had to be vented just prior to charging to prevent their premature rupture.

Charging, melting, and casting were accomplished in a three-chamber vacuum furnace, each with steel walls and valved separately to maintain a vacuum and powered for induction heating. The charging was accomplished by remote control. Engineering considerations took in the high average dew point in

Views Showing Melting and Casting.

the site area for the furnace assembly. The furnace was designed to cast two - 125-135 pound billets that were 27 feet in length and 8 inches in diameter. A third billet could be produced with the insertion of a larger crucible. Three billets could be cast in the mold chamber that was outfitted with water-cooled graphite molds for the production of the control rods. The casting of the 10 percent alloy rods differed in that contamination and extrusion parameters necessitated that the 10 percent alloy be cast in aluminum cans and then capped after they were removed from the mold chamber.

After casting, the aluminum can and cap cleaning that was described above for fuel fabrication was essentially duplicated for the billet preparation albeit at a much larger scale given the large nature of the products. A resistance furnace was then used to remove gas from the billet cans, graphite molds used in the casting process, and the equipment that laundered the furnace between charges used in the casting process. The billets were sent for dimensional inspection and x-rayed to see if they had cracks or voids.

The preparation of the billets for extrusion involved several machining operations. For the control rods (3 1/2 percent alloy) this meant clean-cut ends. For targets, tops had to be counter bored and grooved to prepare it for welding of the aluminum cap to the can to fully enclose the alloy. It was established early on that the accumulation of lithium aluminum dust during these machining operations was sufficiently irritating to production line workers that additional ventilation would be needed.

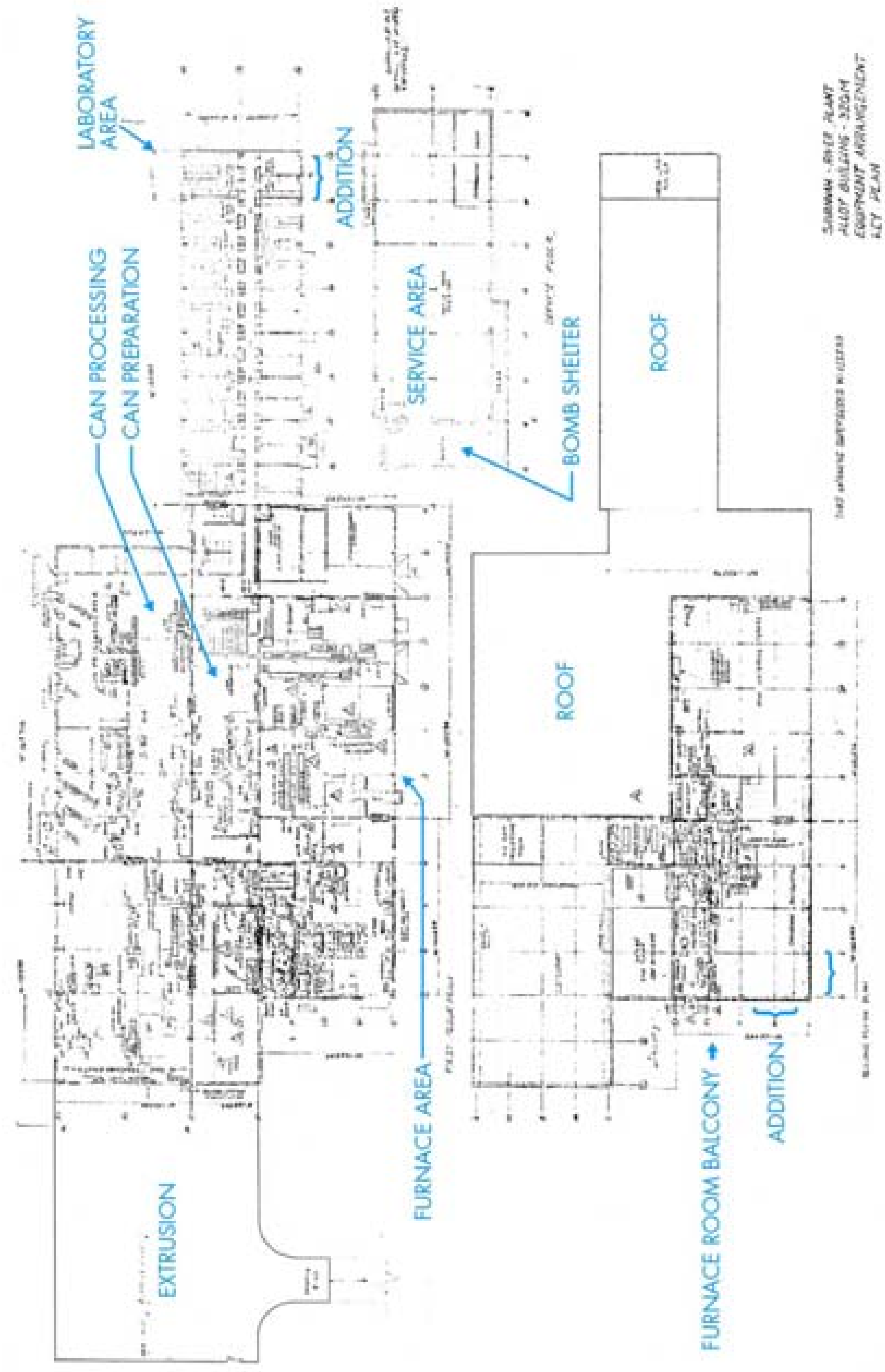
Machining the 10 percent lithium alloy rods also posed problems. The alloy's natural propensity for hydrogen absorption was exacerbated at this stage, as the top end of each billet was open and vulnerable to hydrogen contamination. Du Pont's solution to this was the creation of a humidity-controlled environment through unit air conditioning that kept the billet machining room at 35 percent humidity and at 75 degrees F. Billet dry boxes were developed by AM&F to transport the billets to the machining room where a cap would be welded onto the can immediately after removal from the dry box. The handling of the billets, given their size, predicated the installation of monorails and hand chain hoist throughout the work area.

The next step in the process was extrusion (the shaping of metal by forcing it through a die). Previous experiments showed that 3 1/2 percent alloy rods could be extruded. However the extrusion of the 10 percent alloy rods called for a temperature range and extrusion ram pressures. The cladding of the 10 percent alloy rods in aluminum discussed above made the rods less vulnerable to surface hydrogen contamination and would also act as a die lubricant. Both bare alloy billets and clad billets were to be extruded and the heating of billets occurred first. The 3 1/2 percent alloy billets were extruded bare through a shear die creating an .85-inch diameter rod. The aluminum clad 10 percent alloy billets were to be extruded through a 30-degree cone die creating a rod of the same diameter.

The 300/M workers would work hard over the initial years to find the right combinations of temperatures, pressures and dies to satisfactorily clad the 10 percent aluminum lithium rods and troubleshoot problems such as blistering. On the basis of research from Alcoa, a reduction rate of 100 to 1 yielded the "best" rod for straightness and surface quality and a billet size of 27 inches in length and 8 inches in diameter. Commercially available equipment was used including an extrusion press and a heating furnace. An extrusion press run-out

Views Showing Extrusion Process and the Press.

table designed by AM&F was the final piece of equipment for use in this step. This device held the hot extruded rod straight while soft and allowed two mounted radial saws to cut the extruded rod so that the next rod could be extruded.


LABORATORY AREA
ADDITION
CAN PROCESSING
CAN PREPARATION
SERVICE AREA
BOMB SHELTER
ROOF
ROOF
FURNACE AREA
EXTRUSION
FURNACE ROOM BALCONY
ADDITION

After extrusion, the rods were cropped into 12 feet then 4 feet sections then straightened with a rotary swager. A swager is a machine used to shape cold metal. Next the rods were rough machined to slug length and to finish the entire surface of the 3 1/2 percent rod using commercial turret lathes. This finishing was to make the diameter consistent throughout and to remove any hydrogen contamination. Final slug machining involved a precision cut-off operation so that each slug type were faced to a final length of 10.14 inches. Early on the clad alloy rods had a final length of 8 inches that was equal to the finished length of canned uranium fuel slugs. This similarity caused identification challenges, particularly when both types were submerged in water in the reactor disassembly basins. Therefore, the LiAl targets were lengthened to roughly 10.14 inches to better distinguish them.

Canning was the next step in the process. Caps and cans were cleaned in a comparable manner to fuel slugs operations in 313-M. The major difference was in the accommodation of equipment to handle the larger sized LiAl components. The purchased aluminum cans were slightly over sized so that after die sizing, a tight fit could be achieved. A commercial 10-ton hydraulic sizing press was acquired for use and to maximize productivity it was assigned a site within a humidity-controlled environment.

Cans were trimmed and by lathe given either of two types of closure: "formed over" or circumferential closure. The Du Pont Engineering History reflects on the research and experimentation involved as engineers struggled to identify which was more suitable. In the end, operations personnel were permitted to choose a closure and they opted for the circumferential weld that involved the addition of a second aluminum cap in order to achieve the appropriate end thickness. The die sized can was trimmed flush with the outer surface of the upper cap and the cap of the machined can was sealed to the can with a circumferential weld. This was essentially a reiteration of the welding process for the fuel slugs and the welding equipment is identical to that produced for 313-M.

Inspection of the weld was next in the process flow. A prototype horizontal kerosene bubble tester was developed by AM&F to discern any leaks in the canned assembly. This device subjected canned assemblies to a high vacuum while they were submerged in kerosene. Bubbles rising from the can surface showed leak locations. More conventional equipment was used to check on diameters, length and straightness. After inspection, a process for identification of each can assembly was proposed with a serial number impressed onto the bottom surface of each can with a pneumatic press.

Assembling the canned slugs in rods by encasing them in aluminum tubes and sealing the tube ends was the final step. AM&F developed the process to assemble, size, evacuate, helium fill, and finish the ends of the blanket and control rods. Tubing from 3/4 inch to 1 inch in outside diameter and up to 210 inches in length was needed to provide "leak tight LiAl rods of suitable length for insertion in the reactor." Purchased aluminum tubes were first inspected then cleaned in specially made tubs. Ancillary equipment such as tube and rod handling carts and pallets were also made. Rod assembly took place on a specially designed table that had a "V" shaped trough to hold the tube that was clamped down to better receive the slugs and crimp. Gauges were also attached. A manually operated loading ram placed sixteen canned LiAl slugs in each tube along with top and bottom fittings. After loading, the tube assembly was transferred to a shelf for storage.

The next step was helium filling and swaging to provide a tight fit between canned slugs and the tube. Considered an integral part of the operation, equipment was developed for use with a rotary swager such as a rod feed table a rod discharge table, a helium-filling mechanism and a can-restraining device. These worked in concert to firmly grasp the tube assembly and pull it through the rotary swager; also the tube assembly was evacuated and filled with helium by a mechanism attached to the feed table. After swaging, the rod ends are finished and the canned slugs are sealed in the tube by welding the seam between the top, bottom end fittings and the tube. A mass spectrometer, set up at a leak detector station was to be used to identify helium leaks. The tube assembly was then ready for inspection and straightening. A device was made in which both operations could be accomplished. Each assembly was impressed with a serial number. Finished they measured approximately 1 inch in diameter and 185 inches in length. After cleaning they were either stored or readied for shipment to a reactor area. This identical process was used to manufacture control rods for experimental test reactors to be built in 777-M (777-10-A). The sole difference is that the rods produced for the test reactors were half loaded – 8 canned slugs per tube instead of 16. Finally, salvaging of rejected materials for reuse when possible was also part of the process.

Table 2 provides a list of installed process equipment at the startup of operations in 320-M. The installation of machinery began in May 1952 and the building was formally accepted with exceptions from Construction Division in February 1953.[14]

Table 2. Installed Equipment at Start Up, 320-M

Process Area	Square Feet Allotted	Equipment
Raw Material Storage	9650	• Horizontal band saw • Bench scale • Floor scale • 100 g.p.h. water still
Furnace Room	6280	• Alloy Furnace • Sintering station • Outgassing furnace • 5-ton Crane
X- Ray Room		• 250 KVP industrial X-Ray machine
Billet Machining Room	1625 includes welding area and storage	• Monorail and hoist • 14-in engine lathe
Billet Welding Area		• Welding equipment and transformer • Welding positioner • Monorail and hoist
Billet Storage Area		• Racks, monorail and hoist

Extrusion Area	8600	• Low frequency induction furnace • Die heating furnace • Extrusion Press and run out table • Circular cut off saw (2) • Cropping Table • Rod heating furnace • Quench Tank • Rotary swage with feed and exit tables • Jib crane and hoist (1/2 ton) • 10-ton crane • 5-ton Hydraulic straightening press
Air Conditioned Process Area	1200	• #3 Universal turret lathes (2) • 10-in. Engine lathe • 10-ton Die sizing Press • monorail and hoist (1-ton)
Can Cleaning Area	7950 includes canning and rod manufacturing areas an can and tube preparation areas	• Mild steel degreaser • Stainless steel tanks (7) • Monorail and hoist 91/8 ton)
Can Process Area		• 10-in. Engine lathe (2) • 10-in Engine lathe with hexagon turret • Die forming press • Can welding machine and 300 amp transformer • Hand arbor press • Stamping (can identification) machine)
Tube Cleaning Area		• Underhung bridge crane • Degreaser • 20-feet long stainless steel tanks (7) • 20-feet long Dryer
Rod Manufacturing Area		• Rod assembly table • Rotary swager with feed and exit tables • 10-inch Engine lathes with spindle extensions (2) • Welding torches and 300 amp a.c. welding transformers • Helium leak detector (mass spectrometer) • Rod straightening fixture
Maintenance Area		• 1/2 in. Drill Press • 10-inch Carbide tool grinder • Two-wheel grinder
Finish Product Storage Area		• Monorail, jib crane and 1-ton hoist
Service Area		• Refrigeration compressors and accessory equipment (2) • 52 c.f.m. air compressors • 150 kw diesel generator set • vacuum pump and motor

Miscellaneous Storage Area		• Steel shelving and work benches • Inspection equipment • Monorail and hoist • Platform lift truck and hand trucks • Two-ton freight elevator.

Source: Engineering Department E.I. Du Pont De Nemours & Co. (Inc.), *Savannah River Plant Engineering and Design History Volume IV #300/700 Areas & General Services and Facilities*. U.S. Contract No. AT(07-2)-1, Du Pont Project 8980, DPE-973, 1957, 85, 87-89.

COMPONENT TESTING, 305-M

Canned and bare slugs and control rods produced through the processes discussed above needed to be tested to assure safe and efficient reactor operations. In order to provide quality control, a test reactor (sometimes referred to as a pile) devoted strictly to component testing was built and housed in 305-M. The test reactor examined bare fuel slugs for reactivity. Control rods and canned "producer" slugs were tested for their ability to absorb neutrons, and finally the aluminum components and canned fuel slugs were tested for their purity and to inspect the quality of the canning process. The number of tested components varied with the results.

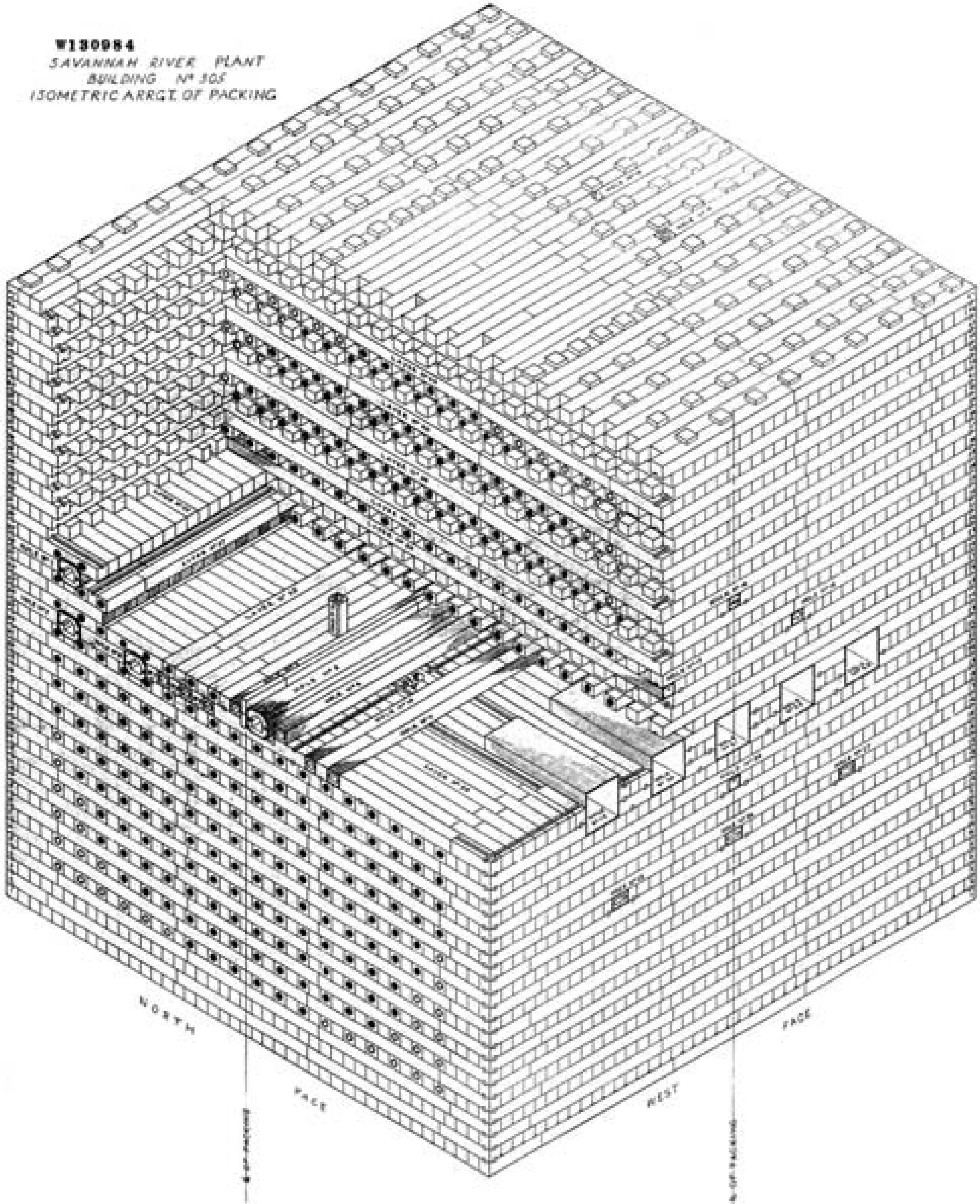
The test reactor, an uncooled natural uranium example with a graphite moderator, was 305-M's main equipment. It was based on a similar design of a test pile at Hanford and the graphite blocks used in its construction were machined at Hanford. It differs from the Hanford example though in that it possessed a blanket gas system using helium that allowed the SRP example to increase its testing productivity by 25 percent. The reactor was fully described:

The pile is controlled by neutron absorbing rods electrically driven through the west face. Gravity driven safety rods are inserted into the top and the west face in case of emergencies, and the pile reaction may also be stopped by dropping neutron absorbing nickel-boron balls into tubes located in the pile.

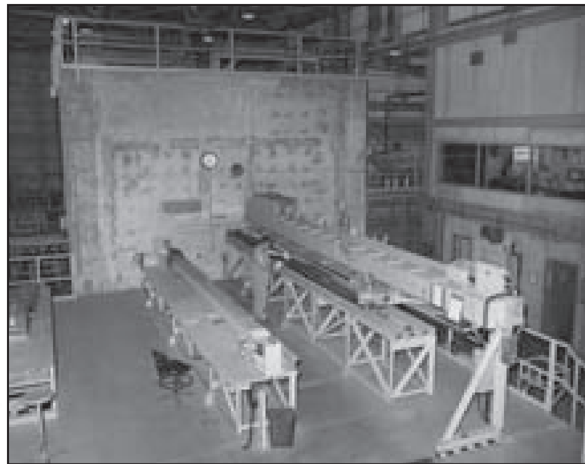
The graphite moderator is 15 ft. square by 16.4 ft high, built up of 47 layers of blocks, each block measuring 4-3/16 in, square by 29" long. There are 360 channels for uranium rods located on an 8-3/8" lattice. The channels are 1.744" holes drilled in alternate blocks of alternate layers along the longitudinal axes of the blocks. No uranium channels are provided in the outer four blocks around the four sides of the pile. The central core, bounded by the outermost uranium channels, is of the highest-grade graphite with the remainder of the 190 tons in the pile chosen from unpurified graphite.

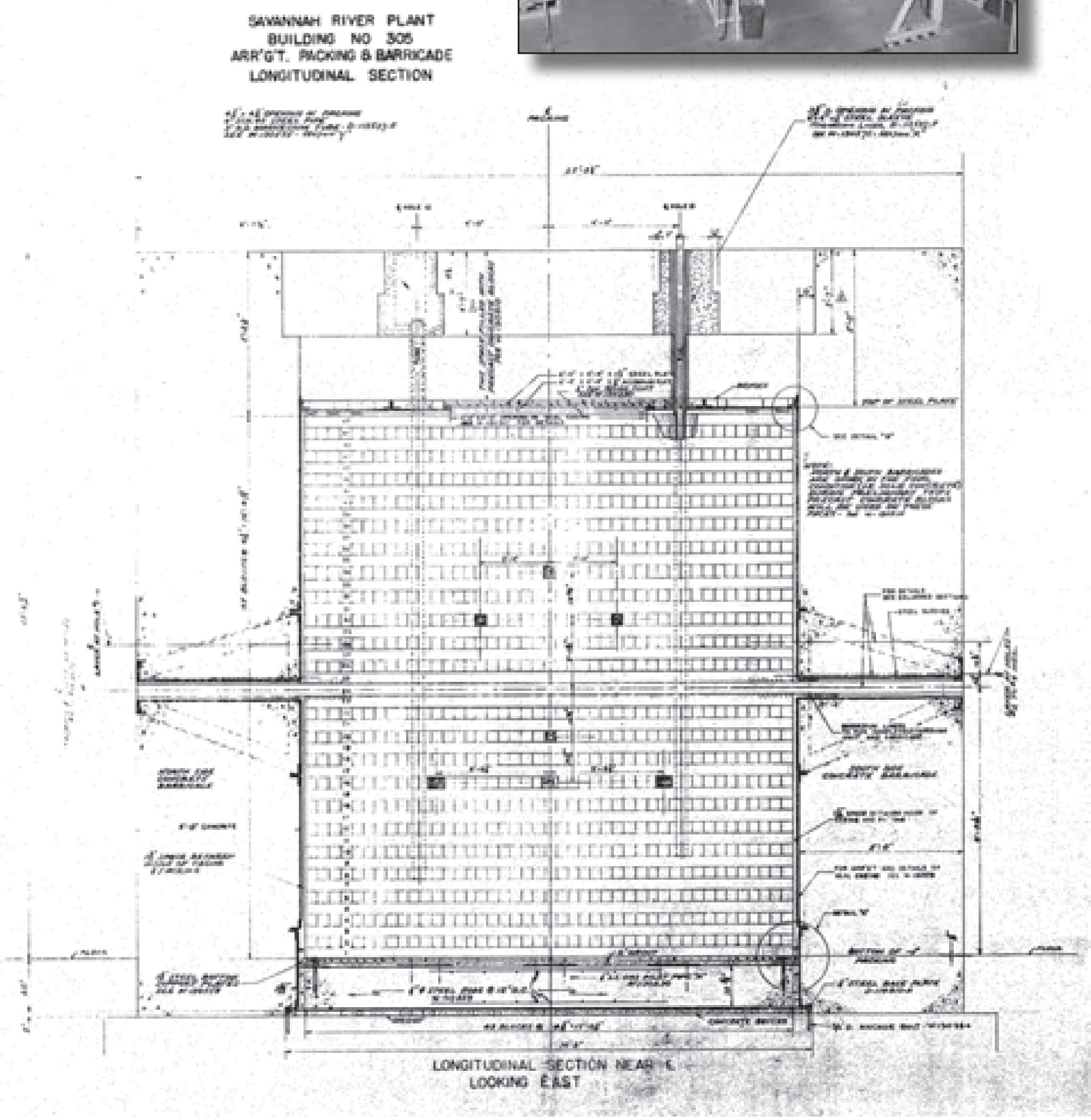
The blocks are stabilized by staggering rows and keying layers together. A total of 27 holes of varying size are provided at various locations throughout the pile. Graphite surrounding these holes is keyed together to prevent displacement of the stack. Of the 27 holes in the pile, four are for vertical safety rods. One of the horizontal holes is for a safety rod, eight for instruments, three for control rods, and eleven are for testing purposes.

The pile is powered by approximately 25 tons of bare natural uranium slugs approximate 1.440 inches in diameter by 8.250 inches long. Each channel contains 16 of these slugs separated by graphite spacers. All of the 360 fuel channels are loaded with fuel slugs of a purity and density comparable to the standard production material supplied by Hanford.[15]


W130984
SAVANNAH RIVER PLANT
BUILDING Nº 305
ISOMETRIC ARRGT. OF PACKING
NORTH
FACE
WEST
FACE

View showing North Face of Test Pile with Loading Platform, Date Unknown.





The graphite moderator was laid up in July 1952 within a 72-hour period, with personnel working around the clock.[16] AED requested that the SRP graphite test reactor be able to handle the testing of 50,000 bare uranium slugs, an equal amount of canned uranium slugs, as well as over 5,000 canned LiAl slugs and over 3,000 Li-Al control rods on a annual basis. Notably, the estimated testing volume for bare and canned uranium slugs was considered to be only 5 percent of the plant's projected throughput, 10 percent of the plant's estimated throughput for canned Al-Si slugs and 100 percent of the control rods.[17]

The testing procedures were based upon comparative analysis using known standards. For example, to test uranium slugs at the start of a work shift, standard samples of uranium would be charged into the reactor that was sufficiently powered so that it could be checked against the standards. First the control rods would be set so that the power level would remain fairly constant. Operators would watch for a change in power level with the rods in that position and take measurements. This change was referred to as "drift." The operator would then move a control rod and take a new drift measurement. Reactivity calculations founded on drift-rod movement-reactivity relationships established when the reactor was calibrated would be completed and if the reactivity value was the same for both measurements this was used as a basis for testing. The standards would then be removed and ungraded uranium slugs inserted. If the operators got substantially different results using the same methods, the standards needed to be checked. All working "standards" were checked against master standards periodically. Also conditions were kept constant such as the use of the same graphite "slippers" for both standard insertions into the reactor as well as production samples.[18]

The actual testing process began with the shipment of components from 313-M and 320-M by covered truck via an air lock. The air lock was fitted with a monorail crane to remove the cover when foils and rods were shipped in boxes then stored in a Cold Assembly Storage area. Prior to insertion they were placed in troughs for loading by the charging machines. An installed crane and other handling equipment facilitated the handling. Slugs and cans were shipped on trays and covered pallets that were unloaded by forklift that would also bring them onto the charging platform. Slug trays were loaded manually and tongs were used to transfer them to the troughs that led to the reactor.

Testing procedure changed given what was to be tested:

- Bare uranium slugs would be placed ten to a hole in two test holes located in center of reactor. The charging action alternates from the north to the south faces of the reactor until completed.
- Canned Uranium slugs followed the same testing procedure as above.
- Canned LiAl slugs were charged into three fringe test holes. The number tested would depend on the reactivity of the pile as well as the alloy used.
- Control Rods were tested in the same holes as the LiAl slugs. The test aimed at detecting abnormalities in the amount of lithium in any one slug or to identify if there were an excessive number of problem slugs.

- Quatrefoils, Septifoils, and slug cans were tested to ascertain the quality of the metal in their fabrication. A hole in the center of the reactor was used for these.[61]

The charging machine deserves mention. The machine was comprised of a 25-foot wide platform that extended 40 feet back from the reactor's face. There were two charging tables fitted with charging troughs; the tables were moveable to align with the hole that was to be loaded. Each trough was fitted with graphite slippers into which the sample would be loaded and then driven into the test hole by the pusher assembly that had a charging speed of 6– 60 feet per minute in either the backward or forward direction. The latter was a moveable unit so that any test hole could be accessed and charged. The Pusher Assembly had two mechanical pushing fingers allowing two holes to be loaded simultaneously.

The slugs and cans were moved manually after testing back to the trays. Notably, no special shielding was used for the hot tested materials after irradiation although a potable Lucite shield was to be provided for worker protection. The installed equipment included instrumentation to measure and record the reactor's behavior and for health monitoring. Five ionization chambers, strategically placed along one face of the reactor, supplied data to two galvanometers, one of which measured reactor power level, and the other measured deviations in power levels. Three other ionization chambers locate in the pile provided important safety functions including the operation of a relay to "scram" should the power level became dangerous.

Table 3. Equipment Installed at Start Up, 305-M

Area	Square Feet	Equipment
Storage and Shipment	3125	• Box Lifting Beam • Crane Rotator • Monorail crane • 3-ton double bridge crane
Test Pile	8375	• Graphite moderated test reactor • Charging and Control Rods • Charging Machine • Pusher Assembly • Safety Tube Hopper Assembly • Vacuum producer and monorail • Ionization chambers (8) • Beta window ionization chambers with gamma window attachments for health monitoring
Laboratory	1200	• Balance and tables • Counting table • Laboratory table • Exhaust hood • Desks and chairs • Neutron counters
Control Room	1135	• Desks, tables, gauge board, amplifier panel

Source: Engineering Department E.I. Du Pont De Nemours & Co. (Inc.), *Savannah River Plant Engineering and Design History Volume IV #300/700 Areas & General Services and Facilities*. U.S. Contract No. AT(07-2)-1, Du Pont Project 8980, DPE-973, 1957, 36-41.

EXPANSION – PROJECT S-8-1044 (1956-1958)

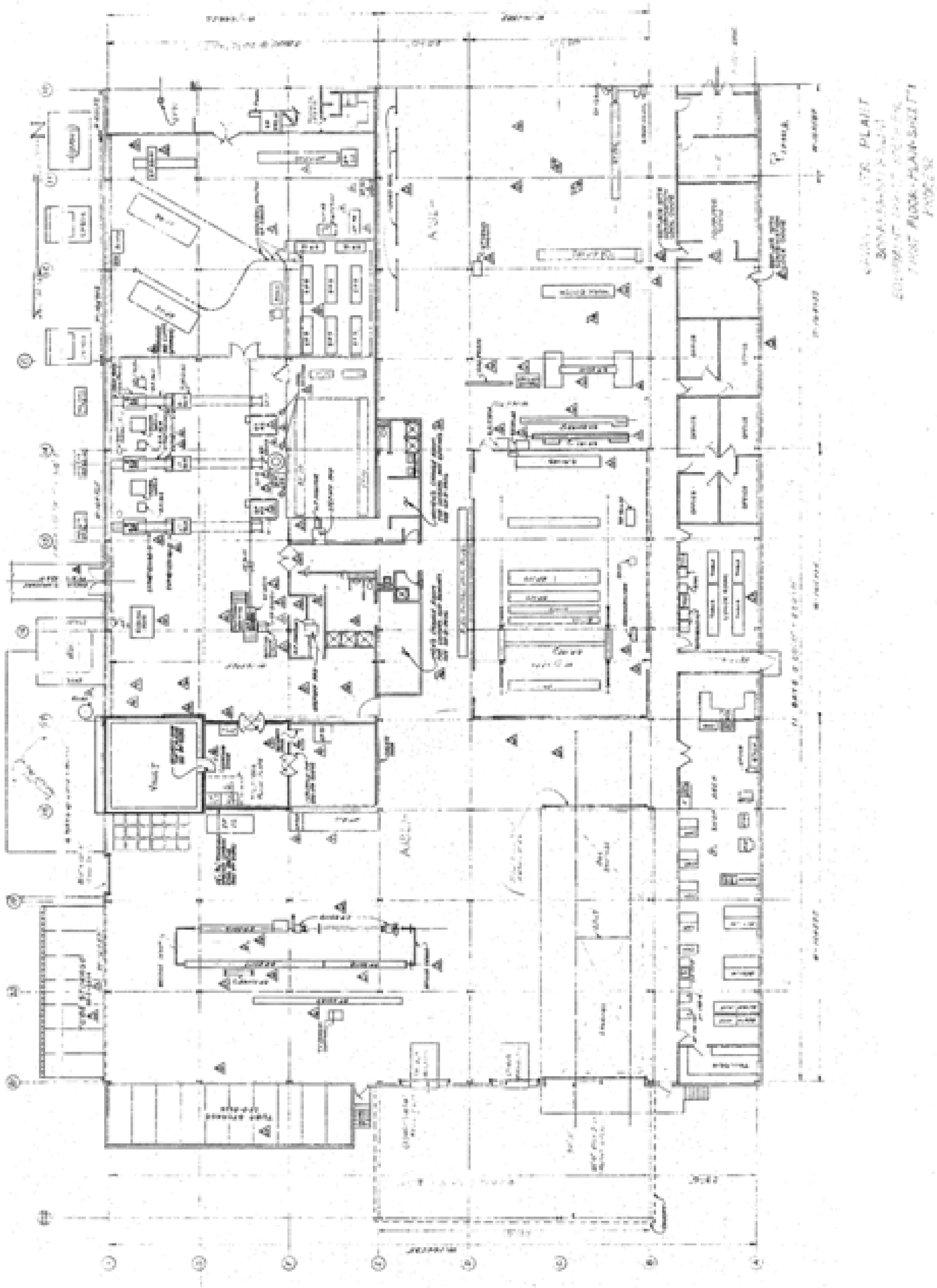
As noted in Chapter III, a $7.5 million expansion of 300/M Area facilities took place shortly after startup. The expansion is described in a special history set aside for projects undertaken immediately after operations began through 1960.[19] A new facility, 321-M, was constructed to house the manufacture of tubular fuel elements using "coextrusion," a process in which highly enriched uranium metal was formed into a fuel tube that was bonded on both its interior and exterior producing a higher surface-to-volume ratio. Referred to as "extended surface elements," experimental work was first completed in 320-M.[20] By early 1955, sufficient study had been accomplished by Savannah River Laboratory personnel and in concert with national laboratories to develop engineering specifications for facilities to produce a new element that was composed of a column of target slugs placed within an enriched fuel tube. The higher surface-to-volume ratio was needed for higher reactor power levels to boost production. In addition, Building 320-M was expanded and some internal rearrangement occurred.

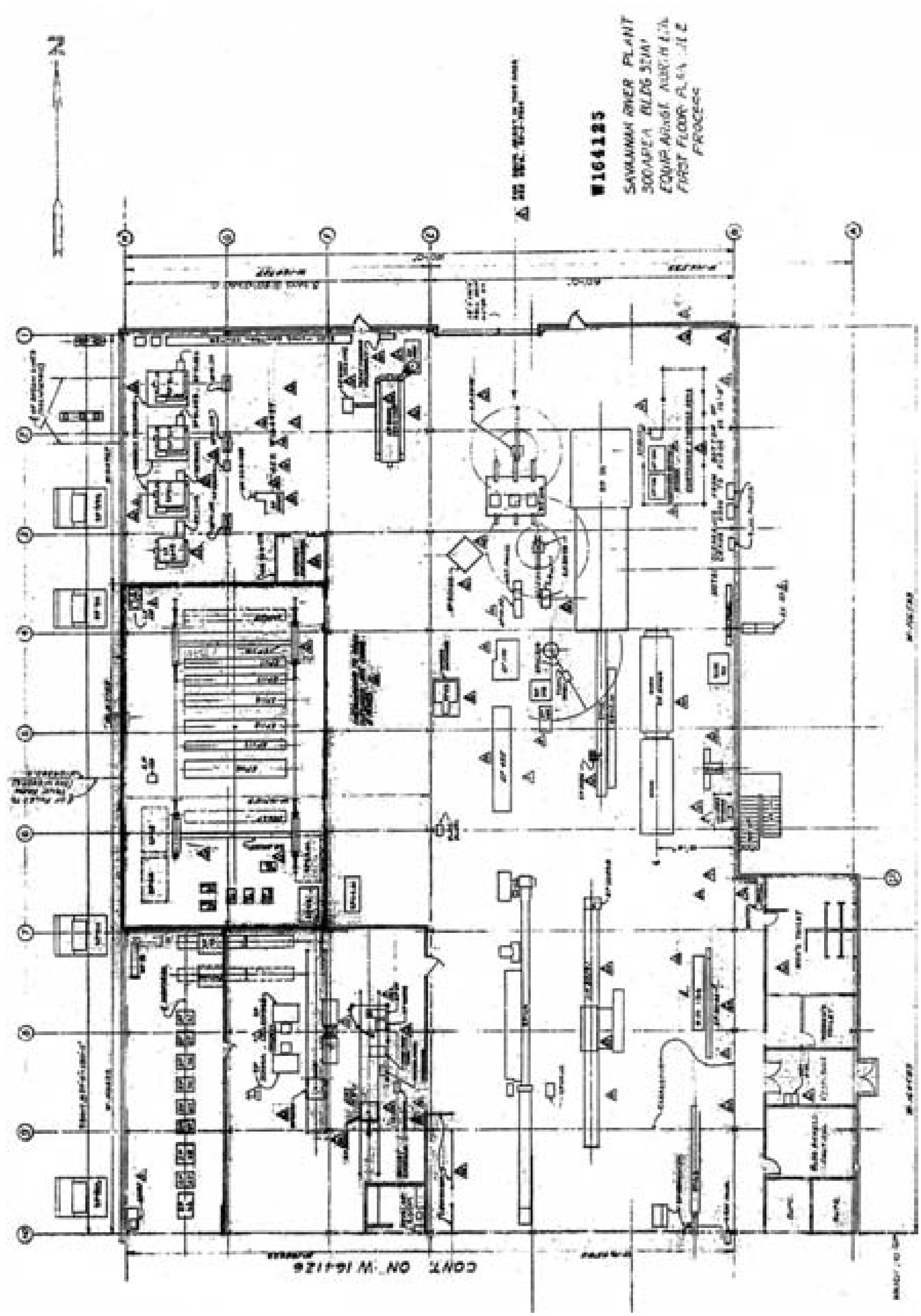
321-M, MANUFACTURING BUILDING

This facility housed equipment used in the production of a new fuel element. The majority of the equipment was dedicated to casting and extruding new tubular elements. The processes described below involves much of the same technology discussed in 320-M to produce the new element which consisted of a column of target slugs centered within an enriched fuel tube. The type of raw material to be used – oralloy or enriched uranium - made for different design parameters. Its value and high reactivity impressed a level of security and accountability not heretofor in place and its potential for criticality was a major safety issue. All shipments were weighed and recorded and scraps were collected and weighed. Totals were then compared with receipts. Exhaust from areas where enriched uranium was weighed, cast or machined was filtered through filters that were later sent to Oak Ridge for the recovery of uranium. Hence, the raw materials used made for different storage parameters.

Furnaces would receive high purity aluminum ingots, oralloy and recastable scraps for weighing and separating into charges. Tilting induction furnaces were charged and the substances heated then stirred. After cooling the charge was poured from a rotating cup into a graphite mold to create tubular castings. A turret lathe was then used to machine the inside and outside diameters and the casting was trimmed on one end to a 16° female bevel and the other end to a 16° bevel.

After passing X-ray inspection, the machined core was assembled into a billet using end plugs and aluminum liners. The billet was then machine welded, pressure tested for leaks, evacuated under high temperature and

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sealed in a vacuum. After this, the billets, protected by a magnesium jacket, are lubricated, preheated, and then extruded in a press. The press unit was fabricated by Lake Erie Engineering Company and was able to extrude solid and hollow billets up to 11 inches in diameter and up to 26 inches long. It was described as precision tooled to provide SRP with a final product that was exactly as specified. A gamma counter enabled personnel to identify core ends and the ends of the extruded piece were trimmed. Cleaning, pickling and the removal of the magnesium lubricant occurred next.

After this, the ends were tapered and the tube readied for the draw bench where it would reach it final size. The ends were taken off; the tube was degreased and then placed in an hydraulic stretcher to a maximum bow of 1/8-inch per 15 feet. A gag press was used if the tube needed further persuasion to lengthen. A special ultrasonic non-bond tester tested the integrity of the bond between the tube core and the aluminum sheaths. Using a moving ultrasonic transducer along the tube while it was immersed in water completed this. The final processing steps involved the machining of the tubes to their final length, the contouring of the ends on an engine lathe, and their storage until needed in the 100 Areas.

320-M - Additional Equipment

With this expansion all target materials could be processed in one building. The addition was intended to house a new melting furnace, a mold out gassing furnace, and an atmospheric remelt furnace.[21] Also, six areas received more equipment. For the most part, the changes allowed additional production capacity such as in improved machining tools for billet preparation, target preparation and canning, and rod handling. For example a bar feed and saw added to the target machining process reduced the machining operation from a twelve-step operation on two lathes to a three step operation on one lathe. A change was also made from permanent containers for rod shipment to impermanent types made from corrugated fiberboard called an egg crate that had a 15-rod vertical capacity.

The air conditioning system was extended to keep better control of temperature and humidity. The raw materials storage area received a crucible holding station with 15 crucibles in which materials could be stored at a constant temperature. The melting capacity of the building was expanded by 50 percent by a new unit, through improved charging, more cooling water lines, the inclusion of a mold cart that allowed direct pouring into molds and other small changes to improve work performance and output.

SUMMARY

To this point, the physical beginnings of the plant have been described. While Du Pont's Engineering Department and other associated groups worked to design and install equipment within the newly built out process area, other Du Pont personnel were hiring, providing security clearances, and training a work force to operate the production lines for fuel and target fabrication. No process area at SRP was an island; each was supported by plant wide organizations that provided security, maintenance, traffic control etc. Finally the production lines and their products were not static. The plant's scientists and engineers housed in the Savannah River Laboratory and in Works Technical developed new fuel assemblies and process equipment making the fuel and target fabrication area a dynamic workplace.

VI. OPERATIONS HISTORY (1951-1975)

> When we went to work there the Cold War was raging and we saw our job as making what the Department of Defense said they needed. And we were going to make it or die trying. That was it.
> - Sherwood Bridges [1]

> In no production area on the plant are people – as contrasted with machines – more important than in M Area. - *SRP News*, Friday, July 20, 1952

This chapter provides an overview of the major operations in the 300/M Area from start up through 1980. William R. McDonell, George R. Caskey and Carl L. Angerman, research associates at Savannah River Laboratory from the early 1950s through the 1980s and pioneers in SRP fuel element technology, define three phases in SRP's fuel production over the first twenty years of reactor operation. [2] The first fuels used were solid uranium slugs, 1-inch in diameter and 8 inches long, machined from rolled rods and clad in aluminum cans for corrosion protection from the coolant water. These were used for the start up of the plant's reactors. Hollow slugs, approximately the same size as the solid slugs, were then developed in the late 1950s to improve heat transfer potential and the slug was covered in aluminum on its inner and outer surfaces. A third improvement was adopted in the early 1960s that further enhanced heat transfer capabilities. Nested assemblies of large diameter (2-4 inches) tubular elements with extruded uranium cores and that were also clad in aluminum were adopted for use.

The movement to tubular elements changed the process flow dramatically, introducing a new major manufacturing facility, and produced an integrated system in which more sophisticated fuel and targets for irradiation in SRP's reactors were produced. Original process equipment was removed and replacement equipment installed particularly in 313-M as the triple dip Al-Si canning process was supplanted by a hot press bond canning system that was in turn replaced by a hot die size system. Other parts of the fabrication process such as the casting and extrusion would remain basically the same although ancillary equipment and tooling would change in response to new configurations needed or content. Oral history accounts (See Appendix E) are excerpted to highlight major events and process changes and more importantly to give a more personal sense of the workplace 300/M Area and SRP represented.

AT THE GATE

"You could get in with clearance, with a Q clearance, you could get in the gate, the front gate." [3] Area workers needed high-level clearance to work in the fuel and target fabrication facilities. Security needs heightened when 321-M's mission involved enriched uranium causing the construction of a lower gatehouse just for admission to 321 and a surrounding perimeter fence. This fence had a separate gate for trucks deliveries that provided sufficient access for the tractor- trailers that brought the enriched uranium in birdcages from Oak Ridge to the

Starting Point Production

Starting point for raw materials in Savannah River's production scheme is M Area. Here metals used in the making of atomic energy products are fabricated for the varied processes they encounter in other production areas.

The job is one where individual skill and attention to detail play a major part. Quality and quantity of the work done by M Area people have their effect on overall Plant production.

Teamwork is important, and the M Area has that, too. In one vital operation, M Area men "talk it up" with a chatter more familiar on baseball diamonds as they perform a job where speed and exactness are important.

In no production area on the Plant are people - as contrasted with machines - more important than in M Area, and pictures here show a few of the people who keep M Area production humming.

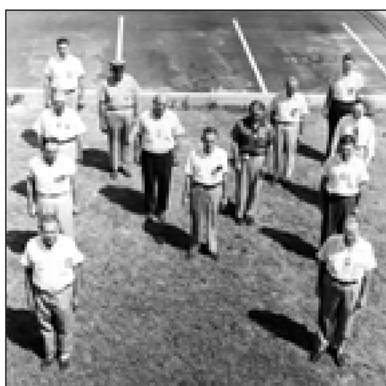
Savannah River Plant News, Friday, July 20, 1956.


Starting Point-Production

Area People Have Varied Interests, Talents

A single oak tree left standing on the west end of Building 313 shaded construction crews in 1951 and later provided a popular lunch spot for early workers. It still stands today.

Letter M is formed by members of Area committee. From left foreground, W.B. Thweatt, Traffic and Transportation; Henry Botkins, Maintenance; Howard Lee, Power; Bob McCroskey, Works Technical; Capt. Walter Holley, Patrol; Eddie Frost, Maintenance; Henry A. Dickerson, assistant superintendent, Raw Materials; Jim McMilan, Health Physics; Walter E. Eckel, Electrical; Spencer Grotheer, Methods and Standards; Lee Overman, Lab; Fred Kaufman, Instruments; Emmett Kauffman, Health Physics.

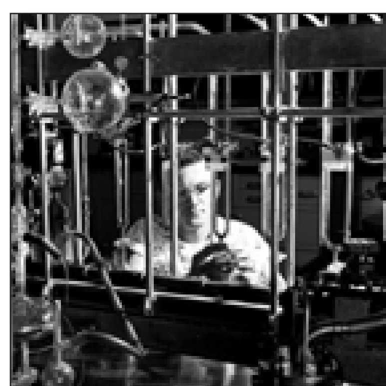


M-Area worker Lynnwood Hightower in work dress on a Coke break.

M-Area workers meet on safety issues.

Work Assignments in 313-M.

John Owens Jr. tests products and equipment in 322-M



plant. Charlie Mettlen recalls that during the deliveries that no personnel movement was allowed from or to that building while the patrolled supervised delivery took place.

Different raw materials were used in each building and the early literature is rich with terms that are no longer used such as oralloy (uranium alloyed with aluminum), birdcages (enriched uranium containers), and derbies:

> We would get the uranium, whatever shape it might be, slug -hollow or solid - whatever from Oak Ridge. Initially everything was natural uranium. But they did get into some low increase in enriched uranium. Again, Oak Ridge. Came to 313 in packed aluminum cans, aluminum wafers to put on top of the core of the can. Other than some chemicals in the cleaning line, that's about all that came in there.
>
> 321 would get everything, many aluminum sizes and shapes to be used in the control rod fabrication. Some billet, aluminum billet components they would assemble there for extrusion in 321. 320 would get …varieties of shapes of aluminum and they would get the lithium from Oak Ridge whichever concentration we were ordering… the feed came from Oak Ridge. Enriched uranium would come from the Ridge. That was always an interesting game because the trucks were completely innocuous. You know just a big old semi. And if you didn't pay any attention to the fact that there were cars in front and behind, you wouldn't have known it. And I don't know why but they always got here about 5:00 in the morning. - Charlie Mettlen [4]

Another oral history notes that in the startup period bare uranium slugs were transported to the area on railroad cars. Railroad tracks extend into M Area to 313-M, its most northern manufacturing facility. By circa 1955, a semi covered Trailmobile trailer was used to move slugs from 313 to the reactors. Tubes were placed in a steel frame, aluminum skinned box that was referred to as a casket which was approximately 20 feet long, four feet wide, and 2 feet high. Tubes were carefully packed with separators to maintain a safe spacing.

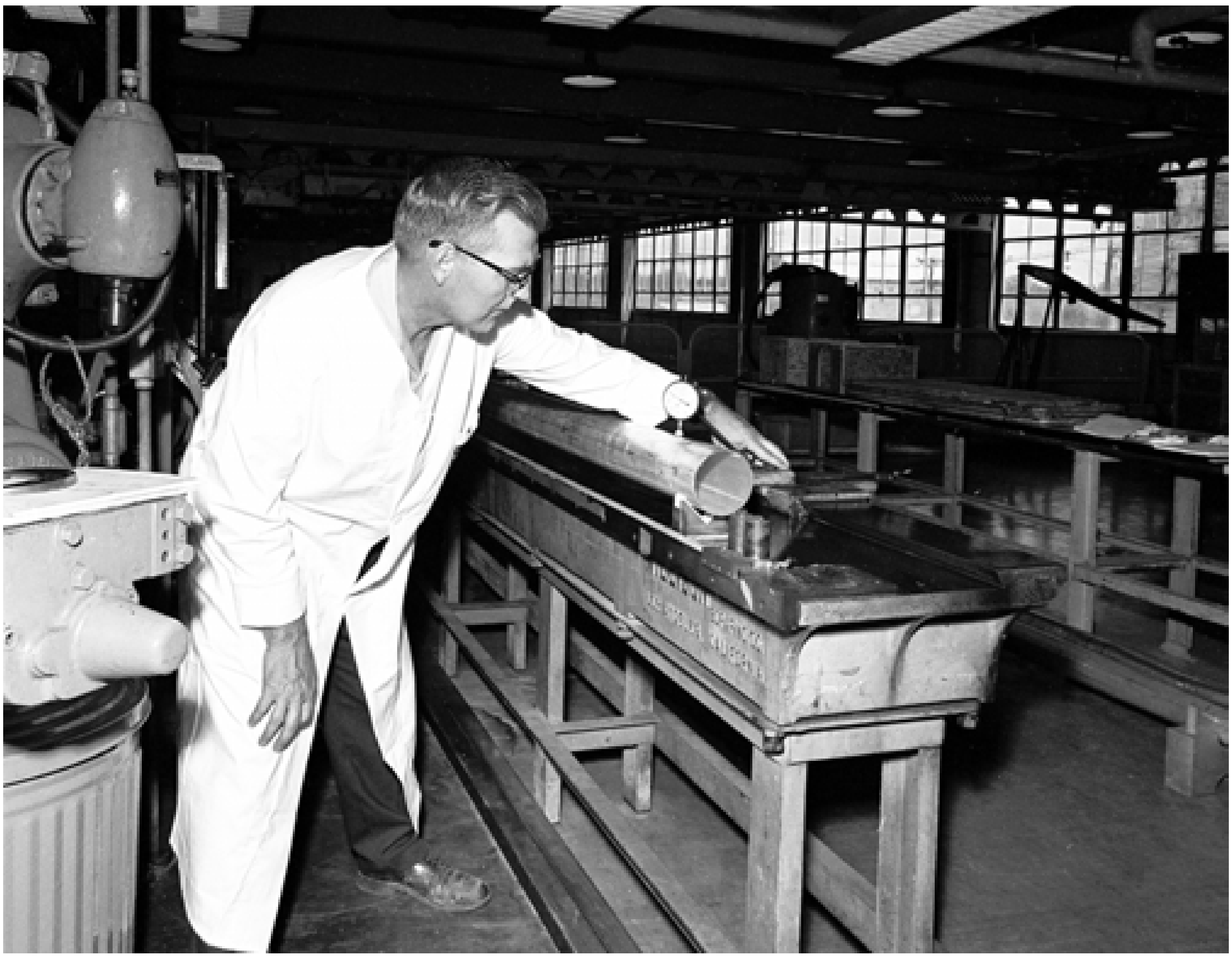
> See you had to handle a fuel tube different than a target tube because of nuclear safety. You couldn't pile up fuel tubes like a cord of wood. If you did you would have a nuclear reaction and kill the whole crowd. So fuel tubes had to be handled separately and they had spacing you had to maintain.…Target tubes you didn't have to worry about. - Norman Brady [5]

Later when nested fuel assemblies of fuel and targets were assembled, they were shipped as an assembly to the reactor in special boxes and a limited number of types could be shipped at a time. The shipment procedures were put in place to avoid any incident that could occur during shipment.

"RIGHT OUT OF THE MIDDLE AGES," FUEL CANNING (313-M)

The first phase was short lived, beginning at startup in 1953 and lasting until the late 1950s. 313-M's acceptance by Operations in March 1953 from the Construction Division is as close as a start date for operations as is known. The major pieces of equipment were installed in that building the summer of 1952 and the first "Wage Roll" personnel hired the same year. Supervisory personnel were trained at Argonne National Laboratory, Oak Ridge National Laboratory and at Du Pont's Atomic Energy Division at Wilmington. Six of these individuals were then sent to Hanford to observe the canning production line there. Training classes began immediately on equipment operations and the first canning operations began in September on a trial basis using reject metal. Actual canning for use in the reactors began in November of 1952 and equipment modifications were made to ensure worker safety and to improve output that was cited as not exceeding 1,200 slugs per day or 1/2 of design capacity.

From the beginning, production personnel were aided by SRL' s Metallurgical Technology Section to create standard operating procedures, improve operating conditions to achieve higher quality, greater yield and lower costs; and to serve as technical consultants. The individuals in this section were specialists in metallurgical studies such as welding or corrosion.



A member of Savannah River Laboratory's Metallurgical Technology Section tests a tube in the "Fab Lab."

In 1955, when all of the Savannah River reactors were on-line, the fuel assemblies were loaded into quatrefoils for the production of plutonium. Each quatrefoil was a four-chambered tube that would hold four columns of uranium slugs. Each slug was a solid natural-uranium cylinder, clad in aluminum to prevent corrosion from exposure to the moderator. Vertical ribs inside the four tube-chambers helped maintain channels for the coolant to pass between the slugs and the quatrefoil housing. The fuel slugs loaded into the quatrefoils were based on the form that had been perfected at Hanford and tested at Brookhaven. These slugs were designated Mark I, to distinguish them from the future designs that were already on the drawing boards. The bare uranium slugs were made at National Lead of Ohio and shipped to Savannah River for canning. After delivery to the Fuel Slug Manufacturing Building, the slugs were canned in an aluminum sheath for protection from water corrosion; the original method for doing this was known as "Al-Si dip canning," developed at Argonne.

From November 1952 to July 1953, 90,109 reactor grade uranium slugs were canned and a number of problems, such as voids, penetration, or bare slug quality were isolated for improvement. Also, initial work was completed in developing a procedure for jacketing enriched uranium slugs. Some equipment was also fine-tuned; two electrical resistance-type furnaces were replaced with two induction type furnaces. The short life span of the heating elements in the original bronze furnaces was problematic, 1954 saw their average life doubled. As the workflow became better defined, injuries on the job also lessened. In a two-month period in 1953, there were 42 injuries. In a comparable amount of time a year later, this number was reduced to six. In 1953, 12 individuals supervised 64 production-line employees.[6] Personnel figures for 300/M Area from 1953 through 1956 are given below.

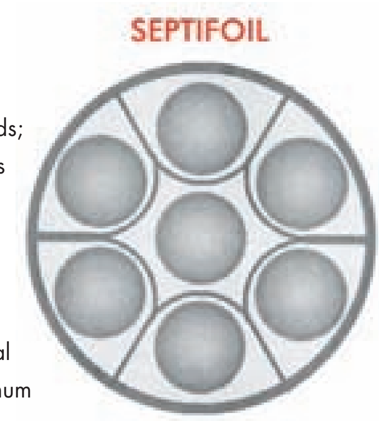
Table 4. 313-M Work Force, 1953-1956

Year	Operators	Supervisors
1953	64	12
1954	136	20
1955 (beginning of 1956)	154	26
1956 (end of 1956)	109	21

Sources: E. I. Du Pont de Nemours and Company, *Savannah River Plant History All Areas, August 1950 through June 1953*, DPSP-53-368. E. I. Du Pont de Nemours and Company, *Savannah River Plant History All Areas, August 1953 through June 1954*, DPSP-54-448. E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Areas, July 1954 through December 1972,* DPSP-55-454-3.

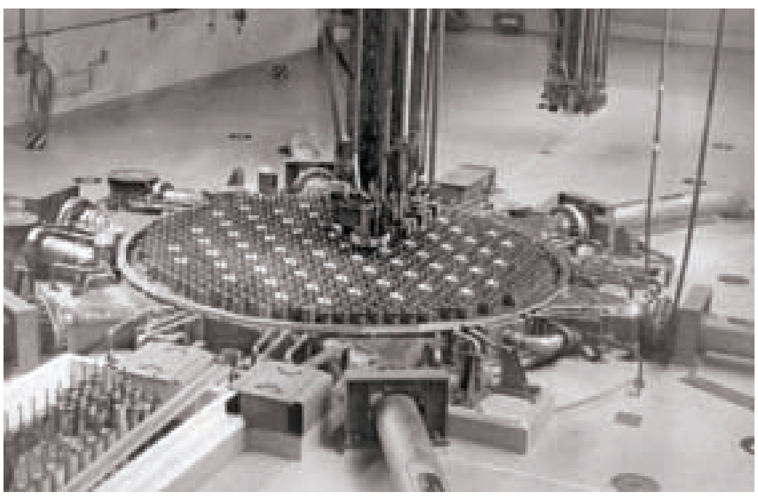
Oral history provides a sense of the early workplace in 313-M and in particular the use of the Al-Si dipping process described earlier. Charlie Mettlen, Norman Brady, Sherwood Bridges, Dave Honkonen, and Fred Rhode, veterans of 300/M Area operations from the 1950s onward, served in a range of positions. For example, Sherwood Bridges, who started off as an engineer, worked in 300/M Area from 1956-1977, after having worked in every building in the area and ended up engineer to the chief supervisor. Norman Brady began as a foreman in 1961 and moved up through the ranks to facility custodian of 320-M. Like Sherwood Bridges, he worked in every production facility in the 300/M Area. Dave Honkonen began his career with Du Pont in 1952 went first to Argonne National laboratory then to Savannah River Plant where he worked in reactor technology then later in 305-M where he focused on the criticality safety program. Charlie Mettlen was a SRL hire transferred to 300 Area when tube technology was underway in 1957. He retired in 1991 as operations manager for 300 Area. Fred Rhode, a metallurgical engineer, worked in support of fuel manufacturing facilities from 1968 to

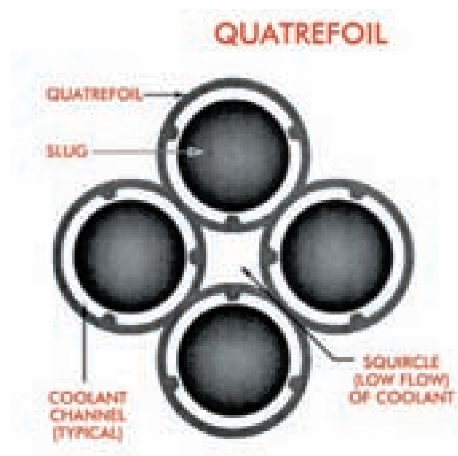
REACTOR DESIGN 2



Savannah River reactor design called for a vertical arrangement of the control rods; the lattice structured the fuel and control rod positions. Each fuel position was to be filled with a quatrefoil housing tube, each with four channels. The control rod positions were to be filled with septifoils that had seven channels, with each septifoil having a combination of cadmium rods and producer rods of lithium-aluminum alloy. When a reactor was charged or discharged, the whole quatrefoil was removed and replaced with one loaded with new slugs. Conversely, individual control rods were removed when necessary and the septifoil, an extruded aluminum insert, stayed in place.

Source: William P. Bebbington, *History of Du Pont at the Savannah River Plant,* (Wilmington, Delaware: E.I. du Pont de Nemours & Co., 1990).





2000 throughout his career primarily in 321-M. When asked about early changes in process equipment in the canning of fuels all pointed to the first canning production line. Their words, "some thing out of the Middle Ages" and "crude," underscore the difficult nature of the early process especially in the heat of a South Carolina summer with no air conditioning.

Charlie Mettlen, who worked in 300/M Area in 1957, recalled the process:

> I was hired to work in SRL at the time when the 300-Area construction was well underway in fact was done. They were expanding and going into the tube business, reactor fuel tubes. I moved since I had been working on that in SRL. I moved to 300-Area about 1957. 313-M contained a canning process of uranium and aluminum cans done in a series of molted melted pots that was best described, I would say, right out of the Middle Ages. It was hair-raising. How those guys were able to do it, I don't know. – Charlie Mettlen[7]

The first canning process in 313-M used pots of molten metal and aluminum silicone compound into which operators, using tongs, dipped the fuel slugs to create a metal envelope around them.

Norman Brady, who began as a foreman in the 300/M Area and worked in all the major facilities there throughout his career, remembered the Al-Si dipping process as well:

> I got to the area in 1961. Prior to that they used a process for canning that involved aluminum silicone. They had this molten aluminum in open pots. And there was an aluminum silicone bath. There was a bronze bath. And there was another bath and, I swear, I can't remember what they called it because that was before my time. But they physically took a slug with a pair of tongs like you would put a piece

of meat on a barbecue grill and stuck it in this molten metal. So you can imagine how careful you had to be doing that. And hot? You had to keep water out of that thing. You couldn't even sweat over it. – Norman Brady [8]

And Sherwood Bridges remembered the overall process vividly:

The original process was about as crude and labor intensive as you can get. You had huge metal pots. One of them would have molten bronze, nickel, and the last one an aluminum silicone compound. And there was no air conditioning in that building and the men, and it was men not women because it was a job that I have seen very few women in my life that could have or would have done. They stood out there, hour after hour, with a temperature at unbelievable levels, with tongs in their hands and these cores would be dipped in that bronze. And it was hot. I can't give you a temperature, I don't remember. But I mean very hot. Hot enough to have molten metal in it. They would dip those in there to heat them up, and then they would pick them up and put them in the next pot. X time passed and they would pick them up and put them in the next pot. Then they would pick them up and they [would take a can] from a rack of extruded aluminum cans that have a bottom but no top and they'd put the slug in those cans. And put a cap in them. The whole process ended up with a weld that sealed it up and then it would go through an autoclave, a steam autoclave to make sure that you don't have a leak anywhere in the weld. Well that was all eventually gotten rid of and they went to a hot-press bonding process that was highly automated. – Sherwood Bridges[9]

313-M area workers on the original canning line would suffer a few more years until this system was replaced. In the interim, SRP continued to request better quality slugs from the producing sites and would implement equipment changes that promoted efficiency and safety such as mechanization of the canning line, resistance furnace replacements, and other updated equipment. Table 5 shows the rate of production at start up and the improvements in cost effectiveness over time. Costs were reduced from $8 per slug to $2.12 in a two-year period. By the close of 1956, the canning process was well entrenched but alternate methods were aggressively pursued to move the canning process from the Middle Ages to the twentieth century.

Table 5. Production Rates, 313-M, 1953-1956

Year	Canned Fuels – Mark I	Time Unit	Shifts	Production Cost
1953	• 1200	• Per day	• Not available	• Not available
1954	• 2700 • 0.5 million	• Per Year • Per day	• 100 man-hours per 100 slugs • 2 shifts	• $8.00 per slug
1955	• 1.2 million	• Per year	• 36 man-hours per 100 slugs	• $4.00 per slug
1956	• 1.8 million	• First six months	• 23 man-hours per slug • 2 shifts	• $2.50 per slug
Second half	• 0.9 million	• Second six months	• 20 man-hours per 100 slugs	• $2.12

Sources: E. I. Du Pont de Nemours and Company, *Savannah River Plant History All Areas, August 1950 through June 1953*, DPSP-53-368. E. I. Du Pont de Nemours and Company, *Savannah River Plant History All Areas, August 1953 through June 1954*, DPSP-54-448. E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Areas, July 1954 through December 1972,* DPSP-55-454-3.

EARLY TARGET AND CONTROL ROD MANUFACTURE (320-M)

Process equipment was installed in 320-M beginning in May of 1952 just as two supervisors, one trained at Argonne and other at Du Pont, arrived. Personnel in the Raw Materials Department in concert with Works Technical checked all equipment. In particular, the alloy furnace and the extrusion press received careful inspection to make sure the vacuum system was tight. As much of the process equipment had been developed by AM&F, members of Works Technical would work as liaisons between the production force and the design group.

Six supervisors, five of whom possessed degrees in engineering, were assigned to 320-M's startup which was monitored by Du Pont's Work Technical group. New production line employees were trained in basic physics and metallurgy and oriented while waiting for their clearances. The Technical Standards governing the alloy fabrication process were readied for distribution in 1952. In January 1953, the first fabrication of dummy control rods began and tests to check the rated capacity of the new equipment was checked. While most of the equipment seems to have worked with some adjustments, other problems such as an electrical switch failure that caused the destruction of the extrusion press run out table was more of a setback causing some time delay.

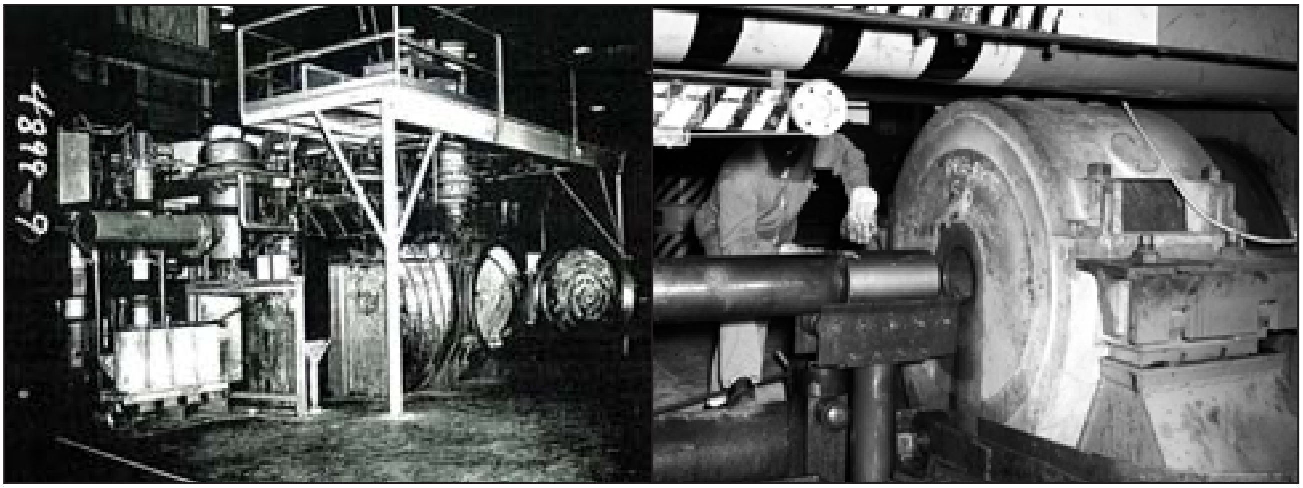
Another concern was that rods left the heat-treating process 1-inch out of line. To correct this, the rods were straightened on a press but this additional step cased some delays. Such challenges did not deter the processing of a special order for 18,000 LiAl slugs for Hanford in 1953 that required a 3-shift operation period of the vacuum melt furnace nor the completion of the first control rods for 105-R in July 1953.[10] In addition, 320-M produced a number of special projects including: fabrication of 3,000 tubes, die-sizing 15,000 cans for PDP, fabrication of enriched uranium slugs and control rods, and thorium slugs for the Process Development Pile (PDP) a test reactor in 777-10M, casting of various alloys, and the extrusion of rectangular tubing. A quatrefoil fabrication unit was added to 320-M in late 1955. The quatrefoils had been acquired from the Reynolds Metal Company but hold ups in schedule pushed Du Pont into more component fabrication. Fabricating aluminum components would remain an issue and one retiree noted that Du Pont would consider the cost effectiveness of in-house manufacture over procurement more than once.

Table 6. Production Rate, 320-M, 1954-1956

Year	Alloy Casted	Control Rods	Targets	Time	Quatrefoil
1954	125 tons	5,000	95,000 (Hanford)	130 per month	N/A
1955	1,000 lbs	1440	Not given	210 per month	N/A
1956	Not given	1750	124,000	Not given	350 tubes per mo

Sources: E. I. Du Pont de Nemours and Company, *Savannah River Plant History All Areas, August 1950 through June 1953*, DPSP-53-368. E. I. Du Pont de Nemours and Company, *Savannah River Plant History All Areas, August 1953 through June 1954*, DPSP-54-448. E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Areas, July 1954 through December 1972,* DPSP-55-454-3.

320-M personnel numbered 103 wage roll employees and 14 supervisors in 1955. Due to an increase in lithium-alloy production, more workers were added to the force in 1956 increasing the number of wage roll workers to 151 and supervisors to 25. The annual histories show an enormous amount of action in 320-M in 1955-56, including the first tubular work, as fuel assembly programs were launched and tested. Much of this work would be housed in 321-M after its completion.



(Left) Vacuum Furnace and (Right) Extrusion Press in 320-M, 1950s.

The focal points of 320-M were the vacuum furnace and the extrusion press:

> It had a vacuum furnace. In that furnace would be a crucible and you sealed it up, pulled a vacuum on it. And then you had a chute that you dropped ingots of high purity aluminum, I mean really high purity down into there. Actually, excuse me that's wrong. You would typically load that furnace with the aluminum first before you'd pull a vacuum on it. But then up on the mezzanine-like area, there was a thing that might remind you of a revolver on a pistol. The lithium that we got came in cans about, oh maybe three inches in diameter and maybe five inches long. They were lithium, which is a very reactive metal, sealed in an aluminum can. Again high purity aluminum. You would load the bores on that cylinder with the can and once you got the aluminum melted, pull a vacuum on it, try to get rid of some of the air in the aluminum itself. Then you would start a process where a pusher would push the can out on down the shoot and fall into that molten aluminum, which would melt the can and melt the aluminum. Then it would rotate one notch and you would push another one through it. Now this wasn't pushed manually, but that is the way it worked.
>
> And so you had a situation with a great big pot of molten aluminum to which you added the lithium. Now the problem with that is, lithium is such a light metal that it just floats. So how do you get that mixed up? You can't get in there to stir it. So they came up with an induction-stirring scheme in that you had a copper coil that wound itself around the furnace, and you could in effect pull on the magnetic field and you could

> pulse the energy to that. And it made sort of a boiling motion. Say this is the pot and it would do like this and basically suck that lithium under and get it all mixed up. It worked pretty darn good.
>
> Now the other big equipment in that building was an extrusion press which extruded the three -quarter inch or so diameter lithium aluminum rod from which you cut short sections to make those slugs I mentioned earlier. Later on we began making other shapes in that press. But it was still the same press. - Sherwood Bridges [11]

Norman Brady describes the processes in 320-M and a major change that had a huge impact on how work was conducted but no impact on the extrusion press equipment:

> The process in 320 basically stayed pretty much the same because what it did was make the lithium aluminum products. Of course the processes changed a little bit over the years because to start with you had to melt an alloy, lithium aluminum, under a vacuum. At least we thought that was something we had to do. And that's what we did for years and years. And that was a booger. You have to imagine putting a big induction furnace inside something that you pull a vacuum on. And that vacuum has to be approaching zero vacuum. So you've got a tank big enough to put your car in see? Anyway. That stayed pretty much the same over the years. Maybe the exact product changed a little bit, but it was still basically lithium aluminum. Along the way the technical boys and the reactor boys and all those folks, they figured out we don't have to do this under vacuum. So we got rid of that, and that was, man, that was like having a ton taken off of your head to have to try to maintain a vacuum furnace that big, see. It was bordering on the impossible to do that.
>
> But anyway. The process pretty much stayed the same. We melted lithium and aluminum, alloyed it together in a casting. We process that casting. Sometimes we machined it, sometimes we didn't. Extruded it into a shape that was wanted to make the final product. Tubes were taken to 321-M and extruded on a press they had over there, which was a better press, a newer press. It worked a little better. And so the beginnings of the target tube was made in 320. The final target tube was extruded and processed in 321. - Norman Brady[12]

The first tubular production work at Savannah River was done in 320-M the Alloy Building in mid-1956, but this work was soon transferred to the 321-M the Manufacturing Building, which was built in 1956 and 1957 specifically for the manufacture of tubes.[13] 321-M was reserved for the fabrication of thin-walled tubes, first for tritium production and later for plutonium target tubes.

Fred Rhode provided a thorough description of fuel and target production after the expansion into tube production and the construction of 321-M, showing the inter-relationship of the products and work space:

> Early [lithium] targets were pins of some sort, canned pins. And I think I am going to say that we probably did that up until the mid fifties. When the tubular fuel and targets came along, I think that is when that ended.

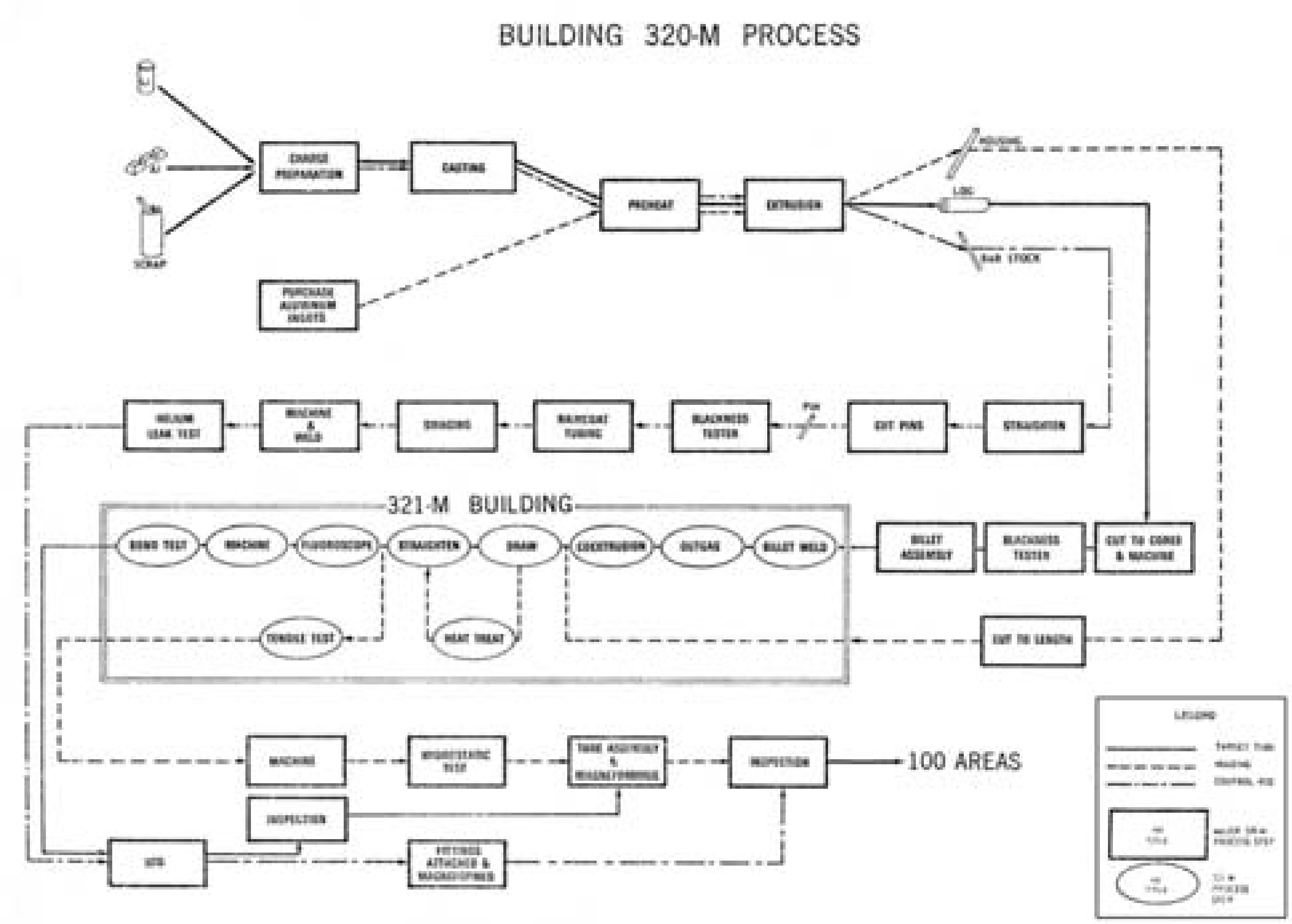


Chart showing the fuel production steps housed in Buildings 320-M and 321-M and the production work flow between buildings. All process steps in rectangles were completed in 320-M, process steps accomplished in 321-M are circled. Chart shows process steps established by the 1970s.

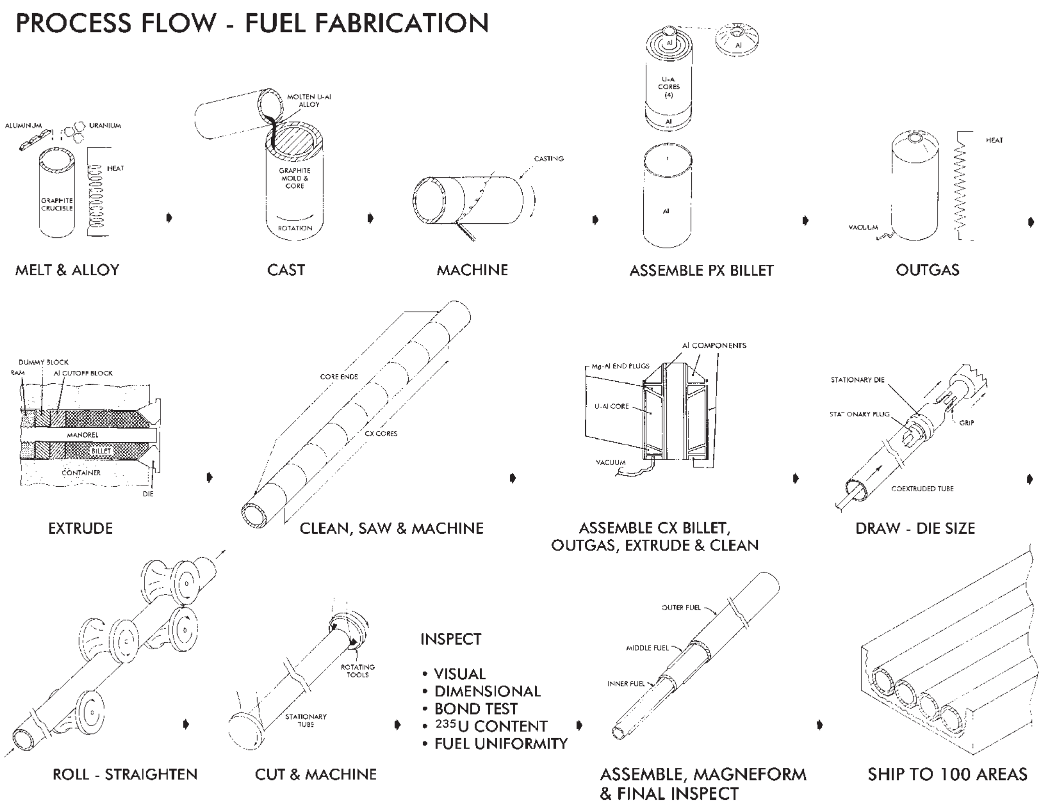
Okay, let's start with the fuel first. The process started with the casting process where we took enriched uranium metal that we got from Oak Ridge, and that was a mixture of either, well I guess in the early days that started out with low enriched uranium, and by the time I got there we were using fully enriched uranium, which at that time was 93 percent 235. In addition, we would get uranium that had been recovered from fuel in our reactors that had been, some of the 235 had been burnt out, and there were some other radioisotopes that come along with that, that aren't in the normal stuff. Primarily 234, 232 and 236 gets concentration. 236 builds up. And we would get a combination of the virgin 93 percent material and the recycled material. We would blend that by weighing out portions of each. And aluminum to go with that, plus scrap from the process. The process was pretty scrap intensive. Probably less than half of what we cast actually ended up in a fuel tube. The rest of it ended up in machine chips and parts that we couldn't use. So that would get recycled. So we'd take a mixture of all that from a calculation, to calculate the right percent proportions of those. That would be melted in an induction furnace and cast into a hollow cylinder.

Let's stop the fuel process right there and ... go back to the lithium aluminum. That process started with enriched lithium metal which came to us from Oak Ridge. And it would be like a one-pound chunk of lithium sealed inside an aluminum can. Those came in various enrichments. And we would select whatever we needed to make a concentration of our alloy correct, and melt that with aluminum in an induction furnace.

It was a larger induction furnace than what we used in 320. Well I think this goes back to maybe some of the problems we had with early targets. I think they had planned to make targets with a fairly high lithium concentration, and lithium will react with air pretty violently and actually burn. And if it doesn't burn it volatilizes and comes off. Okay? So by the time we learned that we couldn't put more than about three weight percent lithium in there, we could cast there in air without any problem at all with very minor lithium loss. So it wasn't a process necessity and operating inside a vacuum furnace was just real bad business, because it's a lot of maintenance and headaches, and a lot of problems. I can tell you some wild stories about that.

So if you are going to make a fuel tube you use the cores that were produced from the UAL casting process, but you're making target tubes you would use lithium aluminum alloy. Those would get put into a composite billet. I think the casting process produced what we called a core which was a hollow cylinder. And that would get assembled inside a co extrusion billet which would provide the inner and outer sheath, [it] would become the inner and outer cladding on the tube, and some other components like end plugs that would go together. Those things would get welded up, both fuel or targets, evacuated and out gassed by heating them up in a furnace and a vacuum pulled on them. They'd get sealed off. And then they would go to the extrusion press and get re heated, and co extruded using for many years a lead oil lubricant, magic mixture of lead particles and oil. Later that was changed to tin because of the environmental concerns with using lead.

And then when you made the extrusion then those little cores that were six or eight inches long ended up being the cores inside the fuel tube that were stretched out to twelve feet or so. And that process would metallurgically bond the cladding and the end plug, and all the components together. It was a very, very unique process from that standpoint. ....We usually processed everything in batches in the building so one week we might be making fuel, the next week we'd switch over and make targets. So the products were sort of segregated in the process. After extrusion they went to a cleaning step where you removed all of the extrusion lubricant. Because you can't extrude very accurately to the size that you want, we processed them through a cold drawing operation where we actually drew the tube... using a draw bench and a die on the outside and a plug on the inside, because that was done at room temperature and you actually reduced a cross-section of the fuel or target tube and stretched it out about, I would say it was about a 10 percent reduction in area. Maybe not that much. Maybe 5 percent reduction in area. Since that was done at room temperature and the die and the plugs stayed at the same temperature, it gave you a really precise control on the diameters of the tubes that you were making. In that process you ended up putting the oil lubricant on them so they went back to the cleaning room. The basic cleaning process there was a degreaser, caustic solution and nitric acid. After the draw bench they went through was a degreaser.



Fuel Fabrication Component Display. A. Uranium; B. Aluminum; C. Crucible; D. Mold and Core; E. U-Al Ingot; F. Pre-Extrusion Billet; G. Log End; H. Core End; I. U-Al Cores; J. Core End; K. Log End; L. Aluminum Weld Rings; M. Aluminum End Plugs; N. Al Sheaths; O. Machined U-Al Core; P. Co-Extrusion Billet (outer fuel); Q. Cutoff Block; R. Dummy Block; S. Mandrel; T. Partially Extruded Billet; U. Coextrusion Die.

After drawing nothing was exactly straight, so they went through a straightening operation. And that from time to time varied from being a press operation, and then in the 1980s or so we bought a thing called a roll straightener which was like a rolling mill with contoured rolls that, with a little bit of magic touch you could pass the tube through there and not screw up the inner and outer surfaces on the tube. And sometimes you'd be lucky and get them straight. When that was done, I guess that was done before they went through that process directly after drawings. They still had the oil on them and then they would go to the cleaning process. The target tubes then went back to 320 to get finished. And we'll get to that, we'll follow that thread in a minute. But the fuel tubes, the next thing they, in about 1970 or so we started, probably '75, we started using a process called the thermal test oven. This was a process [in which] we took the fuel tubes and heated them up to a temperature higher than they'd ever see in a reactor. And so if there was any potential for them to blister they would do that in the oven rather than a reactor. Let's see, I guess that was actually done before we drew the tubes. The fuel tubes, and later target tubes, went through a fluoroscope to look for any non homogeneities in the tube. Primarily looking for small inclusions that might have been in the core that could cause thin cladding on the tubes. And there were criteria for how big or how dense an inclusion could be. And all along the way, as we rejected these tubes, they became scrap that got recycled back into the U-AL casting process.

Went to another device called the fuel distribution analyzer, and this was an x-ray device where, basically a fluoroscope. Well I take that back. It was an x-ray, transmission x-ray device where a detector was held inside the tube and the x-ray beam was directed through the tube. Then basically the tube was rotated and translated, and you were able to look at the entire surface of the tube that way. And by measuring the amount of attenuation that took place from the uranium, you could make an assessment of how well the uranium was distributed in that. And we had a spec of how much variation you could see from, there were small areas of the tube and this was looking at a one inch long by quarter inch wide window in the tube. So there was a spec on how much variation could be inside that size of an area.

From there the fuel went down to the Nuclear Test Gauge, and that was eventually replaced by the new NTG that was sub critical, deeply sub critical, and that was actually built up in 321. So we didn't have to transfer the tubes back and forth. And somewhere along the line in there, I guess before they went to that fuel distribution analyzer, the tubes were final machined after we had used the fluoroscope to find the ends of the cores in the tube. The tube was machined so that the center of the core would be at a certain elevation in the reactor. We would cut the ends of the tubes off and machine those. So after you'd accumulate enough tubes to put a whole reactor charge together, you went through a process called matching where you looked at the individual tubes that you had and selected which ones would go together best in a fuel assembly. Typically there were three fuel tubes in each fuel assembly, and the fuel content varied. If we'd make 300 fuel tubes they all weren't exactly the same. So you did a mix and match process to pick which ones would be best to go together. And they were physically assembled together. The concentric tubes slid inside one another. The ends were attached, and were held together with fittings that went on the end. And we used a joining process called magneforming, which was an electromagnetic forming process which actually puts a crimp on a tube and holds the fittings in place.

Casting



Extrusion



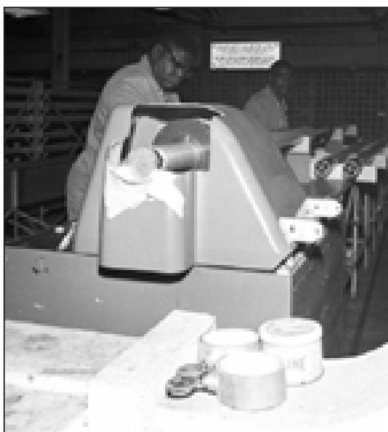


Early photographic series capturing major process steps in tube production circa 1960 showing charge preparation, casting, extrusion, drawing, straightening, and the testing of tubes.

Drawing & Straightening



Cutting & Testing



Testing



> And then they were packaged and either stored in that boreated concrete storage rack that we had, or put in the shipping containers that went out to the reactor areas as needed. On the target tube side of the business, the core ends were located with an eddy current device. You could distinguish where the lithium aluminum ended in the tubes with that. They went through a final machining operation similar to what the fuel tube did. This was all in building 320. They were final machined...most of the finished tubes ended up coming over to 321 because they were assembled with, in some fuel assemblies we had a mixture of fuel and target tubes. Some of the targets were separately dischargeable from the fuel assembly, so those were completed in 320 with the magneforming process by adding end fittings and those sorts of things.
>
> From the criticality standpoint, when the tubes and billets were in Building 321, we treated them as if they were fuel tubes, just from a criticality perspective. We processed everything in batches. As I said we might spend a week making fuel tubes and the next week making target tubes. So they tended to go through the building in discreet batches of fuel or target tubes, but I mean you could be in one side of the aisle and there would be target tubes, and one side of the aisle there would be fuel tubes. - Fred Rhodes[14]

The fuels and targets produced in 313 and 320 were sampled for quality control in 305-A's graphite "pile" (see page 83 for illustration). Modeled after Hanford's Test Pile, it was a large, low-power critical reactor. Like the Hanford example, it required a "highly trained crew operating under extensive procedures" with each component test taking 10 minutes.[15]

> It was about 15-foot cubed. And it had a monstrous shield. You know, in those days they really didn't have a lot of feel for how things are, and they over did a lot of things. And when they tore it down, they only tore down one wall because it was so massive and [had] so [much] concrete, reinforced concrete. They had a terrible time getting that one wall down. And the three other walls still stand today.
>
> The only difference between the one at Hanford, the only significant difference and the one at Savannah River is the one at Savannah River had a helium atmosphere. It had an enclosed shell around it to keep it under a helium atmosphere because if you left it open to the air, then the amount of nitrogen in the air and in the pile would vary and nitrogen developed neutrons and it affects the critical state. It was expensive because we used a good fraction of the country's helium supply on that.
> – Dave Honkonen[16]

The testing program was furthered by the addition of a Nuclear Test Gauge (NTG) in 1955. The NTG concept was the product of Gerhardt Dessauer, the SRL scientist who holds the patent. It was built to complement and later replace the graphite test pile. Thomas F. Parkinson and Norman P. Baumann, SRL scientists, note that the NTG had to match the versatility of the SRP reactors.[17] It had to test components that ranged in geometry from the first assemblies created for plutonium production to the fuels and targets created later for tritium production.

> The NTG was developed later on. But they both ran concurrently. The test pile was used primarily to test the uranium floats and control rods and then we, I think we continued to use that. Yeah, all the uranium metal continued to be tested in there. And we used the nuclear test gauge primarily for the enriched uranium aluminum fill tubes and the control rods and the uranium slugs then you'd be tested in the test pile. - Dave Honkonen[18]

The NTG was installed in 305-M in January of 1954 where it began to out perform the test pile in measuring the reactivity of the 300/M Area products with equal precision.[19] The two devices were used in tandem and the standards used for the test pile were used for the NTG. References to the test pile in the yearly histories typically refer to recalibration efforts or that the pile's operation was operated "on a scheduled basis." No numbers are given to provide a sense of workflow or the number of personnel involved with the testing.

> When I was working on the 305 test pile, we had to calibrate the test pile and the NTG whenever we had a new fuel element that was developed and produced. So we had to calibrate the pile and set up the calibration curves to determine the reading versus the uranium content on the lithium, the lithium six content. And we did do a complete recalibration of the test pile. It was a pretty extensive operation.
>
> Well, we actually did some neutron profiles through the pile to determine where the best location to test each element. And we did things to measure the excess reactivity of the pile to see if it had changed over the years and to check the calibration of the control systems, the control rods, the vine rod, and of course the control rod. Then we installed, no I guess that was the original one. So that was the program to recalibrate it. - Dave Honkonen[20]

The NTG was a nine-foot cube with an adjoining measuring area. While the test pile was used to examine materials with natural uranium and depleted uranium, the NTG was used to test materials that had enriched uranium. The NTG was smaller than the test pile, required only a small crew, and could check nuclear materials ten times faster.[21]

1958 saw the automation of the reactivity testing in the NTG when an IBM automatic production recorder was hooked up to the machine that provided data on the concentration of the element being tested and calculated average and range values. Despite its significant contribution to components testing, the NTG could not perform all the functions of the test pile so the graphite pile lumbered on in action while its smaller cohort increased throughput and would undergo even greater design modifications to further the component testing program and its diverse needs.

PROCESS IMPROVEMENTS, 1955-1969

> You got X days a year you can run those five reactors. Now what can we do to increase that production? And so somebody said here is a way. We can make this tubular thing. We can put more water down it, generate more flux, do all that kind of stuff. And you are going to get more product in the end. And then

> it's our job to figure out how to make those fuel elements, the tubular fuel elements that are required to do that job. So it was geared to increase production. So that was the incentive to make more product. We never missed a production requirement, never. Everything that DOE said we needed, we made.
> - Sherwood Bridges[22]

The creation of new fuel and target assemblies superior to the Mark I was the main thrust of the work of the physicists, reactor technical personnel and Works Technical. The change to a hollow slug or tube is the hallmark of the second process stage in fuel fabrication. The development of a new Mark, a hollow natural uranium slug, was proposed and its advent would engender numerous innovations. This second stage of fuel element evolution at SRP sought to produce higher performance fuel elements in response to the need for higher reactor power levels. Collaboration between SRL, Works Technical and the production line workers was needed to pursue development of the "ultimate fuel and target element:"

> A combination of several groups [got the development of hollow slugs from solid slugs and then large diameter tubes going]. First of all, they were constantly looking for ways to increase the flux level of the reactors to make more product. And so you get the physicists to sit down and say, ok, we got so much ability to pour water, to cool it. You can only do so much cooling with a slug in a quatrefoil. What if we had a hollow tube, aluminum clad, and we could pour water on both sides of it? We could get more cooling so we could put more uranium in it. Now natural uranium wouldn't be good enough. We'd need some enriched uranium. Well, the enriched uranium is made at Oak Ridge, so you contact them. Heh, can you supply us some highly enriched uranium? Yeah what do you need?
>
> So somebody sits down and designed this, in their mind at that time, the ultimate fuel element. And then you get all this flux, what are you going to do with that? Well you don't want just a bunch of control rods against solid rods. You want to be able to flow more water. So again you go to the hollow tubes and pour water over them. And as I say, the reactor guys who designed that reactor had great foresight because it was so adaptable to different shapes of fuel and target elements. Of course SRL is involved in all that....I was in Works Technical group, there were three of them there. We would come in, the guys would come to us and say: Hey, we just designed this new fuel tube and we want it to be 3.25 in diameter. We want it to be 30 mls clad in aluminum. We want the ID to be X, the core thickness to be Y. Can you guys make that?
>
> Now sometimes that would be done over in the SRL, in the early days SRL would do that. Of course they would sit down and do something, come over to our facility and we would make it for them, and they would go back. Well eventually they kind of got out of that particular business. They always were involved in the design of new elements. But eventually it fell to us to design the billets, to design the casting process and all that kind of stuff like to make the billet to make the tube. And so we would sit down and design.
>
> See, the press is actually a reduction process. To get a tube 3.2 inches in diameter with a certain amount of cladding, you've got to design a hollow billet that has inside of it enriched uranium aluminum

core, with thick aluminum on both sides of it. And when you run through the die that gets squeezed down and then you have to know how much to start with to get the 30 mls of clad or whatever on the back. So we would sit down and design it, and then have some made. Get the necessary tooling from the vendor that makes our dies for us. Get the induction heaters to heat those billets, which is a copper coil again with water pouring through it, because it is so much faster than an oven. So you call up that vender and say, Hey I got a billet that's going to be 6.25 inched in diameter by 2 inches ID. It's going to be this long. It's going to weigh X pounds. Got to have an induction coil to heat that. So they send us one. They have to make each one separately. So you do all that and then you extrude it. Well what did you really get?

That's where the Met Lab comes in. So you take the first tube over and say, cut this thing up and tell me what we got here. And they say well your average cladding thickness is not 30 mils like you wanted, it is 33 mils. So that kind of thing. So you go back and adjust a little bit and do it again. Do it again and again if necessary. Now we got to the point fairly quickly where we rarely had to do them again, but that's the kind of thing we did. So you had the physicists, the reactor guys, the SRL guys designing what was in their minds the ultimate fuel and target element to make the product they wanted to make.
– Sherwood Bridges[23]

The plant summary histories show that they tackled the challenge with gusto. Their work led to a whole chain of new assemblies until the optimum fuel and target assemblies were established in the early 1970s. There were at least 79 different Mark designations, most of which were designed at Savannah River (see Appendix B). The purpose of a Mark designation was to clearly identify a complete fuel or target assembly, which would include fuel, target, and housing. Most of the 79 assemblies never left the drawing board, and few were used extensively. There was a relatively simple progression in the development of the new assemblies. As discussed, the original fuel elements were small-diameter solid slugs that in the late 1950s were altered in favor of small-diameter hollow slugs, which provided more surface area to improve fuel cooling. In the early 1960s, the hollow slugs were scrapped in favor of large diameter tubes. The list of Marks indicates this dynamic progression and Raw Materials Areas histories from this point onward extensively detail equipment changes that range from the addition of critical pieces of equipment to slight improvements that increased output.

This developmental progression was particularly apt in the evolution of plutonium producing charges and—with the exception of the hollow slugs—was also followed in the development of the tritium producing charges. Both plutonium and tritium charges were developed simultaneously from 1955 through the early 1960s. The Mark I, III, and VII designs were used with quatrefoils until tubular assemblies were introduced with the Mark V series; this series was used to produce plutonium. In 1955, tritium was produced at Savannah River only in the control rods, which were set up to contain a certain amount of lithium–aluminum. As the demand for tritium increased, and as power levels rose, the first tritium-producing assemblies were introduced, allowing tritium to be created in the principal lattice positions. The first assembly of this sort was the Mark VIII, designed in 1955 and first used in the reactors in 1956. It was followed by the Mark VI series, which included the Mark VI-B, the "workhorse" tritium producer of the 1960s. The tritium producers were improved and eventually perfected with the development of the Mark 22. The early Mark assemblies and their progression are summarized in the table below.[24]

Table 7. Plutonium and Tritium Producers

Plutonium Producers		
Mark	Dates	Design Features
Mark I	1955-56	Solid fuel natural-uranium slug based on a Hanford design that was tested at Brookhaven. U-235 served as the fuel, and U-238 served as the target. This assembly could not withstand high temperatures caused by increases in reactor power
Mark III	Developed 1955-56	Full-length uranium fuel plates designed to allow Mark III-A greater coolant flow around the fuel. This assembly was never used due to problems with fabrication, monitoring, and reactivity
Mark VII	1956-57	Similar to Mark I in size, but with a cavity running through the axial length of the slug. The first of the hollow slugs, also called I & E slugs (internally and externally cooled slugs).
Mark VII-A	1957-1960	Slightly larger than the VII and designed to be used with the largest quatrefoil possible. The slug size was increased to accommodate the greater water flow from the new Bingham reactor pumps. After this, the quatrefoil was abandoned in favor of tubular fuel assemblies
Mark V-B	1960-62	After two years of tubular design work, first used in R Reactor in March 1962. This assembly could not withstand higher temperatures caused by the reactor power increases
Mark V-E	1963-1964	Tubular assembly with a slightly enriched uranium core (0.95 wt% uranium-235), which led to a higher reactivity. Because of the higher reactivity, designed to be used with LiAl blanket assemblies, tritium could be produced in the blanket around the reactor core.
Mark V-R	1964	Modified Mark V for lower enrichment at 0.86 wt% uranium-235
Tritium Producers		
Mark VIII	1955-57	Similar in size and shape to the first solid-slug plutonium assemblies; used in quatrefoil. Contained both fuel slugs (enriched uranium) and target slugs (Li–Al).
Mark VI-J	1958-59	A target slug with a hollow, air-filled Li–Al core and a single outer fuel tube. Highly enriched uranium (HEU) fuel
Mark VI-B	1960s	The tritium-production workhorse of the 1960s. The first to have both inner and outer target tubes, with the outer target tube serving as the outer housing for the assembly itself. Could also endure higher power levels and longer exposures than its predecessor

Source: Reed et al., Savannah River Site at Fifty (Washington, DC:US Government Printing Office, 2002), 338-339.

As fuel and target assemblies advanced from solid slugs to tubular assemblies, a host of manufacturing techniques had to be altered to produce and check the new materials. New buildings were required to house the machinery for tube manufacture, and better canning techniques were developed to seal the uranium and lithium in their protective aluminum sheaths. The change to tubular assemblies also required improved methods of testing or checking the new products. These changes began just a year after the original Savannah River Plant was completed, and continued throughout the 1960s. Notably, the use of enriched uranium predicated a review of procedures and practices as well as the changes to the facilities that were involved. Accordingly criticality alarm systems were added to 300/ M buildings such as 321-M, 305-M where enriched uranium was handled.

Criticality safety was at issue, not just for the handling of fuels and enriched uranium but also for safe storage.

> We were establishing the criticality limits for handling all the fuel and the enriched uranium and all the byproducts. Any time we had a new piece of equipment come in we'd have to evaluate it for nuclear safety and run calculations to determine what the safety limits are for the equipment and any part of an operation. One of the most hazardous problems was the vines. We machined the uranium aluminum elements before we extruded them into two, and that created a lot of fine material. And it only took about maybe a kilogram of those vines in water to cause a nuclear accident, so you had to be very careful with those. And the filters, if you dump one of the filters into a bucket of water, it would go critical, those big Hepa filters. So that was the primary thing on the nuclear safety end of it.
>
> Another nuclear safety item. The enriched uranium aluminum fuel tubes, if you submerged five of them in water, you could have a nuclear accident just by simply submerging them in water. Or if you had them stored in open racks and you turn a sprinkler on them they could go critical, it would be enough

Borated concrete storage racks or "honeycombs" that lined the south end of Building 321-M as well as other buildings. Installed after 1966, these specially-designed racks provided for the safe storage of over 3,000 enriched uranium fuel elements at the Site. Concrete provided a strong advantages even in the event of a natural disaster, and the boron in the concrete would absorb neutrons in the event of a criticality, acting as a built-in neutron poison.

moderation on the sprinkler system. So that was a big concern because that's the first thing you would do is spray water on a fire. And you can't tell the fire department don't do it. It goes against their basic training. So, what we did to assure that that couldn't happen and to provide a significant storage area, we made concrete slabs with a large amount of boron in them. In effect what we did is we said all right, the concrete is going to provide the moderation of neutrons. But we put enough boron in there so that there's no way it could go critical because the boron would absorb the neutrons. So we made these slabs, and they were 16 feet long and six feet wide and about eight inches tall and they had tubes running through them for the storage of the fuel elements. And we stacked those up to, I don't know, 12 to 16 high, something like that. So we had a very large storage area and they extended all the way across the south end of the 321-M building. And around the corner too. – Dave Honkonen[25]

While 320-M was the site of the first tubular element production, its role was short-lived. 321-M became the locus of tube manufacturing in which co extrusion played a central role. Charlie Mettlen worked on early tube development in 1955:

We cast the alloy in SRL. And we would machine and assemble the billets for extrusion. One of my functions early in the game was to take those to 320. They had modified that furnace for outgassing and extruded them in the 321 press. Now this was the first thing and it was interesting. And no real difficulties with it but it was new and different so we went pretty slow. But the only time they would let me near their press was on the 4-12 shift on Friday. And my wife was getting disturbed. Every Friday on 4-12, that was when we started. And as soon as 321 was completed, we moved over there. But it started in 320. It was cast in 773 [SRL], extruded in 320 and shipped back to 773 for machining cleaning up the tube and this kind of stuff. – Charlie Mettlen[26]

The coextrusion techniques used in 321-M had been researched for years at the Savannah River Laboratory. In fact, the first research into the use of tubular elements had been done as early as 1951 by Nuclear Metals, Inc., at the behest of Du Pont. Nuclear Metals pioneered the use of "co-extrusion," which was the simultaneous formation of a tubular fuel core and the aluminum cladding on both inner and outer surfaces of the tube. Norman Brady described it as a "magic process:"

Oh my, co-extrusion. Well, to start with, you had to assemble your billet, what we called a billet was the uranium core or the lithium core whichever it was, and encapsulate it for the co extrusion process... You welded this up airtight and outgassed it. It was heated and a vacuum pulled on it so that you got all the air and all the gasses out of it. Because if you didn't, when you did your co-extrusion the little air bubbles would blister the tube. It would put a little blister on it just like you burned your finger and got a little blister on your finger..... Then you went through the extrusion press, made your tube. The tubes were then processed, cleaned and put through a draw bench which was a piece of equipment that sized the tube, made it down to the final size you wanted. Let's see. You cut off these outside ends to leave your tube to the particular length that you wanted. You put it through an x-ray machine to look at that core in there to make sure that the core was where it was supposed to be, lithium aluminum or uranium aluminum mostly. I guess uranium aluminum went through the x-ray. Lithium aluminum went through another contraption..... Then you had some other processes. You might have attached a fitting to one end or the other. You

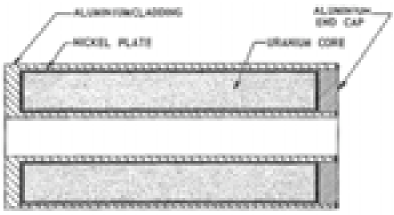


Fig. 1

Line drawings showing a uranium fuel element and an end cap thickness gage.

Line Drawings: R.H. McKane and D.L. Honkonen, "Non-Destructive Testing of Reactor Fuel, Target, and Control Elements" in Non-Destructive Testing in Nuclear Technology ,Vol. II, International Atomic Energy Agency, Vienna, 1965.

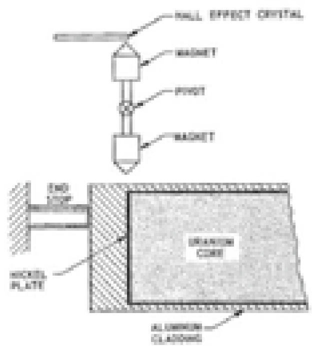
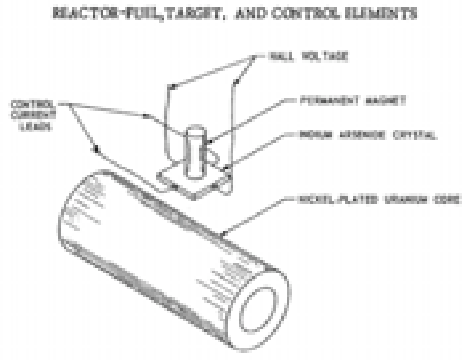


Fig. 4

End-cap thickness gage

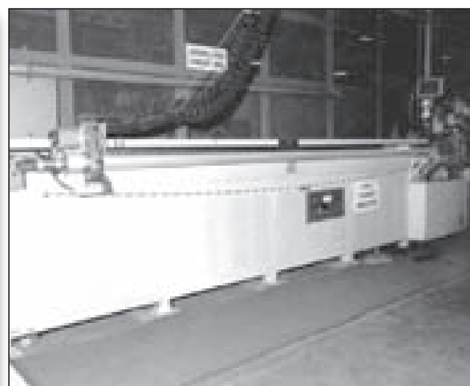


The non-destructive testing of fuel elements was an important part of M-Area operations to avoid failures in the production reactors and to establish that each had the required nuclear properties. Physical testing also occurred after irradiation to check for volume change as well as other physical changes.

Fluoroscopic examination of Fuel Tubes by D. Dorch, Jr., V. L. Smith, L. D Baker, Jr. , 321-M, not dated.

Equipment Engineering Department personnel Roscoe Crane and R.D. Rutland cutting fuel elements for quality control evaluation.

Fuel Density Analyzer in 321-M loaded with fuel tube to test tube density.



J. B. Bond and J. C. Cogdill bond test tubes in 321-M.

Tubes also needed to be straight to work within the reactor. The tube straightening machine was essential to the production process. Tube Straightener, not dated.

Examples of Extruded Tubes.

> might have punched holes in them to facilitate handling of the tube. In later years we had a machine called a magneformer which was a black box machine I called it. You could use it to attach fittings to the tubes without welding without any kind of a mechanical working. It was [had] a n electromagnetic discharge I believe. It had a bank of capacitors in there that charged up and then you'd discharge this, and within a fraction of a second it would transfer that energy to a fuel shaper I believe we called it. A brass looking piece that would shape the tube and would affix that fitting to the tube, just like you had welded it. Although it wasn't welded, it was just mechanically squeezed down. It worked great. It was a great machine. And for there what else did you do to it? I guess once you put your fittings on that that was about it. That was for handling and reactors. – Norman Brady[27]

It soon developed that fuel and target tubes had to be ribbed, to preserve their position and to create coolant channels with accurate dimensions to assure consistent cooling around the tube. In the late 1950s and through most of the 1960s, ribbed tubes were produced from smooth, unribbed billets. The late 1960s saw the first use of ribbed extrusion billets for the production of ribbed tubes.[28]

> There were ribbed housing tubes that were simple to make and we used to buy those from vendors. So at some point in time somebody got the idea to put ribs on them and ... you can do that in an extrusion press. But when they first started out doing it they used just a cylindrical billet. And when you would form the rib on the tube the core material would flow up inside the rib which was undesirable from a couple of aspects. One it put more fuel in that area so it became a hot spot in the tube and actually became power limiting on the tube in the reactor. And it also thinned the cladding because you were stretching all that material out to form the rib. The vendor we worked with, I guess a fellow named Roger, it will come back to me, Roger Leband, I know he is the patent holder on the rib billet. And he was an SRL employee at the time. And that press in SRL, I believe was used to make the first demonstration of the rib billet concept.
>
> What you would do is you would look at the tube you wanted to make and you looked at the extrusion press ratio that you had, and typically. We used an extrusion ratio of about 25 to 1. But each tube had a unique extrusion ratio because if its geometry and that sort of thing. So you would look at the size of the rib that you wanted on the tube and you would multiply that cross sectional area by the extrusion ratio. And you provide that much greater area on the billet. So theoretically when you would extrude that you would have enough metal that would flow down to form the rib on the tube. And it did work much better. And that is about the time I arrived on the plant site. But the process, my claim to fame at Savannah River Plant was I believe I am the guy responsible for optimizing that design of die to make the ribs where we had very little upset in that area. And that was just a matter of controlling the contours inside the die one so that the little rib portion got reduced at the same rate as everything else. And that was pretty well done by, about 1975. We figured out how to do that pretty well. And we used that basic design for all of the rib core extrusion dies. – Fred Rhode[29]

To produce the ribbed fuel tubes, changes in production equipment were made in 320 and 321-M. New tooling for existing equipment was acquired or developed such as extrusion dies, mandrels, draw-bench dies and plugs. And the 1961 work-flow was separated between the two buildings as follows: target alloy casting, pre-extrusion, machining, billet welding and outgassing were to be completed in 320-M. Target billet extrusion and all phases of fuel tube fabrication were focused in Building 321-M.[30]

The use of tubes and the rise in reactor power levels also required improvements in canning techniques. The original method of canning has been well described. Its eventual successor, particularly for canning hollow slugs, was hot-press bonding, a technique developed by Sylvania Electric Products Company's (SEP) Hicksville Plant in NY in the early 1950s. This firm was later known as Sylvania Corning Nuclear Corporation or Sylcor and will be referred to as Sylcor from hereon. In this process, an electroplated uranium core was placed in a preformed can, an aluminum end plug was inserted, and the can was pressed mechanically at high temperatures to allow bonding. The layer of nickel electroplated onto a beta-treated core served as the bond. The can was closed by welding. The bond strength of the hot-pressed elements, an indicator of good heat transfer potential, was about twice as strong as that achieved in the original Al-Si technique and the process offered strong output at reduced costs.[31] The 1954 Raw Material Area history notes that the AEC accepted a proposal from Sylcor with an expectation of costs from $10 to $14 per slug. Given that, the responsibility for the enriched uranium program was placed with SEP and SRP rather than SRL. SRP was tasked with "as–received inspection, machining, welding of the cap, ultrasonic bond testing, reactivity testing, cleaning and final inspection."[32] By the end of 1956 Sylcor could produce 2,000 canned slugs per day.

The use of this new method was delayed at Savannah River because of the anisotropic growth of the irradiated uranium hollow slugs and tubular elements as a result of high metal temperature. Sylcor did all hot-press bonding of Savannah River slugs until 1960, when 313-M, the Canning and Storage Building, was converted to the new process. The installation of 18 new induction furnaces and related equipment was completed in 1961.

The outsourcing to Sylcor of the bonding process began with enriched uranium fuels and would also include elements for the thorium program anticipated to be used in target material for tritium production. SRP began preparing fuel cores and cans in Building 320-M for shipment to Sylcor's Hicksville Plant in New York in 1955. Thousands of slugs were hot-press-bonded at Sylcor in the last five months of 1955 at a cost of $13.36 per slug. Between 1955 and the installation of hot-press-bonding equipment in 1961 at SRP, solid slugs and then hollow fuels continued to be canned using the triple dip Al-Si process. As noted, the SRP work force was also responsible for finishing the Sylcor canned slugs. Table 9 contains the number of canned slugs at the two locations and shows the proportion of canned slugs completed.

Sylcor continued to can fuels using the hot press bonding technique until 1965 for SRP after which all canning was completed by hot die size bonding. Development of hot-die size bonding began in 1963 as a pilot operation at SRP to develop the Mark V-E program, a plutonium producer using enriched uranium cores. Not only did hot-die-size bonding represent a lower cost in the canning of tubes from the previous methods, but the bond strength was greater. In addition, the new method for canning large-diameter tubular elements provided more surface for heat transfer than that offered by the previous techniques.

SRP's equipment was modified to make the outer fuel elements needed while Sylcor would make the inner fuel. The equipment modifications involved a new "interim" sizing press with water cooled water ram on the press, cut

Views show the slugs prior to canning, the movement of fuels through the hot press canning line and finally over to inspection area.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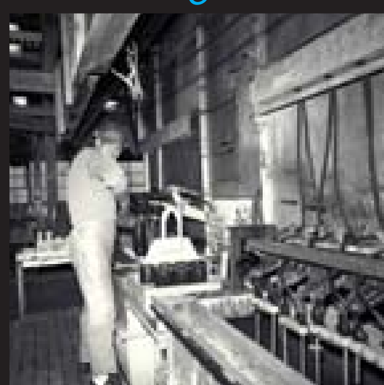
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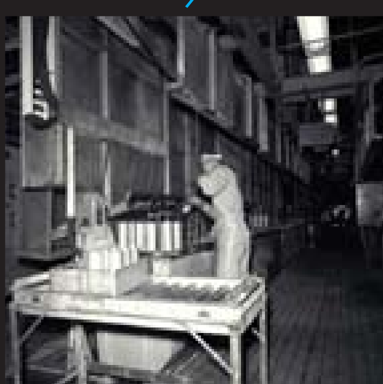
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1-18 Canning Process, Ca.1960; 19-20 Post Canning; 21-22 Pickling, Cleaning.


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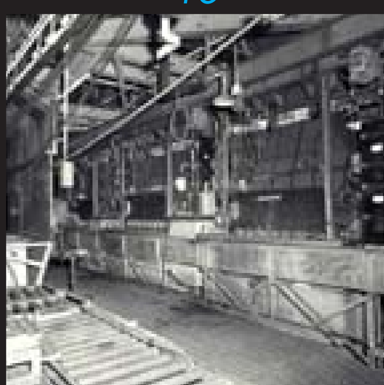
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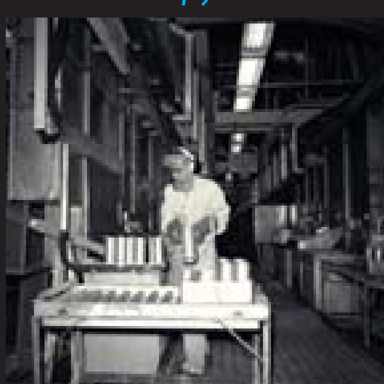
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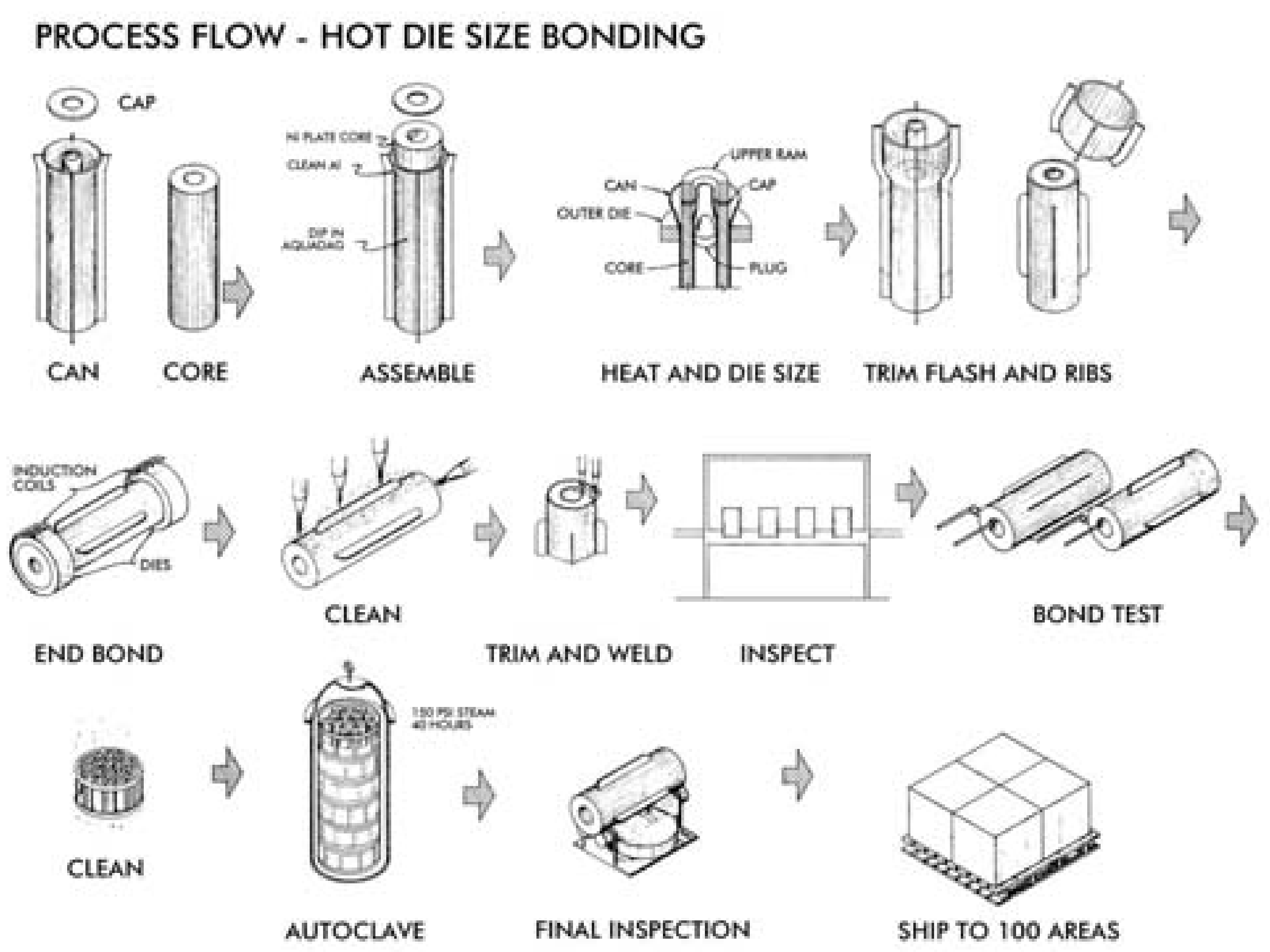
off saw, automatic reset numbering head, sizing tooling, automatic limit switches, and slug lifts, and two position end bonder. In a general sense, the original equipment was mechanized as much as possible with automated horizontal trimmer welder, automatic bond testers, and more mundane but necessary items such as automatic can lubricants.

By 1967, a new automated hot-die-size bonding complex was under development and all equipment was installed in 313-M in 1968. All remaining hot-press bonding equipment was removed.[33] The next year, canning was converted to the new automated system, the building's ventilation was improved, and the reject slug recovery room was renovated. In addition Pangborn equipment for cleaning slugs by blasting them with ground walnut shells was added to the process area.[34] The average cost of canning a slug was estimated at about $22 from 1968 onward.[35]

Hot Die Size Bonding Equipment 2003. Hot-die size bonding was a major advance in canning technique in terms of cost and the strong bond that resulted. Also, the new method for canning large diameter tubular elements provided more surface for heat transfer. This canning system although updated throughout its use remained in place until the close of M-Area operations.



Canning Equipment

Large format photography of major canning equipment in place prior to dismantlement completed in 2003.

1. The process line included a aluminum component preparation line use to etch, size, and clean aluminum caps and cans.

2. The uranium core preparation and nickel plating line where cores were cleaned , plated with a thin film of nickel, assembled with a cap and can into a slug assembly and prepared for bonding.

3. Automated Hot Die System (HDS) included a Accumulator-Dipper, Transfer Turret, Furnace, Press, Quench Tank and Cut Off Saw. The complex could bond slugs at a rate of two per minute.

4. In the End Bonder, a chain conveyor carried slugs to stations where they were prepared for end bonding, end bonded, and then prepared for further operations.

5. The Shell Blast Cleaner used ground walnut shells propelled by compressed air and centrifugal blowers to clean the slugs.

6. The Trimmer-Welder automatically picked up slugs, faced and grooved the end, welded the slug closures using tungsten-inert gas, and then places it on a conveyor for inspection.

7. Inspection involved the cap thickness tester, weld overhang test, length check, content, visual inspection, and the bond tester.

8. In the Autoclave Test, slugs were placed in steam autclaves for a two-day period. If steam penetrated the cladding. the canned slugs are destroyed.

Source: E. I. Du Pont de Nemours and Company, Atomic Energy Division, Savannah River Plant *Automated Hot-Die-Size Bonding Process Building 313-M,* DPSOP 310, 1972.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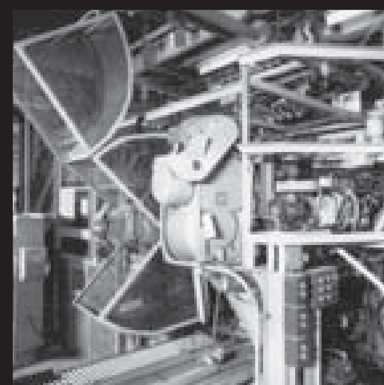
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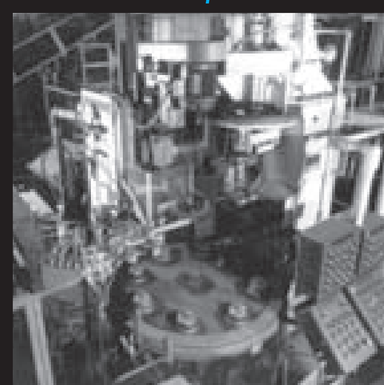
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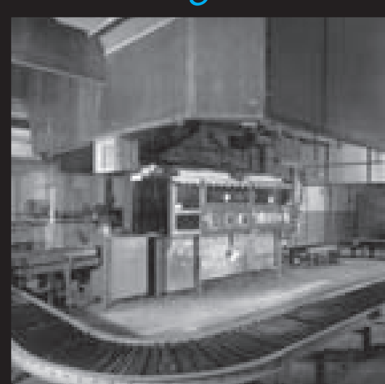
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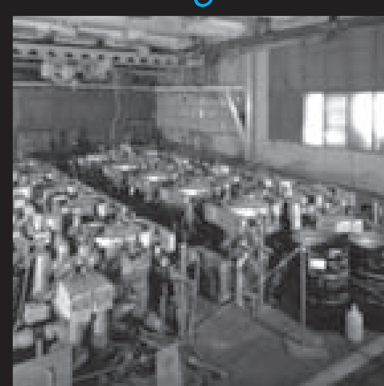
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Statistics on the 300/M Area work force in work are given intermittently in the annual Raw Materials historical summaries. In mid year 1954, the Raw Materials Department consisted of 218 wage roll employees and 43 supervisors.[36] A compilation of the data provided is given in Table 8. Also an index of Savannah River Plant's Manufacturing Division for 1967-68 shows the number of supervisory staff and support personnel in those years. Table 8 underscores the quixotic nature of the 300 Area operations as the production line was retooled or reinvented for a new product type. In some years, operations were on a multi-shift basis (8-4, 4-12, 12-8) only to face a shut down of operations at another point in the year.

> If your production called for it, if you had to meet a schedule and you had to run more than one shift, then it would run whatever it needed to run. We worked a lot of two shifts over there [in 321-M], and sometimes there were four shifts but mostly it was day shift. So the presses they didn't run all the time... You can't compare it to a commercial production like Alcoa or somebody who is running around the clock. – Norman Brady[37]

Also, depending on your job, you might be on a 24-7 schedule but the others in the same building or same process may be on a 40-hour work schedule. Overall, 321-M required the largest work force with peaks in 1966 and 1970 with 70 and 52 operators respectively. In 1969, one of the few years that has consistent numbers for all three manufacturing buildings, there were between 67 and 94 operators and supervisors in the buildings. The personnel figures also reflect changes in the plant's mission. For example, the 1963-1964 numbers show a lessening in product need and the shutdown of the R reactor.

As mechanization occurred jobs declined and as operators gained expertise the number of supervisors decreased. It appears that the work force was fairly adaptable with multiple skill sets. Many of the employees had work experience throughout the area and as production needs expanded, contracted, or changed the work force adjusted. Oral accounts put the 300/M Area staff in the hundreds. Their estimates probably include all the support staff as well as those housed in the area laboratory, administration building, and other support facilities. In 1968, there were 36 upper level superintendents, supervisors and foremen in the Raw Materials Department (see Appendix C). Supervisors and foreman were assigned to shifts; some were assigned to specific buildings therefore processes while others were responsible for multiple buildings. In 1979, there were 49 supervisory personnel (superintendents, area, senior, and shift supervisors, and foremen) spread between a number of sub areas in the Raw Materials Department such as: inspections and control, special services, procedures and training, quality control, and production. Specific process areas such as casting, extrusion and finishing, hot die sizing had specific foremen (see Appendix C).

Unfortunately very little information is included on the work force in 305-M. The 1978 History only notes that the NTG operations had 1 supervisor and 3 operators; no data is given for the Test Pile. This suggest that the work force in both was relatively small in comparison with the other 300/M Area production facilities.

Table 8. 300/M Area Work Force, 1957-1975

Year	313-M	320-M	321-M
1957	•1-shift •Personnel not given	•Work schedule not given •Personnel not given	•Work schedule not given •Personnel not given
1958	• 1-shift, 1-2 canning lines • Personnel not given	• 1-shift • Casting 21 shifts per week (1—10) • 10 shifts (11-12) • Personnel not given	• 15, 10, 5 shifts per week • Personnel not given
1959	• 2 canning lines, 2 shifts • Personnel not given	• 5 shifts per week • casting 10 shifts per week • Personnel not given	• Work schedule not given • Personnel not given
1960	• Work schedule not given • 4 canning line (Jan-Mar) • 3 canning lines (Apr-May) • June-Sept shut down • 1 line (Nov-Dec) • Personnel not given • Personnel not given • Personnel not given	• 40-hour work week	• 40-hour work week
1961	• 4-month canning run then AlSi canning lines shutdown • Personnel not given	• 40-hour work week • Operators reduced from 22 to 17	• 40-hour work week • Personnel not given
1962	• 20 shifts per week • Finishers 10 shift per week • Personnel not given	• Work schedule not given • Personnel not given	• Work schedule not given • Personnel not given
1963	•3-shift 5 day per week canning/finishing • work force reduced by 12	• 40-hour work week • Operators 5 (July) • Operators 19 (Dec) • Supervisors reduced from 5 to 3	• 2-shift operation begins Dec. • Operators 9-24
1964	• 3-shift, 7 day to 2-shift 5-day in June • Personnel not given	• 40-hour work week • Operators 12 -19 • Supervisors reduced from 4 to 3	• 2 shifts • Personnel not given
1965	• 2-shift, 5 day • Personnel not given	• 40-hour work week • Operators 8-19 • Supervisor 1 shift supervisor, 2 foremen	• 2 shifts • Operators 25-40 • Supervisors 4-6
1966	• 3 shifts, 5 days(Jan-May) • 3 shifts, 6 days (Jun-Sept) shutdown (Oct) • 24-hour 7 day (Nov-Dec) • Personnel not given	• Work schedule not given • Operators 8-36 • Supervisors 1-2 • Foremen 1-2	• Work schedule not given • Operators 27-70 • Supervisors 4-8
1967	• 2 shifts 5-day • 3 shifts 7 days • Personnel not given	• 40-hour work week • Operators 10-13 • Supervisors 2-3	• 2 shifts • Operators 22-39 • Supervisors 4-6

Year	313-M	320-M	321-M
1968	• 3 shifts 5 days per week 1-3 • 2 shifts 5days	• 40 hour work week • Operators 10 • Supervisors 2	• 3 shifts (Jan-Mar) • 2 shifts (Apr-Dec) • Operators 22-42 • Supervisors 4-6
1969	• 40-hour work week • Operators 13-23	• 40-hour work week • Operators 10 • Supervisor 1 • Foreman 1	• 2 shifts • Operators 24-51 • Supervisors 5-9
1970	• 40-hour work week • Core plating/mechanical and E & I - 5 day 2 shift • Maintenance 4-12 shift • Operators 2–24	• Work schedule not given • Operators 10-19 • Supervisor1 • Foreman 1	• 5-day, 2 shifts • Operators 29-52 • Supervisors 8-10
1971	• 40-hour work week • Operators 15-20	• 40-hour work week • Operators 18-20 • Supervisors 2-3	• 2 shifts, 5 day per week • Operators 29-36 • Supervisors 8
1972	• 40-hour work week • Operators 7-22 • Supervisors 4-6	• 40-hour work week • Operators 14-23 • Supervisors 3	• 2 shifts. 5 day • Operators 36-62 Supervisors 8
1973	• 2-shifts • Operators 24-28 • Supervisors 5	• Not available	• Not available
1974	• Work schedule not given • Operators 20 • Supervisors 3 • to • Operators 4 • Supervisor 1	• 40-hour work week • Operators 16-20 • Supervisors 3	• 2 shifts then 1 shift • Operators 26-47 • Supervisors 6-10
1975	• Work schedule not given • Operators 4 • Supervisor 1 early in year • Operators 25 • Supervisors 4 end of year	• 40-hour work week • Operators 16-20 • Supervisors 4	• 1 shift • Operators 26-42 • Supervisors 4

Source: E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Areas, July 1954 through December 1972*, DPSP-55-454-3.

Between 1964 and 1979, major improvements to the operation of the Savannah River reactors occurred. One of the first was in the nature of the housing that took the reactor assemblies into the reactor tank.

The first improvement to the housing for the reactor assemblies was called the semi-permanent sleeve. The sleeve was a series of hollow tubes used to guide fuel assemblies into the reactor. First tested in November 1964 in P Reactor, the semi-permanent sleeve went into full operation in 1965 with the Mark V-ELSD — similar to the Mark V-E except that it was specifically designed for use with the semi-permanent housing.[38]

The semi-permanent sleeve was in turn replaced by the Universal Sleeve Housing, or USH. Introduced in 1967–1968, the USH was not only more versatile and less expensive than its predecessor, but it also took full advantage of the openings in the reactor tank, allowing an increase in fuel diameter. This led to the retirement of all previous assemblies, specifically the Mark V-R (plutonium producer) and the Marks VI-B and VI-E (tritium-producers), as new ones were developed to take advantage of the increased size.

> The universal sleeve housing I think came along when we were still buying all that stuff from vendors. The work on physically developing the design of that was probably done at SRTC (SRL). And there's a hydraulics and heat transfer lab there where they probably looked at those designs. But again I am fairly sure that the actual manufacture of those was done off site before the vendor shut that business down and we had to get into it. Now you know the difference between what a universal housing was and all that? Turns out they aren't quite so universal.
>
> In the reactor you need a housing that goes around the outside of the fuel target to get it into the reactor and also to maintain the cooling channel immediately around the fuel because that water is going at a pretty high velocity. Then there is a bulk moderator that is around that so you need to separate [them]. I mean it is just a physical barrier that provides the flow channel around the fuel and separates it from the rest of the bulk moderator. It must be in early times that we had different sleeve housings for different kinds of assemblies and finally someone got the bright idea..Why don't we make one kind of sleeve housing that we can put both fuel and targets in? And that showed. When that came along you could use the same sleeve housing to put the Mark 31 slug assemblies in the same as you use for the fuel. But there actually was a difference. Let me see what the differences were. I guess they were the same and then somebody at some point in time, about the eighties, said gee we could have a reactor accident if we erroneously put fuel in a target position. So we ended up changing that so we had a universal sleeve housing that was for fuel and another for targets. –Fred Rhode [39]

DEVELOPMENT OF OPTIMUM FUEL AND TARGET ASSEMBLIES, 1970-1989

One of the significant achievements during this period—the one that more than any other was responsible for the efficient production of plutonium and tritium—was the development of the optimum fuel and target assemblies for use in the Savannah River reactors. After years of experimentation in the late 1950s and 1960s, mark assemblies were standardized in the early 1970s, as were the lattice arrangements needed to bring them to peak performance.

The development of the new efficient marks, and the mixed lattice arrangement that made them work, owed much to the Transplutonium Programs of the late 1960s. The Transplutonium Programs, championed by AEC leader Glenn Seaborg, involved the exploration of man-made elements heavier than plutonium that could be produced in nuclear reactors. Savannah River reactors played a major role in these programs including the Curium Programs, the High Neutron Flux Program, and Californium Programs. The idea was not only to learn about such elements but to put them to use in medical research and other scientific applications.

This era of production was recalled by Fred Rhode:

> Now there were some activities in 321 that were a little different from the the UAL business. We at one time made some plutonium, some fuel tubes that had plutonium 239 in them. The billets were made up

> in F Area I believe, and then brought to M area where we extruded those into tubes. And we made at least, I'm thinking at least one or two reactor chargers that way. That happened before I got there. We made neptunium targets in that building, where we took the neptunium that was recovered from the recycled fuel and that was put into a billet out in F area and brought up to M area and extruded into a tubular form called a Mark 53.
>
> And there was a whole series of those, Mark 53s, and 53As and 53Bs, a progression with time. Made a plutonium target about the time I got there in '68. And that might have been called a Mark 18A target or something like that. But it had plutonium in it. The plutonium fabrication was initially done out in F Area as the small pins were one inch diameter and six inches long. And those were taken up to SRL and worked in the Fab Lab where they cut those and re formed them, and put them into a billet. Then we extruded that into a target in the M area. – Fred Rhode [40]

The Mark V-R fuel assembly for the production of plutonium, used in 1967–68, was the last to be used with the old semi-permanent sleeves. The development of the Universal Sleeve Housing (USH) required a different design, as did the success of the mixed lattice demonstration that occurred about the same time. A component of the Transplutonium Programs, the mixed lattice arrangement, became a standard of reactor operation in the 1970s and 1980s.[41]

Initial Savannah River reactor operations relied on what was called a uniform lattice, or a reactor core arrangement in which all assemblies were identical, with fuel and target elements within each assembly. A mixed lattice featured a core arrangement that combined uranium-235 fuel assemblies and other assemblies specifically designated as targets. The first mixed lattice operation at Savannah River was proposed in a report to the AEC in 1966, and was conceived in conjunction with the installation of Universal Sleeve Housing. Mixed lattices were used in the Transplutonium Programs, especially Curium II, and the idea was quickly extended to the production of plutonium and tritium as well. In May 1967, a Mixed Lattice Demonstration, using different target materials, was conducted in K Reactor following the end of Curium II. The first assemblies or marks designed for this mixed lattice arrangement were the Marks 50-A and 50-B, which served as targets, and the Mark XII-A, which served as the driver or fuel source. It was not coincidental that Mark XII-A was similar to the Mark XII charge designed for the production of curium. These first marks were soon followed by others: Marks 14 and 16 as drivers, and Mark 30 and 31 as a depleted-uranium target.[42]

By 1968, Mark 14 and Mark 30 had been developed as the driver and the target assemblies, respectively, for the first regular mixed lattice production of plutonium. The Mark 14 assembly contained three highly enriched uranium-235 fuel tubes, while the Mark 30 series of target assemblies contained depleted uranium.59 The Mark 30-series charges became the standard for the new plutonium producers. The Mark 30 series were mixed lattice assemblies that always required enriched uranium drivers, usually Mark 14 or 16. The Mark 16 assemblies contained twice as much uranium-235 as the Mark 14's, and this allowed for several target stages for each Mark 16 cycle, with each successive Mark 30 assembly containing less depleted uranium. This lattice arrangement had the advantage of better "neutron economy," which made possible more products per reactor exposure, as a result of the increased level of uranium-235. It also meant a reduction in fuel assembly costs, since the Mark 16 assemblies could stay in the reactor longer than was possible with the Mark 14s. By the 1970s, the MK16-31 configuration had become the plutonium-producing workhorse at Savannah River, and remained popular until the reactors were shut down in 1988. Even though Mark 15, tested in 1983 in a uniform lattice, proved to be the single most productive of all the plutonium-producers used on site, its use was limited due to the high cost of feed material. Its high composition of 1.1 percent uranium-235 could not be manufactured without expensive adjustments to the existing uranium-enrichment facilities.[43]

A similar standardization occurred in the production of tritium, even though in this instance a uniform lattice, not a mixed lattice, became the norm. Early in the 1970s, the Mark 22 was introduced as an improved charge for tritium production, and was designed to take full advantage of the Universal Sleeve Housing. Mark 22 had two concentric fuel tubes of enriched uranium-aluminum alloy, placed between inner and outer target tubes of lithium-aluminum alloy. Its semi-permanent outer housing contained no lithium so that it could be used in the reactor for years before it had to be replaced. The first full load of Mark 22 charges was placed in operation in 1972, and Mark 22 quickly became the standard in K Reactor. It quickly became the tritium-producing workhorse of Savannah River.[44]

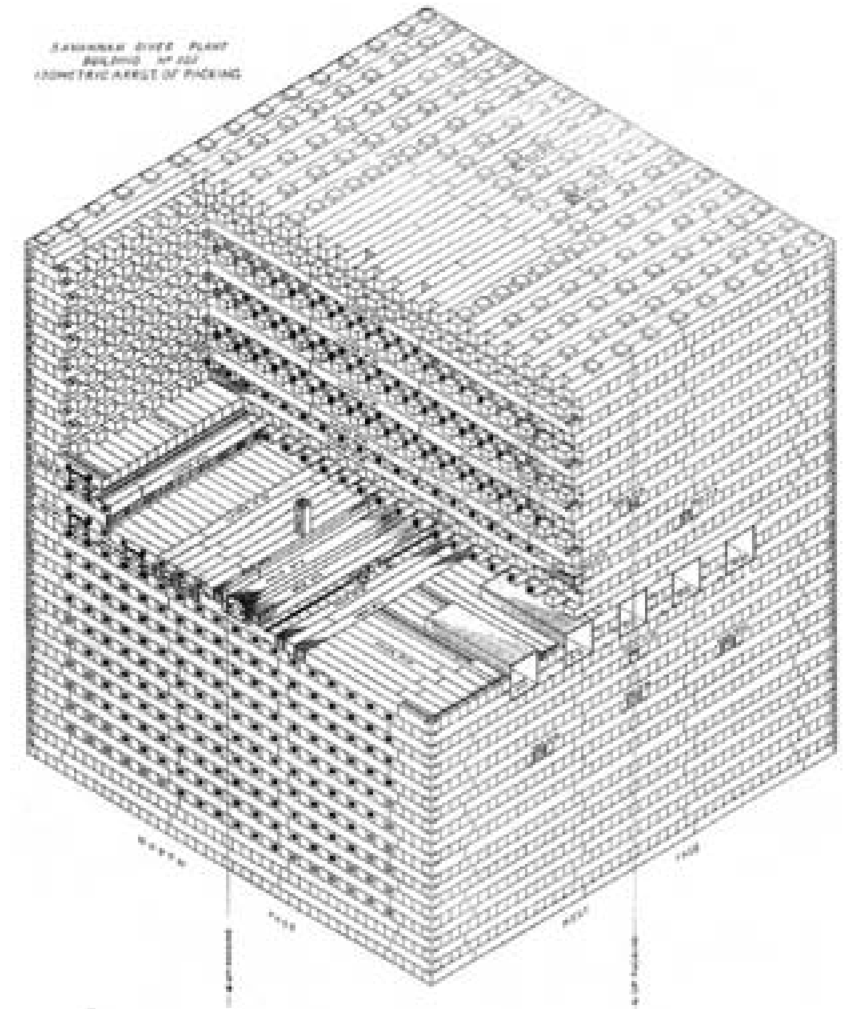
The mixed lattice arrangement, and the new marks that followed, proved to be highly successful, and were custom-made for an era in which the reactors were producing a variety of nuclear products, particularly plutonium-238. The versatile mixed lattice arrangement also had other ramifications. It gave the Savannah River reactors a distinct advantage over the Hanford reactors at a time of reduced plutonium production. As a result, the success of the mixed lattice at Savannah River is believed to have been a major factor in the AEC decision to shut down all the reactors at Hanford—with the exception of N Reactor, which also produced electricity for the Pacific Northwest. Because N Reactor produced plutonium with a higher percentage of plutonium-240 than that required by the AEC for weapons-grade plutonium, the Savannah River reactors had to produce plutonium with a lower percentage of plutonium-240, so it could be blended with the Hanford material to create the required percentage.[45]

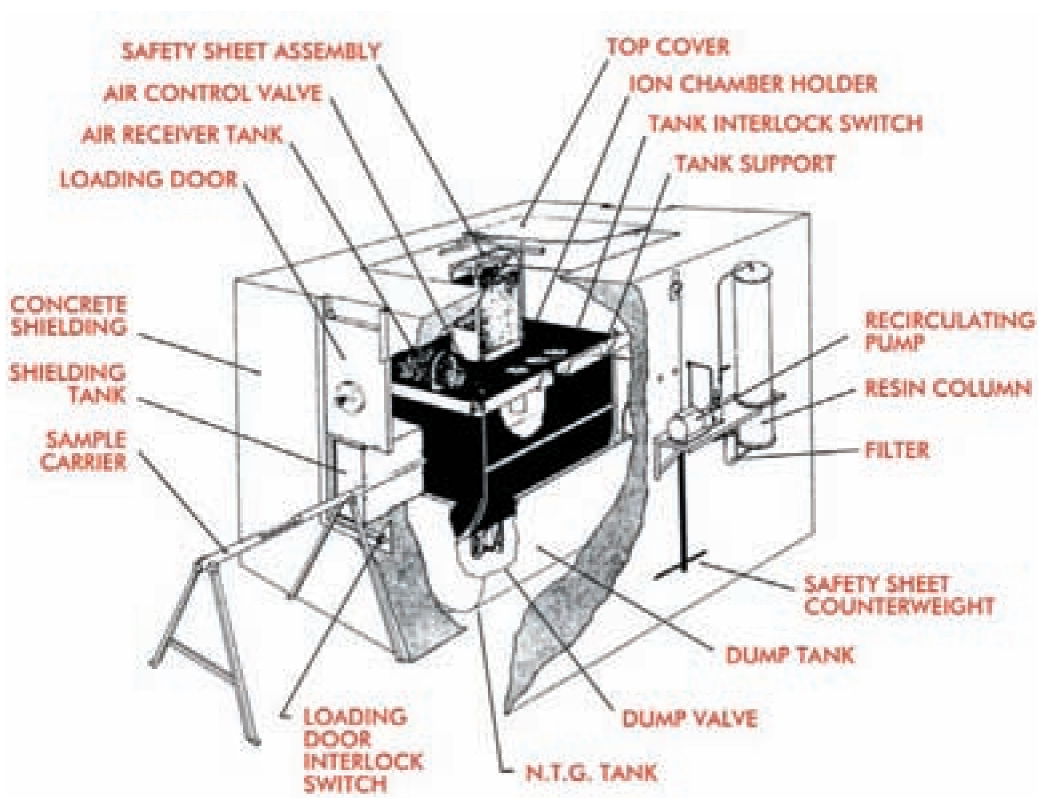
At Savannah River itself, perhaps the best indicator of the success of the new assemblies and lattices was the retirement of the Process Development Pile (PDP) in 777-10M in 1979. Having outlived its usefulness, the PDP saw its last experiments in March, and was shut down in September of that same year.

300/M AREA MANUFACTURING INNOVATIONS

There were numerous improvements to equipment and techniques throughout the 1970s. Perhaps the greatest of these was the replacement of the first NTG with the second set of smaller NTGs in the late 1970s. Unlike the original NTG, which operated close to criticality, the new NTGs, or "Mini-NTGs," had better instrumentation and were safer, since they operated well below criticality. Unlike the old NTG, which used radium-beryllium as source material, the new NTGs used californium-252, which meant a reduction in hazardous gamma rays.[46] The new NTGs also had the advantage of being much smaller than the original. About four-feet square, they had a test port allowing access to the active area, which was about 16 inches long. Rods, targets, and fuels were passed through to test their reaction to neutron flux.

305-A Test Pile and Early Nuclear Test Gauge (NTG) Compared. The 305-A Test Pile contained 47 rows of graphite blocks (each 4" by 16") for an approximate height of 17'6" (barrier not included). The early NTG shown below had a compact design, and was only 9' feet in height. This was a strong advantage and later NTG's would be even smaller, allowing them to be stationed in process buildings such as 320-M and 321-M.





Example of 1980s era Nuclear Test Gauge that was located in 321-M. The Nuclear Test Gauge (NTG) tested materials with enriched uranium. Smaller than the test pile and operated by a small crew, it could check nuclear materials ten times faster than the 305-M test pile.

Other improvements included the installation of the first computers in the tube manufacturing building. The integration of computer technology into the workplace was daunting at first:

> Well it certainly was for us that struggled with it. I don't know how in 321 we ever kept track of accountability. It was all done on a piece of paper and people, I mean there was little cards filled out, numbers entered and all kinds of errors made. I don't know how we ever kept track of that stuff. And it was really a nightmare. I mean, like I said, half of what we cast ended up as scrap, and its composition got changed because some of it had cladding on it, some of it was bare. There were different enrichments. Some scrap from early campaigns would have a different enrichment than other campaigns ... I don't know how those folks ever kept that straight. And I guess about 1980 or so they put, we put our process monitor in the building that really started out ... to collect process data, temperatures, times and all that stuff. But it turned out that it was really a blessing from the accountability perspective, and that's probably where most of the effort went to develop it. So it kept track of the composition of each little piece of material, and also collections and process data. - Fred Rhode[44]

In 1977, the MODCOMP II/26 replaced the first computer process monitor, the MODCOMP III/15, installed in the early 1970s.[45]

In the late 1970s, almost all production fuel assemblies consisted of fuel tubes, no matter what the production techniques. Fuel assemblies had a 12.5-foot-long core that usually consisted of three concentric tubes, with interior and exterior diameters that ranged from 1.75 to 3.75 inches. The fuel was mixed with aluminum to facilitate the separations process, and it was also clad in aluminum to prevent contamination of the heavy-water moderator. The manufacturing of tubes was improved by the introduction of the die-and-mandrel process for extruding aluminum tubes from cylindrical billets. Also, titanium molds and cores replaced the graphite molds first used in making lithium-aluminum alloy tube, eliminating graphite inclusions in the metal.[46]

Powder metallurgy, a much more radical technology, was thoroughly tested during this period and a four-story, one-room building (324-M) that housed a press was constructed in M area behind 321-M.[50] As uranium was reused, Uranium-236 and Uranium-238 built up. Powder metallurgy would have enabled continued use of recycled uranium and indeed production of Plutonium-238.

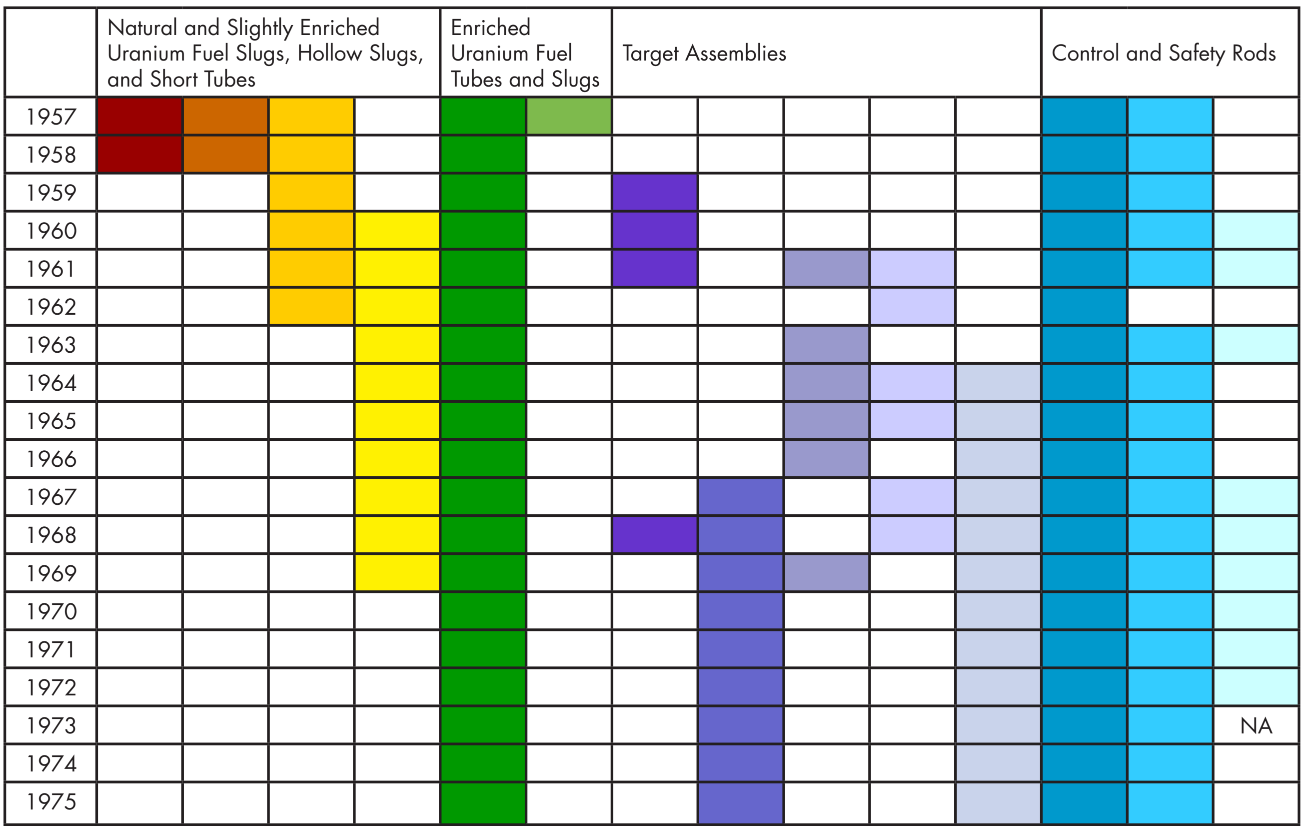
> There was another building [324-M) that's probably gone from your map. As you recycle uranium the 235 gets burned out in it so that the concentration of the 236 and 238 and 234 increases. So to keep the same amount of 235 in the fuel tube as you make use of this recycled inventory, you have to put more and more total uranium in the fuel. Well the co-extrusion process doesn't work, even the casting process [is affected]. That requires higher casting temperatures because you put more uranium in and the melting temperature goes up. So you're challenging your materials and the process, the casting process. And then the ductility of the UAL alloy goes down because you're putting so much uranium in it. All the uranium bonds, when you melt uranium and it solidifies it, uranium forms compounds with aluminum UAL3 and UAL4 particles. And they are not very ductile. So the more uranium you put in there the more aluminum it eats up, and the material just doesn't want to extrude like metal. It will break and crack and everything. I guess the lab for many years promoted the use of powder metallurgy. And probably if you're going to build a plant that made aluminum-based fuel these days you would do it with powder metallurgy. I think one of the reasons we didn't do it was it's expensive to make that change. But the benefit is that the outside is very stable and you can put more uranium oxide in the aluminum than you can just as pure metal. So when you make the compact and extrude it, it's more ductal and you can actually put more total uranium in the fuel and make use of the recycle.
> – Fred Rhode [47]

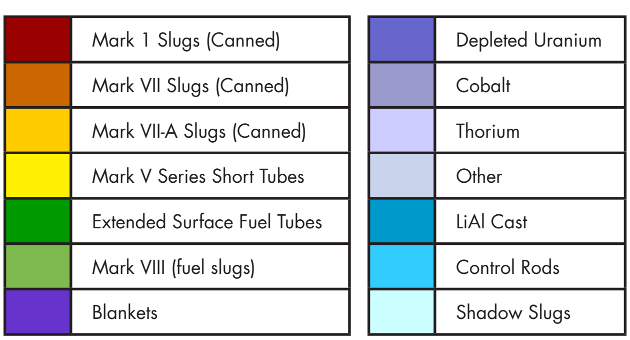
This technology would have created fuel tubes with a higher weight–percentage of uranium through the use of uranium oxide–aluminum tube cores, rather than the usual uranium–aluminum alloy. The powder metallurgy tubes would have been made by isostatic compaction, and would have been assembled in billets and extruded using conventional co-extrusion techniques. This technology was tested and tinkered with throughout the 1970s, but it was never implemented.[48] Even though it could have been an improvement over the older method of tube manufacture, with the declining demand for nuclear materials, it was simply not worth changing over the whole system to accommodate the new technique.

The inclusion of a quality assurance program in 1978 should also be considered a manufacturing improvement. From 1978 onward, each annual Raw Material Area History provides a summary of Quality Assurance actions instituted that year. In the first year, a process monitor computer was in use in 321-M that allowed the NTG to collect data remotely from the production associated computer, an instrument was evaluated for its ability to assay uranium scrap, and analyses were underway to evaluate diversion path s for the enriched uranium fuel tube fabrication process. Through the 1980s, discussed in the following chapter, the Quality Assurance program would grow in scope and importance.

PRODUCTION STATISTICS, 1957-1975

The annual histories include production statistics that show 300/M Area's versatile product base during this era. While the writers of the annual reports sometimes differed in their organization of production statistics, a general sense of what was made and the volume of production are evident. The graph below presents the products of the area divided into four general categories to show the progression of product types, their abandonment and vigor, and simply the range of products over time.





Source: E. I. Du Pont de Nemours and Company, Savannah River Plant History Raw Materials Areas, July 1954 through December 1972, DPSP-55-454-3.

In addition, four tables, each showing one of the four product categories, are presented. Table 9 shows the production of natural and slightly enriched uranium fuel slugs, hollow slugs and short tubes between 1957 and 1969. Individual production rates are given for SRP's 300/M Area and Sylcor. The data also shows the changes in technology as Al-Si triple dip yielded to hot press bonding which, in turn, yielded to hot die size bonding. The latter would be used until production ceased in the late 1980s.

Table 9. Natural and Slightly Enriched Uranium Fuel Slugs, Hollow Slugs, and Short Tubes

Year	Mark I Slugs Canned	• Mark VII Slugs Canned	Mark VII-A Slugs Canned	Mark V Series Short Tubes
1957	• SRP-AlSi • 0.4 million canned 84% yield	• SRP-AlSi 162,500 (canned app.) • SCNC-HPB • 181,000 canned • 82% yield	• 8000 total • SRP-AlSi yield 52.3% • SCNC-HPB yield 78.7%	
1958	• Discontinued • Surplus canned • SRP-AlSi 12,000 canned	• Discontinued • Surplus canned • SRP-AlSi 40,000	• 788,000 total • 0.6 million SRP-AlSi • 68.8 % yield • 188,000 SCNC HPB • Finished at SRP 85% yield	
1959			• 1.6 million total • 1,140,000 SRP-AlSi • 390,000 SCNC HPB • 59,000 Lead dipped • 36,000 SCNC SRP finished	
1960			• 1,106,500 total • 412,000 SRP-AlSi • 600,000 SCNC-HPB • 46,000 SRP HPB • 48,000 lead dipped	
1961			• 712,500 total • 925,000 SRP • ALSI • 375,000 SRP HPB • 245,000 SRP HPB • 26,296 FOR CIVILIAN APPLICATION PROGRAM (CAP)	• 11,000 slugs 90 w/ integral ribbed cans
1962			• 887,000 total • All HPB • 414,000 SRP • 474,000 SCNC • 12 shipments to CAP	• 38,000 Mark V-B-outer fuel tubes-SRP • 30,000 Mark V-B-inner fuel tubes-Sylcor ribbed and ribless • Mark V-E program development
1963			• Discontinued	• 203,933 Mark V-B Outer fuel slug, HPB • 26,000 Mark V-E outer fuel slug-SRP • 160,738 Mark V-B canned at Sylcor HPB SRP finished (ribbed examples ribless discontinued) • 14, 154 Mark V-E Inner Fuel slug Sylcor canned SRP finished

Year	Mark I Slugs Canned	• Mark VII Slugs Canned	Mark VII-A Slugs Canned	Mark V Series Short Tubes
1964				Hot Press Bonded: • 78,400 Mark V-B Outer Fuel Slug • 5,350 average rate per mo • 84,000 Mark V-B Inner Fuel Slug Sylcor pressed SRP finished • 60,300 Mark V-E Inner Fuel Slug Sylcor pressed SRP finished
				Hot Die Sized Bonded: • Mark V-B- number not given • 2,418 Mark V-B • Inner Fuel Slug • 3,492 Mark V-E Outer fuel slug • 4,766 Mark V-E Inner fuel slug
1965				Hot Press Bonded: • 7,600 Mark V Outer Fuel • 24,500 Mark V-B Inner Fuel Sylcor bonded SRP finished • 9,630 Mark V-E Outer fuel slug (SRP) • 38,600 Mark V-E inner Fuel (Sylcor) and finished at SRP
				Hot Die Size Bonded: • 26,693 Mark V-B Outer fuel 3 month campaign (averaged 310 per shift) • 24,500 Mark V-B Inner Fuel Sylcor finished by SRP • 34,570 Mark V-E Outer Fuel Elements in 4 campaigns 360 averaged per shift • 2,996 Mark V-E Inner Fuel, (averaged 157 per shift) • 15,916 Mark V-R Outer fuel (averaged 328 per shift) • 7,674 Mark V-R Inner (averaged 345 per shift)
1966				• 44,880 Mark V B Outer Fuel • 2,0733 Mark V-B Inner Fuel • 11,111 Mark V-E Outer Fuel • 18,678 Inner fuel • 76,614 Mark V-R Outer • 80,072 Inner
1967				• 139,667 Mark V-R Outer • 136,706 Inner • 2,538 Mark V-F Outer
1968				• 26,026 V-R Outer • 37,552 V-R Inner
1969				• 16,951 V-R Outer Fuel and Inner Fuel

Key: SCNC, SEP,and Sylcor refer to one firm -Sylvania Corning
SRP Savannah River Plant 300/M Area
HPB refers to Hot Press Bond
(a) For Mark 15 in 1972 see Table 11

Source: E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Areas, July 1954 through December 1972*, DPSP-55-454-3.

Table 10 shows enriched uranium fuel tube and slug fabrication figures from 1957 to 1975. The data includes actual production figures as well as monthly averages and production costs albeit intermittently.

Table 10. Enriched Uranium Fuel Tubes(a) and Slugs

Year	Extended Surface Fuel Tubes	Mark VIII Program (fuel Slugs)
1957	• Mark VI fuel tubes 390 per month prior to 321-M • 808 per month in 321-M • 70,000 target slugs	• Sylcor Hot Press Bond- 14,575 yield 93.5%
1958	• Averaged 600 tubes per month Mark VI-J 700 tubes 140,000 target slugs 9,000 Mark VI-J target slugs	• Not produced
1959	• Averaged 246 per month • 23,000 Mark VI-J target slugs • 8,000 Mark VI spike slugs	• Not produced
1960	• Average 377 per month Mark VI-J Tubes • 42,000 Mark VI-J hollow target slugs • 7,000 Mark VII-J spike slugs	• Not produced
1961	• 1,900 Mark VI-J fuel tubes • 51,700 hollow target slugs • 5,340 Mark VI spike slugs • Development work on Mark VI-B	• Not produced
1962	• 236 fuel tubes Mark VI-B • 315 target tubes Mark VI-B	
1963	• Average 356 tubes per month • 85% production for Mark VI-B both fuel and target • 42,000 lbs enriched alloy for Mark VI-B target tubes	
1964	• 11,244 tubes (average of 937 per month at a cost of $250 per tube) • 15% Mark VI-B targets = 1686.6 • 21% Mark VI-B fuel = 2361.24 • 48% fuel for thorium and curium charges, also high flux fuel, plutonium-aluminum alloy and Mark VI spikes = 5397.12 • 1300 cores for Mark VI-B targets	
1965	• 14,864 tubes total • 16% Mark VI-B targets = 2378.24 • 9.5% Mark VI-B fuel = 1412.08 • 44% high flux fuel =2080.96 • 9% curium spikes, and remainder pu-al spikes, 3-tube driver = 1337.76 • 2600 target extrusion cores	
1966	• 18,300 Production • 750 Experimental (Mark VI-E, Mark XII, Mark XII-A, Np-Al, Mark 14 and drivers for Cm II and high flux	
1967	• 13,464 fuel and targets extruded inc. Mark XII, Mark XII-A, Mark 14, Mark I-E, Np-Al, Blanket	
1968	• 6201 enriched U-Al fuel and targets • 1214 Mark XII-A • 4529 Mark 14	

Year	Extended Surface Fuel Tubes	Mark VIII Program (fuel Slugs)
1969	• 12,538 total • Mark 14 2620 • Mark 16 851 • Mark 18 9067 • 534 Mark 16 inner target tubes	
1970	• 17,735 total • 430 Mark 16 inner target tubes	
1971	• 6,264 total Mark 14, 16, 16A • 1054 enriched lithium target tubes	
1972	• 5,433 total Mark 14, 16, 22	
1973	data not available	
1974	• 3,422 total Mark 16, 22	
1975	• 3457 total Mark 16	
Note:(a) Includes target tubes integrated into assemblies		

Source: E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Areas, July 1954 through December 1972*, DPSP-55-454-3.

Table 11 shows production statistics for target assemblies from 1959 through 1975 including blanket rods, depleted uranium, cobalt, thorium and others created for special charges during the 1960s Transplutonium Programs.

Table 11. Target Assemblies (a)

Year	Blankets	Depleted Uranium	Cobalt	Thorium	Other
1959	• 11,000 blanket rods				
1960	• 28,000 blanket rods • 664 plutonium/ aluminum alloy rods assembled				
1961	• 11,000 Mark VIII enriched blanket rods		• Die sizing of special slugs for use in Food Process Development Irradiation Program for US Army	• 417 target slugs	

Year	Blankets	Depleted Uranium	Cobalt	Thorium	Other
1962				• 14,000 Mark VIII-T slugs	
1963			• Inspection of canned cobalt strips slugs for Brookhaven National lab		
1964			• 217 slugs containing pellets wafers and slabs	• 13,600 thorium slugs • 9,600 solid metal Thorium Mark VII TS slugs (Sylcar)	• 17 slugs containing rare earth were canned • 3,247 curium irradiation target rods • 46 bismuth slugs cast into aluminum cans
1965			• 950 slugs	• 28,160 thorium oxide slugs	• 21 bismuth slugs • 25 ORNL slugs canned • 5 U-Al flat plates
1966			• 73 control rods from cobalt slugs		• 12 Thulium slugs converted to control rods •10 bismuth slugs canned • Tube cladding • Housing tubes • Alloy cast and extruded for Douglas Nuclear Inc.
1967		• 8,841 Mark 30A • 8,918 Mark 30B • 341 Mark 30C • 457 Mark 30D		• Thorium slugs	• 27 Thulium slugs • 48 bismuth • 63 ORNL europium cores canned
1968	• 109 blanket tubes	• 30 now standard • 19,097 30A • 15,886 30B • 15,058 30C • 17,668 30D		• 376 thorium slugs	• 488 bismuth slugs • 28 Np-Al • 60 Pu-Al
1969		• 67,951 Mark 30 A,B,C,D	• 250 cobalt rods		• 2,332 Mark 40 239 Pu-Al target tubes • 86 242 Pu target housing tubes • 300 Mark NpO2Al
1970		• 144,631 total Mark 30 A,B,C,D			• 110 assemblies of Pu-Al fuel targets • 3000 Mark 1B aluminum inner housing
1971		• 66,483 Mark 30 A,B,C,D			• 246 MARK 40A PU-AL (californium) • 78 Mark 53 NpO2-Al tubes (military and heat source application) • Aluminum housings for Mark 14, 30, 53

Year	Blankets	Depleted Uranium	Cobalt	Thorium	Other
1972		• 119,159 total Marks 30, 31 • 11-inch long Mark 15 (b)			• 87 Mark 53 A • NpO2-Al target tubes • 3500 aluminum housing (five designs) and for Mark 15 cores fabricated
1973		• 177,468 total Marks 31A, B			
1974		• 96,344 Mark 31 A, B			• 66 NpO2-Al target tubes • Billet design for PuO2-Al target tubes • Assembly of 4170 Mark 16, 31, 53 tube and end fittings
1975		• 83,202 Mark 31 A, B			• 103-Mark 53A Target NpO2-Al tubes • 30 Mark 41 PuO2-Al Target
Notes: (a) Including blankets b) See Table 9					

Source: E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Areas, July 1954 through December 1972*, DPSP-55-454-3.

Table 12 shows the production statistics for control and safety rods. It also shows the quantity of lithium alloy casted annually. The amount casted was prodigious in the late 1950s with 1957 as a peak year. The casting operation diminished in the early 1960s in sync with the ebb and flow of reactor operations and shutdowns.

Table 12. Control and Safety Rods

Year	Control and Safety Rods
1957	• 245,000 lbs LiAl • 3,000 control rods
1958	• 240,000 lbs LiAl cast • 5,000 control rods
1959	• 147,000 lbs LiAl cast • 4,300 control rods
1960	• 182,000 lbs LiAl cast • 3,200 control rods • 500 double can shadow slugs
1961	• 174,000 lbs LiAl cast • 2,981 control rods • 800 double can shadow slugs
1962	• 211,000 lbs LiAl alloy cast • 15,000 enriched LiAl alloy for Hanford

Year	Control and Safety Rods
1963	• 116,000 lbs LiAl alloy cast • 34,000 lbs enriched LiAl alloy for Hanford • 32,000 slugs (control rods, shadow rods, target slugs) • 2,480 control rods
1964	• 176,000 lbs LiAl alloy cast • 4,046 regular control rods • 52,700 slugs (unknown whether fuels or targets) • 496 cadmium core control and safety rods for High Flux irradiation program
1965	• 104,500 pounds LiAl cast • 2,650 control rods • 360 curium irradiation control rods • 430 cadmium control rods • 35,000 control rod slugs
1966	• 122,500 lbs LiAl cast • 1,685 double sheath control rods • 628 single sheath control rods • 2000 cadmium control rods
1967	• 77,247 lbs LiAl cast • 4,070 control rods • 1,455 shadow slugs
1968	• 50,585 lbs LiAl cast • 3355 control rods • 879 regular shadow slugs • 273 large diameter shadow slugs
1969	• 39,000 lbs LiAl cast • 975 natural lithium control rods • 350 enriched lithium control rods • 350 cadmium control rods • 789 shadow slugs • 524 large diameter shadow slugs
1970	• 55,200 lbs LiAl cast • 1980 natural lithium control rods • 500 enriched lithium control rods • 566 lithium-aluminum shadow slugs
1971	• 75,000 lbs LiAl cast • 3,282 natural lithium control rods • 902 enriched lithium control rods • 1,424 enriched lithium shadow slugs
1972	• 105,000 lbs LiAl cast • 2,268 control rods • 775 shadow slugs • 2,626 enriched lithium target tubes (five designs)
1974	• 114,500 lbs LiAl cast • 2,905 control rods • 2,304 target tubes: Marks 16, 18A (enriched), 220, 221, 60A, B

Year	Control and Safety Rods
1975	• 62,225 lbs LiAl cast • 1,728 control rods • 1,756 target tubes

Source: E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Areas, July 1954 through December 1972*, DPSP-55-454-3.

A summary table showing annual production statistics by year rather than by type is included in Appendix D.

SUMMARY

The 1970s is considered to be a period of stabilization for fuel and target fabrication at SRP. The rush of startup and the incredibly productive era that followed in the 1960s led from solid slugs to high performance elements for irradiation in the Site's reactors. The major process buildings were retooled and new equipment installed early on when needed and the early expansion of the area in the late 1950s would be unmatched over the next two decades. Essentially only 315-M, a prefabricated warehouse, and the vertical press were added to the area's building stock. By the 1970s and the end of the Transplutonium Programs, SRP had come far closer to its goal for designing and producing high performance fuels and targets. However, a combination of factors, such as the Three Mile Island incident in March 1979 and the resultant expansion of the Nuclear Regulatory Commission and nuclear regulations, the age of the plant and its facilities, and a changing workforce, would all have ramifications on the next and last decade of operations, the 1980s.

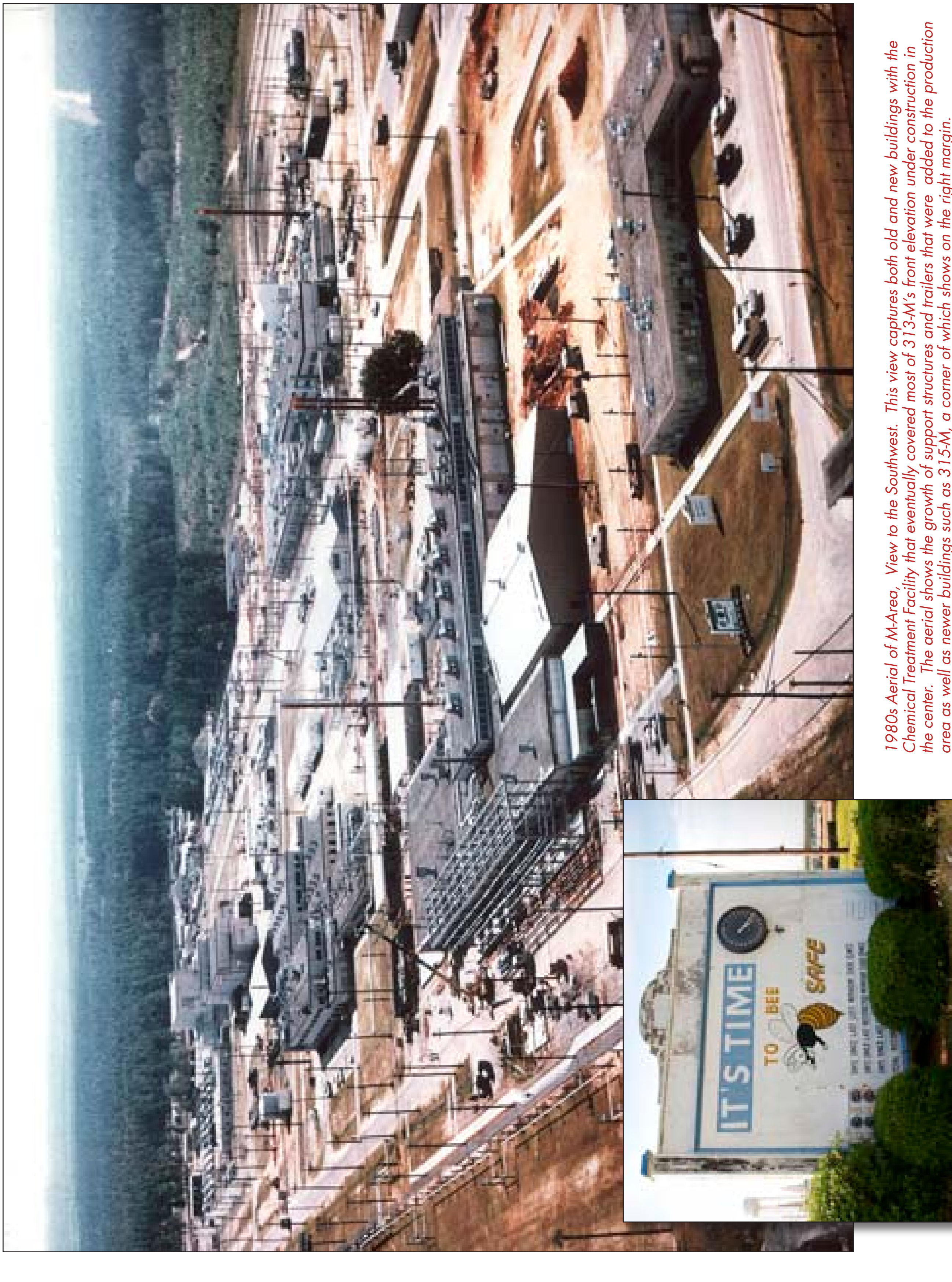
VII. MISSION ACCOMPLISHED

The 1980s began with a renewed vigor in production and in environmental remediation. Compliance with new environmental laws and regulations was a focus in 300/M Area where environmental monitoring by SRP personnel identified non-radioactive industrial chemicals in shallow groundwater under the 300/M-Area seepage basin. The nine-year clean up effort would require new facilities and environment. The 1980s were a decade of high action at SRP. In the early part of the decade, Savannah River had to accommodate renewed demands for more weapons-grade plutonium and tritium which led to the program to restart L-Reactor, that had been on standby since 1968, as well as other initiatives. As Historian W.P. Bebbington stated, "Early in the deacde new production records were set. At the end all reactors were shut down."[1] The 1980s history of the 300/M Area echoes the reactor storyline. Early in the 1980s the production of fuel and targets swelled to meet demand but by the end of the decade the fuel and target facilities were shut down along with the SRP reactors.

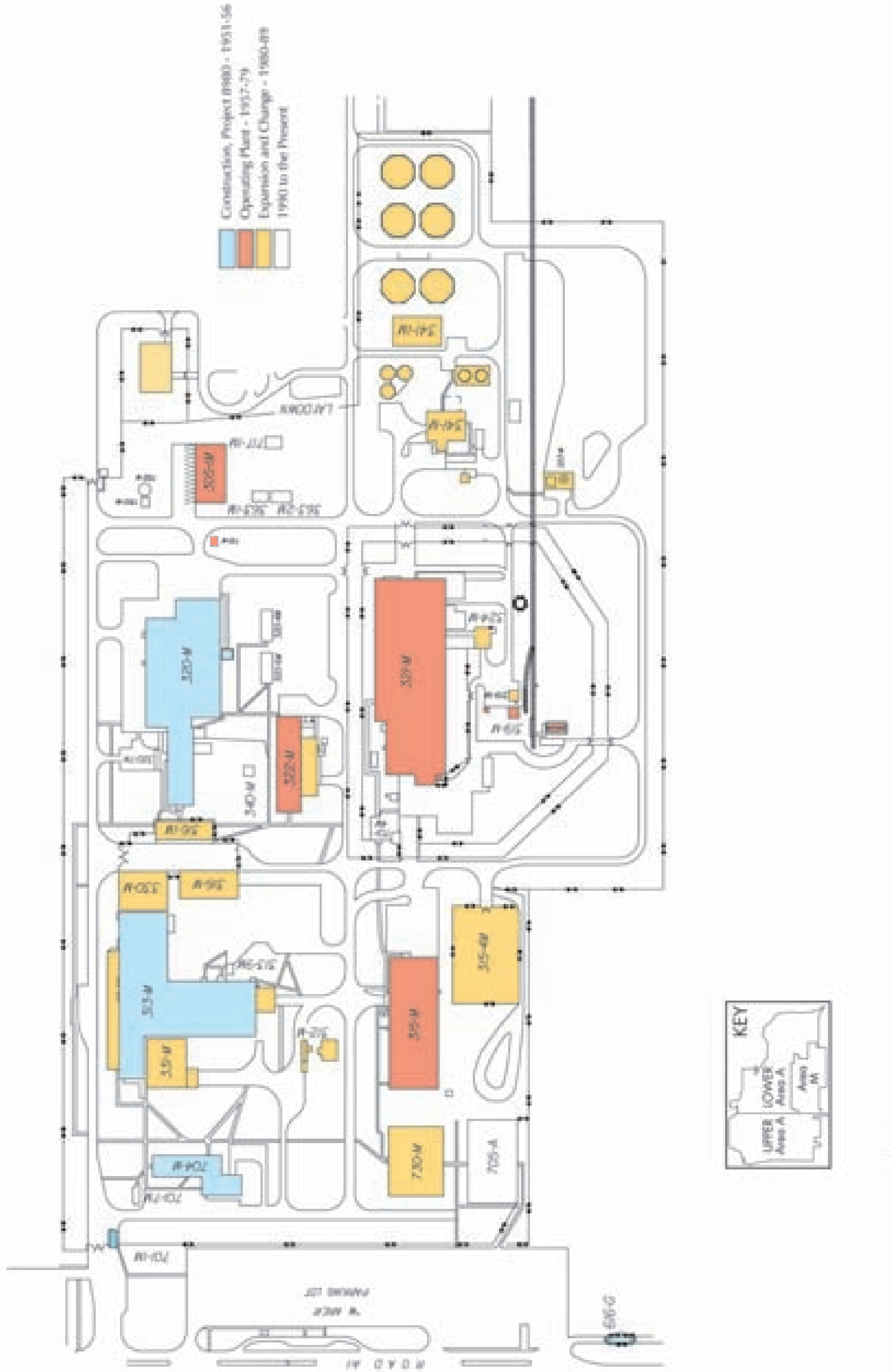
ENVIRONMENTAL REMEDIATION AND NEW CONSTRUCTION

Environmental studies and efforts to decrease the impacts of production on the environment and to monitor its effects had been ongoing from startup. In 1981, SRP personnel identified two non-radioactive industrial chemicals in shallow groundwater under the M Area seepage basin. South Carolina Department of Health and Environmental Control (SCDHEC) was notified and a plan for groundwater cleanup was created. The seepage basin, constructed using industry standards, was used from 1958 through 1979 received wastewater from degreasing operations in the fuel fabrication facilities. About two million pounds of trichloroethylene and tetrachloroethylene, both chlorinated degreasing solvents similar to those used in the dry cleaning industry, was released to the basin. The basin overflowed at times spreading the contamination into an adjacent natural seepage area and Lost Lake, a Carolina bay. The groundwater cleanup operation began in 1981 and a prototype facility began in 1982 to remove these organics by a process known as air stripping in which air was used to strip the chemicals from the groundwater. The settling basin was certified closed in 1991 under the Resource Conservation and Recovery Act.

A small group of other facilities associated with environmental actions were constructed in 300/M Area in the early 1980s. 341-M, a pre-engineered wastewater treatment facility, was built to handle wastewater from the major M Area production facilities. The facility consisted of a two story steel frame metal panel building with an open bay on its lower level and a small wing on its north side. 341-1M was an associated Tank Farm. It was in operation from 1985 through 1990 when the manufacturing facilities were shut down. Other waste facilities were also introduced to 300/M Area such as 340-M, a Lab Waste Treatment Facility and 323-M, a Stripper Building. Both these facilities would also be operated for a short period of time.



1980s Aerial of M-Area, View to the Southwest. This view captures both old and new buildings with the Chemical Treatment Facility that eventually covered most of 313-M's front elevation under construction in the center. The aerial shows the growth of support structures and trailers that were added to the production area as well as newer buildings such as 315-M, a corner of which shows on the right margin.



300/M Area – 1997 Map Showing all Building Locations Prior to Demolition.

INCREASED REACTOR PRODUCTION

Despite the increased environmental pressure of the early 1980s, Savannah River reactor production began a sustained increase for the first time since the 1960s, reaching a peak in 1984 and 1985, before dropping back in 1986 and 1987. In 1980, SRP's P, K, and C reactors were operated for 13 subcycles, a number comparable to 1970s era production rates. Using subcycles as a measure of productivity, the same reactors had 17 subcycles in 1982, 18 in 1983 and 21 in 1984. Tritium, neptunium and plutonium -238, -239, and –242 were made. The Mark-22, the tritium assembly, was a key producer and Mark 22 charges for C-Reactor in January 1985 would each 2829 MW, a record high power rating.[2]

By the end of 1985, there were four reactors in operation at Savannah River, a first since 1968, when L reactor was placed on standby. After a five-year restart program that began in 1980, L reactor was brought online in October 1985. With L reactor online, 20 reactor subcycles were completed and using Mark 16B-31 and Mark 22 charges, the reactors produced tritium, neptunium-237, and plutonium-239.[3]

This increase in reactor production levels greatly affected 300/M Area production with personnel working two shifts and at some points around the clock. To facilitate the increased production a number of new facilities were constructed such as 316-M, a drum storage facility; additional air compressor houses and storage facilities; 330-M, a slug warehouse; 331-M, Bare Core Storage Warehouse; and 730-M, the Engineering and Training Building. Except for the last, each was a pre-engineered gable roof metal panel building on a concrete slab. Building 730-M is a one-story, rectangular office building with a steel frame, an exterior insulation finish system, and a single-ply membrane flat roof. As noted, a Waste Water Treatment Facility (341-M), a steel frame, metal sided building, was constructed to treat wastewater from Buildings 313-M, 320-M, 322-M, and 321-M. A Stripper Building was also added to the 300/M Area complement for use in groundwater remediation. Another 1980s era change was the addition of the Chemical Treatment facility to the east elevation of 313-M. This addition, which enveloped the separate facility, housed pumps, storage tanks, and equipment used for chemically treating materials and byproducts of the canning process. This large two-story metal panel addition dramatically altered the appearance of the 1950s Transite™ and concrete building.

Other changes include the end of the operational life of the test pile in May 1981 and the placement of low power NTG's in Buildings 321-M and 320-M. Safer and easier to operate, these machines repesented an increase in safeguards by testing fuel tubes in the same building in which they were processed. The NTG in 305-A continued in use but dismantlement of the graphite pile began in 1984. Its north wall was removed and "99 percent of the nuclear material was removed."[4] 305-M is no longer mentioned in Raw Material histories after 1985, suggesting that the NTG in that facility was no longer in use.

The 300 Area work force changed in the 1980s reflecting larger changes in the Plant workforce. Up until this time, a cadre of experienced long time Du Pont employees had operated the plant. The 1980s saw the retirement of this original SRP workforce, causing a shift that occurred just as the production needs for SRP were dramatically increased, facilities were being judged as needing repair and updates, and new design and construction missions were being added to the Du Pont contract. Bebbington noted that as a result of all this, SRP began the hiring and training of new employees with a vigor that matched the original staffing of the plant.[5] And for the first time, Du Pont's operating staff was signficantly augmented with subcontractors.

This shift is evident in the 300/M Area workforce. The 1981 annual summary noted that 15 of the 25 operators in 313-M had less than one year's experience. To offset this, a foreman was added and an additional shift. However, producton yields decreased in 1981 due to inexperienced personnel and also high downtime rates for equipment repair. The labor force in 321-M also experienced problems with operator turnover at 30 percent. In 1984, the production personnel in 313-M were placed on three shifts a day and new hires were brought in to fill positions. Each Wednesday the day shift was used for preventative maintenace and safety, security and training meetings, leaving 14 production shifts and 7 PM shifts.

> Due to the increased production and associated additional staffing, a large training effort continued throughout the year. The third shift contained essentially all new employees and required exttra effort to achieve a safe and successful transition. 53 of the 95 hourly roll people in the building were assigned during 1984, and six of the 11 Foremen were promoted from the local role that year.[6]

Further reading in the year's process changes shows that this new training was occurring simultaneously with major improvements in process equipment including robotics and other equipment that automated processes, upgrades in monitoring and inspection systems, and a host of other changes. Working in 313-M and probably 321-M in 1984 ws a heady experience.

Table 13. Work Force, 1980-1987

Year	313-M	320-M	321-M
1980	• 1-shift • 4 productionsupervisors • 16 production operators • 2 inspection supervisors • 12 inspectors	• 1-shift • 4 production suervisors • 14-17 production operators • 2 inspection supervisors • 5-7 inspectors	• 1-shift • 9 production supervisors • 3 clerks • 36-40 production operators • 2 inspection supervisors • 11-13 inspectors
1981	• 1-shift, 2 shifts • 5 productionsupervisors • 14-17 production operators	• 1-shift • 4 productionsupervisors • 1 typist • 13-16 production operators	• 1-shift • 9 supervisors • 3 clerks • 36-40 production operators
1982	• 1-shift, 2 shifts (April – December) • 4 productionsupervisors • 25-27 production operators	1-shift, 2 shifts (April-December) • 4 productionsupervisors • 1 typist • 16 production operators • 2-shifts –8 operators each, and 2 supervisors	• 1-shift, 2 shifts (April-December) • 1-shift, 2 shifts (April-December) • no supervisory staff given • 39 production operators • 2-shifts – 43 operators
1983	• 2 shifts –five day per week • 8 productionsupervisors • 37 production operators • 6 inspection supervisors • 23 inspection operators	• 2 shifts • 2 productionsupervisors per shift • 1 typist (day shift) • 8 production operators per shift • 2 inspection supervisors • 8 inspection operators	• 2 shifts – 43 operators initially, 14 added and then 11 added for L-Reactor Startup • 17 supervisors • 76 production operators at year end • 3 inspection supervisors • 24 inspection operators

Year	313-M	320-M	321-M
1984	• 2 shifts –five day per week, then 3 shifts • 60 production personnel • 46 inspection personnel • 12 Tool Room personnel	• 2 shifts • 1 production supervisors per shift • 1 typist (day shift) • 8 production operators per shift	• 2 shifts on charge preparation, casting and machining • 4 shifts tbe extrusionand finishing • 17 supervisors • 87 production operators at year end • 3 inspection supervisors • 24 inspection operators
1985	• 3 shifts –five day per week • 72 production personnel • 38 inspection personnel	• 1 shift • 4 production supervisors • 1 typist • 12 production operators	• 2 shifts on charge preparation, casting and machining • 4 shifts tbe extrusionand finishing • 19 supervisors • 104 production operators
1986	• 3 shifts, and 2 shifts • 41 production personnel • 17 supervisors • 3 clerks • 47 inspection personnel	• 1 shift • 4 production supervisors • 1 typist • 12 production operators • 6 inspection personnel	• Day schedule • 16 supervisors • 58 production operators
1987	• 3 shifts initially then 1 shift • 9 production operators • 7 supervisors • 5 inspection personnel	• 1 shift • 5 supervisors • 1 typist • 12 production personnel • 6 inspection personnel	• 1 shift • 17 production supervisors • 74 production operators

Source: E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Area January 1976 through December 1987*. DPSP-77-454-3. Deleted Version (Savannah River Plant: Aiken: South Carolina, 1988).

The ramp up in production needs was short lived as the above Table shows. The early 1980s were fraught with tension on a number of fronts. The restart of L Reactor was complicated by new environmental concerns that warranted the creation of L Lake to mitigate the high-temperature effluent water from L Reactor. And when the restarted reactor went critical in October of 1985, controversy delayed its restart.

As noted in the Cold War context, the nuclear accident at Chernobyl at the Chernobyl Nuclear Power Station would have a large impact on DOE's nuclear reactors. The High Flux Isotope Reactor at Oak Ridge, Hanford's N Reactor, and SRP's C reactor would all be shut down. Media attention on problems within the industry, especially within the aging DOE facilities that served the military needs of the Defense Department, increased. The announcement that Du Pont would not accept another extension of the Savannah River contract when the existing contract expired in 1989 further heightened the tension. And public debate continued over the safety of the SRP reactors.

The fact that the Savannah River reactors had all been shut down in 1988 was almost lost in the public debate. Although this shutdown was initially intended to be temporary, it soon became permanent. In March 1987, administrative limits were placed on power levels at K, L, and P reactors due to remaining uncertainties over the cooling systems. The following year, all three were shut down. The ripple effect of these shutdowns passed through other areas of Savannah River as well. The production of fuel tubes ended in 321-M as did canning in 313-M.

By the time Westinghouse Savannah River Company assumed the facility from Du Pont in April 1989, all of the reactors were shut down, and the U.S. had ceased the production of weapons grade fissionable materials altogether. 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.

FACILITY DECOMMISSIONING

The shutdown of the major production facilities including the 300/M Area production lines engendered a plant-focused as well as national DOE policy of accelerated decontamination and decommissioning of facilities that were no longer in use. The first items to be affected were process equipment. A precedent had already been set with the disassembly of facility/equipment in the heavy water area. Large stainless steel towers, once the hallmark of SRP's heavy water production in D Area, were dismantled and sold. The same process occurred in 300/M

1992 Photograph of M-Area Personnel. Left to right, R. V. Gunn, Eric Plantz, Richard Newman, Mark Decosta, Charlie Varner, Teddy Crafton, Mary Fuller, James Wiederkehr and Nick Floyras.

Area. Prior to 1997, the extrusion presses were sold to private businesses and other equipment was dismantled for use elsewhere on site where needed. The new construction associated with environmental technologies for 300/M Area wastewater was the first to be removed and the historic Transite and concrete block-like buildings were targeted for demolition in 2003.

A sole tree associated with the pre-federal history of the Site remained standing in M Area after construction. Located at the southwest corner of 313-M, it was a reminder of the site's past and a welcome visual anomaly within the stark industrial landscape that became M Area. Carefully stewarded by D&D personnel, it stands today adjacent to 313-M's concrete footprint which is all that remains to indiacte the area's Cold War past.

The material culture - the installed equipment, tools, and dress - that characterized the 300/M Area processes quickly disappeared either to the excess yard, to new users on Site, or to the burial grounds. The railroad bed that connected the area to the reactor areas was eliminated in the late 1980s. Only 313-M, and only a portion of that facility, its autoclave area, inspection station, welding, etch tanks, Pangborn walnut shell slug blaster, were left in 2003 for documentation.

CONCLUSION

300/M Area has a rich history. Referred to as a machine and foundry operation in much of the nuclear literature, it was far more than that. The equipment assembled at SRP that produced the fuels and targets may have been available in commercial industrial settings but what made them so significant at SRP was their union in this unique work context. From 1952 to the late 1980s, men and women worked on the production line in concert with metallurgical experts, physicists, engineers in various departments across the Site to produce nuclear fuels and targets within an evolving technology that strove for better and better ways to make the most of each reactor charge and in turn create the product the nation needed for its Cold War defense. Likened to something out of the Middle Ages in its inception, the 300/M Area's production lines less than four decades later operated with robotics and remote systems, efficiently, precisely, and safely turning out fuels and targets to exacting standards. In the words of Engineer and long term SRS employee Tom Gorrell, "what they did was magic."

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GLOSSARY

A

Alpha Particle
A positively-charged particle from the nucleus of an atom, emitted during radioactive decay.

Atom
A particle of matter which cannot be broken up by chemical means. Atoms have a nucleus consisting of positively-charged protons and uncharged neutrons of the same mass. The positive charges on the protons are balanced by a number of negatively-charged electrons in motion around the nucleus.

Atomic Bomb
An explosive device whose energy comes from the fission of heavy elements such as uranium or plutonium.

B

Becquerel (Bq)
A unit of radiation equal to one disintegration per second.

Beta Particle
A particle emitted from an atom during radioactive decay.

Biological Shield
A mass of absorbing material (e.g., thick concrete walls) placed around a reactor or radioactive material to reduce the radiation (especially neutrons and gamma rays respectively) to a level safe for humans.

Breed
To form fissile nuclei, usually as a result of neutron capture, possibly followed by radioactive decay.

C

Chain Reaction
A reaction that stimulates its own repetition, in particular where the neutrons originating from nuclear fission cause an ongoing series of fission reactions.

Containment Building
A containment building houses the reactor, pressurizer, reactor coolant pumps, steam generator and other equipment or piping containing reactor coolant. The containment building is an airtight structure made of steel-reinforced concrete. The base slab is approximately 9 feet thick; the vertical walls are 3 3/4 feet thick; and the dome is 3 feet thick.

Control Rods
Devices to absorb neutrons so that the chain reaction in a reactor core may be slowed or stopped.

Coolant
This is a fluid, usually water, circulated through the core of a nuclear power reactor to remove and transfer heat energy.

Core
The central part of a nuclear reactor containing the fuel elements and any moderator.

Critical Mass
The smallest mass of fissile material that will support a self-sustaining chain reaction under specified conditions.

Curie (Ci)
A unit of radiation measurement, equal to 3.7x1010 disintegrations per second.

D

Decay
Decrease in activity of a radioactive substance due to the disintegration of an atomic nucleus resulting in the release of alpha or beta particles or gamma radiation.

Decommissioning
Removal of a facility (e.g., reactor) from service, also the subsequent actions of safe storage, dismantling and and making the site available for unrestricted use.

Depleted Uranium
Uranium having less than the natural 0.7% U-235. As a by-product of enrichment in the fuel cycle it generally has 0.25-0.30% U-235, the rest being U-238. Can be blended with highly-enriched uranium (e.g., from weapons) to make reactor fuel.

Deuterium
"Heavy Hydrogen", an isotope having one proton and one neutron in the nucleus. It occurs in nature as 1 atom to 6,500 atoms of normal hydrogen, (Hydrogen atoms contain one proton and no neutrons).

Dose Equivalent
The absolute measurement of exposure to a dose of ionising radiation depends upon the type of particle and the body tissue with which it interacts - hence the conversion to dose equivalent, which has units of rem. Rads are converted to rems by multiplying by a factor that depends upon the type of ionising radiation and it's biological effect. For example, with gamma radiation the factor is 1 and a rad is equal to a rem.

E

Element
A chemical substance that cannot be divided into simple substances by chemical means; atomic species with same number of protons.

Enriched Uranium
Uranium in which the proportion of U-235 (to U-238) has been increased above the natural 0.7%. Reactor-grade uranium is usually enriched to about 3.5% U-235, weapons-grade uranium is more than 90% U-235.

Enrichment
Physical process of increasing the proportion of U-235 to U-238.

F

Fast Breeder Reactor (FBR)
A fast neutron reactor (qv) configured to produce more fissile material than it consumes, using fertile material such as depleted uranium.

Fast Neutron Reactor (FNR)
A reactor with little or no moderator and hence utilising fast neutrons and able to utilise fertile material such as depleted uranium.

Fertile (of an isotope)
Capable of becoming fissile, by capturing one or more neutrons, possibly followed by radioactive decay. U-238 is an example.

Fissile (of an isotope)
Capable of capturing a neutron and undergoing nuclear fission, e.g., U-235, Pu-239.

Fission
The splitting of a heavy nucleus into two, accompanied by the release of a relatively large amount of heat and generally one or more neutrons. It may be spontaneous but usually is due to a nucleus absorbing a neutron.

Fission Products
Daughter nuclei resulting either from the fission of heavy elements such as uranium, or the radioactive decay of those primary daughters. Usually highly radioactive.

Fuel Assemblies
These are a group of fuel rods.

Fuel Fabrication
Making reactor fuel elements.

G

Gamma Rays
High energy electro-magnetic radiation.

Graphite
A form of carbon used in a very pure form as a reactor moderator.

H

Half-Life
The period required for half of the atoms of a particular radioactive isotope to decay and become an isotope of another element.

Heavy Water
Water containing an elevated concentration of molecules with deuterium ("heavy hydrogen") atoms.

Heavy Water Reactor (HWR)
A reactor which uses heavy water as its moderator.

High-Level Wastes
Extremely radioactive fission products and transuranic elements (usually other than plutonium) separated as a result of reprocessing spent nuclear fuel.

Highly (or High)-Enriched Uranium (HEU)
Uranium enriched to at least 20% U-235. Uranium in weapons is about 90% U-235.

I

Isotope
An atomic form of an element having a particular number of neutrons. Different isotopes of an element have the same number of protons but different numbers of neutrons and hence different atomic masses, e.g., U-235, U-238.

J

Joule
A unit of energy.

K

KeV
One thousand electron-volts. An electronvolt (symbol: eV) is the amount of energy gained by a single unbound electron when it falls through an electrostatic potential difference of one volt. This is a very small amount of energy.

Kilowatt
A Kilowatt is a unit of electric energy equal to 1,000 watts.

Kilowatt-Hour
This is a unit of energy consumption that equals 1,000 watts used for one hour. For example, ten 100-watt light bulbs burned for one hour use one kilowatt-hour of electricity.

L

Lattice
Structural configuration in a reactor organizing positioning of fuel rods, control rods, and safety rods.

Light Water
Ordinary water (H20) as distinct from heavy water.

Light Water Reactor (LWR)
A common nuclear reactor cooled and usually moderated by ordinary water.

Low-Enriched Uranium (LEU)
Uranium enriched to less than 20% U-235. Uranium in power reactors is about 3.5% U-235.

M

Megawatt (MW)
A unit of power, = 106 Watts. MWe refers to electric output from a generator, MWt to thermal output from a reactor or heat source (e.g., the gross heat output of a reactor itself, typically three times the MWe figure).

Metal Fuels
Natural uranium metal as used in a gas-cooled reactor.

Micro
One millionth of a unit (e.g., microsievert is one millionth of a Sv).

Millirem
This is a measurement of the biological effects of different types of radiation equaling 1/1000th of a REM.

Mixed Oxide Fuel (MOX)
Reactor fuel which consists of both uranium and plutonium oxides, usually with about 5% Pu.

Moderator
A material such as light or heavy water or graphite used in a reactor to slow down fast neutrons so as to expedite further fission.

N

Natural Uranium
Uranium with an isotopic composition as found in nature, containing 99.3% U-238, 0.7% U-235 and a trace of U-234.

Neutron
An uncharged elementary particle found in the nucleus of every atom except hydrogen. Solitary mobile neutrons travelling at various speeds originate from fission reactions. Slow neutrons can in turn readily cause fission in atoms of some isotopes, e.g., U-235, and fast neutrons can readily cause fission in atoms of others, e.g., Pu-239. Sometimes atomic nuclei simply capture neutrons.

Nuclear Reactor
A device in which a nuclear fission chain reaction occurs under controlled conditions so that the heat yield can be harnessed or the neutron beams utilised. All commercial reactors are thermal reactors, using a moderator to slow down the neutrons.

O

Oxide Fuels
Enriched or natural uranium in the form of the oxide U02, used in many types of reactor.

P

Plutonium
A transuranic element, formed in a nuclear reactor by neutron capture. It has several isotopes, some of which are fissile and some of which undergo spontaneous fission, releasing neutrons. Weapons-grade plutonium is produced with >90% Pu-239, reactor-grade plutonium contains about 30% non-fissile isotopes.

Pressurised Water Reactor (PWR)
The most common type of light water reactor (LWR).

R

Radiation
The emission and propagation of energy by means of electromagnetic waves or sub-atomic particles.

Radioactivity
The spontaneous decay of an unstable atomic nucleus, giving rise to the emission of radiation.

Radionuclide
A radioactive isotope of an element.

Radiotoxicity
The adverse health effect of a radionuclide due to its radioactivity.

Rads
A unit to measure the absorption of radiation by the body. A rad is equivalent to 100 ergs of energy from ionising radiation absorbed per gram of soft tissue.

Reactor Vessel
It is the steel pressure vessel that holds the fuel elements in a reactor.

rem (Roentgen Equivalent Man)
REM is the common unit for measuring human radiation doses, usually in millirems (1,000 millirems = 1 rem).

Reprocessing
Chemical treatment of spent reactor fuel to separate uranium and plutonium from the small quantitiy of fission products (and from each other), leaving a much reduced quantity of high-level waste.

S

Shielding
Material, such as lead or concrete, that is used around a nuclear reactor to prevent the escape of radiation and to protect workers and equipment.

Spent Fuel
This is used nuclear fuel awaiting disposal.

Stable
Incapable of spontaneous radioactive decay.

T

Thermal Reactor
A reactor in which the fission chain reaction is sustained primarily by slow neutrons (as distinct from Fast Neutron Reactor).

Transuranic Element
A very heavy element formed artificially by neutron capture and subsequent beta decay(s). Has a higher atomic number than uranium (92). All are radioactive. Neptunium, plutonium and americium are the best-known.

U

Uranium
A mildly radioactive element with two isotopes which are fissile (U-235 and U-233) and two which are fertile (U-238 and U-234). Uranium is the basic raw material of nuclear energy.

Uranium Oxide Concentrate (U308)
The mixture of uranium oxides produced after milling uranium ore from a mine. Sometimes loosely called yellowcake. It is khaki in colour and is usually represented by the empirical formula U308. Uranium is exported from Australia in this form.

V

Vitrification
The incorporation of high-level wastes into borosilicate glass, to make up about 14% of the product by mass.

W

Waste
High-level waste (HLW) is highly radioactive material arising from nuclear fission. It is recovered from reprocessing spent fuel, though some countries regard spent fuel itself as HLW and plan to dispose of it in that form. It requires very careful handling, storage and disposal.

Waste
Low-level waste is mildly radioactive material usually disposed of by incineration and burial.

Y

Yellowcake
Ammonium diuranate, the penultimate uranium compound in U308 production, but the form in which mine product was sold until about 1970.

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APPENDIX A

SUMMARY OF AMERICAN MACHINE AND FOUNDRY COMPANY PROCESS DEVELOPMENT TASKS FOR 300/M AREA

Summary of American Machine and Foundry Company Process Development Tasks for 300/M Area					
Job No.T	Machinery or Process Name	Quantity Fabricated	Purpose	Facility	Date Completed
3.01-1	"F" Canning Tools for Tinning & Al-SI Furnace – Tinning Furnace tools: tinning basket agitator, tinning baskets, centrifuge basket, single and double centrifuge tongs (3), single and double inserting tongs (12), and tin basket. For Al-Si Furnace: submerged canning lifts, canning basket, single insert tongs (right hand and left hand) (3), cap tongs (6), flaring tools, Al-Si agitator, quench baskets, retrieving tongs, spatula, metal addition tongs, double row can assembly tray.	2 Tinning basket agitators; 3 tinning baskets, 2 centrifuge baskets, 15 single and double inserting tongs, 3 tin baskets, 4 canning lifts, 11 canning baskets, 9 tongs, 4 flaring tools, 1 agitator, 8 quench baskets, 1 retrieving tongs	Handling tools for bathing fuel slugs in tin and aluminum alloy	313-M	11/26/52
3.01-2	"F" Canning Tools for Bronze Furnace – bronze agitator, double row pin tray, wire tray, vertical bronze tongs (3), horizontal bronze tongs (10), bronze tongs cast ends, tray sling.	1 agitator, 2 pin trays, 8 wire trays, 13 tongs,1 cast end	Handling tools for placing fuels in bronze furnace	313-M	11/26/52
3.01-3	Can Welding Machine	7 for production; 2 prototypes for Du Pont's Engineering Research Laboratory	Fused weld a circumferential or fold-over closure on aluminum cans	313-M	10/20/52
3.01-4	"F" Can Assembly Design Can, Pin, and Cap Assembly) and Miscellaneous Drafting	(1) set of drawings	Showed can assembly	313-M	1/15/52
3.01-5	Fuel Can Assembly Identification – Pneumatic Bench Press with Work Locating Fixture and Steel Stamp Type Holder	1	Machinery to permanently mark can assemblies with lot number, canning line number, and canning date encrypted in a code	313-M	
3.01-6	"F" Can and Cap Inspection Methods - Pratt and Whitney Air-O Limit Comparator, I.D. Mandrel, Maximum Ring Gauge, Minimum Ring Gauge and Snap Gauge		Inspection of fuel cans, hollow cap cans, can sleeves, and targets	313-M	6/24/52 shipped to site
3.01-7	"F" Pin Inspection Methods – pin straightness gauge and test bar	1	Inspected for straightness and concentricity of assemblies	313-M	7/21/52
3.01-8	Hollow Cap Assembly Press	1	Corrected problem with can caps by adding weight and an aluminum plug	313-M	12/11/52
3.01-9	"F" Can Samples – 1" flat bottom can. 3/4" flat bottom can	Not given	Used for testing and developing final can design and quatrefoil design	313-M	5/21/52

Summary of American Machine and Foundry Company Process Development Tasks for 300/M Area					
Job No.T	Machinery or Process Name	Quantity Fabricated	Purpose	Facility	Date Completed
3.01-10,12	"F" Can Assembly Lathe Tooling – tooling on a Warner & Swasey #3 Turret Lathe	2 sets	Cutting tools used to remove some of hollow cap section, chamfer, and groove cap	313-M	9/9/52
3.01-11	Hollow Cap Assemblies	Order of 25,000 reduced to 11,000	For assembly at site along with an assembly machine	313-M	Cancelled 11/17/52
3.02	Target Billet Furnace		Follow up and assist experimental work at National Research Corporation on target prototypes	320-M	4/10/53
3.02-2c	Miscellaneous Parts Rack	1	Used to receive billet cans and ceramic launders and acts as container during outgassing	320-M	11/19/52
3.03-1,2,3,4,8,9	T Bar Extrusion and Straightening (Watson Stillman Company Extrusion Press)	1	Extrudes alloy billets into rods, heats billets and extrusion dies for extrusion, cuts rods, and stores for cooling	320-M	8/19/53
3.03-5	Target Alloy Extrusion Press Runout Table		Auxilliary to extrusion press keeps extruded rod straight during process	320-M	6/18/53
3.03-6	Target Alloy Straightening Furnace	1	Auxilliary to straightening process for 10% Li Al target alloy	320-M	4/28/52
3.03-7	Target Alloy Straightening- Torrington No. 7 Rotary Swager, Swager Feed, Swager Runout Table, alloy Rod Feed Hole Drilling Fixture and Drill for Swaging Process and Spindle Guide Tubes	1 set	Sized and straightened 10% target Alloy. Only straightened 3 1/2% target alloy	320-M	12/11/52
3.03-10	Sheathed Target Alloy Production by Billet Swaging		Production of sheathed target alloy directly from billets by hot rotary swaging. Considered too problematic.	320-M	Cancelled 1/18/52

Summary of American Machine and Foundry Company Process Development Tasks for 300/M Area					
Job No.T	Machinery or Process Name	Quantity Fabricated	Purpose	Facility	Date Completed
3.03-11	Unsheathed Target Alloy Rod Heat Treating – oven and tank		The 3 1/2 % LiAl target alloy required heat treatment to "obtain the proper metallurgy for reactor processes." The alloy was heated then cooled to room temperature. Alloy was to be process in 4" lengths, 7/8" in diameter and 2 lbs in weight.	320-M	9/30/52
3.03-12	Bar Cropping Bench and Bar Drilling Fixture	1 bench Assembly and one fixture to 320-M	Machines receive extruded aluminum alloy bars from extrusion press, crops them to predetermined length, deburrs both ends, and drills hole in one end.	320-M	12/12/52
3.03-13	Bar Swaging for SRP	608 ponds of low percent unsheathed alloy bar from Argonne National Laboratory and Hanford	For site use	320-M	5/21/52
3.04	Target Pin Preparation and Canning Process – raw material inspection gauges, cleaning tanks, vapor degreaser, drying oven, welding		Target assembly for a production rate of 600 targets a day	320-M	5/20/53
3.04-1	Pin cut off machine – Pin Turret Lathe (Warner & Swasey #3 Turret Lathe), Pin Turret Lathe Tooling (Sheathed and Unsheathed Alloy)	Specifications only on lathe, 2 sets of tooling	Crop rod length to produce 3 1/2% or 10% alloy targets from 44" lengths of bar stock. 3 1/2 % alloy targets turned from .840"diameter to .808" diameter and cut to 10-7/16" lengths. The 10% alloy targets are cut to 10-7/32" lengths from bars for alloy stock measuring .808" diameter by 44" in length.	320-M	5/20/53
3.04-2`	Raw Material Inspection - Gauges	Specifications only	Preparing specifications for inspection of fuels and targets can, caps, assemblies, sleeves, etc.	313-M and 320-M	1/2/52 – 1/10/52

Summary of American Machine and Foundry Company Process Development Tasks for 300/M Area					
Job No.T	Machinery or Process Name	Quantity Fabricated	Purpose	Facility	Date Completed
3.04-3	Cleaning – Tanks, Degreaser, Drying Oven	Commercially acquired and supplied	Supplied cleaning facilities at XYZ laboratory	New York	
3.04-4	Welding Equipment – Can Assembly Welding Machine, Can Assembly Welding Transformer	1 Welding machine prototype, specifications only on transformer	Welding equipment for use at XYZ Laboratory	New York	6/21/51
3.04-5	Leak Testing prototype	2 prototypes	Prototypes were horizontal bubble test machines in which cans were immersed in kerosene to high vacuum. Leaks were observed visually.	313-M and 320-M	
3.04-6	Process Inspection - Gauges	Specifications only	To test neutron absorption of target materials. Cancelled by Du Pont.	320-M	Cancelled 3/17/52
3.04-7	Dry Box operation prototypes	10		320-M	
3.04-8	Assembly of Pins, Caps & Cans –"Hannifin" – 10 ton Hydraulic Can Sizing Press; Can Sizing Press Tooling; Cap Inserting Fixture prototype; Head Forming Press prototype by Bergen Engineering and Development Co.	1 Press, 2 sets of tooling, 1 Inserting Fixture Prototype, 1 Forming Press prototype		320-M	7/27/51-8/27/51
3.04-9	Final Machine "T" Pins – Monarch 10" Pin Engine Lathe; Pin Engine Lathe Tooling (Sheathed and Unsheathed	Specs only on lathe, 2 sets of tooling		320-M	2/27/52
3.04-10	RS Pins – related process production work in area laboratory as a service to Du Pont	None		320-M	
3.04-11	Outgassing Operations – Pin Rack, Pin Rack Container, Outgassing Rack Grab	1 prototype with 3 racks, 3 containers and 1 grab		320-M	
3.04-12	"T" Can Trimming – Monarch 10" Can Trimming Engine Lathe; T-Can Trimming Sheathed and Unsheathed, T-Can Trimming Arc.Weld (sheathed and unsheathed)	2 sets		320-M	2/27/52

Summary of American Machine and Foundry Company Process Development Tasks for 300/M Area					
Job No.T	Machinery or Process Name	Quantity Fabricated	Purpose	Facility	Date Completed
3.04-13	Helium Filling – Experimental work not chosen for final process		Technique not used after testing	320-M	
3.04-14	Capping Sheathed Pins – Experimental work in 300 area laboratory		Technique not used after testing	320-M	
3.04-15	Can Welding	Experimental work in 300 laboratory	Technique applied to process	320-M	
3.04-16	"T" Can Finishing – Monarch 10" Head Finishing Engine Lathe with hexagonal turret attachment; Head Finishing Lathe Tooling; Can Assembly Coining Press Tooling; Armco Arbor Press Can Assembly Coining Press	Specification only on Head Finishing lathe, 2 sets of tooling, 2 sets of tooling, Can Assembly Press purchased commercially		320-M	6/12/51
3.04-17	"T" Can Identification – Identification Press, Identification Code Mechanism, Identification Work Fixture, Identification Symbol Stamps	Specifications only		320-M	11/23/51-1/10/52
3.04-18	"T" Pin Salvage Fixture – Pins Salvage Slitter	1 prototype		320-M	
3.04-19	Canned Samples – Miscellaneous production welding at 300 Area laboratory as service to Du Pont				

Source: American Machine & Foundry Company. *Savannah River Plant Engineering and Design History* Volume III of IV U.S. Contract No. AT (07-2)-1 Du Pont Project 8980 Subcontract No. AXC-81/2, DPEZ-215, 1954, 771-879.

APPENDIX B

FUEL ASSEMBLY NOMENCLATURE

1953-1973

FUEL ASSEMBLY NOMENCLATURE, 1953-1973			
TYPE	DESCRIPTION	END PRODUCT	DATE OF USE
Bismuth Assembly (Single Column)	Hollow aluminum-clad bismuth slugs in an aluminum housing	210 po	
Bismuth Assembly			
(Double Column)	Two concentric columns of hollow aluminum-clad bismuth slugs, with inner and outer housing tubes of aluminum. Used in mixed lattices	210 po	
Mark I	Quatrefoil loaded with solid natural uranium slugs	239 pu	Obsolete
Mark II	Quatrefoil loaded in a striped pattern with solid enriched U-Al alloy fuel slugs and solid thorium target slugs	233 u	Obsolete
Mark III	Assembly of natural uranium plates	239-pu	Abandoned
Mark III-A	Assembly of natural uranium plates with wider coolant channels than the Mark III assembly	239 pu	Abandoned
Mark IV	Tubular fuel assembly of enriched U-Al alloy with an internal column of solid thorium target slugs	233U	Abandoned
Mark V	Two concentric tubular fuel tubes of natural uranium about 14' long. Series coolant flow.	239 Pu	Abandoned
Mark V-A*	Two concentric columns of short tubular fuel slugs of natural uranium with aluminum outer and inner housing tubes. Parallel coolant flow	239 Pu	Abandoned
Mark V-B*,**	Two concentric columns of short tubular fuel slugs of natural uranium surrounded by an aluminum housing tube.	239 Pu	Obsolete
Mark V-C	Two concentric columns of short tubular fuel slugs of natural uranium with an outer aluminum housing and a central core rod of enriched uranium.	239 Pu	Abandoned
Mark V-D	Two concentric columns of short tubular slugs of natural uranium with an outer housing containing enriched uranium.	239 Pu	Abandoned
Mark V-E*,**	Two concentric columns of short tubular fuel slugs of slightly enriched uranium with aluminum outer and inner housing tubes.	239-Pu/Tritium	Obsolete
Mark V-EL*,**	Similar to Mark V-E except that the outer housing is larger to permit higher outer annulus coolant flow.	239Pu/Tritium	Obsolete
Mark V-ELSD*,**	Two concentric columns of short tubular fuel slugs of slightly enriched uranium with aluminum semi-permanent outer housing and separately dischargeable fuel and inner housing.	239 Pu/Tritium	Obsolete
Mark V-ESD	Similar to Mark V-E except that the outer housing is reusable (experimental assembly for testing the semi-permanent housing)		Obsolete
Mark V-F	Two concentric columns of short tubular target slugs of depleted uranium with aluminum semipermanent outer housing and separately dischargeable targets and inner housing. Blanket for 233U program	239 Pu	
Mark V-R*	Two concentric columns of short tubular fuel slugs of slightly enriched uranium. This assembly is similar to Mark V-ELSD except that the uranium is slightly les enriched and the fuel slugs are 1/2" longer for identification purposes	239 Pu/Tritium	
Mark V-TO	A column of 15.2" long tubular slugs of compacted thoria in Mark V-E housing tubes	233U	Obsolete
Mark VI	Tubular fuel element of enriched U-Al alloy with an interval column of solid Li-Al target slugs	Tritium	Obsolete

TYPE	DESCRIPTION	END PRODUCT	DATE OF USE
Mark VI-A	Two concentric fuel tubes of enriched U-Al alloy that are contained in a Li-Al target tube	Tritium	Abandoned
Mark VI-B	Two concentric fuel tubs of enriched U-Al alloy with two Li-Al tubes, one internal and one external.	Tritium	
Mark VI-C	Two concentric fuel tubes of enriched U-Al alloy with or without an internal Li-Al target rod. Driving Curium I and thoria (Mark V-TO) charges		Obsolete
Mark VI-CS	Two concentric fuel tubes of enriched U-Al alloy with a removeable Li-Al target rod. Driving Curium II charges.		Obsolete
Mark VI-E	Two concentric fuel tubes of enriched U-Al alloy with three Li-Al target tubes, two internal and one external. The innermost target tube is separately dischargeable.	236Pu. 237 Np/ Tritium	
Mark VI-F	Two concentric fuel tubes of enriched U-Al alloy with a 6' active core and no targets Used for high Flux		Obsolete
Mark VI-II	Tubular fuel element of enriched U-Al alloy with an internal column of solid Li-Al target slugs. This assembly is similar to Mark VI except that the fuel alloy has a higher 235 U content and the target alloy contains enriched lithium. Also called Heavy Mark VI.	Tritium	Abandoned
Mark VI-J	Tubular fuel element of enriched U-Al alloy with aluminum housing tubes and an internal column of hollow core Li-Al target slugs.	Tritium	Obsolete
Mark VI-JL	Tubular fuel element of enriched U-Al alloy with aluminum housing tubes and an internal column of hollow-core Li-Al target slugs. This assembly is similar to Mark VI-J except that outer housing tube is larger to permit higher outer annulus coolant flow.	Tritium	Obsolete
Mark VI-JS	Assembly with a Mark VI fuel tube (enriched (U-Al alloy) and low concentration Mark VI_J (Hollow-core Li-Al) target slugs. Its purpose to spike low reactivity fuel charges.		Obsolete
Mark VI-N	Assembly with single column of element consisting of two Np-Al alloy tubes and either two Li-Al targets, or two Al spacers, or one enriched U-Al spike at each end.	238 Pu	
Mark VI-P	Two concentric fuel tubes of Pu-Al alloy with a separately dischargeable internal Li-Al target rod. Purpose: Target for Curium I charges; also used for production of 240 Pu		
Mark VI-PS	Two concentric target tubes of Pu-Al alloy with a separately dschargeable internal Li-Al target rod. Purpose"Target for Curium II charges; used for production of 244 Cu.		
Mark VI-O	Experimental assembly consisting of an enriched U-Al alloy fuel tube between two target tubes. The fuel tube has knurled ID and OD surfaces to improve heat transfer. In 1973, there were no plans to replace Mark VI-B or Mark VI-E with this assembly.	Tritium	
Mark VI-S	Tubular fuel element of enriched U-Al alloy with an internal column of solid Li-Al target slugs. This assembly is the same as Mark VI except that the traegt alloy has a lower lithium content. Purpose: spiking low reactivity fuel charges.		Obsolete
Mark VI-SS	Originally used to designate the short spike in the Mark VI-N assembly, now an obsolete term.		
Mark VI-T	Tubular fuel element of enriched U-Al alloy with aluminum housing tubes and an internal target tube. This assembly is similar to Mrk VI-J except that a coextruded target tube is used instead of hollow target slugs.	Tritium	Abandoned
Mark VII*	Quatrefoil loaded with hollow natural uranium slugs.	239 Pu	Obsolete

TYPE	DESCRIPTION	END PRODUCT	DATE OF USE
Mark VII-A*	Quatrefoil loaded with hollow natural uranium slugs. This assembly is similar to Mark VII except that the slugs and quatrefoil are larger to permit operation at higher coolant flows.	239Pu	Obsolete
Mark VII-AL	Quatrefoil loaded with hollow natural uranium slugs. The assembly is similar to Mark VII-A except that the quatrefoil is larger to permit higher coolant in the annular subchannels.	239 Pu	Obsolete
Mark VII-C	Quatrefoil with hollow natural uranium slugs. The assembly is similar to Mark VII-Al except that elements are larger and heavier.	239 Pu	Abandoned
Mark VII-T	Assembly of hollow thorium slugs in a Mark VI-Al quatrefoil.	233U	Obsolete
Mark VII-TS	Assembly of solid thorium slugs in a Mark VII-Al quatrefoil. The assembly is similar to Mark VII-T except that the thorium slugs are longer and are solid rather than hollow.	233U	Obsolete
Mark VIII	Quatrefoil loaded in a striped pattern with a solid enriched U-Al fuel slugs and solid Li-Al target slugs.	Tritium	Obsolete
Mark VIII-A	Quatrefoil loaded in a striped pattern with solid enriched U-Al fuel slugs and solid Li-Al target slugs. This assembly is similar to Mark VIII except that the quatrefoil contains 3 additional fuel slugs and 2 additional target slugs.	Tritium	Obsolete
Mark VIII-S	Quatrefoil loaded in a striped pattern with solid enriched U-Al fuel slugs and solid Li-Al target slugs. This assembly is similar to Mark VIII-A except that the target alloy has a lower lithium content. Purpose spiking low reactivity fuel charges.		Obsolete
Mark IX	Single column of short tubular ful slugs of natural uranium with inner and outer housing tubes of aluminum.	239Pu	Abandoned
Mark X	An enriched U-Al alloy fuel tube and Li-Al target tube within an outer housing.	Tritium	Abandoned
Mark XI	Two concentric columns of short tubular fuel elements of aluminum canned UO2, dischargeable separately from an outer sleeve-housing.	239Pu	Experimental design
Mark XII	Three concentric fuel tubes (10’core) of enriched U-Al alloy and an aluminum inner housing which are separately dischargeable from an aluminum semipermanent sleeve-housing. Purpose Driver for Curium II charges.		
Mark XII-A	Three concentric fuel tubes (12.5”) of enriched U-Al alloy. This assembly is similar to Mark XII except for its core length and higher enrichment. Purpose Driver for 233U charges (with Mark 50-A and 50-B).		
Mark 14	Three concentric fuel tubes (12.5” core) of enriched U-Al alloy and an inner housing which are dischargeable as a unit from an aluminum universal sleeve-housing. Used as a medium weight driver in 236 u program.		
Mark 15	Two concentric columns of 11.5-inch-long tubular slugs of slightly enriched uranium and an aluminum inner housing which are dischargeable as a unit from an aluminum universal sleeve-housing.	239Pu	
Mark 16	Three concentric fuel tubes (12.5’ core) of enriched U-Al alloy resting on a separately dischargeable bottom fitting in an aluminum universal sleeve housing. A separately dischargeable Li-Al target is contained inside the inner fuel tube. Purpose: heavy driver for enriched-depleted charges in 236U program.		
Mark 16A	Same as Mark 16 except the outer and middle fuel tubes will have thinner claddings and thicker cores. Used as a heavy-weight driver in E-D program.		

TYPE	DESCRIPTION	END PRODUCT	DATE OF USE
Mark 18	Three concentric fuel tubes with 6' long cores of enriched U-Al alloy and an aluminum inner housing which are dischargeable as a unit from an aluminum semipermanent sleeve housing. Used as driver for Californium I program.		
Mark 18A	Three concentric fuel tubes of enriched U-Al alloy and an aluminum inner hosing which are dischargeable as a unit from a semipermanent sleeve housing which contains a 242 Pu target. Used as a driver for Californium I program.	Transplutonium isotopes	
Mark 18B	Three concentric fuel tubes with 6'=long cores of enriched U-Al alloy and a Li-Al absorber tube which are separately dischargeable as a unit from an aluminum universal sleeve-housing. Inside the Li-Al tube there is a separately dischargeable aluminum basket tube which may or may not contain Cm-Am target slugs. Used as driver for Californium II program. Known as Cm-Am slugs.	252 cf	
Mark 18C	Three concentric fuel tubes with 6'-long cores of enriched U-Al alloy and a Li-Al absorber tube which are separately dischargeable as a unit from a semipermanent sleeve-housing which contains a 242 Pu target. The plutonium coextruded with aluminum cladding is an integral part of the housing. Inside the Li-Al tube there is a separately dischargeable aluminum basket which may or may not contain CM-Am target slugs. Used as a driver for Californium II Program. The Cm-Am slugs produce 252Cf and the pu targets produce transplutonium isotopes	252 Cf, transplutonium isotopes	
Mark 22	Two concentric fuel tubes of enriched U-Al alloy and two Li-Al target tubes, one internal and one external. All four tubes are separately dischargeable as a unit from an aluminum universal sleeve-housing. The inner Li target tube is also separately dischargeable from the other three tubes.	tritium	
Mark 22A	Two concentric fuel tubes of enriched U-Al alloy and two Li-Al target tubes, one internal and one external. All four tubes are separately dischargeable as a unit from a semipermanent sleeve-housing which contains a plutonium-242 target. The inner Li target tube is also separately dischargeable from the other three tubes.	Li target tube produces Tritium, plutonium target produces transplutonium isotopes	
Mark 30A	Two concentric columns of 8.72-inch-long tubular target slugs of depleted uranium and used as a stage 1 target and blanket assembly for enriched depleted charges for production of 239 Pu during 236 U program	Plutonium-239	
Mark 30B	Single column of 8.72-inch-long tubular target slugs of depleted uranium and an aluminum inner housing which are dischargeable as a unit from an aluminum universal sleeve housing. Used as a stage 2 target assembly for enriched-depleted charges for production of 239 plutonium during 236 U program.	Plutonium 239	
Mark 30C	Same as Mark B except core 62% as thick. Single column of short tubular target slugs of depleted uranium with aluminum universal sleeve-housing and separately dischargeable targets and inner housing. ,Used as a stage 3 target assembly for enriched-depleted charges for production of 239 plutonium during 236 u program	Plutonium-239	
Mark 30D	Same as Mark B except core is 545as thick. State4 target assembly for enriched-depleted charges during 236 U program	Plutonium-239	
Mark 31A	Two concentric columns of 8.26 in. long tubular target slugs of 0.20 wt % depleted uranium and an aluminum inner housing which are dischargeable as a unit from an aluminum universal sleeve-housing. Used as a stage 1 target and blanket assembly for enriched-depleted charges for production of 239 Pu during 236U program.	Plutonium-239	
Mark 31B	Single column of 8.26 in. long tubular target slugs of 0.20 wt % depleted uranium and an aluminum inner housing which are dischargeable as a unit from an aluminum universal sleeve-housing. Used as stage 2 target assembly for enriched-depleted charges for production of 239Pu during 236U program	Plutonium-239	

TYPE	DESCRIPTION	END PRODUCT	DATE OF USE
Mark 31C	Same as Mark 31B except core is 62% as thick. Used as stage 3 target assembly for enriched-depleted charges for production of 239 Pu during 236U program.	Plutonium-239	
Mark 31D	Same as Mark 31B except core is 54% as thick. Used as stage 4 target assembly for enriched-depleted charges for the production of 239Pu during 239U program	Plutonium-239	
Mark 40	Three concentric fuel tubes with 12.5-foot long cores of Pu-Al alloy in an aluminum universal sleeve-housing with a disposable inner housing. A separately dischargeable target can be used instead of the inner housing. Used to produce 242 Pu feed material for the 252Cf program	242-Pu feed material	
Mark 40A	Same as Mark 40 except thinner cladding and thicker core. Used to produce 242Pu feed material for the 252Cf program.	242Pu feed material	
Mark 50A	A column of`~15.2-inch-long tubular slugs of compacted thoria and an aluminum inner housing which are dischargeable as a unit from an aluminum semipermanent outer housing. Used as stage 1 and stage 2 target assemblies for production of 233U.	233U	
Mark 50B	A column of ~9.5 inch-lon tubular target slugs of compacted thoria and an aluminum inner housing which are dischargeable as a unit from an aluminum semipermanent outer housing. Used as stage 3 target assembly for production of 233U	233U	
Mark 51	Quatrefoil containing up to four columns of 6-inch-long slugs, each of which contains a blend of Cm-Am oxide and aluminum Used in Californium I program	252Cf	
Mark 52	Single column of elements consisting in part of two or three NpO2 and aluminum coextruded tubes. Either li-Al targets or aluminum spacers are used above and below the NpO2 tubes.	238Po	
Mark 53	Single 8-foot-long column consisting of coextruded NpO2-aluminum tbe(s) with aluminum spacers and an aluminum inner housing which are dischargeable as a unit from a universal sleeve-housing.	238Pu	
Mark 53A	Single 10-foot-long column consisting of coextruded NpO2- aluminum tube(s) with aluminum spacers and an aluminum inner housing which are dischargeable as a unit from a iniversal sleeve-housing.	238Pu	
Mark 60A	A convection-cooled Li-Al alloy coextrusion with Al cladding. Used as a blanket assembly to reduce thermal shield heat load.		
Mark 61	A sleeve housing the bottom half of which contains an 8-foot-long aluminum-clad coextrusion of NpO2 and aluminum. The cladding, the coextrusion, and a bottom fitting are welded into the sleeve-housing to form a single unit. Used to produce high purity 238Pu by irradiation in the reflector region of the Californium I charge.	238Pu	
Mark 62	Li-Al target tube which is separately dischargeable from an aluminum universal sleeve-housing.	tritium	
Mark 62A	Li-Al target tube that is separately dischargeable from a Mark 18C sleeve-housing during pre-radiation of the Pu target in enriched-depleted charges prior to Californium II. The Li-Al core will have 2 different concentrations with more Li in the lower section opposite the pu in the sleeve-housing. Used for reactivity control.	tritium	
Source: E. I. Du Pont de Nemours and Company, *Savannah River Plant History Raw Materials Area July 1954 through December 1972,* Deleted version, DPSP-55-454-3.			

APPENDIX C

RAW MATERIALS SUPERVISORY STAFF

1967-1968, 1979-1980

RAW MATERIALS DEPARTMENT

- SUPERINTENDENT — K. W. Millett
  - PRODUCTION ASSISTANT — R. E. Spencer
  - ASSISTANT SUPERINTENDENT — R. H. Dietz
    - AREA SUPERINTENDENT — P. D. Deans
      - SENIOR SUPERVISOR - NEW EQUIPMENT COORDINATOR — J. K. Brown
        - PROCEDURES — D. A. Anderson* — P. B. Huffman*
        - CONSTRUCTION LIAISON — J. J. Walsh
        - CHECK OUT — J. N. Beatty — O. W. Francis
      - ASSISTANT AREA SUPERINTENDENT - QUALITY CONTROL — K. L. Flanders
        - SENIOR SUPERVISOR — S. P. Day
          - SHIFT SUPERVISOR - MATERIAL CONTROL — L. E. Stewart
            - FOREMAN - 300 AREA — A. H. Eleazer
            - FOREMAN - CENTRAL SHOPS — B. D. Vardell*
          - SHIFT SUPERVISOR - 313-M INSPECTION — J. E. Parker
            - FOREMEN — R - J. E. Watson — S - O. R. Williamson
            - FOREMAN - RELIEF — R. J. Norton
          - SHIFT SUPERVISOR - 305-M, 320-M, 321-M INSPECTION — J. R. Culp
            - FOREMAN - 305-M — J. R. Neverla
            - FOREMAN - 320-M, 321-M INSPECTION — J. S. Hungerpiller
      - ASSISTANT AREA SUPERINTENDENT - 313-M — W. L. Worth
        - SENIOR SUPERVISORS — C. K. Brendell — C. W. Mettlen
          - SHIFT SUPERVISOR - R SHIFT — V. L. Smith
            - FOREMAN — T. W. Woodward
          - SHIFT SUPERVISOR - S SHIFT — M. T. Johnson
            - FOREMAN — C. B. Mathis
          - SHIFT SUPERVISOR - TOOL CONTROL, MAINT. COORDINATOR — H. L. Martin
            - FOREMAN - TOOL CONTROL — D. C. Lee
            - FOREMAN - RELIEF — H. B. Blanton

* On loan from Reactor and Separations Departments.

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RAW MATERIALS DEPARTMENT - Continued

ASSISTANT AREA SUPERINTENDENT - 320-M, 321-M	J. M. Thompson
AREA SUPERVISOR	P. T. Ferriter
SHIFT SUPERVISOR - 320-M	T. O. Sanders
FOREMAN	W. E. Northington
SHIFT SUPERVISOR - 321-M	N. A. Brady
FOREMEN	R - B. H. Garner S - K. F. Melton
FOREMAN - RELIEF	J. D. Funderburg
SHIFT SUPERVISOR - PROCEDURES	C. R. Van Neil*

* On loan from Reactor Department.

RAW MATERIALS DEPARTMENT

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    - AREA SUPERVISOR - PRODUCTION SCHEDULING — C. E. Varner
    - AREA SUPERINTENDENT - INSPECTION AND CONTROL — C. W. Mettlen
        - STAFF PRODUCTION ASSISTANT — K. L. Flanders
        - AREA SUPERVISOR — T. O. Sanders
            - SHIFT SUPERVISOR - ESSENTIAL MATERIALS — L. E. Stewart
                - FOREMAN - CENTRAL SHOPS — H. E. Halbrooks
            - SENIOR SUPERVISOR - PRODUCT INSPECTION — C. E. Olsen
                - SHIFT SUPERVISOR - 313-M INSPECTION
                    - FOREMAN — A. Q. Patterson
                - SHIFT SUPERVISOR - 305-M & 320-M — P. F. Pustolski
                    - FOREMAN - 305-M — B. D. Powell
                    - FOREMAN - 320-M — W. Jordan, Jr.
                - SHIFT SUPERVISOR - 321-M — F. M. Harter
                    - FOREMAN — C. B. Pate
                - SHIFT SUPERVISOR - SPECIAL ASSIGNMENTS — J. E. Watson
        - AREA SUPERVISOR - SPECIAL SERVICES — P. T. Ferriter
            - SHIFT SUPERVISOR - ENGINEERING & CONSTR. LIAISON
            - SENIOR SUPERVISOR — N. A. Brady
                - FOREMAN - EQUIPMENT CONTROL COORDINATOR MAINTENANCE COORDINATOR — L. E. Johnson
                - FOREMAN - TOOLING & GAGE CONTROL — T. W. Teague
        - AREA SUPERVISOR - PROCEDURES & TRAINING — P. B. Huffman
            - SENIOR PRODUCTION ASSISTANT - TRAINING — R. E. Spencer
                - SHIFT SUPERVISOR - TRAINING — L. B. Jones
            - FOREMAN — R. J. Norton
            - FOREMAN — J. F. Rodgers
            - FOREMAN — M. W. Shealy
        - SENIOR SUPERVISOR - QUALITY CONTROL & QA COORDINATOR — W. J. Johnson
            - SHIFT SUPERVISOR - QUALITY AUDITS — J. C. Clark
            - FOREMAN - SPECIAL STUDIES — J. R. Neverla
            - FOREMAN - PROCESS MONITOR — J. S. Hungerpiller

RAW MATERIALS DEPARTMENT - Continued

AREA SUPERINTENDENT - PRODUCTION	L. C. Brown
AREA SUPERVISOR - 313-M	J. R. Culp
SHIFT SUPERVISOR - 313-M	B. H. Garner
FOREMAN - HDS COMPLEX	W. H. Larisey
FOREMAN - PLATING & RECOVERY	J. C. Harrison
AREA SUPERVISOR - 320-M	C. K. Brendell
SHIFT SUPERVISOR - 320-M	S. T. Boyd*
ENGINEER	M. F. Dodge
FOREMAN - EXTRUSION, LATHES & ROD FABRICATION	K. F. Melton
FOREMAN - CASTING & FINISHING	W. H. Pennington
AREA SUPERVISOR - 321-M	C. E. Varner
ENGINEER - SCHEDULES, SHIPMENTS, ACCOUNTABILITY	V. L. Smith
SHIFT SUPERVISOR	J. D. Flake
FOREMAN - CASTING	W. E. Northington
FOREMAN - MACHINING & BILLET ASSEMBLY	R. W. Cook
FOREMAN - EXTRUSION & FINISHING	C. M. Rhoten
ENGINEER - RELIEF & SPECIAL ASSIGNMENTS	S. C. Pye
SHIFT SUPERVISOR - RELIEF & MAINT. COORDINATOR	D. C. Lee

* On Loan to Personnel Department

APPENDIX D

300/M AREA PRODUCTION

1957	
Mark I Slugs Canned	
	• SRP-AlSi • 0.4 million canned 84% yield
Mark VII Slugs Canned	
	• SRP-AlSi 162,500 (canned app.) • SCNC-HPB • 181,000 canned • 82% yield
Mark VII-A Slugs Canned	
	• 8000 total • SRP-AlSi yield 52.3% • SCNC-HPB yield 78.7%
Extended Surface Fuel Tubes	
	• Mark VI fuel tubes 390 per month prior to 321-M • 808 per month in 321-M • 70,000 target slugs
Mark VIII Program (fuel slugs)	
	• SCNC HPB 14,575 yield 93.5%
Control and Safety Rods	
	• 245,000 lbs LiAl • 3,000 control rods
1958	
Mark I Slugs Canned	
	• Discontinued • Surplus canned • SRP-AlSi 12,000 canned
Mark VII Slugs Canned	
	• Discontinued • Surplus canned • SRP-AlSi 40,000
Mark VII-A Slugs Canned	
	• 788,000 total • 0.6 million SRP-AlSi • 68.8 % yield • 188,000 SCNC HPB • Finished at SRP 85% yield
Extended Surface Fuel Tubes	

	• Averaged 600 tubes per month • Mark VI-J 700 tubes • 140,000 target slugs • 9,000 Mark VI-J target slugs
Control and Safety Rods	
	• 240,000 lbs LiAl cast • 5,000 control rods
1959	
Mark VII-A Slugs Canned	
	• 1.6 million total • 1,140,000 SRP-AlSi • 390,000 SCNC HPB • 59,000 Lead dipped • 36,000 SCNC SRP finished
Extended Surface Fuel Tubes	
	• Averaged 246 per month • 23,000 Mark VI-J target slugs • 8,000 Mark VI spike slugs
Target Assemblies: Blankets	
	• 11,000 blanket rods
Control and Safety Rods	
	• 147,000 lbs LiAl cast • 4,300 control rods
1960	
Mark VII-A Slugs Canned	
	• 106,500 total • 412,000 SRP-AlSi • 600,000 SCNC-HPB • 46,000 SRP HPB • 48,000 lead dipped
Extended Surface Fuel Tubes	
	• Average 377 per month Mark VI-J Tubes • 42,000 Mark VI-J hollow target slugs • 7,000 Mark VII-J spike slugs
Target Assemblies: Blankets	
	• 28,000 blanket rods • 664 plutonium/ aluminum alloy rods assembled
Control and Safety Rods	

	• 182,000 lbs LiAl cast • 3,200 control rods • 500 double can shadow slugs
1961	
Mark VII-A Slugs Canned	
	• 712,500 total • 925,000 SRP • ALSI • 375,000 SRP HPB • 245,000 SRP HPB • 26,296 FOR CIVILIAN APPLICATION PROGRAM (CAP)
Mark V Series Short Tubes	
	• 11,000 slugs 90 w/ integral ribbed cans
Extended Surface Fuel Tubes	
	• 1,900 Mark VI-J fuel tubes • 51,700 hollow target slugs • 5,340 Mark VI spike slugs • Development work on Mark VI-B
Target Assemblies: Blankets	
	• 11,000 Mark VIII enriched blanket rods
Target Assemblies: Cobalt	
	• Die sizing of special slugs for use in Food Process Development Irradiation Program for US Army
Target Assemblies: Thorium	
	• 417 target slugs
Control and Safety Rods	
	• 174,000 lbs LiAl cast • 2,981 control rods • 800 double can shadow slugs
1962	
Mark VII-A Slugs Canned	
	• 887,000 total • All HPB • 414,000 SRP • 474,000 SCNC • 12 shipments to CAP
Mark V Series Short Tubes	
	• 38,000 Mark V-B-outer fuel tubes-SRP • 30,000 Mark V-B-inner fuel tubes-Sylcor ribbed and ribless • Mark V-E program development

Extended Surface Fuel Tubes	
	• 236 fuel tubes Mark VI-B • 315 target tubes Mark VI-B
Target Assemblies: Thorium	
	• 14,000 Mark VIII-T slugs
Control and Safety Rods	
	• 211,000 lbs LiAl alloy cast • 15,000 enriched LiAl alloy for Hanford
1963	
Mark VII-A Slugs Canned	
	Discontinued
Mark V Series Short Tubes	
	• 203,933 Mark V-B Outer fuel slug, HPB • 26,000 Mark V-E outer fuel slug-SRP • 160,738 Mark V-B canned at Sylcor HPB SRP finished (ribbed examples ribless discontinued) • 14, 154 Mark V-E Inner Fuel slug Sylcor canned SRP finished
Extended Surface Fuel Tubes	
	• Average 356 tubes per month • 85% production for Mark VI-B both fuel and target • 42,000 lbs enriched alloy for Mark VI-B target tubes
Target Assemblies: Cobalt	
	• Inspection of canned cobalt strips slugs for Brookhaven National lab
Control and Safety Rods	
	• 116,000 lbs LiAl alloy cast • 34,000 lbs enriched LiAl alloy for Hanford • 32,000 slugs (control rods, shadow rods, target slugs) • 2,480 control rods
1964	
Mark V Series Short Tubes	

	Hot Pressed Bonded: • 78,400 Mark V-B Outer Fuel Slug • 5,350 average rate per mo • 84,000 Mark V-B Inner Fuel Slug Sylcor pressed SRP finished • 60,300 Mark V-E Inner Fuel Slug Sylcor pressed SRP finished **Hot Die Sized Bonded:** • Mark V-B- number not given • 2,418 Mark V-B • Inner Fuel Slug • 3,492 Mark V-E Outer fuel slug • 4,766 Mark V-E Inner fuel slug
Extended Surface Fuel Tubes	
	• 11,244 tubes (average of 937 per month at a cost of $250 per tube) • 15% Mark VI-B targets = 1686.6 • 21% Mark VI-B fuel = 2361.24 • 48% fuel for thorium and curium charges, also high flux fuel, plutonium-aluminum alloy and Mark VI spikes = 5397.12 • 1300 cores for Mark VI-B targets
Target Assemblies: Cobalt	
	• 217 slugs containing pellets wafers and slabs
Target Assemblies: Thorium	
	• 13,600 thorium slugs • 9,600 solid metal Thorium Mark VII TS slugs (Sylcar)
Target Assemblies: Other	
	• 17 slugs containing rare earth were canned • 3,247 curium irradiation target rods • 46 bismuth slugs cast into aluminum cans
Control and Safety Rods	
	• 176,000 lbs LiAl alloy cast • 4,046 regular control rods • 52,700 slugs (unknown whether fuels or targets) • 496 cadmium core control and safety rods for High Flux irradiation program
1965	
Mark V Series Short Tubes	

	Hot Press Bonded: • 7,600 Mark V Outer Fuel • 24,500 Mark V-B Inner Fuel Sylcor bonded SRP finished • 9,630 Mark V-E Outer fuel slug (SRP) • 38,600 Mark V-E inner Fuel (Sylcor) and finished at SRP **Hot Die Size Bonded:** • 26,693 Mark V-B Outer fuel 3 month campaign (averaged 310 per shift) • 24,500 Mark V-B Inner Fuel Sylcor finished by SRP • 34,570 Mark V-E Outer Fuel Elements in 4 campaigns 360 • averaged per shift • 2,996 Mark V-E Inner Fuel, (averaged 157 per shift) • 15,916 Mark V-R Outer fuel (averaged 328 per shift) • 7,674 Mark V-R Inner (averaged 345 per shift)
Extended Surface Fuel Tubes	
	• 14,864 tubes total • 16% Mark Vi-B targets = 2378.24 • 9.5% Mark VI-B fuel = 1412.08 • 44% high flux fuel =2080.96 • 9% curium spikes, and remainder pu-al spikes, 3-tube driver = 1337.76 • 2600 target extrusion cores
Target Assemblies: Cobalt	
	• 950 slugs
Target Assemblies: Thorium	
	• 28,160 thorium oxide slugs
Target Assemblies: Other	
	• 21 bismuth slugs • 25 ORNL slugs canned • 5 U-Al flat plates
Control and Safety Rods	
	• 104,500 pounds LiAl cast • 2,650 control rods • 360 curium irradiation control rods • 430 cadmium control rods • 35,000 control rod slugs
1966	
Mark V Series Short Tubes	
	• 44,880 Mark V B Outer Fuel • 2,0733 Mark V-B Inner Fuel • 11,111 Mark V-E Outer Fuel • 18,678 Inner fuel • 76,614 Mark V-R Outer • 80,072 Inner
Extended Surface Fuel Tubes	

	• 18,300 Production • 750 Experimental (Mark VI-E, Mark XII, Mark XII-A, Np-Al, Mark 14 and drivers for Cm II and high flux
Target Assemblies: Cobalt	
	• 73 control rods from cobalt slugs
Target Assemblies: Other	
	• 12 Thulium slugs converted to control rods • 10 bismuth slugs canned • tube cladding • Housing tubes • Alloy cast and extruded for Douglas Nuclear Inc.
Control and Safety Rods	
	• 122,500 lbs LiAl cast • 1,685 double sheath control rods • 628 single sheath control rods • 2000 cadmium control rods
1967	
Mark V Series Short Tubes	
	• 139,667 Mark V-R Outer • 136,706 Inner • 2,538 Mark V-F Outer
Extended Surface Fuel Tubes	
	• 13,464 fuel and targets extruded inc. Mark XII, Mark XII-A, Mark 14, Mark I-E, Np-Al, Blanket
Target Assemblies: Depleted Uranium	
	• 8,841 Mark 30A • 8,918 Mark 30B • 341 Mark 30C • 457 Mark 30D
Target Assemblies: Thorium	
	• thorium slugs
Target Assemblies: Other	
	• 27 Thulium slugs • 48 bismuth • 63 ORNL europium cores canned
Control and Safety Rods	
	• 77,247 lbs LiAl cast • 4,070 control rods • 1,455 shadow slugs
1968	
Mark V Series Short Tubes	

	• 26,026 V-R Outer • 37,552 V-R Inner
Extended Surface Fuel Tubes	
	• 6201 enriched U-Al fuel and targets • 1214 Mark XII-A • 4529 Mark 14
Target Assemblies: Blankets	
	• 109 blanket tubes
Target Assemblies: Depleted Uranium	
	• 30 now standard • 19,097 30A • 15,886 30B • 15,058 30C • 17,668 30D
Target Assemblies: Thorium	
	• 376 thorium slugs
Target Assemblies: Other	
	• 488 bismuth slugs • 28 Np-Al • 60 Pu-Al
Control and Safety Rods	
	• 50,585 lbs LiAl cast • 3355 control rods • 879 regular shadow slugs • 273 large diameter shadow slugs
1969	
Mark V Series Short Tubes	
	• 16,951 V-R Outer Fuel and Inner Fuel
Extended Surface Fuel Tubes	
	• 12,538 total • Mark 14 2620 • Mark 16 851 • Mark 18 9067 • 534 Mark 16 inner target tubes
Target Assemblies: Depleted Uranium	
	• 67,951 Mark 30 A,B,C,D
Target Assemblies: Cobalt	
	• 250 cobalt rods

Target Assemblies: Other	
	• 2,332 Mark 40 239 Pu-Al target tubes • 86 242 Pu target housing tubes • 300 Mark NpO2Al
Control and Safety Rods	
	• 39,000 lbs LiAl cast • 975 natural lithium control rods • 350 enriched lithium control rods • 350 cadmium control rods • 789 shadow slugs • 524 large diameter shadow slugs
1970	
Extended Surface Fuel Tubes	
	• 17,735 total • 430 Mark 16 inner target tubes
Target Assemblies: Depleted Uranium	
	• 144,631 total Mark 30 A,B,C,D
Target Assemblies: Other	
	• 110 assemblies of Pu-Al fuel targets • 3000 Mark 1B aluminum inner housing
Control and Safety Rods	
	• 55,200 lbs LiAl cast • 1980 natural lithium control rods • 500 enriched lithium control rods • 566 lithium-aluminum shadow slugs
1971	
Extended Surface Fuel Tubes	
	• 6,264 total Mark 14, 16, 16A • 1054 enriched lithium target tubes
Target Assemblies: Depleted Uranium	
	• 66,483 Mark 30 A,B,C,D
Target Assemblies: Other	
	• 246 MARK 40A PU-AL (californium) • 78 Mark 53 NpO2-Al tubes (military and heat source application) • Aluminum housings for Mark 14, 30, 53
Control and Safety Rods	

	• 75,000 lbs LiAl cast • 3,282 natural lithium control rods • 902 enriched lithium control rods • 1,424 enriched lithium shadow slugs
1972	
Extended Surface Fuel Tubes	
	• 5,433 total Mark 14, 16, 22
Target Assemblies: Depleted Uranium	
	• 119,159 total Marks 30, 31 • 11-inch long Mark 15 (see table 9)
Target Assemblies: Other	
	• 87 Mark 53 A • NpO2-Al target tubes • 3500 aluminum housing (five designs) and for Mark 15 cores fabricated
Control and Safety Rods	
	• 105,000 lbs LiAl cast • 2,268 control rods • 775 shadow slugs • 2,626 enriched lithium target tubes (five designs)
1973	
Extended Surface Fuel Tubes	
	• No data available
Target Assemblies: Depleted Uranium	
	• 177,468 total Marks 31A, B
Control and Safety Rods	
	• No data available
1974	
Extended Surface Fuel Tubes	
	• 3,422 total Mark 16, 22
Target Assemblies: Depleted Uranium	
	• 96,344 Mark 31 A, B
Target Assemblies: Other	
	• 66 NpO2-Al target tubes • Billet design for PuO2-Al target tubes • Assembly of 4170 Mark 16, 31, 53 tube and end fittings
Control and Safety Rods	

	• 114,500 lbs LiAl cast • 2,905 control rods • 2,304 target tubes: Marks 16, 18A (enriched), 220, 221, 60A, B
1975	
Extended Surface Fuel Tubes	
	• 3457 total Mark 16
Target Assemblies: Depleted Uranium	
	• 83,202 Mark 31 A, B
Target Assemblies: Other	
	• 103-Mark 53A Target NpO_2-Al tubes • 30 Mark 41 PuO_2-Al Target
Control and Safety Rods	
	• 62,225 lbs LiAl cast • 1,728 control rods • 1,756 target tubes

APPENDIX E

ORAL HISTORY INTERVIEWS

Oral History Interview – Norman Brady

Mr. Brady, an Aiken resident, began his career at Savannah River as a foreman in 1961 and worked the next 32 years in the 300/M Area. During those three decades, he had experience in all the major process buildings, 313-M, 320-M, and 321-M, during their operational life. When he retired in 1993, he was custodian of Building 320-M.

Interview Transcript

Interviewee: Norman Brady

Interviewer: Mark Swanson, New South Associates

Date of Interview: June 13, 2003

Mark Swanson: If you would, state your name.

Norman Brady: Norman Brady.

MS: And if you would, state your position at Savannah River.

NB: From start probably on up to the end, is that what you're talking about?

MS: If you can.

NB: Well I started out as a foreman at, I guess that's a low level. Let's don't say it like that, but that's the first level. And then I was promoted up a couple grades over through the years, and I guess eventually when I retired was custodian of one of the production buildings, 320 building.

MS: How long were you employed at Savannah River?

NB: 32 years.

MS: Okay. Starting when?

NB: Starting February 1, 1961.

MS: Let's see, and did you work all over M area?

NB: All over M area, yes. Not all over the plant, but all over M area right.

MS: You mentioned 330, right? I mean, sorry, 320?

NB: 320 yeah, right.

MS: That was your main..?

NB: Well no. There were three main production buildings, 313, 320 and 321. And I worked in all three buildings over the years. In the last, I guess my last assignment was in 320 the last years that I worked, from say about '80 through '93 when I retired.

MS: Okay. What were the original functions or processes, in like for example 313?

NB: 313 was a building with all the, the canning building where they encapsulated the slugs, uranium slugs in aluminum sheathing. And those slugs then, uranium slugs were used as a target in the reactor to produce plutonium. I guess plutonium 238 mainly. Yeah I believe that's right, 238.

MS: Okay. What about 320? What was the original function?

NB: 320 was a target building, they called it a target building. They manufactured target tubes consisting of lithium aluminum cores, lithium aluminum innards that were used to produce tritium. So those two buildings there made two different things, two different products now. Also 320 was used in making lithium aluminum control rods which were used to control the reactor, the reaction in the reactors. So that was not a product there, not an end product. It was just a product that was used to control the operation of the reactors that made the other products.

MS: What about 321?

NB: 321 now was the fuel building. That's where the enriched uranium was encapsulated in aluminum to make tubes, which was used as a fuel, which was used in combination in the reactors. The fuel is what drove the reaction, and the targets was what made the product. So you bombarded, in one case the uranium slugs which were very slightly enriched. Some of them were. There were some different processes over the years. Most of it was natural uranium product that was bombarded by the neutrons and the reaction from the fuel tubes, so that that product was made. But the 321 building was mainly, was only the fuel tube production, where highly enriched uranium was processed. And that's where your enriched uranium was stored.

MS: So there were no slugs.

NB: There was nothing in 321 except highly enriched uranium. Well that's not quite so. Along the years other different products were produced, were used as fuel. For instance neptunium and some plutonium was used as fuels.

MS: Yeah, that's part of the special programs.

NB: Yeah that happened periodically along through the years, yeah.

MS: Later on.

NB: But mainly it was the fuel.

MS: Okay. What about building 305?

NB: 305 was a test building. It had a test reactor in it called a nuclear test guage. It was a great big block of super-refined graphite. And when we made a product, either a slug

MS: You mean the test pile, right?

NB: The test pile. Are you familiar with the test pile?

MS: Mm-hmm.

NB: Okay. The test pile was in 305. And that was its' main, at least in my recollection that was its' main reason for existence, just to test. The slugs were put in there and tested. The target tubes were put in there and tested. The fuel tubes were put in there and tested. So that, okay yeah this is what we thought we made. Yeah, here's one we tested and that's what we made. So it was to test what you made.

MS: Right. And then that later on was replaced, or augmented by that NTG.

NB: Nuclear test gauge. Much smaller, much smaller. And yes it was big as a pick-up truck. Whereas this test building, that pile was half-again as big as a house.

MS: What about, what do you remember about the whole transition from like slugs to hollow slugs?

NB: Well, there was always improvement, I guess you'd say. I don't know if improvement is the right word or not, but there was different type of slugs used with different, I'd guess you'd say with different processes. Although the process was basically the same. You put a uranium slug in the reactor and something happened, and over the years you just put a different size one in there. And it started out, from my recollection, was a small uranium slug. I don't know, an inch or so in diameter, and about seven or eight inches long. And it had a little hole in it that was called a 7A I believe. Then over the years we went from that size to a bigger slug. It was bigger around. It was a tad longer maybe, I can't quite recollect. I think it was a little bit longer. Then we went to a, well there were two slugs, outside and inside, an inner and outer slug. And then along the way there came along a four slug arrangement, nesting. You put four different slugs inside one another. Big, little, small and on down. There were four of them.

MS: These were like tubes though right?

NB: No, no these were slugs.

MS: Really?

NB: Yeah. They were about seven, eight inches long. And then what they did was they, in part of the reaction they put all four slugs in there. Then they would take out this slug and that slug, and they'd radiate a while, and they would change their arrangement. But they still called that slugs.

MS: Okay.

NB: And that changed again over the years to where instead of using all four sizes nested together, they only used two sizes nested together. So there was all sorts of different arrays, different sizes.

MS: Right, okay. What about, going back to original functions and processes, were there any other buildings in M area that you recall having any special significance? I mean aside from 313, 320, 321. And let's say 305.

NB: Well we had the laboratories. We had physically attached to building 320 was a chemical laboratory that did all the testing of material. You know if you had a sample of uranium piece that you wanted analyzed for one reason or another, or maybe it was a routine analysis. But there was a chemical laboratory, yeah.

MS: Was that 322?

NB: No that was the metallurgical lab.

MS: Oh, okay.

NB: This I'm talking about was called the 320 lab, which was literally happened to be hooked on to the building. And that's the only reason it had the same number. And then the 322 was a separate building, and it did all the metallurgical, all the microscopic work on the uranium itself to make sure the grain size were right and all those kind of things, you know.

MS: Right.

NB: Let's see. So that would be the chemical lab, the met lab. We talked about the NTG that was in the test pile, graphite pile. 313. I guess that covered the main.

MS: Those were the main ones. I didn't know if like the other smaller buildings, or they may have been later, like 315?

NB: Well they were warehouses.

MS: Oh, okay.

NB: They were basically warehouses. No processing went on. I know no processing of product went on in those buildings. They stored the aluminum products mainly. The uranium was all stored in 321. That was security and all that. So you had to store that in the, that was not stored in warehouses. Same thing with lithium for 320. It was a much lesser security problem, but anyway it was stored in 320. So all those other buildings were strictly warehouses of aluminum products.

MS: Okay, right. What about, going back to building 313, how did that process that went on in 314, how did that change over time?

NB: Oh my goodness, drastically. As I said, I got there to the area in '61. Prior to that they used a process called the canning process which used, it was

MS: Wasn't that aluminum silicone?

NB: Aluminum silicone outside because aluminum silicone they used, they had this molten aluminum in open pots. And there was an aluminum silicone bath. There was a bronze bath. And there was another bath, and I swear I can't remember what they called it because that was before my time. But they physically took a slug with a pair of tongs, like you'd put a piece of meat on a bar-b-que grill and stuck it in this molten metal. So you can imagine how careful you had to be doing that.

MS: And hot.

NB: And hot. You've got to keep water out of that thing. And you can't sweat over in it, you know? So anyway that was the original process, called the canning process. That was changed sometime before I got to the plant, to a hot-press bond process. And that was fairly complicated, although it was not as, it didn't have as much safety problems as the other did. You just used a slug. You put it in a can. You put this combination into a dye contraption with a cap on the bottom and a cap on the top, you put it in the press, you heated it and you pushed on the ends of it. And so then when time was up you had to disassemble all this tooling with it. There was an outer sheath, inner sheath, top sheath, bottom sheath that you used to apply pressure to this combination can/slug. That worked on there for several years. That process was improved to a hot dye size bonding process. And that was, you had the same combination of a slug and a can, but you just forced it through a dye on a hydraulic press. And you just sized it. It was like, well I can't think of like what, but it forced that slug and that can through a dye that made the can then bond to the slug, and you had a much better bond between the slug and the can, which is what you wanted for heat transfer processes in a reactor.

MS: `Right.

NB: And that was the final process, hot dye size bonding.

MS: Okay, right. When did that come in? Roughly.

NB: Probably mid sixties. Yeah I think that's right, about the mid sixties.

MS: Okay. And that, after that hot dye size bonding, that was probably the last major

NB: That was the last method that was used to can those slugs, that's right.

MS: Okay. What about, talking about changes to the building. We've been talking about 313, what about 320? How did that change over the years?

NB: 320, well basically it stayed pretty much the same because what it did was made the lithium aluminum products. And that was, of course the processes changed a little bit over the years because to start with you had to melt an alloy, lithium aluminum, under vacuum. At least we thought that was something we had to do. And that's what we did for years and years and years. And that was a booger. You had to, you can imagine putting a big induction furnace inside something that you pull a vacuum on. And the vacuum has got to be approaching zero vacuum. So you've got a tank big enough to put your car in see? That you're pulling a vacuum on. Anyway. That stayed pretty much the same over the years. All the, maybe the exact product changed a little bit, but it was still basically lithium aluminum. Along the way the technical boys and the reactor boys and all those folks, they figured out we don't have to do this under vacuum. So we got rid of that, and that was, man that was like having a ton taken off of your head to have to try to maintain a vacuum furnace that big, see. That was a booger. It was bordering on the impossible to do that. But anyway. The process pretty much stayed the same. We melted lithium and aluminum, alloyed it together into a casting. We processed that casting. Sometimes we machined it, sometimes we didn't. Extruded it into a shape that was what we wanted to make the final product. And then in later years, well I guess we ought to say in earlier years, the tubes were extruded in 320. Well no wait a minute. No the target tubes never were extruded in 320. All this was taken to 321 and extruded on a press they had over there, which was a better press and, well I don't know better press, different press. It was a newer press, a different kind of press. It worked a little better. And so the target tubes were, the cores, the beginnings of it, of the target tube, were made in 320. The final target tube was extruded and processed in 321, because they had tube processing equipment in that building that 320 didn't have.

MS: 321 I guess was totally built for that.

NB: Yes. Now I'd have to say also in the earlier days, before tubes were made, there weren't any tubes in 320. And there wasn't any 321 building at all.

MS: Yeah that came in a little bit later.

NB: Yes. The 321 building I believe was built in 1958. And so as you're going back earlier than that you didn't have tubes. Now what 320 was doing in those days was making the little control rods, which is a little rod about 3/4 inch in diameter and different lengths to control the reactor that I was talking about a while ago. And that was their main function then. Then when the target tubes came into being, the tritium production and all that sort of thing, 320 expanded into making tubes.

MS: If I remember correctly, when they first made tritium at Savannah River, didn't they only make it in the control rods? Before they did the tubes.

NB: That was sort of a by-product see. Because the tritium is made by radiating lithium. And so when you had your little lithium control rod in there, you were getting a by-product of tritium. And then on up through the years you're still getting a little bit of by-product.

MS: Right. What about 305? I know we talked about the test guage, I mean the test pile and ......

NB: I never worked in 305. I don't know how come, but I never did. But that was I guess 100% test, testing of material.

MS: There was no production going on.

NB: No production, no. The test pile, the graphite pile in the early days was strictly for testing. Testing our product, and I don't know maybe some other people on the plant may have used it because that wasn't something that had to run all the time. So I'm sure that, it at least would have been available. And I don't know that anybody else ever used it to test material because the material we made was all they needed tested, in that way I mean.

MS: Right, yeah. Let's see, well we talked already about like the development from like slugs to hollow slugs, then the large diameter tubes. And also about the different bonding processes they used. Were there any particular marks that you all made in M area that were memorable? I was thinking specifically about that fuel plate that they tried in the early days. I don't think it was successful. I mean they could make it but I don't think they used it in the reactor.

NB: I'm not sure I know what you're talking about.

MS: Mark 3?

NB: Okay, this was a, I wasn't there then.

MS: This may have been back in the fifties.

NB: It was before my time, but I think I recollect they tried to clad a plate in the extrusion process, or else in the, I guess it would have been the extrusion process. I don't think that was successful. They tried to extrude it, a plate with aluminum cladding all the way around. No I never got in on that. I believe I heard the guys talking about that, if that's the same thing you're talking about.

MS: I think it was done in the fifties.

NB: Early fifties.

MS: Yeah, early fifties. It was one of the very first fuel plates they tried.

NB: There was something the SRL would have dreamed up in the Savannah River lab, and tried.

MS: Right. How did they work things out between Savannah River lab and then M area? There was a lot of back and forth?

NB: Yeah, oh yeah. Those guys, those were all the engineers and the guy who, they were the guys that developed the hot dye size bonding.

MS: So that was done at Savannah River.

NB: Yeah. Oh yeah. A guy named Bob May was the main man on that. Anyway they, yes they worked, we worked with them hand in glove over the years. When they were trying to develop something new they were over in the 300 area every day you know, just about, or whatever it took. But yeah we worked real close with them. And in fact a lot of those fellows transferred over to 300 area, and maybe some of them went the other way. I forget, yeah I'm thinking of one guy who transferred out of M area back over into the lab over the years. So yeah they worked

MS: Yeah. What about, do you remember a problem with fuel tubes swelling? Some of the early fuel tubes they put in the reactor, they swelled and so the walls got .... And they had some kind of solution that they called rust and sand. I think they added some extra ferrous oxide something and some silicone or whatever, and they got it so that it worked okay.

NB: You got me there. I can't recollect that.

MS: This may have been totally in the lab. I don't know if it, it may not have been something that

NB: I know now and then you would get a failure, we called then failures in the reactors, which was bad. You didn't want that because that just screwed up everything. When the cladding would fail and the water would get, the cooling water, the heavy water, not the cooling water but the heavy water would get to the cores and that wreaked havoc on everything. But a swelling, I can't quite recollect.

MS: If I remember correctly, this occurred like in the early sixties. It may have been before you got there, I don't know.

NB: There was always a problem with the slugs would swell land fail, as I've just talked about. But they would literally disintegrate. And of course all that uranium has got to go some place, and all in your heavy water in the reactor. That screws things up pretty good. So we had a process in 313 that tested for that. And as a matter of fact it did more than test, if a slug was going to fail it would make it fail. So you fail there rather than in a reactor.

MS: Was this the autoclave?

NB: That's it.

MS: These were all in 313.

NB: The swelling business, I'm kind of drawing a blank there. I can't quite

MS: That's interesting. I talked to Sherwood Bridges yesterday and he didn't recollect the swelling problem.

NB: Sherwood Bridges!

MS: Anyway, how did tubular elements get started at Savannah River?

NB: Well now you got me there. I assume that that was, it came out of the Savannah River laboratory people as a way to make whatever it was they wanted to make. You see a tube, the tubes were lithium and uranium. Different tubes, lithium tubes, uranium tubes. So I suppose it was just, that was a process dreamed up by the laboratory boys. And you put an enriched uranium fuel tube in there, in the reactor, with a lithium aluminum target tube, and you get tritium by radiating the lithium. So how exactly I don't, I guess I couldn't say to that. But it had to come out of those people. Everything did, the technical stuff.

MS: Well I know we've talked a little bit about this other thing, but what about the co-extrusion process? What do you remember about that?

NB: That was a magic process. Co-extrusion was a way of cladding. You had your uranium core

MS: This co-extrusion occurred in 320 and 321? Is that correct?

NB: 99.99% in 321. There may have been just a little tad of co-extrusion done in 320 along the years, but I ain't sure. I'm not sure about that even. So I'm going to say that co-extrusion was mainly in 321.

MS: Basically in 321, okay.

NB: You took a lithium aluminum core, or you took a uranium aluminum core, and you put an aluminum sheath outside, inside and on the ends. And you extruded that through a co-extrusion dye. And it was a conical shaped dye and it extruded a little bit of this and a little bit of that. And then you had a coating of aluminum on the outside, inside and on the ends. It was a great process. Worked great.

MS: How many of those presses did you all have?

NB: Two. They had a press in 321 which was the main, and we also had the one in 320 which we didn't do, as I said earlier, we didn't do co-extrusion there. But it was an extrusion press.

MS: Was that thing, back in its' heyday, the one in 321, was that working all the time?

NB: No. Well, no it wasn't working all the time, but it would, if your production called for it, if you had to meet a schedule and you had to run more than one shift, then it would run whatever it needed to run. It'd run two, we worked a lot of two shifts over there, and sometimes there was four shifts, but not, mainly mostly it was day shift and then two shifts. So the presses they didn't run all the time because you didn't need to run them. You could make enough product by running, like I said either the day shift or maybe two shifts. You can't compare it to a commercial product like Alcoa or somebody who's running around the clock.

MS: Right.

NB: No they didn't do that.

MS: Oh okay, just depending on what the schedule required.

NB: Yeah what the reactors needed.

MS: I should know this and I don't, but when they were making fuel or tubes, was there any particular length that they used?

NB: Tube, the tube length?

MS: Mm-hmm.

NB: Well yes there was a particular length.

MS: Did that depend?

NB: There was a length and that varied some. But not a lot. If you were making this kind of tube it was this long. If you were making that kind of tube it might have been an inch or two shorter, or one foot longer.

MS: It wasn't like the slugs that were standard. Like one inch by seven inches or something like that.

NB: Well I guess you could say it was standard, yeah. But the, an outer fuel tube was this size. And it was, this particular fuel tube was always that size. Now tomorrow you might make another fuel tube that's some other size, but it's a different fuel tube. So they were unique in their own, you didn't make an outer fuel tube for a mark 16 today that was a foot long, and tomorrow make one that was three feet long. You didn't do that.

MS: Depending on the mark and everything you'd have different lengths.

NB: Yeah, yeah.

MS: So I guess after they switched from like the slugs and the hollow slugs to the fuel tubes, they didn't need those quadrifoils anymore did they?

NB: Oh yeah.

MS: Oh they did? Okay.

NB: Quadrifoil, yeah. Quadrifoil, I'm thinking about a septafoil.

MS: Yeah that's the one.

NB: Septifoil had seven.

MS: And the quadrifoil, as I recall and I could be wrong, that's like the quadrifoil held the

NB: There were four of them.

MS: Yeah, and they held the four slugs, four groups of slugs or lines of slugs, and then by the time they get to fuel tubes they don't need that anymore, I would assume.

NB: I don't think so. I don't recollect ever working on a quadrifoil. I remember knowing what they were and seeing some over the years, but we never did make those things.

MS: Oh okay, right.

NB: A lot of that aluminum product too was made off the plant by

MS: Right.

NB: Civilian vendors, outside vendors.

MS: Right. And they would just get that stuff in. Who were some of the main vendors, do you remember?

NB: Oh my Lord. Alcoa. Reynolds. And there were some other smaller ones, I can't think of the names of it, their names. There was an outfit in Orangeburg that processed a lot of aluminum products for us, strictly aluminum. And I can't even think of the name of that place now. And there were, oh there were a lot of other vendors over the country, machine shop vendors that would make various things for us.

MS: What about, what was the different equipment that was used in the co-extrusion process?

NB: Oh my, co-extrusion. Well to start with you had to assemble your billet, which we called a billet which was the uranium core, or the lithium core whichever it was, and encapsulate it for the co-extrusion process which we talked about. Then you had to, what you did was you welded this up air-tight and out-gassed it we called which was, it was heated and a vacuum pulled on it so that you got all the air and all the gasses out of it. Because if you didn't, when you did your co-extrusion the little air bubbles would blister the tube. It would put a little blister on it just like you burned your finger and got a little blister on your finger. So they had to get all that gas out of there, the ...... gas .... Then you went through the extrusion press, made your tube. The tubes were then processed, the chemical bath, cleaned up good, put through a draw bench which was a piece of equipment that sized the tube, made it down to the final size you wanted. And then you, let's see you cut off these outside ends to leave your tube to the particular length that you wanted. You put it through an x-ray machine to look at that core in there to make sure that that core was where it was supposed to be, lithium aluminum or uranium aluminum mostly. I guess uranium aluminum went through the x-ray. Lithium aluminum went through another contraption. You couldn't hardly see a lithium aluminum core, the difference between aluminum and lithium aluminum through an x-ray machine you couldn't hardly tell the difference, density-wise. Uranium you could. So anyway you put it through there and see if that core is where it's supposed to be. Then you had some other processes. You might have attached a fitting to one end or the other. You might have punched holes in them to facilitate handling of the tube. In later years we had a machine called a magniformer which was, a black box machine I called it. You could use it to attach fittings to the tubes without welding, without any kind of a mechanical working. It was a electromagnetic, let's see, electromagnetic discharge I believe. It had a bank of capacitors in there that charged up, and then you'd discharge this, and within a fraction of a second it would transfer that energy to a fuel shaper I believe we called it. A brass looking piece that would shape that tube and would affix that fitting to the tube, just like you had welded it. Although it wasn't welded, it was just mechanically squeezed down actually. It worked great. It was a great machine. And from there what else did you do to it. I guess once you put your fittings on that was about it. So that was for handling and reactors.

MS: Right. And all this occurred in like 321?

NB: Yes. Yes.

MS: The magniformer and all that.

NB: Magniformer, we did that in 320. They also did it. We did it on target tubes in 320, fuel tubes in 321.

MS: Oh, okay. So it was used on both.

NB: See you had to handle a fuel tube different than a target tube, because of the nuclear safety. You couldn't pile up fuel tubes like cord wood. If you did you'd have a nuclear reaction and kill the whole crowd. You know you don't want to do that. So fuel tubes had to be handled separately and they had spacing that you had to maintain, and all that was done in 321. Target tubes you didn't have to worry about that. Of course you had to worry about them, knowing which one was which. That is you couldn't, if you took a target tube into 321, you'd have to treat it like it was a fuel tube. And outside of that you did not bring fuel tubes into 320. They didn't have the facilities to handle them correctly in that building. So you had to watch that.

MS: Right. What do you recall about the development of ribbed fuel in target tubes? Was there anything special about that?

NB: Well yeah, it took a special dye, extrusion dye, special co-extrusion dye which gave us some difficulties for a time. But again the techno boys, they straightened all that out by trial and error.

MS: Yeah.

NB: nd once it was, this extrusion dye was designed properly and you had it right, then you had no problem with ribs. And it worked good. You just co-extruded over that rib just like you did if the rib wasn't there. So it worked great.

MS: Right. What about the, talking about, in 305 talking about the NTG, because I understand there was like an earlier version of the NTG and a later version.

NB: Yeah, that's true. They went from the big test pile to an NTG which was quite an improvement. And I don't know the technical descriptions of these things, but yes that NTG was used for many years. And then each building, 321 got their own NTG, and 320 got their NTG. And these were much smaller, more compact pieces of equipment that you could put in a building.

MS: Yeah, the original NTG was only in 305.

NB: 305 yeah.

MS: And the smaller NTGs were

NB: Originally the huge building there had the big graphite test pile sitting right in the middle of the floor. When they went for the NTG test guage, it set over to the side here, although the big old pile was still setting there. Okay? And it was again much, much, much, much smaller. And of course when each building got one you avoided all that transportation. Because when you transport a group of tubes from 320 to 305, you've got to do it in a certain array which is a real chore. You've got to have little special trailers to pull it in and you've got to worry about weather and all that kind of stuff when you're going from this building to that building. So you got away from all that. Plus you had a little smaller piece of equipment that was again much, much smaller and was a real step forward in testing equipment.

MS: What were some of the major problems that you all had logistically, as far as moving equipment, since you referred to that, moving equipment around from building to building?

NB: Well that didn't happen a lot. You had a piece of equipment in this building, then that's where it was. You didn't move, because the process just, well the process didn't call for that and you didn't need to. There was no need.

MS: Well let's say back in the early days of, if they were moving fuel or target tubes to the reactors, would they have used trucks or trains?

NB: Yeah, they used trucks. I think in the very early days raw materials, bare uranium slugs, were brought into 313 on railroad cars. I know they were. That's before my time, but the railroad was still there. There was a little semi, covered semi Trailmobile trailer. That's the name of a company that makes trailers, if you know Trailmobile. Anyway we had one of those, the plant had one. And they hauled slugs in that trailer from 313 to the reactors forever. They were always hauling. And that's the way the slugs got there, through this little, and it was a little small trailer. It wasn't one of these big forty-footers like you see on the road now. But slugs went that way. The tubes were put in a steel frame, aluminum skinned box we called a casket. It was about twenty feet long and about four feet wide, and about maybe two feet high. And you put your tubes in there. You had separators in there to keep them apart so that you maintained your nuclear spacing that you had to do with fuel tubes. And they were shipped to reactors on a trailer, a semi, in those caskets. Again, there was never no problem with that. You might have a problem, an occasional rain storm that you might get into that might cause you a problem, but things were covered so you didn't, I don't ever recollect a problem. But everything was in its' place and that's the way it had to be shipped. Target tubes too because in later years target tubes and the fuel tubes were assembled one inside the other. And then that assembly was shipped to the reactor.

MS: So that was put together in M area.

NB: In 321, yeah.

MS: Okay. As I understand it, M area had never missed a production deadline.

NB: Not that I know of. I expect I would have known it because there would have been some fussing. I don't think we ever missed one. Which was, I guess normally you had enough time to get your job done, yeah.

MS: Right, yeah. What about, that sort of leads into the next series of questions I've got about special programs they did back in the late sixties and early seventies, that were kind of sponsored by Glen Sebourg, and other people too? Like when the did heat sources, and they also worked on the curium and californium programs?

NB: Yeah that's what I mentioned earlier, we extruded some neptunium one time, well over a period of time, to make, and I can't recollect

MS: I think it was plutonium 238 as a heat source?

NB: Yeah. That's what you put in the satellites, yeah.

MS: They also did cobalt 60, but I don't know

A: Oh yeah. There was some cobalt over there one time, and I can't remember what we did to it. Plutonium, we extruded some plutonium .... one time, we had to take extreme care with those. Because if you were to expose plutonium to the air, you had all kind of problems. So we did some of that. And I believe that was associated with the californium.

MS: That could be part of the, I think the curium program was before the californium. It was always like a matter of bumping the material up.

NB: Yeah, you changed something, you changed uranium 238 to I believe there's a uranium 239, then there's a plutonium 238 and a plutonium 239 I think. And then what's californium, it's

MS: Californium is 252 I think?

NB: 252, yeah. I think that's right. Yeah, I believe it is. And the neptunium is in there somewhere.

MS: Yeah, neptunium 237?

NB: I think it is. I think it's 237.

MS: As I understand there were like special marks that were made for those things.

NB: Yeah. Special programs. We had, we'd have to do special things. We'd get, let's see I believe it was maybe the 200 area who had to assemble the neptunium billets for us. And they were put together over there and they were brought over to 300 area to be extruded. Again co-extruded. And I guess the plutonium was done the same way. The billets had to be assembled in the 200 area, brought over, we'd extrude them, finish them, ship them out. So yeah there were a lot of special programs like that. Well maybe not a lot, but there were special programs where you had to do special things. I guess the special things were mainly from a health physics point of view. Radiation, contamination, make sure that didn't happen and all those kind of things. Well 321 always had the nuclear safety thing. You know you had to keep spacing right. That was a common everyday thing, so that wasn't no problem to maintain that.

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MS: What about, did you all have anything specifically to do with the californium? Were there any, I think there were some special marks associated with it, but I don't know where they were, where they got that stuff from.

NB: Now the californium, well no, we made those tubes that we talked about earlier that were used in the reactors to make the californium, but as far as ever getting it back to us for doing something with it, maybe there was a little tad of that that went in those nuclear test gauges. I don't know about that. I don't know about that. You had to have some kind of a source in those things, and I don't exactly know what I'm talking about technically.

MS: I only vaguely have some recollection that there was something like that.

NB: I think that there was some kind of a little minute, like a little bit or a little speck you know, but as far as us ever getting that product back to do anything with it, I don't know.

MS: Okay. I know they had what they call a californium loan program where they loaned californium out to hospitals ....

NB: Yeah but we didn't do that. The other guys may have done that.

MS: And the material is so small they probably did that in the lab. What about slotted septicoils? Did you all ever make any of that stuff?

NB: Yeah.

MS: We just went downstairs to look at some examples of some septicoils. What about in the development of semi-permanent sleeves and the universal sleeve housing? Did you all have anything to do with that?

NB: Oh yeah, we had, universal sleeve housing. That was an aluminum tube. It had no lithium, no uranium, nothing in it. It was strictly a

MS: Support tube.

NB: Support tube, that's right. Universal sleeve housing. That went in the reactor and stayed in the reactor. And the fuel, the target, whatever, went in and out of that as it was processed.

In later years we made those. For a long time they were bought off-plant. In later years we extruded those and processed those right there in the plant.

MS: Okay.

NB: I can't remember what year we started doing that.

MS: If I remember correctly, universal sleeve housing came in about '67, '68.

NB: Well we didn't start working on them, doing what I'm talking about, ... until much later.

MS: Okay, I got you.

NB: Say mid eighties probably. Well yeah the housing tube itself was used for a long time. And you know these kind of things you rock back and forth between, it's cheaper to buy them than it is to make them. The it gets cheaper to make them than it does to buy them.

MS: You go back and forth ....

NB: You're running back and forth, yeah.

MS: Well that's the problem in tracking down the dates for when anything's used at Savannah River because it's such a long period of time between the time they first conceived the idea, and then the got the prototype. Then you try it. Then you switch over everything to it. That could be five years.

NB: Oh yeah, could be. Absolutely.

MS: What about first computer use in the M area?

NB: The computers, when in the world did the computers come in?

MS: My information has it as like the first ones came in, like the Medcops came in in the early seventies, but I don't know what they did.

NB: Well I don't either. I didn't, I wasn't in the computer business end of it too much. I wasn't in it at all you might say. The first computer I recollect, or computers, would have been in the section of M area that did the matching of the tubes. That is you had to put particular tubes in particular places in the reactors. And the reactor department would send all that information to you knowing what you're going to send them more or less. So they tell you, this is where I want you to put it. And that's all got to be introduced in the computers. Would that have been in the late sixties maybe? Or the early seventies? Anyway you had your material, all the data on your tubes in your computer, and you run it through your particular program and it would tell you which tube needs to go where. And so .... in the reactor, particular tubes has to go in a particular places.

NB: And that's the first recollection I remember of probably the computers, because they had the card, they had to run all those dang cards through the computer you know. And there was a big old thing there. And that thing was always giving you problems. I didn't work with that directly. In fact it was sort of a black box thing to me. I didn't know what they were doing. I didn't have to know. So I didn't fool with it.

MS: I could be wrong on this, but the impression I got was that the computer use in M area was not part of the main process. It was sort of like what you're saying, for arranging stuff to be shipped out.

NB: That's right. Are you talking about as far as controlling the process? Actually controlling the machines or something?

MS: Yes, right.

NB: No, no, no. No we didn't have any of that. The only thing I can recollect is in the late days, late years, that we had a numerical controlled machine, lathe machine, turning lathe, that they used in 321. But that was very, that was very simple as far as computer things go. It was really a numerical control and I don't even know if that qualifies as computer control or not. I guess it does in a way, but nothing like going to the moon, that kind of stuff. But none of the rest of the process.

MS: The impression I got was that the computers in M area were nothing like what they had later in the reactors.

NB: Oh no. No, no, no, no. I'm sure not. And in later years we all had our little desk computer you know. But that was for record keeping and this and that and the other. It didn't have nothing to do with the process, other than you might store some data in there that says, okay I got to do this tomorrow and that the next day. But it's got nothing to do with the process.

MS: Right. What about, did you all have any dealings with powder metallurgy?

NB: Yes we did. Powder metallurgy.

MS: As I understand it, it was a technique that they basically perfected over the years, but they never used it because it just wasn't economical.

NB: That was another building that we had that I had forgot about. It was attached on to 321, and I can't remember the name of the building, the number. But it had a big press in it, a vertical press. And it was going to be used for powder metallurgy.

MS: I have a map. There's 300 area.

NB: Yeah it was a little old building right there. It don't have a number.

MS: Okay. But it was right off of 321?

NB: Right behind 321.

MS: Right behind 321, okay.

NB: Yeah. And I call it a building. It wasn't much bigger than this room right here. It was about four stories tall because the press set in there vertically. And that was going to be used to form cores using powder metallurgy. That was, I guess we figured out how to do it, but somehow we never did it. I can't think of the main reason why we didn't do it.

MS: I think I ran across some source that said that even though they figured out how to do it, it wasn't economical enough to switch everything over to ....

NB: I think that's the answer, yeah. It was a real neat process, but we didn't need to do it.

MS: Yeah, right.

NB: And it would cost too much to change over. Then I believe somewhere along the way we had another proposal that some vendor was going to do it for us, and I really don't know whatever happened to that. I think cost was probably what killed that. And I'm not sure about that even. Yeah, I can't quite say.

MS: What about, how did security change in M area over the years?

NB: Well, we always had to go through guard check points and all that of course from day one. We were all Q-cleared personnel. Well most everybody was. A lot of, some people were L-cleared and had different jobs that they had to do. And then in the later days, I suppose as you got into terrorism and fears of terrorism and all that sort of thing, the security around 321 building it increased 100-fold. It really increased. You had separate guard shacks in there. You had a much, much increased volume of security around that building. And the rest of thebuildings though didn't, well it was not necessary for the rest of the buildings. Used to be that 321 was in M area in the fence. You went in the M area you were in the fence. 321 was fenced off, had its' own guard shack. It was another layer of security that we had to go through. And so it was greatly increased.

MS: I heard they had like fences, and I even heard that at one point they had machine guns on the roof or something.

NB: I don't know about that. May have, but I don't know. They may have after I left there. I don't know about that. They may have.

MS: One of my interviewers was talking about, not even this particular project but earlier.

NB: I don't know, I couldn't say about that. May have been.

MS: I think they called it like, I forgot the brand name of the machine gun, but it was something like an M-60 machine gun.

NB: I was going to say it wasn't, what's that Russian, AK47? No I couldn't say that. It may be so.

MS: Well that pretty much covers all the main questions I've got. Just for the record, if you would, if they have raw material coming into M area, if you would just sort of like roughly run it through. Like where it has to go, in what buildings in order to ....

NB: Oh my goodness. Well, let's see. The, what would we have? The three main raw materials, four main raw materials would be natural uranium for the slugs. And in fact, in later years, it would have been depleted uranium. Somewhere over the years we used a slug that was slightly enriched, which was less than 1% enriched uranium. And that of course would come in the 313 building. The other raw material that I'm talking about, the aluminum raw material which was the cans that was used to encapsulate the uranium, that of course had to come to come to 313. As far as 320 goes, the enriched lithium came to 321 that was in little two pound cans. Lithium being like the second lightest element there is, or the lightest metal anyway. Anyway this little two pound can was almost the size of a little tomato juice can, a little bigger. That came to 320. Again the aluminum products would come to that building. And then over in 321 the enriched uranium would come to 321 from Oak Ridge.

MS: Okay.

NB: And again the aluminum products would come to that building. Of course we had those warehouses there that stored, kept a good supply of the aluminum products. The cans, the caps and the aluminum sheathing for the billets and all that kind of stuff. So that was kept in the warehouses. And in fact some of the depleted uranium and the natural uranium was kept in a warehouse because of its', well you had to make sure it was secure but it didn't have the value that enriched uranium would have. And the same way with, well lithium had to be kept dry of course. You couldn't get water in the lithium, that would be a no-no. But anyway that's kind of where that, natural uranium, enriched uranium and lithium were sort of the three main products, main raw materials I mean.

MS: Okay.

NB: Does that answer what you're looking for?

MS: Yeah I think it's, and I guess by the time you get to, I guess the 313 building was pretty much where they did the canning, right?

NB: Yeah, all the canning. All the canning of the slugs was done in that building.

MS: Yeah, right. And the, all the extrusion material, all that kind of activity was in 320 and 321.

NB: Right. Lithium products in 320 and uranium in 321. In general. Well for sure on the uranium. The lithium aluminum target stuff would go from 20 to 21 and back and forth like that. But the uranium always stayed in 321.

MS: Right. Okay. Well that's pretty much all the questions I can think to ask. If you think of anything else that you want to add.

NB: It covers thirty years in a hurry, don't it?

MS: It can do that.

NB: Well, I can't think of anything else other than we had a good time over them thirty years. Everybody worked, did their job and we got done what we had to do I think.

MS: Yeah, I think that's

NB: I guess you got some people nowadays that would say, well you didn't need to do all that. Well, I don't know whether we did or not, but at the time we thought we did.

MS: Right. Okay, well thank you very much. I appreciate it.

NB: You're welcome.

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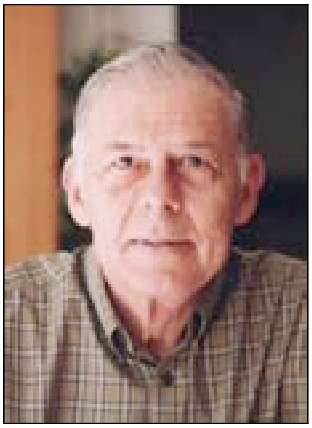


Oral History Interviews – Sherwood Bridges

Mr. Bridges, a native of Sharpsburg, Georgia, was hired at Savannah River as an engineer in 1956, after graduating from Georgia Tech with B.S. degrees in mechanical engineering and industrial management. He was first assigned to Reactor Materials Technology where he advanced from engineer to chief supervisor. His work with the 300/M area occurred during a critical time as fuel and target fabrication improvements occurred. In the 1977, he was transferred to Separations Technology where he worked in F and H areas. He retired in 1987 and currently resides in North Augusta.

Interview Transcript

Interviewee: Sherwood Bridges

Interviewer: Mark Swanson, New South Associates

Date of Interview: June 11, 2003

Mark Swanson: Okay, if you would state your name.

Sherwood Bridges: Sherwood Bridges.

MS: And what was your position at Savannah River?

SB: Well I had many positions. Started off as an engineer, ended up as a superintendent in various plant facilities, different areas, in the 300/M area. Engineer to the chief supervisor.

MS: Okay. What about length of employment?

SB: I started April 1, 1956 and retired October 31, 1987. 3-M area, I left there in 1977.

MS: Where did you work specifically in M area?

SB: Every building in the area, with the exception of the metallurgical laboratory which was in another department's domain.

MS: What were the original functions or processes in building 313-M?

SB: 313 was the canning, that is cladding of natural uranium slugs, solid slugs about an inch in diameter, about a foot long. Cladding with aluminum to provide the fuel for the production reactors.

MS: Okay. What about building 320-M?

SB: 320 was the building that provided the control rods for those original reactor charges. This was lithium aluminum alloy that was clad in aluminum as a slug, and then put in a long aluminum tube and sealed up again to make a long rod. And these again were, oh, they were a little less than an inch in diameter, and about ten, twelve inches long.

MS: What about, same question, the original functions or processes in building 321?

SB: 321 actually followed development work which was done in a small area of 313 to melt aluminum, alloy it with enriched uranium, and make the enriched uranium fuel elements. 321 was then built to do the whole process including the extrusion of aluminum clad enriched uranium aluminum alloy tubular fuel elements. And this was done to get a high power level in the reactor so you could make more tritium, which was really what the plant was built for to begin with. In the early days the tritium that you got was only what you could get out of the lithium aluminum control rods. But by going to the enriched uranium fuel elements, you had more power and flux so that you could put more lithium six, which was the isotope of interest, in the reactor. And that was done in the form of tubes also.

MS: What about, what was the original function or processes that occurred in building 305-M?

SB: Okay, to get the plant going you needed really three buildings. 313 to make the enriched uranium slugs, 320 to make the lithium aluminum control rods. But before you could put any of that in the reactor you had to check the reactivity of those elements, because you couldn't take the chance that you'd just stick them all in there and hopefully everything worked right. Because even though the uranium cores that we got from National Lead Company were supposed to be natural uranium, which has got as I recall about 0.7% U235. There's enriched uranium around. And if you ended up with enriched uranium you could let a reactor get away from you in a hurry. Likewise, the lithium that you had, we bought, I think it was from Lithium Corporation of America, again it was supposed to be natural. But there was a process ongoing at that time to enrich lithium, and what you ended up in the two products was, enriched lithium which had more than normal lithium 6 isotopes, and then depleted lithium which had almost none. Now if they goof up and mix some of that up, you know you've got a big problem. So every sample of every lot of uranium cores was put in the SR305 test pile, which was a graphite pile reactor, powered by natural uranium cores. And then they started out putting the lithium aluminum control rods in there as well. Now later on, in fact I was working on this project at the time, it was obvious to me that if you take a rod that has got ten or twelve or, I forget how many there was in it, slugs end-to-end and stick it in this big graphite moderated reactor, you are going to get a reading of the reactivity of the entire rod. But what if you've got one really bad slug in that rod? So we had another instrument in the 305 building called a nuclear test gauge, which looked at a small window of the element that you're looking at. So we, I designed really the apparatus to put those rods through that device instead of the big reactor. And therefore you could look at every slug individually. And if you had a bad slug, which could potentially give you a real hot spot in the reactor and let something melt down in the reactor. So we then abandoned the test pile for lithium aluminum rods and put them all, every one of them, through the nuclear test guage.

MS: And is it true that we, that the initial slugs were not made at Savannah River?

SB: They were never made at Savannah River.

MS: Okay.

SB: They came in as bare cores. They came from really two places that I recall, National Lead Company in Fernald, Ohio, but there was another one, I think it was operated by ………………., but I can't remember exactly where it was.

MS: I remember some name like Silicore.

SB: Silicore is right, that's it. And they made the natural uranium slugs, shipped them to us in boxes, and then it was our job to can them or clad them in a manner that would withstand the heat and water coolers and stuff in the reactor.

MS: Okay. What about any original functions or processes in any other M area building?

SB: Okay. The 320 building had a wing on it that was the analytical laboratory. We did extensive sampling of all the products we were making, and the raw materials that you received, to make sure that you were getting what you wanted and it was safe to use to make production pieces, and safe to ship out to the reactor. Now a small portion of that analytical laboratory was devoted to metallurgical examination. That was the original met lab. But it became obvious that there was so much work that needed to be done in the met lab portion of that analytical lab wing, that they quickly realized that they had to build a separate building for the metallurgical laboratory, which they did. And I can't remember the date, but it came along around the time the 321 building was built, which would be late fifties as I recall.

MS: Yeah, '56, '57, something like that.

SB: Yeah, '57, maybe somewhere in there. I can't remember the number of that building. Anyway the metallurgical lab.

MS: Here's a map of the 300 area right there.

SB: That lab was located sort of between 320, 313 and 321. Where are we, let's see.

MS: Here's 313.

SB: No it would be 315. I started at 315, yeah 315.

MS: 315 was the metallurgic lab you were talking about?

SB: Wait a minute. Yeah. Yeah. There's 321, okay. Yeah that, …

MS: Yeah here's 320 and here's 321.

SB: Yeah there's 321. But I would have bet you that, see there's a, something strange here. The road that runs in front of 321 really runs to this side of 315.

MS: Yeah that may have changed, that whole arrangement.

SB: Yeah it could be. Anyway it was right on here. So I guess 315.

MS: Yeah this is a recent map, so

SB: Wait a minute, here we go. Here we go. Here's the problem. There it is, 322. See it's on that side of the road.

MS: So 322 was?

SB: I guess that was the Met Lab.

MS: That was the Met Lab, 322?

SB: I guess so. We never referred to it by number, just "Met Lab."

MS: Right, okay. What changes were made to the 313=M building, as far as the processes go, from let's say the original process in the 1950s up until the 1980s?

SB: Well there was a total change in the process. The original process was about as crude and as labor-intensive as you can get. You had huge metal pots. One of them would have molten bronze, nickel and the last one an aluminum silicone compound. And there's no air conditioning in that building and the men, and it was men not women because it was job that I have seen very few women in my life that could have or would have done. They stand out there hour after hour with a temperature at unbelievable levels, with tongs in their hand and these cores would be dipped in that bronze. And it was hot. I can't give you a temperature, I don't remember. But I mean very hot. Not 200 degrees. I mean hot enough to have molten metal in it. Dip those in there to heat them up, and then they'd pick them up and put them in the next pot. X time passed and they'd pick them up and put them in the next pot. Then they'd pick them up and they've got a rack of extruded aluminum cans that have a bottom but no top, and they'd put those in those cans. And put a cap in them. And the whole process ended up with a weld that sealed it up and then you go through a autoclave, a steam autoclave to make sure you don't have a leak anywhere in the weld, say. Well that was all eventually gotten rid of, and they went to a hot-press bonding process which was highly automated. And you didn't have those open pots of metal. It was a different way of forming the bond.

MS: Right. When did they come in with the hot die size bonding?

SB: Yeah, that's when.

MS: Oh that was part of the same thing?

SB: Yes.

MS: Okay. What about, what changes were made to building 320? If you want to incorporate that with a discussion of 321 that's fine too, I don't know, since they're kind of related.

SB: Let's see, I don't know that there were any big changes, when the building was built it had a vacuum, I guess it did. It had a vacuum furnace. In that furnace would be a crucible and you sealed it up, pull a vacuum on it. And then you had a shoot that you dropped ingots of high purity aluminum, I mean really high purity, down into there. Or actually, excuse me that's wrong. You would typically load that furnace with the aluminum first before you'd pull the vacuum on it. But then up on the mezzanine like area, there was a thing that might remind you of a revolver on a pistol. The lithium that we got came in cans about, oh maybe three inches in diameter and maybe five inches long. They were lithium, which is a very reactive metal, metal sealed in an aluminum can. Again, high purity aluminum. You would load the bores on that cylinder with the cans, and once you got the aluminum melted, pull a vacuum on it, try to get rid of some of the air in the aluminum itself. Then you would start a process where a pusher would push the can out on down the shoot and fall into that molten aluminum, which would melt the can and melt the aluminum. Then it would rotate one notch and you would push another one through it. Now this wasn't pushed manually, but I mean that's the way it worked. And so you had a situation with a great big pot of molten aluminum to which you added the lithium. Now the problem with that, lithium is such a light metal that it just floats. So how do you get that mixed up? You can't get in there and stir it. So they came up with an induction stirring scheme in that you had a copper coil that wound itself around the furnace, and you could in effect pull on the magnetic field and you could pulse the energy to that. And it made sort of a boiling motion. Say this is the pot and it would do like this. And basically suck that lithium under and get it all mixed up. It worked pretty darn good. So that furnace was there. Now later on they added a furnace to do some reclaiming of lithium aluminum alloy. And they improved, they put a new version of the vacuum furnace in, but it was still a vacuum furnace for alloy. Now the other big piece of equipment in that building was an extrusion press which made the, which extruded the three-quarter inch or so diameter lithium aluminum rod from which you cut short sections to make those slugs that I mentioned earlier. Now that press stayed there the whole time. The only thing that was different later on was, we began making other shapes in that press. But it was still the same press. So I would say that there were no fundamental changes in processes in that building.

MS: Okay, and you're talking about 320.

SB: 320. Lithium aluminum.

MS: Okay. What about 321?

SB: 321, we started off with open furnaces for, again melting aluminum and, not melting but dissolving uranium in it. Uranium melts at a very high temperature, but most people don't realize it. They think of aluminum being such a benign material, but molten aluminum will dissolve about anything. So what you do is, you get the molten aluminum up, again I forget the temperatures, 1400 or something like that, drop the uranium in it and it dissolves it. But again you had just the opposite problem that you had over in the other building. In that building you had molten aluminum and the lithium wanted to float on top. In the 321 building you had molten aluminum, and the uranium was so heavy it went to the bottom. So I was involved in the process to add the induction coils and induction stirring to those furnaces. And again that was a lifesaver because prior to that the furnaces were in hoods, exhaustatory, a tremendous amount of air would float over it and keep the contamination from coming out in the room. And the guys running them would actually work through a small window inside of the hood. And so that guy would stand there with a graphite stick and stir it this way. And you could wear your arm out and you'd hardly ever get it thoroughly mixed. But once we got the induction stirring in, it worked like a charm. So again, that was the furnaces and those stayed there forever.

The other big piece of equipment of course again was the extrusion press. And there were no modifications to the press per say, but again we extruded many different forms and stuff. So you have different sizes containers into which the piece was put that you were going to extrude, and different dies to give it different shape, that sort of thing. But it was basically the same process. Now we did other things in that building of course. In the 200 area, again I was involved in that. We made plutonium aluminum alloy, put those in billet form. They had no presses so they shipped those over to 321 and they were extruded in that same press. Likewise we processed neptunium aluminum, both on oxide and alloy form. Neptunium 237 is the …… material for plutonium 238. So we, once the billets were made in 200-F area, they were shipped over and then all the rest of the processing, including extrusion, was done in 321 on that original press. So that was a busy press.

MS: What about building 305? We were talking a little bit about the NTG.

SB: Right. The 305 started out with just the graphite, natural uranium powered power, as they called it, reactor. And we built the much smaller, but in many, many ways far more valuable and effective nuclear test, the NTG. And all of the enriched uranium, fuel elements, all the plutonium, everything of those natural or depleted uranium slugs was tested in the NTG, 100% tested. And once we got the NTG and we developed the process for testing the rods, control rods, all of those went through there. So the NTG replaced a lot of the workload on the test pile.

MS: And the test pile was basically Hanford Technology wasn't it?

SB: Yeah, same type reactor as DuPont built in here. Just a power graphite with holes down it that you put slugs in. Of course you had inert gas flowing through it to cool it. It was a sealed, more or less a sealed unit.

MS: What about, we've already talked about to some degree, I mean like the differences between slugs and the hollow slugs, and large diameter tubes. But do you have any information on like how these things got developed?

SB: Well, it could be a combination of several groups. First of all, they were constantly looking for ways to increase the flux level of the reactors to make more product. And so you get the physicists to sit down and say, okay, we got so much ability to pour water, to cool it. You can do only so much cooling with a slug in a quadricoil. What if we had a hollow tube, aluminum clad, and we could pour water on both sides of it? We could get more cooling so we could put more uranium in it. Now we, and natural uranium wouldn't be good enough. We'd need some enriched uranium. Well the enriched uranium is made at Oak Ridge, so you contact them. Hey can you supply us some highly enriched uranium? Yeah, what do you need? So you just, somebody sits down and designed this, in their mind at that time, the ultimate fuel element. And then you got all that flux, what are you going to do with it? Well you don't want just a bunch of control rods, again solid rods. You want to be able to flow more water. So again, you go to the hollow tubes and pour water over them. And as I say, the reactor, the guys who designed that reactor had great foresight because it was adaptable to different shapes of fuel and target elements. So once that goes, of course SRL is involved in all of that. And then they would, I was in a technical group, works technical group, there were three of them there, and where we would come in, the guys would come to us and say, 'Hey we just designed this new fuel tube, and we want it to be a 3.25 in diameter. We want it to be 30 mils clad of aluminum. We want the ID to be X, the core thickness to be Y. Can you guys make that?'

Now sometimes that would be done over in the SRL, in the early days SRL would do that. Of course they would sit down and do something, come over to our facility and we would make it for them, and they'd go back. Well eventually, they kind of got out of that particular business. They always were involved in the design of new elements. But eventually it fell to us to design the billets, to design the casting processes and all that kind of stuff, to make the billet to make the tube. And so we would sit down and design a, see what, the press is actually a reduction process. To get a tube 3.2 inches in diameter with a certain amount of cladding, you've got to design a hollow billet that has inside of it enriched uranium aluminum core, with thick aluminum on both sides of it. And when you run that through the die, that gets squeezed down and then so you have to know how much to start with to get the 30 mils of clad, or whatever, on the back.

So we would sit down and design it, and then have some made. Get the necessary tooling from the vendor that made our dies for us. Get the reinduction heated those billets, which is a copper coil again with water pouring through it, because it's so much faster than just an oven. So you call up that vendor and say, hey I got a billet that's going to be 6 inches in diameter by 2 inches ID. It's going to be this long. It's going to weigh X pounds. Got to have an induction coil to heat it. So they sent us one. They have to make each one separately. So you do all that and then you extrude it. Well what did you really get? That's where the Met Lab comes in. So you take the first tube over and say, cut this thing up and tell me what we got here. And they said, well your average cladding thickness is not 30 like you want it, it's 33 mils. So that kind of thing. So you go back and adjust a little bit and do it again. Do it again and do it again if necessary. Now we got to the point fairly quickly where we rarely had to do them again, but that's the kind of thing we do. So you had the physicists, the reactor guys, the SRL guys designing what was in their minds, the alternate fuel and target element to make the product that they wanted to make. And then early days SRL would do some of the billet and tube design and so forth, bring it over, we'd extrude it. But then eventually we got in that business. So there were those three groups that were involved.

MS: You said that you were involved in doing the design and the research and all this. What building would that have taken place in? Would that have been the Met Lab?

SB: I wouldn't call it, we didn't do research. We did process improvement and process development. As I say, it was our job to come up with what we needed to make this thing that they had said they wanted. But, and when I was in 321 if we had a new plutonium aluminum, neptunium aluminum, or uranium aluminum tube to make, you'd just set at your desk and figured it out and did it. There was no lab experimentation in order to do that.

MS: Okay, right. I know we've talked about the aluminum silicone, was it dip bonding?

SB: Yeah.

MS: Process?

SB: Well yeah, I guess dip bonding is a good name, yeah.

MS: I've seen that in print.

SB: Yeah, that's a good name.

MS: How exactly did that work? Was that the thing you were talking about with the tongs?

SB: Right. Very labor-intensive.

MS: When did they switch over to the hot press bonding?

SB: Gosh I can't remember. They ran the old process for, you know it was quite a few years really. I'd say they ran it, this is a, I shouldn't even guess. I can't remember. My memory is not what it used to be. But they switched over as fast as they could.

MS: Is there any major difference then between the, you were talking about hot press bonding and then hot die size bonding? Is there some difference between those two?

SB: I'd better pass on that. I'm sorry my mind has left me there. I think of two major processes. The die size bonding was, I think there was some degree of automation for die size bonding when you got that thing canned you pushed it through a die like you .... something. You got the die that's like a smaller, then the other one push it down through there and you then trim off the excess and weld it up. Now the other one is a more automated product which squeezes it like this.

MS: Okay. Of course they had lots of different marks and stuff that were made at Savannah River. Do you have any recollection of like the Mark 3 that was that fuel plate that they tried early on? It really didn't work out.

SB: Yeah. It was never, we extruded some of those. SRL came up with that and talked to us, and we designed the, well first of all we went to the person, the people who made our extrusion dies. We said, hey can you do this? Can you take a round billet and make a flat plate like this? And he says, well we think we can do pretty good. So we got dies and we extruded some, but it never quite got off the ground. As far as I know never was one put in a reactor. I may be wrong, but I don't think there was.

MS: I think you're right. I don't think, what about there was some discussion about when they first came up with fuel tubes in the reactors and they ran them in the reactors, and they had a problem with swelling? And then they came up with what they called the rust and sand solution?

SB: First fuel tube was a Mark 6. They ran that Mark 6, Mark 16 I believe. They ran that for quite a while. I don't know the rust and sand.

MS: This could have been before that I think. This was, well this may have all been SRL, I don't know. But they determined that if they did something with, I don't know kind of like iron and silicone or something like that, some kind of treatment on the tube, that apparently it would resist the swelling when it got over-heated in the reactor.

SB: That must have been something SRL did. You know, anytime anything went wrong with anything in the reactor that we made, you know we heard about it. I mean big time. So we never heard about that from stuff we made. Now it could have been, now the

MS: It may have been a .... thing.

SB: Yeah. It might be this. If you ended up with a, first of all when you made uranium aluminum cores and you extruded them, sometimes. Well, let me back up. Quite often, most of the time, they would not be totally uniform. You would have little areas in the tube, little pea size things that just were conglomerations of arc side of whatever, and it would be like a rocking issue almost. They would tend to not want to squeeze down and you'd end up with a thin spot in the cladding. And you'd have unbelievable amount of water flowing down those tubes and they're super hot. And if you didn't have water it would melt in a second I guess. And so if you have very thin cladding on there, you could easily expose that uranium aluminum core. And when you did that you began to get a steam reaction and you would eat a hole in it. But as far as just a general swelling, I don't remember that. Now we had plenty of the, you know we had plenty of attention to the thing I just talked about, and the same thing in slugs. And that was the reason that all of the uranium slugs, natural or otherwise, they were made in 313. 100% of them went through the steam autoclaves, because they didn't want that to happen in the reactor. But we didn't have a steam autoclave for the long tubes.

MS: Right. How did the tubular elements get started at Savannah River?

SB: Well as we were talking about earlier, you know there was somebody making a study on how can we get more production. You see the one thing that kind of galls some of us old-timers is that, when we went to work there the cold war was raging and we saw our job as making what the Department of Defense said they needed. And we were going to make it, or die trying. That was it. And so one aspect of that is for somebody to sit down and say, how can we make more? You know if they want XKGs of plutonium, or YKGs of tritium, what can we do to get more out of this reactor time? Because that's a critical element. You got X days a year you can run those five reactors. Now what can we do to increase that production? And so somebody said, well here's a way. We can make this tubular thing. We can put more water down it, generate more flux, do all that kind of stuff. And you're going to get more product out in the end. And then it's our job to figure out how to make those fuel elements, the tubular fuel elements, that are required to do that job. So it was all geared to increase production. So that was the incentive to make more product. And I started to say, that's kind of a gall for some of us is that, we never missed, never missed a production requirement, never. Everything that DOE said we need, we made. Now for the last X years of course nothing in the way of making product is even running out there.

MS: Yeah, that's true, yeah. We've talked a lot about the co-extrusion process. Anything you want to add on to that? Like the, where did that raw material come from?

SB: Well in the co-extrusion process we made several products. The first one, and this was the first of the tubular products to make more production in the reactors, I believe it was the Mark 16, and the uranium we used was highly enriched. I don't think the enrichment is classified anymore, but in Oak Ridge, see backing way up the two bombs that were dropped on Japan, one of them DuPont made the product for at Hanford in those old graphite reactors.

MS: The plutonium bomb.

SB: Plutonium bomb. The other was highly enriched uranium made at Oak Ridge. So they had the enrichment facilities there to enrich uranium to get the U-235 up to over 90% instead of 0.7%. So these guys that sat down and said, how can we get more production? Well if we had more 235 in there, we could do it. Yeah, but 235 is going to generate a whole lot more heat. Well, how can we get rid of the heat? Well you've got to go to a tubular element to put more water through it. So that's the signature thing that happened. So we got our uranium, highly enriched uranium, from Oak Ridge. It came in. They made buttons in the reduction bomb, a button that would probably be about 4 kg something like that, broke it up in pieces and shipped it to us. We alloyed it with the aluminum, etc. I've lost the, what was the question?

MS: Oh about the co-extrusion process?

SB: Yeah. And so then we initially made those alloys in a little room up in 313, the uranium aluminum, highly enriched, just boiled in a room. And then we extruded in the 320 press, the lithium aluminum press with different dies and different containers to hold the billets. And so once we did all that we said, hey this works. So then they got busy and built 321. So we moved the process down there, the die casting there, the cladding there, and the core extrusion there. So that was kind of the way things got started. And from there, oh I started to say something else. So that was the enriched uranium. Now a similar thing happened in, I think it was around 1960 or so, they wanted some plutonium aluminum alloy. And we, me really, went over to 235-F, 200 area, and worked on a contained line, glove-box line, in which we alloyed and cast plutonium aluminum, made a billet, shipped it over to 321 and extruded those there. So the plutonium came from 235-F. Then later on as we were, they were trying to make more plutonium-238, which you get from neptunium-237, and that process started out in the early days with solid neptunium oxide slugs. Very inefficient way to do it. So a couple of us said, Hey, why can't we take those cores, I'll design a billet, we'll put it in a billet, and we'll extrude it and make a tube out of it. And everybody liked that so we did that. So that raw material came from 235-F. Plutonium and neptunium came from there. The uranium raw material, enriched, came from Oak Ridge. I think that was the question you asked.

MS: Yeah, right. I know we've talked about this to some degree already, but just to refresh my memory if you would, run through the equipment that was used in the co-extrusion process.

SB: Okay. You had a very large hydraulic extrusion press. And the main parts of that was a ram just like a jack say, great big piston that had bolted on the front end of it a stem they call it. It was finger shaped and had [a mandrel] like this. You got a piece of paper?

MS: I do, yes.

SB: You had this large hydraulic ram and out here you had a, I think it was shaped like this. It was bolted to the front end of this ram. That would push the billet. Now here you had a, I did that poorly, you had a container, hollow container, and you could heat this. So you put a billet, you pulled this back out of the way. A man puts a billet in there and that billet is typically going to be shaped like this. And it's going to be like this. And inside of there, this is a cross-section, inside of there is uranium aluminum core. And you've got a, this is a two-piece ram. Inside of here is another stem that pokes up through here. Now when this comes forward you've got a die sitting here, sort of shaped like this, and right here in the

MS: That's what actually shapes that?

SB: That's what shapes it. So what happens is, this comes, I've got it all out of proportion. This comes and sticks through this opening to form a hole like that.

MS: Okay, right. As it pushes on through it, it creates

SB: Yeah. You put the billet in there and then this part pushes the billet, and this part is already through there. And so you put pressure on it and the only place it can go is through these little, through these areas here.

MS: And this is in building?

SB: Both, 321. But the 320 press is the same except it was an older press and not quite as big and not quite as powerful and so forth.

MS: Alright.

SB: Boy I sure could draw that better if you gave me another chance. But basically you form a donut shaped hole with the mandril on the ram going through the die. Then you force that billet through there.

MS: I should know this and I don't, was that heated?

SB: Yeah. The billet was heated. As I recall we used to heat it up. You heated that in that induction heater that I talked about, which is a copper coil with water pouring through it. So induction heat is extreme, it forms a magnetic field and it's extremely fast on that. Whereas if you put it in an oven, you'd have to wait for hours and hours and hours for it to get uniformly heated. So we used induction heating. Now the cylinder that you put the billet in, it was just heated. It stayed the same temperature all the time. But the billet was the thing that needed to be hot.

MS: What about rib tubes?

SB: Yeah. Well that die, if you look straight on to a die it looks like this. And then your stem goes in there like that to form that. But a rib tube has just got some cut-outs.

MS: Okay, right.

SB: And you still start out with a round billet. But the pressure that just forces some of the aluminum up in these little cut-outs.

MS: Okay, right. So it wasn't like a major…

SB: No.

MS: A major difficult thing.

SB: No. You just had to control the shape of the rib because if you get them too tall or too skinny, or whatever, you could force so much up in there that you'd get some of the core going up in there.

MS: Right, right, yeah. Let's see.

SB: Oh by

MS: Go ahead please, yeah.

SB: This is, I don't know whether this, can you, I was just going to tell you a little aside but I don't know whether you want it.

MS: Go ahead, that's fine. Yeah. We've got plenty of time here.

SB: We got all of our induction heating coils from Ajax in Detroit, I believe. And we got all of our dies, no excuse me, just the opposite. We got our, yeah just the opposite. We got our induction heating coils from a little outfit up in Philadelphia I believe, called Induction Heating Incorporated, something like that. And the guy who ran it we called him up, his name was Hank Roland, and we would call him up and he'd come down and say, yeah I think I can do that. And he'd come down and we'd sit down and show him what we wanted and work with him. And he'd say, okay I got what you need. Let me go back and design it. So he'd go back and design it. And we'd just, you know you pretty much paid him what he asked you to pay because he was the only one that we knew in the world that could do this. But we got the impression that he was just a sort of a technician kind of fellow. And so a week or two later here would come this copper induction coil. You'd hook it up to your furnace and, voila, it works. So we repeated that scene time and time and time again. Well, it wasn't too long after I retired that I read a little article in the news that Hank Roland had donated the most money ever given by an individual to a college. It was a little college in Maryland I believe, which was re-named Roland College. It was something like $100,000,000.00 or $200,000,000.00. So he must have made a lot of coils.

MS: Yeah I think he did pretty well.

SB: But I tell you, boy they were worth it. Whatever he charged they were worth it.

MS: Yeah, right. Wow. I know we've talked about the 305M test pile and the first NTG. Wasn't there a later version of the NTG that came in?

SB: Oh gosh. Well the NTG was from time to time improved. The NTG was powered by some enriched uranium elements in it. And in fact there was a time when we would have to change out elements, depending on what you wanted to run. But then they came up with sort of a universal core. Maybe that's what you're talking about.

MS: It wasn't a drastic change. I think it was like a, I think it was made somewhat smaller and they still called it NTG.

SB: Oh yeah, yeah. I know what you're talking about now. I was, that was beyond me. I didn't participate in that. I think they did that after I left.

MS: Okay. What about the, what kind of involvement in M area and in the Glenn Sebourg's special programs? The transplutonium work that went on at Savannah River? This would have been like in the sixties, and maybe into the early seventies. You mentioned something about it.

SB: Well the plutonium-238 program. We've already talked about it. You make that with neptunium-237. And we did the extrusion of the tubes that contained the neptunium. And then we made, oh plutonium, what were we making? I guess that was a curium program.

MS: Yeah they had the curium.

SB: The curium program was, when I was assigned temporarily which lasted a year or two, to 235 to design and build that line that made the plutonium billets.

MS: Let me stop us here because this tape is about to run out, then I'll flip it over.

End tape side.

SB: For the curium program the billets were made in 235-F in that special line that I worked on. And then the billets were shipped over to 321, and we extruded those tubes to go in the reactors. So that part was there. We did process some plutonium-242 oxide elements at one time, although we did not make the, these were little pellets in a rod. We just processed them. And what other isotopes have we been talking about?

MS: I know they had cobalt 60?

SB: Oh yeah. Yeah we

MS: As a heat source I think.

SB: Yeah, mainly we did testing on those.

MS: Right. And you mentioned the curium programs. The one mark number that I've heard was associated with that was like the Mark 6C, was the driver for the curium program?

SB: That doesn't ring a bell with me. The plutonium aluminum tubes were what we made for that. I don't remember what we called them. I don't remember.

MS: What about the, there was something about slotted septicoils.

SB: Yeah. Now that kind of stuff, the reactor guys did that design and we did some processing of septicoils. But we were not heavily involved.

MS: Okay. What about, and you may not have been involved in this at all, I don't know. The development of the semi-permanent sleeve or the universal sleeve housing?

SB: No we were not. I know what you're talking about, but they bought those basically.

MS: Oh, okay. What about the first computer use in M area?

SB: Oh gosh.

MS: If my information's correct it got that it started in the early seventies or something. I'm not sure what the computers did.

SB: Oh gosh. You know I guess you have to define computer because there were certain instruments or devices that had what I would consider small, hardwire, dedicated computers. But as far as a stand-alone computer system, I would guess 321. We had a system there that, I don't know when the first. Sorry. I had guys that worked on the 321 versions, but I don't remember the earlier, if there were any.

MS: Yeah. I remember some name like Metcom 2 or 3 or something.

SB: I don't know.

MS: What about, I know they worked on this technology for a long time, but as I understand it it was never used, powder metallurgy?

SB: Yeah. Yeah that's true. They started out working on it for fuel tubes. And you'd make a core by pressing powder together and forming a core that would stick together. And we did a lot of that, extruded a lot of it. And frankly I can't remember why that never flew. Now on the other hand, we did use powder in the neptunium. We made neptunium oxide tubes with powder. We started out with small slugs and put a ring of them in a billet, extruded it. So that was, we almost did that by default. We just, instead of sticking them in a can we said, give us some, put them in a billet and we'll try it. You know it wasn't any great scientific study, we just said, hey there's little risk here, let's try it. And it worked and we used it, routinely. But as far as the uranium, I don't think we ever, I know we never had a, we would make some, SRL was deeply involved in the powder process. And they would make some. We would extrude them. They'd send them out to the reactor. But we never used that process.

MS: Right. How did security change over time, at M area? The only reason I mention that is, I think I talked to Mel Sires at one point during an interview I had with him years ago, and he had mentioned that by the eighties, if not before, they had some machine guns on top of the roof in certain buildings and a fence was put around M area. Whereas earlier that had not been the case.

SB: That's true. Now, I wasn't there. I left in the middle of 80, middle of '77. But I know that's true. Wait a minute, let me back up. I left M area in '77, and I worked in 200 area for two years, then I worked up in the main administration area for several years, then went out to F area. And I guess they did do that while I was still there, because if I would have a need to go to the 300 area I would see that fence. But I had no occasion to go, I might have gone back in that building once, but you're right. It would be between '77 and when I retired in '87, but I don't know the exact year. But things kind of went in a cycle. When I first went there in '56 security was quite tight. In fact, one example which may, a sample example, when I went there they still had anti-aircraft gun sites throughout the plant. They were gotten rid of.

MS: Yeah I've heard about that.

SB: But then you had to have the right kind of clearances to get most anywhere, and just everybody couldn't get the clearances. And so there was a lot of, a lot more checking of people and that sort of thing. And then over the years that gradually reduced somewhat. But then the period you're talking about it went back the other way.

MS: Was there anything else that you wanted to talk about as far as M area? Anything, any major thing that I may have missed in trying to direct these questions?

SB: Well I think you asked about all the buildings and all the processes.

MS: could have easily skipped some. But you never know.

SB: In 321 in particular, we made a wide variety of enriched uranium tubes. The one time we went through a deal where they wanted some Californian, was it 252 I guess, ran the high flux charges. That was sort of an exciting period because you'd make those tubes, I think they were mark 18 as I recall, and they'd last only about six days in the reactor, something like that. So you were just working 'round the clock just making so many tubes you couldn't keep up with it hardly. But that was a different period at the time. I guess the main thing is that it was really like all the rest of the plants, metal production builders and did it safely.

MS: When you were doing the stuff like with the cobalt-60 or plutonium-238, curium program or the Californian stuff, during the heyday of those programs did you divide your time like how? Between doing the regular plutonium and tritium of the main mission, and then the special programs. Or is that still classified?

SB: Well the production operation is just one of scheduling. I forget the number, tubes, the number of positions in a reactor, but it's 500 let's say, something like that. Well that extrusion press can turn out more than enough to meet that need. So it's a matter of scheduling. So let's say we're making those, so you've got five reactors and typically only one of them would be on something special. So you've got four reactors that the buildings and three of them are churning out, 3 or 3.5 inch diameter .... ring and tubes, and you've got to keep that going. So you do that, but meanwhile let's say that I'd been assigned out to the 200 area to help with the design and construction and operation of that plutonium facility. So we get that going and we make billets. And then it's a matter of saying, hey we're going to have 50 billets come Monday. When can you extrude them? But basically that part of the scheduling was always left up to the 300 area because the 300 area would be given the schedule for the reactor.

SB: The reactor says, we're going to start this reactor up on June 17th. We have got to have all of your tubes, plutonium tubes, whatever you're going to put in there, we've got to have them by May 4th or whatever. Give us time to do whatever we're going to do to them. So when we got that date of May 4th, and then we're going to schedule that press and all the other operations with the proper amount of people to make those, sandwiched in with all the stuff we're making for the four repeat reactors I'll call them. So the capacity was there, it's just a matter of scheduling. The only time when it really got hairy was when you make a charge and a week later they're ready for another one, you know.

MS: And all that was going on in the late sixties, early seventies?

SB: That's about right.

MS: That must have been a pretty hectic period to be doing all that stuff at the same time.

SB: Oh yeah, yes it was.

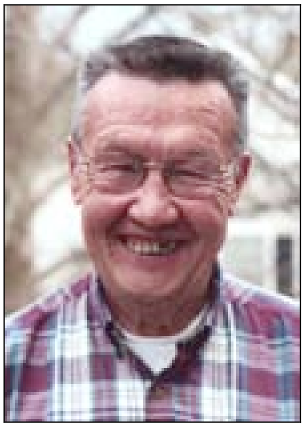
MS: Well that pretty much is all the questions I can think to ask right now.

SB: I have something I want to ask. Don't go home and compare this tape to the other tape will you? And bear in mind I'll soon be 72, so I probably forgot half the things I should have said to you.

MS: That's okay. I went through my notes from a couple years earlier as I was trying to make sure I would hit all the points that I knew of anyway. But that doesn't mean they are all the points that need to be hit. But thank you very much for the, for taking the time. I appreciate it.

SB: You're welcome.

End of tape.



Oral History Interview – Dave Honkonen

A Massachusetts native, Mr. Honkonen got a job with Du Pont after completing his BS in physics at Tufts University. Hired on for the Savannah River Plant, he was first trained at Argonne National Laboratory then sent to Savannah River where he worked in the new laboratory's Reactor Technology group. He was part of the technical support for the startup of R, P and C reactors and later worked with the Experimental Physics group in 777-M and also at the test pile operations in 305-M. He would later supervise the nuclear criticality safety program at SRP.

Interview Transcript

Interviewee: Dave Honkonen

Interviewer: Mark Swanson, New South Associates

Interview Date: January 12, 2005

Mark Swanson: This is the 12th of January, 2005 and this is interview with Dave…

Dave Honkonen: Honkonen.

MS: Honkonen. Okay. Is it is doctor or?

DH: No.

MS: Okay. So Dave Honkonen. And if you would just for the record, give us a little bit of biographical information.

DH: Okay.

MS: And then how you started with the Savannah River Site.

DH: How far do you want me to go back?

MS: As far back as you want to go.

DH: Beg your pardon?

MS: Far back as you want to go.

DH: I was born in Massachusetts and went to college at Tufts University where I got my BS in physics. And directly from there went and joined DuPont and this was in '52. There was no facilities for the new hires at the Savannah River at that time, so we went to Argonne National Laboratory for about a year doing some training and working with the Argonne people, helping them out. Then in April of '53 we came to Savannah River and I started out working with the reactor technology group in our reactor[R]. And that was, we started working before, let's see, it was April, and then the reactor went critical, the first critical was in December. So I was on the technical support group for our start up group and after they got that going I went to P area for their start up. Then from there to C area for their start up. I stayed there for a couple of years afterwards. Then I transferred to 777, the experimental physics group and I forget now how many years I was there, maybe five, something like that. Then I went into the ((inaudible)) area and took over the nuclear criticality safety program at the ((inaudible)). And also, well, first of all I went and took over the technical support for the

305 reactor for the test pile run. And then gradually worked into the criticality safety end of it and then about five or ten years I devoted all my time to the criticality safety area.

MS: Going back to the critical test pile in 305, was it M back then?

DH: 305.

MS: Yeah. When did you first start working there?

DH: It was in; I think it was the late '50s.

MS: Okay. So you were not there at the beginning?

DH: No, I was not there for start up.

MS: Oh, okay.

DH: I don't know if there is anybody left that were, well, Frank Crusi, no, I don't think he was involved with it. He may have been involved with it. But he's dead. He was responsible. They wrote a couple of reports on start up and the initial calibration.

MS: What about, how long did the critical test pile in 305, how long did that last before, wasn't it replaced by the…

DH: Nuclear test gauge. No, they used those continuously until they shut them down.

MS: Oh really?

DH: The NTG was developed later on, probably in the early '60s. But they both ran concurrently. The test pile was used primarily to test the uranium floats and control rods and then we, I think we continued to use that. Yeah, all the uranium metal continued to be tested in there. And we used the nuclear test gauge primarily for the enriched uranium aluminum fill tubes and the control rods and the uranium slugs then you'd be tested in the test pile.

MS: Okay. So you mentioned the NTG, the first one got established in like the early '60s.

DH: Yeah.

MS: And didn't they have another, a newer NTG that…

DH: Well yeah. The original NTG sprung leaks. There was a galvanic corrosion set in and between the stainless steel and the aluminum. But the tank was an aluminum tank and so it started leaking and they replaced it and the modified the design a little bit and Norm Baumann was the engineer that worked on it and designed the new nuclear test gauge. But it was essentially the same, you know, just a little different test hole and maybe a little different pitch on the fuel slough valve.

MS: When did that happen?

DH: Dates are hard for me. I would say in the early '70s. There are a lot of reports on those, I don't know if they're still available.

MS: Yeah, I think that's probably where I saw those. The first mention of them was probably in the archives where they talk about it. And when we were doing that history… a lot of that stuff we would run into and we wouldn't know exactly what it was. But then that's why, we're going to figure out, or talk to people to find out what it did and things like that.

DH: Yeah.

MS: But I have heard, I may have gotten this from Mary Beth that you had some contribution with borated concrete.

DH: Yeah. Yeah.

MS: Was that used in the test pile?

DH: No. No. It was purely a nuclear safety item. The enriched uranium aluminum fuel tubes, if you submerged five of them in water, you could have a nuclear accident just by simply submerging them in water. Or if you had them stored in open racks and you turn a sprinkler on them they could go critical, it would be enough moderation on the sprinkler system. So that was a big concern because that's the first thing you would do is spray water on a fire.

MS: Right.

DH: And you can tell the fire department don't do it, but…

MS: Yeah. Right. Exactly.

DH: It goes against their basic training. So, what we did to assure that that couldn't happen and to provide a significant storage area, we made concrete slabs with a large amount of boron in them and in effect what we did is we said all right, the concrete is going to provide the moderation of neutrons. But we put enough boron in there so that there's no way it could go critical because the boron would absorb the neutrons. So we made these slabs, and they were 16 feet long and six feet wide and about eight inches tall and they had tubes running through them for the storage of the fuel elements. And we stacked those up to, I don't know, 12 to 16 high, something like that. So we had a very large storage area and they extended all the way across the south end of the 321-M building. And around the corner too.

MS: This was primarily for the 321 building, right?

DH: Yeah. It was the 321 building.

MS: Okay. Was that later, was that borated concrete, was that used in other areas as well?

DH: After we built them in the 300 area, the 100 areas used them in all the assembly areas. So, that was about the only place that they used neutron absorbers.

MS: Okay. When was this done, this borated concrete?

DH: You know, I've got a, let me go upstairs. I think I may have…

MS: Let me turn this off real quick.

DH: Yeah, yeah.

MS: Oh, okay.

DH: My resume'. I left reactor technology in 1955 and went to the experimental physic group. And I stayed there three years to 1958. In 1958 I went into technical support of the 305 test pile. And then they changed organizations.

MS: Yeah. As they often do.

DH: Yeah. So I was, we were originally a part of engineering and systems, and then they realized that test pile and nuclear test gauge were actually reactors, so we really belonged in reactor technology. So that…okay. All right. Let's look at what else I've got in here. Nothing in there. I kept a…

MS: Those look like reports.

DH: Beg your pardon?

MS: Look like reports.

DH: Yeah. Yeah. This one…there's the original test pile. I thought it might have some dates in here. Oh. I guess that's in an individual section. Okay. Yeah, I think that's the report on the test pile in 1956, I mean on the nuclear test gauge 1956, ((inaudible)). Now here's a quote on a borated concrete slab at the beginning of 1979.

MS: Oh, okay. Right.

DH: That's what they individually would look like.

MS: Uh-huh. Right. So you could actually just stack them.

DH: Yeah. Yeah. That's what they were. They were stacked three high.

MS: So then if the sprinkler system went off it wouldn't affect…

DH: No. No. No.

MS: The tubes or anything.

DH: No. Even if the concrete absorbed more water it wouldn't make any difference.

MS: Right.

DH: I thought there might be some more dates in here but I don't know.

MS: If you want to get it I can turn this back off and you can…

DH: Okay. Yeah.

MS: Well, as far as the other dates go I can always get it from somewhere else.

DH: Yeah. Yeah. I'm sure there are other…

MS: The major thing. But when did you leave work at Savannah?

DH: I left in '94.

MS: Okay, so that's after…

DH: After Westinghouse came.

MS: Right.

DH: I worked with Westinghouse for about four years.

MS: Okay. What were you doing for Westinghouse?

DH: Same thing. I was a nuclear safety ((inaudible)).

MS: Where were you in the 300 area?

DH: Well, we moved around. We started out in the 305 building. And then, let's see, we moved from there to 320 and I don't think I was in 321 at all. I spent most of my time in the 320-M building. In the lab section. They had a lot of office space in there.

MS: Okay.

DH: And towards the end the new building, it was completely different, complete administrative building ((inaudible)).

MS: Okay.

DH: Right next to it. I was close. It was close to 313.

MS: Okay. So in other words it's closer to the administration area, right?

DH: Yeah.

MS: Okay. All right. What were you doing when you were working with ((inaudible))?

DH: What time?

MS: Let's say when you were working for Health Physics in general.

DH: No, I wasn't work for Health Physics.

MS: Oh, I'm sorry. But for nuclear safety.

DH: Nuclear safety. We were establishing the criticality limits for handling all the fuel and the enriched uranium and all the byproducts.

MS: So it was all working with the nuclear test pile and then the NTG.

DH: Okay. That was strictly nuclear safety.

MS: Okay.

DH: On the nuclear safety end we, any time we had a new piece of equipment come in we'd have to evaluate it for nuclear safety and run calculations to determine what the safety limits are for the equipment and any part of an operation. One of the most hazardous problems was the vines. We machined the uranium aluminum elements before we extruded them into two, and that created a lot of fine material. And it only took about maybe a kilogram of those vines in water to cause a nuclear accident, so you had to be very careful with those. And the filters, if you dump one of the filters into a bucket of water, it would go critical, those big Hepa filters. So that was the primary thing on the nuclear safety end of it.

When I was working on the 305 test pile, we had to establish new, we had to calibrate the test pile and the NTG whenever we had a new fuel element that was developed and produced. So we had to calibrate the pile and set up the calibration curves to determine the reading versus the uranium content on the lithium, the lithium six content. And we did do a complete recalibration of the test pile. It was a pretty extensive operation.

MS: What exactly did that entail when you had to recalibrate it?

DH: Well, we actually did some neutron profiles through the pile to determine where the best location to test each element. And we did things to measure the excess reactivity of the pile to see if it had changed over the years and to check the calibration of the control systems, the control rods, the vine rod, and of course the control rod. Then we installed, no I guess that was the original one. So that was the program to recalibrate it.

MS: Uh-huh. And again, I know you don't want to hear this, but when was that roughly?

DH: That was probably in the early '60s. And of course then we had to recalibrate the nuclear test gauge when the new nuclear test gauge came in. And went through the same process for the NTG. You've got to be careful about what you tested in there, but if you put too much uranium in a vial and you test ((inaudible)) it can run away on you, so.

MS: Right. What was the, I know it was the critical test pile, I know this in a certain way, but in a way I don't. When I say critical test pile what exactly does that mean?

DH: That means the pile is not critical at the point where it's just at an equilibrium and if you increase the reactor and you pull the little control rod out the pile levels start to rise. If you put a little more in, more control rod in, it starts to drop.

MS: So it's right at the threshold.

DH: That's why you call it critical; it's at a critical position.

MS: It's like a threshold of taking off I guess.

DH: Yeah. Yeah. Yeah. That's how we make all the measurements. We put some target material in there like a control rod and you check the position of the reactor controls against what they were without any control, any test piece in there. And that's calibrated to determine how much the reactivity of that piece is.

MS: How big was that test pile?

DH: It was about 15 -foot cubed. And it had a monstrous shield. You know, in those days they really didn't have a lot of feel for how things are, and they overdid a lot of things. And when they tore it down, they only tore down one wall because it was so massive and [had] so [much] concrete, reinforced concrete. They had a terrible time getting that one wall down. And the three other walls still stand today.

MS: Oh, okay. They decided to leave those then, right?

DH: Yeah.

MS: Oh, okay. Were there any differences at all between the test pile in 305 and what they had at like Hanford?

DH: They had a 305 test pile at Hanford.

MS: They did? Oh, okay.

DH: Yeah. And the one here is almost identical to it.

MS: Do they go by the same number? Was it 305 or?

DH: Yes it did. Yeah. And the only difference between the one at Hanford, the only significant difference and the one at Savannah River is the one at Savannah River had a helium atmosphere. It had an enclosed shell around it to keep it under a helium atmosphere because if you left it open to the air, then the amount of nitrogen in the air and in the pile would vary and nitrogen developed neutrons and it affects the critical state.

MS: Oh okay. Uh-huh. Right.

DH: So putting a helium atmosphere on it, then you didn't have to make a correction for the atmospheric pressure.

MS: So they didn't have that at Hanford?

DH: No.

MS: Okay, so that was just on SRSs.

DH: Yeah. But it was expensive because we used a good fraction of the country's helium supply on that.

MS: Wow. Yeah, I'd heard that in the heyday of like AEC Construction in the mid '50s for example that a sizeable percentage of the concrete and steel and everything went to nuclear facilities.

DH: Yeah. Yeah.

MS: And it was like 10 or 15% or something.

DH: A lot of the rare elements were here too.

MS: Yeah. Right. Did you do any work with the special programs they had in the '60s with Glen Seaborg in particular, who is sponsoring?

DH: We did work on when they were producing the plutonium elements to ((inaudible)) higher isotopes.

MS: Right. Americium and curium and all that.

DH: Yeah. We, what we did is the 200 area fabricated the plutonium aluminum billets and then they were shipped to.. I don't know if they, yeah, I think they encased them in aluminum, sealed in aluminum and then 300 area screwed it on to the fuel tubes. So I established the criticality goals for the 200 area process where they made the plutonium aluminum and the billet and also they handle them in the 300 area products.

MS: Oh, okay. Right. ((Inaudible)).

DH: We got in on that. It seems like there was another program that…we did irradiate thorium at one time. And of course we made the thorium out of elements in the 300 area, not thorium but metallic thorium slugs. We irradiate those.

MS: See, I've read that they did a lot of work, or they thought about doing a lot of work with thorium in the very early days.

DH: Yeah. Oh yeah.

MS: But they didn't do it later on.

DH: No. No. That pretty well died.

MS: What were they hoping to make with the thorium?

DH: There's a thistle isotope with thorium, maybe it's 233. I'm not sure. But I think that was the goal.

MS: Oh, okay so to make another thistle material they actually put it to reactors.

DH: Yeah.

MS: Yeah. What about, I guess if you were working in the 300 area you were there sort of at the beginning where they were doing the fuel and target tubes.

DH: Yeah.

MS: Versus the slugs.

DH: Yeah.

MS: How big a problem was that to have to switch over?

DH: Well, they had to build a new building. That was a whole new process.

MS: That was 321, right?

DH: Yeah. They built a new building and a new process, so. That came on fairly early.

MS: Uh-huh. Yeah, that was done like in the '50s wasn't it?

DH: Yeah, I think so.

MS: Now the technology they used at Hanford, was that purely slugs and then they…

DH: Yeah. They didn't have any enriched uranium reactors. They may have made tritium by some other process, but they were, all the production reactors were natural uranium and graphite and then they made, produced the plutonium ((inaudible)). The early Hanford reactors were all plutonium. They made, they built several more reactors, but they were mostly for experimental purposes.

MS: In Hanford's day, I mean the early days during World War II for example, they didn't care about tritium.

DH: No. That came on several…

MS: That was only after the hydrogen bomb.

DH: Yeah. Yeah.

MS: I still find it hard to believe that you can just have, you can just add tritium gas to the whole equation of an atomic bomb and you can make it a hydrogen bomb and make it infinitely more powerful.

DH: That has a lot of energy. And they had to concentrate it. Well, they still do concentrate it very, very highly under unbelievable pressures so they get…

MS: Is that a part of the little reservoirs that they did in the tritium?

DH: Yes. Yeah, the pits. That's the containers that they put the tritium in.

MS: Now what's the name of it?

DH: Beg your pardon?

MS: What was the name of it?

DH: They call them pits.

MS: Oh okay. Yeah, I've heard that, one word that I've heard anyway is like those little reservoirs that they used later on. And actually, those were actually components that went directly to the weapon and that…

DH: Yeah.

MS: And like Bebbington said, that was the closest that Savannah River Site actually came to being what all the locals called it, the bomb plant.

DH: Right. Yeah. Yeah. Yeah. And that was really the highest security agent facility on the site, still is.

MS: Yeah. That's true actually. You still have to go through, you have to remember your PIN number all that kind of stuff and be cleared to go into tritium.

DH: As a matter of fact, I was asked to do a nuclear safety evaluation of that building, and I did and I wrote up my report and I turned it in. A month later I said where's my report? So I called them up and they said you don't have clearance to get that report. Can you believe that?

MS: That just goes to show…

DH: Soon it was out of date.

MS: Yeah right. You had clearance to write it, but…Yeah, that's the way it goes.

DH: Bureaucracy.

MS: Yeah right. In the work that you did what were the major changes that you saw at Savannah River Plant over the years? And you can take that any way you want to, whether it's just in the kind of work that was done or just in the nature of the work environment.

DH: Well, the work environment of course changed drastically when we first went, I mean I had a BS in physics, had taken two nuclear courses at Tufts. There weren't many given in the early '50s. And most of my training came from on the job training. I had a great mentor, Hugh Clark, Dr. Hugh Clark. And that's where I picked up the majority of my nuclear criticality safety knowledge from him.

MS: Was he here at the Savannah River Site?

DH: Yeah. Yeah. Yeah.

MS: Okay.

DH: He was a great guy. He developed computer codes early on, you know, when they had to punch cards and all that stuff.

MS: Oh okay. You had to put them in right.

DH: And I remember I did one problem and it took 3,000 punch cards to do the problem. So that was a, that was a big change going, getting more advanced and better computer codes. Oh yeah, after, you know, the 777, the PDP test pile was built to determine nuclear characteristics of the reactor fuel lattice that was going into there and it was all done experimentally. I mean we'd go in and stack thin gold foils through them, drill a hole in a few of them and stack those in there and then irradiate it and then take them out and count them and plot the flux profiles through the fuel assemblies and then it wasn't many years after that that that became no longer necessary. They could calculate the critical configurations very accurately. Like I said, computer codes were so accurate and it took a very powerful computer to do that. And follow 30,000 neutrons through a lattice and follow each interaction each neutron has as it works its way through the lattice and finally absorbed. That's a lot of calculations. And in so doing I now can predict very accurately with the, what the characteristics of any new lattice is going to be. That's one of the big changes I saw.

I started out when I was at Argonne Laboratories working with a guy; he was writing a report comparing the Hanford reactors and the Savannah River reactors. And all day long I sat punching ((inaudible)). So I remember those days. And also, I don't know if it was because of the fact, but everybody felt they were on the breaking edge of technology and all in those days. And I really enjoyed going to work. I really enjoyed going to work. I mean it was challenging, and the DOE wasn't there on top of you micromanaging everything. It was a great place to work. And then when all the anti-nuclear sentiment broke out in the country and then DOE felt they needed more supervision and more oversight, things got terrible and then they finally shut down the reactors. And the last three or four years I was there it was not very good because all we were doing is writing reports and there was no… I couldn't get my hands dirty anymore and I enjoyed that. In earlier years we could do almost any kind of experiment that you wanted to do as long as it was safe. That changed very drastically. And it was more of a family thing, even the DuPont Company in general. I'd only been working about four years and I developed very severe stomach ulcers and I had to have my stomach dropped out and DuPont carried me on the rolls, full pay for four months. I don't know if that would happen today.

MS: Yeah, that sounds pretty rare.

DH: So it was a very good atmosphere to work in. Everybody enjoyed it. And from the standpoint of nuclear safety, the same is true. In the early days they had to run experiments to determine what the reactivity of any assembly would be and how ((inaudible)) that reactor would be.

MS: Uh-huh. They can almost do the calculations and just forego the ((inaudible)).

DH: Yes. Absolutely. You always throw a little good margin of safety on that just because you don't know if those conditions are going to change at all.

MS: Yeah. I wonder nowadays if they were doing a project like this they probably wouldn't even need to have things like the CMX and TNX.

DH: Or the test pile or the NTG.

MS: Oh yeah, and right, all that stuff was like…

DH: Well, I guess you still need something to test the elements. You'd still need a, you'd still need to run nuclear tests on the material you produce to try to determine what the initial critical reactor is going to be. You can calculate pretty accurate.

MS: Did you ever have to go to CMX, TNX in that area?

DH: No, I never had much occasion to go down there.

MS: What about the laboratory?

DH: Oh yeah. Well, I worked, as I say, I worked very closely with Hugh Clark. And he was in the lab. And whenever I got stumped I'd always go over and talk to Hugh. Great guy.

MS: Is there anything else about the critical test pile at 305 that I have failed to ask that might be good to put on record?

DH: Well, the original nuclear test gauge had a radium beryllium neutron source. It had five grams of radium in it, which at that time was a good portion of the whole supply.

MS: Was that the test pile or the…

DH: No, the nuclear test gauge.

MS: Okay. Nuclear test gauge. Okay. All right. Yeah.

DH: And they replaced it with, what did they replace it with?

MS: Yeah, I think I remember hearing about that, but it's been a while since I did any reading on it.

DH: And you handle it on the end of a 20-foot long rod.

MS: And that was to replace the radium, right?

DH: Yeah.

MS: How many ports or openings did the original test pile have or do you remember?

DH: Oh, it said it had, let's see, there was two shot tubes where they had boreated steel ball bearings that acted as a last safety surface. So they came out and took two of those and it had one vertical safety rod that we could drop in. And it had a horizontal safety rod that was spring loaded. And then it had a line control rod and a cross control rod. That was the control system. And then it had I think two major test ports horizontal on the, towards the center of the pile. And then it had, I'm not sure, maybe four to six quarts ((inaudible)) on the outer fringes of the pile because the test pile had such a low excess reactivity. If you took a reactor control rod and put it in the center and you couldn't bring it to power it would shut it down. So they had to test those on other fringes of the test pile. And they had these small holes on the outside of the fringes. I'm not sure exactly how many of them were there. But we generally only used one ((inaudible)) which one was best suited for the particular control rods we were running and all the control rods were essentially the same. We didn't ever test the cadmium rods because they were such strong neutron absorbers. So when you tested the lithium aluminum.

MS: Okay. Uh-huh. Right. Yeah. Well that's all I can think of to ask right now.

DH: Okay.

MS: And that's probably more of a function of my not knowing enough questions to ask. But if I think of something else to ask though if you don't mind I might give you a call back.

DH: Oh that's quite all right.

MS: And I can't think of any other questions that might be able to get some other aspect of in particular the test pile in 305. You don't know when that was built because that was done long before you got here.

DH: No. It went critical of course before the pile reactor did, so that was probably '51.

MS: Yeah, I think Bebbington made some mention of that in his book.

DH: That was the first critical facility.

MS: The first thing, the first critical facility at Savannah River Site, and he gave a date for it. And I think, I could be wrong on this, but I think it was December of '51.

DH: That's, that's pretty close to it I think.

MS: Okay. Yeah. So that meant that 305 had to be built really early on.

DH: Yeah.

MS: For it to hold that. What was the rough order of construction of buildings at Savannah River Site? I mean I know that, I mean clearly they got CMX was one of the first things they built down there, the river pump houses. 305 had to be one of the first sites that they built there.

DH: Yeah. And obviously they had to have 313 built to get the fuel for the reactor.

MS: Right. Yeah.

DH: So I'm sure there was a lot of that stuff going on.

MS: Generally the reactors went in first and then the separations area.

DH: Yeah. Well, first the fuel fabrication and the testing facilities and all that.

MS: Then the reactors, then the separations and within the separations I think F area basically was going first and then there was lots of overlap, but still you've got F area first then H area.

DH: Yeah. ((Inaudible)) heavy water facility…

MS: That happened fairly early, right. It looked like a lot of facilities on the river were done first.

DH: Yeah. And there was a lot of those that were going on concurrently.

MS: Right. Exactly. There was a lot of overlap there and only one ((inaudible)). And of course the administration building.

DH: Yeah. You've got to have that first.

MS: Yeah, that's true. Got to have that always, yeah.

DH: Well, as I say, when we came down here April of '52, there was no, still no office space for us. And we were, they set up our office in our reactor building in the contaminated tool room because they were…

End of tape side.

MS: How about, there was another question I was going to ask. It'll come to me in a minute, I can't think of it right off the bat. But it had to do with the early days in particular. You didn't have any dealings with Ruth Patrick did you? She was the one that was doing that biological study.

DH: No. No.

MS: I know she was working along the river primarily back in the early days.

DH: Yeah. They didn't worry much about anything but the river in the early days. It was standard practice to dump all your waste into a filling basin, you know.

MS: Right. Uh-huh. Yeah.

DH: That was standard industrial practice in those days.

MS: Yeah. Uh-huh. Right. When did they stop doing that at Savannah River Site?

DH: Well, you know they continued that into the '80s. That was just standard industrial practice. And of course from a nuclear safety standpoint we've got to worry about that too because a lot of the waste went out there in the settling basin. So we would monitor what was going out and the accumulations that we were having.

MS: Right. What about there was mention of Clarks Hill Dam was like one of the first dams at the Savannah River upstream from Savannah River Plant.

DH: Do you know when that went in?

MS: It was almost…

DH: It was close to when we came down.

MS: Yeah, it was very close. And that was one of the things they had to worry about when they did CMX - was what effect the dam was going to have on the river temperature and river water quality, that kind of thing.

DH: Yeah. When I was doing an overall safety evaluation of the 300 area, I had to consider if the dam failed and Clark Hill would have flooded the 300 area and caused a nuclear accident. But we were too high for that.

MS: Oh, okay. Right. I'm sure that F and H would be too high for that.

DH: Yeah.

MS: They are on the bluff. Well, that's all the questions I can think to ask.

DH: Well all right.

MS: One more thing. This may be not terribly significant, but what was a nickel gauge?

DH: A what?

MS: A nickel gauge?

DH: A nickel gauge.

MS: Supposedly it was, it measured nickel plate thickness.

DH: Yeah. Yeah. Yeah. It measured the thickness of nickel. What they did is they coated, is that nickel? No, it wasn't, it was an ((inaudible)) aluminum silicon when they coated the uranium ((inaudible)).

MS: Was that like a lock or something?

DH: It was a molten vat of aluminum nickel. And I think they talked about one of those, well all right. You're right. It was. Why did they call it nickel? Nickel plate, yeah. Here it is here.

MS: Oh, okay.

DH: It's nickel plate aluminum cores.

MS: Oh, okay.

DH: Okay. I guess they nickel plated them and then when they canned them they submerged everything in an aluminum silicon vat and inserted the uranium slug into the can after the slug had been nickel plated.

MS: Oh, okay. Okay.

DH: So that's what it was, yeah.

MS: Okay.

DH: Nickel gauge, yeah, there it is right there, nickel gauge.

MS: Oh, okay. That's right.

DH: Yeah.

MS: Yeah, I think it may have been that same report there that somebody was talking about a hall device, hall like somebody's name, h-a-l-l.

DH: Yeah. Yeah. Probably. This was a paper that had certain non-destructive testing, described several non-destructive testing equipment and this is how the nuclear test gauge got in there.

MS: Okay. I'm sorry. I had to write that stuff down. If I don't write it down I'll forget it later.

DH: All right.

MS: I can't think of anything else to ask at this point.

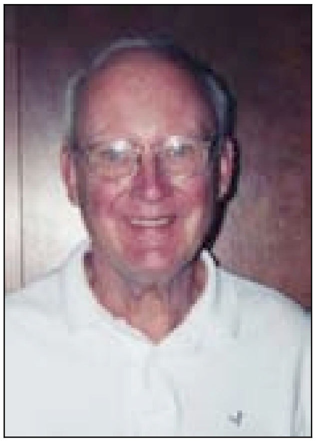
DH: Okay.

MS: If you don't mind I might give you a call back if there's some other material.

DH: Okay. Glad to help. So, when do you expect you're going to have something published?

MS: Let's see, I don't know. I can go ahead and turn this…

End of tape.



Oral History Interview – Charlie Mettlen

Mr. Mettlen worked at SRP's M Area from 1957 through his retirement in 1991. He started in 320-M and worked his way up through the ranks. By 1968, he was a Senior Supervisor for operations in 313-M and ten years later; he served as Area Superintendent for Inspection and Control for the Raw Materials Department. In 1991, the year he retired, he held the position of Operations Manager for the Raw Materials Department.

Interview Transcript

Interviewee: Charlie Mettlen

Interviewer: Mark Swanson, New South Associates

Interview Date: June 13, 2003

Mark Swanson: If you would, state your name please.

Charlie Mettlen: Charlie Mettlen.

MS: Okay. And what was your position at Savannah River?

CM: When I retired I was I think the operations manager 300 Area, Raw Material Department.

MS: How long were you employed at Savannah River?

CM: Since late '54 through '91.

MS: Okay. What about when you first started out at Savannah River, what did you work in?

CM: I was hired to work in SRL at the time. And when the 300 area construction was well underway, in fact it was done. They were expanding and going into the tube business, reactor fuel tubes. I moved, since I'd been working on that in SRL. I moved to 300 area then, and that's like probably '57.

MS: Where did you work when you worked in the M area? Was there any particular building that you specialized in?

CM: I started out 320 building, 320-M. Spent a little time in 313, but not long, primarily 321-M.

MS: And the next series of questions we just want to know basically what went on in the different buildings in M area. And so just starting out with building 313, what were the original functions and processes used in 313?

CM: It was a canning process of uranium and aluminum cans done in a series of molten metal pots that was best described, I would say, right out of the middle ages. It was hair-raising. How those guys were able to do it, I don't know. But that disappeared, I can't give you a year, but they moved to a hot die sizing business later in the game which was very good. Automated. And that was[for] instance where the uranium core was plated and put in the can, put through a die pressing operation. Worked good. Everything, early on failures in autoclaves in the area were pretty high. As they should be. If there's a weakness in the slug, fail it. But that improved considerably. It got better and better, and by the time they got to the hot die sizing business, failure was way down.

MS: Okay. What about the original functions or processes in building 320?

CM: 320, that early in the game, the control rods for reactors. Moved to tube fabrication primarily because 321 was being built. 320 had some operations they could help with, even though a major part of the business took place over in the lab, 773. It was, believe me, hair-raising. And they ended up finally casting lithium aluminum alloys for targets in the reactor. And canning them, and well actually, late in the game, final product was a billet which is a combination of aluminum housing inside and out, about so long, evacuated and extruded in 321 into a tube, varieties of tubes.

MS: Okay, right. The next question was going to be about 321, so that's[handled], what about 305?

CM: 305 was a test reactor. Looked at content of fuel. I don't think the target went, no I don't remember the targets ever going down there, no lithium that is. But the, well I might also back up a little bit. You mentioned 320. When business was slow as far as reactor demands, DOE or somebody would come up with for instance, encapsulation or canning of anything you can think of and ……….. Salt, pepper, sugar, tomatoes, I don't know. We canned and supplied the reactor with all kinds of things. But some of the things we didn't understand. It was easy. It was different.

MS: Right. What about any other M area building besides the major ones, which were 313, 320, 321? They had like 322.

CM: That was the metallurgical laboratory. Did the structural evaluation of just about everything made in the area, from slugs in 313, targets in 320 and the tubes in 321.

MS: Okay. What about some of the buildings like 315?

CM: 315 I believe was

MS: I've heard it was like storage or something.

CM: It was kind of an after-thought. Thank goodness we got it because we stored everything there that was going to be used in pretty much, it was a warehouse for everything we were going to use in any of the buildings. Aluminum and all that stuff.

MS: Right. What changes were made to the 313 building? Let's say the processes in the 313 building, over time. Let's say from the 1950s to the 1980s.

CM: Oh boy. Oh boy. Since I was not there when they started changing things, I know we ended up with hot die sizing. Alright let's go from the first manual operations of canning. Okay. Whew. That's hair-raising. Anyway, I guess we had some furnaces put in where we could put a slug in and squeeze it. And finally we ended up with die sizing I guess was the last product that went through there. Again everything went through one press. All of them automated. And that's about it really. The three; canning, hot press, hot die sizing. That's about it.

MS: Okay. What changes were made to building 320?

CM: I'm going to talk equipment now. Early in the game had fairly, well it wasn't, okay we're talking early fifties. The furnace for the melting of the lithium aluminum alloy was made, was early in the game. We up-graded that thing and improved that operation considerably. Actually it meant building a new furnace. And finally we were actually able to do away, this was all under vacuum because that seemed to be the thing to do. And finally we discovered it didn't have to be under vacuum. And the vacuum part was the biggest pain in the whole thing. So same furnace doing the same thing, but it got more practical. Let's put it that way.

MS: Why did they think they had to have a vacuum?

CM: I think way back, early days, they, I can't answer, they thought, somebody thought that when you're going to work with, it wasn't just the aluminum because good Lord .... had been melting aluminum for Alcoa for years and years and years not in a vacuum. But I guess the addition maybe of the, they were unsure as to how much lithium you were going to lose under the temperature and so forth if it wasn't contained.

MS: Is that because lithium is such a light metal?

CM: Yeah. And what we ended up doing, once some of the folks got smart enough to figure out, okay let's run without vacuum and see what effect it has on what we charge as far as content goes. And pretty soon we got a .... put on the lithium we added, we're out in the air now. We were able to control content that way. We were working with really low contents of lithium in the thing, maybe 1%, 2%, something like that, very small.

MS: Okay. What about changes made in building 321?

CM: As far as the casting business went, probably the only, I don't know. These were not major changes. We just got better at enclosures on the furnaces and evacuation of it. Not vacuum furnace, but just air movement, controlling the air flow. Same thing applies up-stream, billet assembly. Maybe we changed size and shape, but the same basic business. Out-gassing. I'll tell you a story about out-gassing in a minute. Out-gassing was where we. Each billet would be ..... in diameter, had an aluminum tube attached we'd hood up to a vacuum system, pump it down. I don't know how many hours. I don't remember how many hours we pumped. Then we pinched it off and took it to the press within X amount of time and extruded it into a tube. We would periodically get requests from separations through 703 to get into some business other than uranium aluminum. We actually got into some business of some pretty hot stuff coming out of separation. And that was the nearest thing we had to a major problem. The alloy, I don't remember what it was, it was one of the things they'd separated. It had been irradiated and separated out there, made into a, they assembled the billets, came up, we out-gassed. And one batch we got had something in it that wasn't supposed to be there. And we got a reaction that, I'd best describe it this way; the temperature guage on the furnace pegged, went clear over. And alarms went off everywhere and this kind of thing. That's the only real problem we had. That was kind of thrilling at the time. Nobody got hurt, nothing like that. But it was terrifying. And then they finally figured out something got hung in the iron or something in the alloy.

MS: When was that? Do you remember?

CM: I lose track of time I'm afraid. It had to be in the seventies I think, but I couldn't say when. I'm sure it never got, we investigated the hell out of it, I know that. The up-grading equipment, the major piece of equipment in the building was the extrusion press. And other than maybe improving our design for dyes and etc. like that, because we were changing shapes all the time as far as what we extruded, that's not a major change, that was a tooling change. Down-stream from that, fluoroscope same thing. .... No real, other than just minor improvements as we discovered them as we were trying to operate the stuff, that's all. No major equipment changes.

MS: Okay. What about building 305? Any changes from the fifties to the eighties?

CM: Not that I'm aware of. Nope.

MS: What about the, like NTG?

CM: Well, the NTG, I'm trying to remember how it started and how it finished. Whether it was up, it probably, I don't know. It could have been up-graded. I just don't know. I should, but I don't.

MS: Yeah. What about development of like fuel elements? Like the whole process from slugs to hollow slugs, to large diameter tubes?

CM: Size-wise, or?

MS: Yeah, what part of that were you familiar with? Or was that process already

CM: The starting part, slug, was maybe an inch diameter. Solid piece. Didn't really have any contact with that. That was in 313. By the time they had moved to a hollow uranium piece, clad in the can, I was in 321 or 320. 321, 320 were kind of interchangeable. Many things that went on here were moved there for part of the operation. Now the tube, fuel and target tube design changes, which came periodically pretty much based upon demand for be it tritium from the lithium, or I guess that was probably the major factor and that would be, we would respond to design changes in tube from what do you finish with. Blossom that back to, what do you have to go in the extrusion press with to get that tube. So we would have some developmental work. But we made so many different sizes and shapes over the years that we got a little smarter. It usually didn't take us too long to do some funny things.

MS: Right. What about, you mentioned briefly like the hot press bonding and hot die size bonding? How did that whole thing develop between let's say aluminum silicone dip bonding all the way through? That was the original process right? Where they used the tongs and dipped it in.

CM: I only spent a very, very short time in 313, I remember those offices, because 321 wasn't built yet, or was being built. But it was, I don't know the steps. I know they had to do something because that was beyond belief there. That's my opinion. It worked. I think it was a technology that came from Hanford. .... operated that thing up there.

MS: That's what I've heard. A lot of the original technology did come from Hanford, like the original dip bonding that they did in building 313. For that matter, the original test pile in 305, that was Hanford technology. Graphite, air cooled.

CM: Yes, yes. I'm not familiar at all with what was next in line. Hot press I guess before dye sizing.

MS: Yeah, as I understand the process was like the aluminum silicone dip bonding, and then hot press bonding, and then hot die size bonding.

CM: Right.

MS: What was the difference between the last two?

CM: The hot press was a case whereby you would have, this is one I'm not real familiar with. I know you had a bigger uranium slug, and it would go into an impact aluminum can. You got an aluminum cap on top of the slug in the can. But I don't know how they got it to bond. They almost had to, see it's hot press though. I don't know where the, I remember seeing a series of furnaces, but I don't know what went on there. I really don't. Now the last one, I was in the building for.

MS: The hot die size bonding.

CM: Hot die size. And that was a press that literally took uranium core that had been plated with, I'm pretty sure it was, what the hell I don't know what we plated it with. I'm getting confused now with 320. Anyway it was plated, let's put it that way. And it was loaded into a can. And each and every assembly, can, slug, cap went through a press which sized it. And then you had to cut off the excess aluminum at the top and weld the top, weld it in place. It was pretty wild, but it worked. It was fairly simple once you got a hold of it. 313 was a unique place as far as operations in the 300 area went. It was, I guess it was because it was a lot harder to handle some of these hunks of uranium that might weight 16, 18 pounds. Whereas the other processes didn't have anything like that at all. Weight-wise, just plain physical. Let alone numbers, because they'd give you thousands of the things.

MS: Yeah. What about the, was there any like differences that had to be maintained between the fuel targets and the tube? I'm sorry the fuel tubes and the target tubes. I mean since they were, did they have to be stored separately? Or was that a consideration that you really had to worry about?

CM: It wasn't a real consideration. I think that we had the fuel, we did. We had the fuel tubes, once they'd been completed, fabricated, machined, etc., etc., ready to go into an assembly of some kind, in 321. Target tubes were in 320 for a long time. Not because they had to be, but they didn't want to take up room with them in the, call it a honeycomb that you would shove the tubes in because they're, unto themselves you didn't want to bunch them up or anything. You don't know what might happen. So I think the target left, then when they were preparing an assembly for reactors we would have to do some, the computer would match what kind of content of target you had to put with whatever fuel, and we would assemble in 321. But if we stored anything in 321 it was short-term, we were going to use it tomorrow. So why take it to another building and bring it back? They stuck it in a hole there temporarily. We did that, but that was more ease.

MS: What about, were the any marks that were generated or created in M area that were particularly memorable? Like when they first got going.

CM: I don't know, let's see. I have to think on this.

MS: I know for example, they had that Mark 3 which was like a fuel plate. This was like in the early to middle fifties.

CM: See that was fabricated in SRL. And we really didn't get, as far as the .... is concerned we didn't have anything to do with them, other than being aware they were processing those. It never got off the ground.

MS: Yeah I think that's what everybody says. They said that they, I think it was like one of the first things they created beyond a slug. I mean they wanted to see what the possibilities were. It didn't really work out and they finally went with tubes. Were there any like, in the tube creation were there any particular marks that were difficult? Or was it pretty much the process was fairly standard?

CM: Well, let's see. Of course each and, we would change shapes and contents, not regularly but frequently depending upon, and as the feed from Oak Ridge, enriched uranium 235 content, which was being used up in the reactors, was coming down. Therefore our total uranium in the alloys we were making was going up to keep that 235 where the physicists wanted it. So we got some pretty high, we would creep up in content which meant we had to look at the alloys we were using in cladding. But we were able to, I don't think we ever really, we couldn't change the clad too much, in fact we couldn't change it at all because then you're going to screw up the reactors as far as operations go. So we couldn't do that. And there were, I think we, I can't remember how low we got in 235 content before the total uranium got too high for us to handle. When that happens, Oak Ridge had to juice up the 235 content in stuff they were sending us.

MS: Right. What about, were there any problems with fuel tubes swelling? Remember the old problem they had with rust and sand? They added rust and sand to some tube elements to get it to take care of the swelling problem they had. But this was like very early on when they first were doing some tubes. And to be honest with you, nobody else seems to recall this being a problem in 300 area. So this may have been totally SRL.

CM: I don't remember that now. That would be interesting, but I don't remember it.

MS: Yeah, well. Well how did tubular elements get started at Savannah River? You can answer that anyway you want to, whether it's just like how they physically got started, or what was the rationale for having tubes.

CM: The best, let's see. If we go back to the start of 300 area, we had the 313 building for slugs, uranium. We had 320 for lithium alloy control rods. That's about what was made. But the, that's the starting place. Then I think, a couple things, and I don't know if these were generated and pursued by the physics folks over in SRL, I think, and design. We had to get more power, and you had to start using, the tritium demand was going up. So that started the generation of tubes. The first lithium aluminum alloys were made in 320. That was part of the cause or reason for construction of 321 I think. Not just the fuel tubes, because we could still, we had a press in 320 that was older, not nearly as well aligned. It couldn't, it was a commercial extrusion press from the forties. That's about all you can say. So we put a much better machine in 321, and got into the tube business.

MS: What about co-extrusion? When did that get started?

CM: It was started in S design, SRL. 320 in about, well I can probably come down to a year at least, '56. That's where I got in the tube business and that's really why I left SRL and went to the 300 area. We cast the alloy in SRL. We would machine and assemble the billets for extrusion SRL. And one of my functions early in the game was to take those to 320. They'd modify that furnace for out-gassing, and extrude them in the 320 press. Now this was the first thing, and it was interesting. And no real difficulties with it. But it was new and different so we went pretty slow. The only time they let me get near their press was on the 4-12 shift on Friday. And my wife was getting disturbed. Every Friday on [the] 4-12 shift. But that was, that was where we started. And soon, of course, as soon as 321 was completed, we moved over there. But it started in 320. It was cast in 773, was extruded in 320, shipped back to 773 for machine, clean up the tube and this kind of stuff.

MS: Right, okay. What equipment was used in the co-extrusion process?

CM: The tooling for co-extrusion was pretty, let's say you had a mandril to form the ID of the forthcoming tube. It was a straightforward piece of tool steel and machine there too. But the dies got a little hair-raising because particularly when, first tubes were simple, round tubes. Then some smart physicist put ribs on them. And that blew the, that caused some concern. So we had dies designed to handle the rib. But, I don't know whether I can show you or not. You can see the cross sections here. This is target. That's housing. That's target. That's fuel. That's fuel. That's fuel.

MS: Okay, right. The end of the ribs are all these little?

CM: But you can see, but it would pooch up into the rib and that would screw up, so we went from a simple round dye with some slots in it, to all sorts of lead-ins. If you talk with Fred Rhode, he pretty much designed that thing.

MS: Yeah in fact, yeah I think he was talking about that there, for that question. He said, ... specific question here about rib fuel and ....

CM: He did the die development.

MS: Right, yeah. He explained how he worked that out. So anyway you got the billets assembled?

CM: Okay, we cast, machinery casting. This is just bare, not aluminum and uranium. We assemble that into a billet that is, depending on what size you're making is the size of the, the shape of the dome. It goes into out-gassing. And following X hours, and the out-gassing time depended pretty much on how big a thing you were out-gassing. Some of them came down pretty fast. Some of the bigger billets took a little longer in out-gassing. Then we lubricate the graphite, lubricate the billet, go into the press, they've both been induction heated, and extrude there. Now we've got excess aluminum for an end and rear of the tube. There's some, let me get this straight. We've got to draw it sometime. Before we ever get to the fluoroscope and look at it, it goes through a drawing operation which utilizes the excess aluminum on one end. I can't remember which we used, the front or the rear. But, it …….. from this ……… pounded down by the machine, pull through a draw match and sized. Then we cut her off. Then we sent it to the, I'm not pretty sure of the sequence here. I don't know what, we drew right there. Then we fluoroscoped. That just looked at the continuity, the quality of the core primarily. After coming out of there we're going to go to, I think we'd go to a, now we've got some cleaning here in betwixt. Coming off the press we've got to go through the cleaning room to get that graphite off from extrusion. Then we'd do the other operations. Now we had to clean it up. Following the cutting to length and the fluoroscope, we go through a bond tester rotating tube underwater with a beam shooting through, looking for anything that breaks up the beam, which would indicate a non-bond someplace in the core. Then we'd pull it out and we'd have to look at it. Then we're going to go through a final cleaning operation. So we come out of fluoroscope, and then we go through a bond tester there, again looking for defects. Final cleaning and into storage. Wrong. I told you wrong. We've got to go to 305 to put it through the NTG. Because each tube is unique in content, a little bit. So that's fed back into the computer program and so forth, and it tells you to use this tube, if you had an assembly with three fuel or two or three fuel, use this content with that content with that content. And the guy would pull those and assemble those ……… in the back of the building. And the last part of the business is putting on the fittings, whatever they might be for the particular assembly.

MS: Okay. What information would you have on the very first NTG and how that replaced the test pile? Or that may have been done before you got there.

CM: The test pile was not, I never was aware of its operation. So they had an NTG to measure, that's the first time I ever got near the thing down there. Now they came in with a better model, another NTG.

MS: Yeah I heard that. They got what they call a smaller NTG or something at some point.

CM: It was a big piece of equipment. And they did simplify it considerably, plus increase the accuracy of it.

MS: And they had it in different buildings too. Whereas the first one was just there right by the test pile.

CM: Yeah.

MS: What about the, like in the special programs they had in the late sixties? You know where they were doing the, well cobalt 60 was actually a little bit earlier.

CM: That was strictly 320 building. They'd work on that.

MS: And cobalt 60, okay. What about that plutonium 238, another heat source?

CM: That was, I think that may have been part of the process where we got in trouble with our, in 321 out-gassing.

MS: Oh, okay.

CM: I think it was. We would get periodic, the tooling area could only put the billets together so fast, and they didn't handle many at a time, so they might ship us six. And it was one of those batches, I think, I think, where we had the reaction in it.

MS: Now that's where they had the, they were making these tubes out of neptunium, right? And then they were taking .... and turning them into plutonium 238.

CM: Right.

MS: I heard they had like a Mark 53?

CM: I can't remember, yeah. But those were all applied to a particular isotope in the alloy. And the separation folks were, it was all pretty much a powder metallurgy business there, as far as a core fabrication was concerned. So they'd mix up the plutonium, whatever, with, and that was strictly, because this, from our point of view we had simple stuff. Not high radiation, nothing. It was just straightforward. So when those things came in the building we had to shut parts of it off, rope it off and folks dressed up differently just so we'd know what they were doing. It was just safety preoccupation stuff.

MS: How often did that sort of thing occur, back in the late sixties?

CM: There for a while we, they had a pretty big program going on. I really can't remember. It was no major dumping because it took them time to do what they needed to do to get them for us.

MS: Right.

CM: And the tooling used for theirs, the tubes they were going to be making, were the same size that we were making. So we had the tooling. The only thing we'd worry about there is that something would rupture on one of theirs and contaminate, and we never had that. It didn't contaminate our tools or press in any way, thank goodness. But it was sporadic. Now there was also a program back in there where we radiated all kinds of things. But that was done strictly salt, pepper, sugar, coffee and I don't know. That was done strictly in 320.

MS: And that was done just to see what would happen.

CM: I guess somebody someplace, I don't know. It was almost fun. It was different. It was not extrusion process at all.

MS: Right, yeah. What about the, was there anything memorable about the curium programs they did? They were taking that stuff and eventually bumping it up to californium I guess.

CM: No, again we would work with, we would provide the aluminum components for them to use in assembling whatever size billet, or whatever size feed they had. Then we'd get the billet and that's about all we had to do with it.

MS: You got the billet and you just ran it through.

CM: That's all. Sent it back. Made the tube, finished the tube. Not even take it to the final NTG and stuff. I don't know if we even went through that. May have, I just don't know. It was, we would, it is entirely possible that any kind of standards for some of the stuff that they made we didn't have. I don't know. I don't remember that at all.

MS: Out of curiosity, how did you clean the equipment in between these different episodes?

CM: The press was, the extrusion press was our most vulnerable. We were very fortunate in that if we ever got anything it was very low level and we never could fully understand how we got it in there. We couldn't find a tube or anything that failed, so we had to almost figure that somehow or other we had gotten it, but we never could figure it out. It worried us to death. Low level, nothing. And not frequent. Very infrequent. Probably we were a little lazy in our business someplace. See the building is really clean, except casting, 321. It was, because you were working with uranium metal and high temperatures and stuff. But that was monitored very closely. Even respirators and all that mess.

MS: How many people worked in M area?

CM: In its full, all-out, 313 generating slugs as fast as they could go, 320 it's target tubes and control rods, 321, oh my. We were running, I don't know if we ever went to four shifts. I know we were running three. Three shifts, five day weeks. So there was a pretty big number. I don't know if I can, I'd have to guess. Because I don't remember what, fully manned we were probably, I think on a shift, if we ever got as high as 300 people total, that's everything, I might be way off base. It might be 400, it might be 200. No, it would be more than that. I'm just guessing. I don't think I have anything at all that would give me a hint. The biggest count got about that kind of number. Now that's operating [personnel] now. That's not our technical support and all this mess. I don't, those guys are probably going to add another 60, 50-60 at least to it. You might say 400 total.

MS: What did technical support consist of?

CM: Well there was a fair amount of, well of course when we were putting something new in the business, they were the prime movers. They had to worry about a lot of things there and help us get out of trouble if we got into it. But because the operating folks had pretty much grown up with the processes like some of the support folks, it was pretty standard operation really. Changes, of course they would cover us completely. They had to participate in all that mess. And there were very frequent changes of size, shape, color, whatever over the years of the, when we were going all out. Then she started to taper. When I retired they were down to maybe, counting everybody in the area, maybe 100, maybe.

MS: Yeah. That's still a lot of people though.

CM: But primarily they were spread out pretty thin in the buildings that were doing anything.

MS: What about slotted septifoils? Did you all ever do any work on that?

CM: Never got in that.

MS: Yeah.

CM: We may have. Now we tried. We tried doing some things in 320 that reactor folks indicated they'd like for us, we may have tried to extrude some of those, not particularly successfully. We tried extruding, in fact we got pretty good at the housing tubes going into reactors. They went, in fact they would stay into a position in the reactors. And the fuel assemblies would be going in and out of them over the…

MS: Is that the universal sleeve housing?

CM: Yes, yes. We made some of those, but we, to be very honest we couldn't compete cost-wise, we were getting them I think from Alcoa in Pittsburgh. I think it's where we were getting those. But yeah we made some, but just test. We never made anything truly production quantities or anything like that. Now when they wanted something to play with, down there in their assembly. Yeah we'd make things like that.

MS: Okay, right. Let's see, what about the semi-permanent sleeve which was the earlier thing they had before they had the universal sleeve housing?

CM: Didn't get near those. Not that I'm aware of.

MS: They just did some experimentation with the universal sleeve housing, the USH?

CM: Yeah.

MS: What about the first computer use in M area? Was that a big thing?

CM: It was scary for some of us that didn't know a computer from third base. Pretty much originated in the technical side. And I would suspect that it was early in the game. 321 of course had to have it there because of content, and there were variations. When they were working with straight uranium, depleted uranium in 313, they'd run a chemistry sample, but it had already been sampled to death up at Oak Ridge someplace. So we needed it there. But the isotopic content of some of the stuff coming from the Ridge on the enriched side of things, we had to, I know 321, yes from day one like '57, '58 whenever they got serious about things. We got a computer there. Had to. Did matching and everything else. 320 never had, I don't remember if we ever got in the computer business, at least in the operations side. No. 313, no, not really.

MS: What about powder metallurgy? You mentioned that just briefly I think with some of the other special programs, but was that ever experimented with and stuff in the M area?

CM: Only if it came to us. We didn't get into that ourselves. I said that wrong. We did some encapsulation I call it. Again, same thing. .... maybe about the size of 50 universal sleeve housings, 3. whatever. We'd put some stuff in cans and didn't, it wasn't anything. We tried a variety of elements that way. I don't, in fact I don't remember what all we did put in.

End tape side.

CM: We came enclosed, encapsulated, whatever you want to call it .... Considered irradiation of various elements, materials in case of, that would go underground someplace for storage in case of disaster and stuff like that. We played with that. I don't know, other than it was easier to work with than our normal stuff, so we didn't worry about that too much.

MS: What about, there was something that Fred Rhode was talking about where they had some, I don't know some kind of a, some program they were experimenting with over at SRL, and they had some kind of a device that was rigged up in M area to do it. And it was like some kind of like a shot program or something, and it turned out to be a gigantic boondoggle.

CM: Yes. Let me see if I can back up on this one now. It couldn't be called powder metallurgy because it wasn't powder. It was shot.

MS: Yeah, something related but it was sort of a…

CM: What in the world were they trying to do? I can't even remember. I can't remember if we ever, I think they were trying to figure out some way to get shot, like shot gun shell stuff anyway, into containers for irradiation. But I don't know what the heck for. It never got off the ground. So I can't even remember what all they may have tried.

MS: There was some kind of a deal where they went all the way up to Wilmington I think before somebody, some executive up there said, well where do we get the shot from. And then they didn't have a vendor for it, so they didn't have a method of producing it.

CM: I remember, as you talk I remember discussions on that. In fact one of the guys from SRL hit the road and went to Alcoa, to Reynolds Aluminum, because they had some shot business with aluminum. I don't know what, anyway, and somebody up in, I remember, I can't remember the guy's name. He was one of their PhDs. Deep thinker. Couldn't find his way from here to the door, but that was alright he was a deep thinker. But I don't remember, we never got near the thing.

MS: Right, yeah. What building was that in?

CM: They did all their stuff over in 773. Back in the Fab Lab I guess we called it initially. It's the back end of the 773 building. That's basically similar equipment to 300 area, except extrusion. Didn't have that. But they had some of the other like measuring stuff, inspection materials, or equipment, stuff like that over there.

MS: Going back to powder metallurgy, was that, why did that never take off? Was it just too big an expense to have to re-tool everything?

CM: It would have been pretty interesting. I never got to watch, the only thing I ever got near was a dissertation I went through someplace where they were talking about the Civil War, had a big powder mill and in Augusta. It's that big, still there, humongous thing. And I don't know what we, it's interesting how they made their powder for the Confederacy there. But it's not, it wasn't then, I don't know if it is now, maybe it is now, something you can control very well. It's a matter somehow of molten or, I guess it's got to be molten, ends up in pellets or, I don't know. But it was not, it was pretty advanced, certainly for the kind of stuff we were working with out there.

MS: What about security in the M area? How did that change over time?

CM: You could get in with clearance, with Q clearance you could get in the gate, the front gate. Now there was, when 321 where the enriched uranium was being handled, was constructed, another fence was added to that fence and another gate-house, another gate entrance was for 321. So even though you could get in the area, you couldn't necessarily get into 321. You'd have to have had, I can't remember what the badge, the badge had a particular additive access letter on it. There was another gate at the back of that gate, but that could only, that was a gate for trucks. We got all our stuff from Oak Ridge so we had to bring in some pretty big tractor-trailers. They would come in there, but nobody else could come in and out. That was strictly controlled by patrol. And do we have a gate down to 305? Had to. I'm trying to get, by the time I left we'd taken down some fences. Things were being a little, we were very open, opened up entirely. I believe we had a gate to go out between the 300 area and the 305 building. I don't know why it was there, but we had to get patrol to open that for us to let us haul stuff out of there to the test reactor down in 305.

MS: What about like machine guns and things like that? I heard some stories about in the 1980s they actually had a machine gun in placement up there on top of building 321.

CM: I don't remember that. Now I do know that, of course we had at least annually, maybe twice a year I don't know, our patrol folks would play war games and we might have something simulated then. But we never had permanent placements. Now there might have been, there may have been some sort of, I can't remember where he'd be on top of the building. The building was so covered with exhaust systems and big, I don't know about that one.

MS: Yeah, right. Now the original metallurgy laboratory, was that in like, was that like in a back wing of 320?

CM: Yeah.

MS: Right. And that was, and then they, did they build a separate building for that later?

CM: 322.

MS: Okay, that's 322. What about just a rundown, what were the raw materials that went into M area, building by building?

CM: Okay. The 313, we would get the uranium, whatever shape it might be, slug. Hollow or solid, whatever, from Oak Ridge. And we would, of course initially everything was natural uranium. But they did get into some low increases in enriched uranium. Again, Oak Ridge. Came to 313 in packed aluminum cans, aluminum wafers to put on top of the core of the can. And that, other than some chemicals in the cleaning line, that's about all that came in there. Nothing considered highly wanted by anybody. You couldn't haul too much of it off, it was too heavy. So it was not isolated from the rest of the area. It was, they had an inventory there of depleted or slightly enriched uranium. 321 would get everything, many aluminum sizes and shapes to be used in the, primarily the control rod fabrication or, well let's see. Some billet, aluminum billet components they would assemble there for extrusion in 321. But still they'd come into 320. Varieties of shapes of aluminum, and they would get the lithium from Oak Ridge, whichever concentration we were ordering or wanting at that time as far as lithium, I want to say 6, it might be 7. Anyway, lithium that was used in control rods and/or the target tubes. That's about all they'd get. Maybe some chemicals in cleaning again, for cleaning the components. That's it. 321 would get aluminum components going into the fuel billet fabrication. The feed came, well Oak Ridge, and that could be, well were we working with neptunium, that came out of separations. So it'd be the enriched uranium that would come from the Ridge. That was always an interesting game because their trucks were completely innocuous. You know just a big old semi. And if you didn't pay any attention to the fact that the cars in front and behind, you wouldn't have known it was kind of weird. There was nothing there. And I don't know why they always got here, but they always got here about 5:00 in the morning. So occasionally there would be, if we were working 24-hour days, fine we had people there. But we didn't, as business declined shall we say, we were cutting back on shift work and so we had some interesting requests then.

MS: Right. What about moving raw material around in M area? Or for that matter finished product? Have they ever used railroads? Or was that all trucks?

CM: Everything going to reactors, be it control rods, fuel tubes, …….. tubes, assemblies, whatever, were shipped in, I call it a cart like thing. Two-wheeled box if you will, maybe 20 feet long, and 3 feet square, something like that. And you could put a layer in and divide it and put some ……….. Control rods went that way. I don't know, I guess we could have sent them by truck. It kind of depends, there was no demand for them so let them go that way. But we would make shipments of fuel, which maybe required a little more attention, in these containers, and/or we had some boxes when we were doing assembly of housing tubes, fuels, targets, everything, we had an assembly in the area that needed to go to a reactor in, let's say 4 feet long, 10 inches, not long wide, 20 feet long by 4 feet wide and maybe 10 inches high, and we could only put in specified numbers. That's why the size of the container because of the amount of stuff you wanted to put together. But you could maybe ship, if I say 20 that might the number. Two layers of, that would be too many. Maybe 10 or 12 is about all you could ship at a time. The driver drives into a river out there someplace on the plant. I don't know where you're going to find one, but if he finds one it's not critical or anything like that. So we were limited as far as movement goes, in that consideration.

MS: Right. So there was always some consideration of criticality involved as well. Okay. Well that covers all the questions I can think of to ask. Is there anything else that you can think of that I haven't hit?

CM: No you've asked a lot of things that I wouldn't have thought of. Maybe some of them I'd just as soon forget.

MS: I can't think of anything else that I need to ask. But if there's anything else you want to add, you're welcome to.

CM: Okay. Or if anything comes to mind later give me a call. If I can, I can't remember a lot of detail, but generally I can.

MS: Okay, well thank you very much. I appreciate it.

CM: Thank you. This was kind of interesting.

End of tape.

Oral History Interview – Fred Rhode

Mr. Rhode, a North Augusta resident, worked at Savannah River as a metallurgical engineer in the 300 Area. He began his tenure at SRP in 1968 and his workdays were mostly spent in 321-M where his work on the production of dies was a major contribution to 300/ M area operations. Mr. Rhode's tenure at the site continued through the 1990s and he was present at the closure of the 300/M facilities.

Interview Transcript

Interviewee: Fred Rhode

Interviewer: Mark Swanson, New South Associates

Date of Interview: June 12, 2003

Mark Swanson: If you would, state your name please.

Fred Rhode: Fred Rhode.

MS: Okay. What was your position at Savannah River?

FR: had a number of assignments, mostly technical in nature. I'm a metallurgical engineer. Most of my work there was in support of operation of the fuel manufacturing facilities.

MS: How long were you employed at Savannah River?

FR: Thirty-two years.

MS: Starting when?

FR: 1968.

MS: Okay. And then you retired?

FR: October, 2000.

MS: Okay, great. Where were the main areas that you worked in, in the M area?

FR: Primarily building 321M.

MS: Okay. The next series of questions, we're trying to establish what the original functions were in the different buildings, and I'll just sort of run through these. What were the original functions or processes in 313? And if you don't know, just say you don't know, that's fine.

FR: Okay, I believe it was, it started out as the building where the fuel was made that they always, and at the beginning of the plant operation the fuel was a slug form. And so throughout its history that building had made various types of slugs. In the early days they were enriched uranium. When I got there they were making depleted uranium slugs that were used for making plutonium.

MS: Okay. What about building 320, original functions and processes?

FR: That started out in life I believe as a lithium alloy fabrication building, making targets that were used to produce tritium. And somewhere along the line I think they extruded enriched uranium, probably when we first started processing enriched uranium. I think the fuel tubes might have been made in that building for a couple years, but I'm not, that was before my time, so I'm not sure. I know there were some various artifacts in the building that lead me to believe that they did process enriched uranium in the building. There were, I think when I first went there, there were still the old NIM stations, although they had been removed. And there was still some Hepa-filtered ventilation I think from back in the days when they processed enriched uranium.

MS: Okay. What about building 321?

FR: Okay, 321 was built I think in the mid fifties, and it was built primarily to extrude, to fabricate the enriched uranium tubular fuels that we used up until the plant shut down.

MS: Okay. What about building 305?

FR: 305 was a, basically a test reactor. It was a reactor assembly that was a graphite core. I think it was natural uranium. And it was used to test the fuel and target, test and determine the reactivity of the fuel and targets that were manufactured in the M area facilities.

MS: Right. What about other M area buildings? Those were the main ones, the ones that we've already covered. I know they had some smaller buildings, 315?

FR: 315 was primarily a warehouse facility where we received purchased materials, ranging from raw aluminum, billets, things that we would then send off to vendors and get machined into aluminum components. And then those machined components would come back to the building, be inspected, and then dispersed to the various buildings where they were utilized.

MS: Okay. Any other building?

FR: 704 building was an office building. It had a lunch room and that kind of stuff. In later years there were some buildings built adjacent to building 313, I think there was 340 and 341M, and they were basically warehouses for storing either the uranium metal slugs as the site received them, or the can slugs ready to go to the reactor areas. And I forget which one was which. There was also some waste water treatment facilities built. They must have built those in the, I guess late eighties. And one of those was a building adjacent to 313, and I don't know what the number of that one was. And then there was another building with a tank, I guess storage tanks that were used to receive all of the plant effluent and then treat it.

MS: I brought a little thing here if you want to take a look, just to you know. Just in comparison with the other interviewers, most of them don't have any recollection of the smaller buildings aside from just 313. But I figured since there were other buildings there

FR: Okay. I can't read a number on it, but this is where the.........

MS: In other words, that's right behind

FR: Well 321 would be, the ....

MS: It's kind of adjacent to 777- 10A.

FR: Right. And 777-10A you want to know about that building? It wasn't really M area.

MS: Yeah that's true. In fact originally it was 777M.

FR: Was it?

MS: Way back, originally. And then they changed it to I think that designation.

FR: Well that was basically a test reactor. We used to put, before when a new fuel was designed and fabricated, before it went to the reactor, in the early days they used to load it into that reactor and do physics tests on it. So it was a full-core reactor, but it never went, it was never really powered up. They would just do physics measurements on the fuel as they'd add a moderator to it and everything. And it had capabilities for storing heavy water in the storage tanks and all that good stuff.

MS: Right. Yeah, they told me kind of to stay away from triple 777 10A. But it was originally in the M area.

FR: Okay.

MS: Even though it's not considered that now.

FR: I guess in addition to doing the fuel, we actually took some of the fabrication forms, intermediate products, the UAL ingots, and they were placed in some part of that facility where they did physics measurements on it for criticality purposes and stuff, and that sort of thing.

MS: Okay, right. What about, talking about building 313M right now, what were the changes that were made in the processes that went on in that building?

FR: Well before I got there the canning process involved, it was the process used in aluminum silicone alloy to bond cladding to the uranium slugs. And at some point in time before I got there, the process was changed to a one in which the slugs were nickel plated and hot press bond dye sized to bond the cladding to the uranium metal.

MS: Okay, right. And talking about that, that was another question I've got further down but I think I'll ask it now. The original method of bonding, wasn't that aluminum silicone?

FR: Right.

MS: ALSI? Dip bonding?

FR: Right.

MS: And then it went to hot press bonding, and then I'm not sure if I know the difference between hot press bonding and hot die size bonding.

FR: My guess would be it's the same thing, but I'm not sure

MS: Well the impression I got was that it's very close to the same thing, or it's the same thing.

FR: I don't know that. I don't know that part of the history.

MS: Okay. What about changes that were made over time, say from 1950s to the 1980s, in building 320? And there may not have been that many.

FR: Yeah we, I guess one of the things we started doing there that we didn't do early on was, many of the aluminum components like what we call the universal sleeve housings that were all aluminum components, they were a tubular piece about 20 feet long. We used to buy those directly from Alcoa. And in later years, I guess both through a combination of Alcoa not wanting that business anymore, and I think that's what drove us to it primarily was we were forced to make those components, at least the final assembly of those components in that building. We would buy extrusions from, probably still from Alcoa, and machined components from other local vendors, well just commercial vendors. And we would put those together in that building. I think early on, the control rods that we made, or many of the lithium targets that we made were slug size and it was probably only in later years that we extruded the target tubes. And I think that came about the same time as building 321. When we went to the tubular fuel it made sense to go to the tubular targets also. Again that happened before I got there.

MS: Alright. What about 321? I know 321 was built for the tubular elements.

FR: Right. I don't think there were any great changes there. The basic process of casting the UAL alloy, assembling it in billets and co-extruding them into the fuel tubes, and also co-extruding the target tube, the lithium aluminum target tube material, although that was all the casting of the lithium aluminum work was done in the 320 building. And then the billets were brought over. So the process of turning those into tubes was the same as it was for the fuel tubes. What was the original question again?

MS: What changes might have occurred in those buildings like from the 1950s, the original configuration, to let's say the 1980s?

FR: It seems to me there used to, oh we didn't talk about the met lab. It seems to me that originally there used to be a metallurgical lab in 320, and somewhere along the line they built building 322M which took over those functions.

MS: Oh, okay. When did they build building 322?

FR: I don't know that. Let's see, there's also part of, and this facility didn't belong to the department that was making the fuel, but in part of building 320 was a lab that belonged to the analytical chemistry guys. I don't know what they call them now, it wasn't the Savannah River Lab, but it was the lab that supported the plant activities. And they did most of the analyses for M area, plus they did a lot of analyses for other, I think they did a lot of heavy water analyses. I take that back. They probably would not have done that. They did analyses for other departments on the site, and I don't know what that was. I know the heavy, the reason I mentioned heavy water, heavy water had their own lab. But those people used to swap back and forth between there. So they may have done some of the work there, but not all of the heavy water.

MS: Yeah. Apparently there was a lot of back and forth between SRL and the 300 area, with laboratory people coming over and sort of experimenting around or getting somebody to experiment for them. Or was that in the early days?

FR: It probably was more in the early days. Now there was a group in the lab that was, in fact I even worked there for, that's where I started working on the site was in SRL in part of, what did we call ourselves, it was a technical group devoted to fuel fabrication. I can't remember what their name was. And for the first couple of years I worked there I walked over to M area probably at least once or twice a day to, and ran experiments in building 321 and that sort of thing. So that part is true about people coming and going from there.

MS: Okay. What about, as far as the processes changing over time, what about building 305? I know they had the big 305 ....

FR: In addition to the test pile there was a thing there called the nuclear test guage. And I'm not sure when that was built. That may have come along about the same time that building 321 and the tubular fuel and target business started. And it was also a, I think, we did treat that as a reactor. It was a sub-critical ray of enriched uranium, and you'd stick fuel or target tubes in it and measure the reactivity change. Similar to just what the test pile did. And somewhere along the line, in like 1990 or so, that nuclear test guage was modified so that it was sub-critical. Prior to that it had the potential to have, for criticality to occur and we treated it like a reactor. And somewhere around 1990 we made a modification to it so that it could not go critical. And it's not a reactor anymore.

MS: Right. You don't have to worry about that. What about, in the development of fuel elements we have the basic progression from slugs to hollow slugs to large diameter tubes. What do you remember about that, that whole transition?

FR: By the time I got there the fuel they were making was basically the same fuel that we made.

MS: It was all tubes by then, right?

FR: All tubes. All fuel and lithium targets were all tubes. In addition, the tubes that we, I mean,

MS: Lithium targets were always tubes, right? Is that correct?

FR: No we, early ones were pins of some sort, canned pins.

MS: Okay.

FR: And I think we probably did that up until, I'm going to say the mid fifties. When the tubular fuel and targets came along, I think that's when that ended. Although there were still a couple of reactor components that did require a little aluminum can slugs, and I forget what we called those things. And I think we made those up until the plant shut down. There was very few. I mean they would make a couple hundred one year and then they wouldn't need anymore for the next five years, and everybody would forget how to make them.

MS: Right.

FR: Now there were some activities in 321 that were a little different than the UAL business. We at one time made some plutonium, some fuel tubes that had plutonium 239 in them. The billets were made up in F area I believe, and then brought to M area where we extruded those into tubes. And we made at least, I'm thinking at least one or two reactor chargers that way. That happened before I got there. We made neptunium targets in that building, where we took the neptunium that was recovered from the recycled fuel and that was put into a billet out in F area and brought up to M area and extruded into a tubular form called a mark 53. And there was a whole series of those, mark 53s, and 53As and 53Bs, progression with time. Made a plutonium target about the time I got there in '68. And that was a, that might have been called a mark 18A target or something like that. But it had plutonium in it. The plutonium fabrication was initially done out in F area as the small pins were one inch diameter and six inches long. And those were taken up to SRL and worked in the Fab Lab there where they cut those and re-formed them, and put them into a billet. Then we extruded that into a target in the M area.

MS: It was all part of the special programs that they were doing in the late sixties, early seventies?

FR: Yeah that was the californium program.

MS: I've got questions about that a little bit later, so I don't forget it. We've already talked about the bonding process and how that changed. What about, were there any memorable marks that you recall being constructed? Like, this would have been before your time, but Mark 3 which was a fuel plate that they fabricated, but it never was used?

FR: No. I don't, I'm vaguely aware of it but I couldn't tell you what it was or anything.

MS: Right. What about, do you remember any problems with fuel tubes swelling? This again may have been before you got there. This was like in the early sixties.

FR: No I don't.

MS: It was some kind of a funky thing where they discovered they had a solution like what they called rust and sand, added to it, and it wouldn't swell.

FR: This must have been when we were still making the uranium metal slugs.

MS: As I understand, it was when they first started doing the tubes and jacking up the power in the reactors. And because of the extra heat, the tubes started swelling differentially and they had difficulty retracting them out of the, and they decided that putting some kind of coating on it, which was like some ferrous material and then some silicone that it would, like rust and sand, it sort of took care of that problem.

FR: No.

MS: Ironically, nobody that I've talked to, out of the people that I've talked to that worked in M area, are familiar with that.

FR: Well there were some problems I know with

MS: I guess that may have been totally a Savannah River Laboratory issue. I don't know.

FR: Well there were some problems with the uranium metal slugs and probably the

MS: Hollow slugs?

FR: No the original solid slugs. And that problem was solved by heat treatment at, a small alloy addition in the heat treatment to get it into a certain microstructure that wasn't susceptible to dimensional changes with heat cycling. And I think there was some problems with lithium swelling. And I think that was solved by just keeping the lithium concentration down below about 3 weight percent. But by the time I got there it was a premature process.

MS: Yeah, okay. How did tubular elements get started at Savannah River? Again this would have been started before you got there, but you may have some input.

FR: Well, the process I think was initially proposed, and maybe even developed by MIT. And there was a little extrusion press over in SRL that may have, that I think may have taken that information and maybe developed it a little further. Although I don't, that press is so small it was not a production facility, at most they would have just been a small scale demonstration thing. But you know, other than the initial work that MIT did, I'm unaware of the rest of the history that went along with that.

MS: Okay. What about the co-extrusion process?

FR: Well let's back up. That's what I thought we were talking about. Let's go back to your first question.

MS: Well actually they are related. But as far as co-extrusion at Savannah River. Or is that just pretty much intrinsically tied up with 321 and that whole development of that building?

FR: Again, I believe that all that started with MIT and they developed some stage, and there may have been some more work done in SRL. But I think from that they just jumped into building 321-M.

MS: Right, yeah. What equipment was used in the co-extrusion process? Again we've talked about this to some degree, but this will sort of like bring all that around.

FR: Do you want to start all the way back in the casting process and then work forward?

MS: Whatever you want to say.

FR: Okay. Well to make

MS: I get different answers from different people, so it's always good to see what

FR: Okay. Do you want to talk just about the fuel, or the

MS: Well either one. I realize they're different requirements.

FR: Okay, let's start with the fuel first. The process started with the casting process where we took enriched uranium metal that we got from Oak Ridge, and that was a mixture of either, well I guess in the early days that started out with low enriched uranium, and by the time I got there we were using fully enriched uranium, which at that time was 93% - 235. In addition, we would get uranium that had been recovered from fuel in our reactors that had been, some of the 235 had been burnt out, and there were some other radioisotopes that come along with that, that aren't in the normal stuff. Primarily 234, 232 and 236 gets concentration. 236 builds up. And we would get a combination of the virgin 93% material and the recycled material. We would blend that by weighing out portions of each. And aluminum to go with that, plus scrap from the process. The process was pretty scrap intensive. Probably less than half of what we cast actually ended up in a fuel tube. The rest of it ended up in machine chips and parts that we couldn't use. So that would get recycled. So we'd take a mixture of all that from a calculation, to calculate the right percent proportions of those. That would be melted in an induction furnace and cast into a hollow cylinder. And let's stop the fuel process right there and we'll go back to the lithium aluminum. That process started with enriched lithium metal which came to us from Oak Ridge. And it would be like a one pound chunk of lithium sealed inside an aluminum can. Those came in various enrichments. And we would select whatever we needed to make a concentration of our alloy correct, and melt that with aluminum in an induction furnace. It was a larger induction furnace than what we used in 320. And I guess getting back, a change that took place in 320 was initially that was done in a vacuum furnace. And by the time I got there we had abandoned the vacuum furnace and just used an open air........ furnace. And that was what we did in 321 also. That was just an open furnace.

MS: Yeah, to interrupt real briefly I think, I was talking with Norm Brady this morning and he mentioned that they had used the vacuum furnace initially, and then they determined later they didn't need it.

FR: Right.

MS: Why did they think they needed it to begin with?

FR: Well I think this goes back to maybe some of the problems we had with early targets. I think they had planned to make targets with a fairly high lithium concentration, and lithium will react with air pretty violently and actually burn. And if it doesn't burn it volatilizes and comes off okay? So by the time we learned that we couldn't put more than about three weight percent lithium in there, we can cast there in air without any problem at all, very minor lithium loss. So it wasn't a process necessity and operating inside a vacuum furnace was just real bad business, because it's a lot of maintenance and headaches, and a lot of problems. I can tell you some wild stories about that. So if you are going to make a fuel tube you use the cores that were produced from the UAL casting process, but you're making target tubes you would use lithium aluminum alloy. Those would get put into a composite billet. I think they were, the casting process produced what we called a core which was a hollow cylinder. And that would get assembled inside a co-extrusion billet which would provide the inner and outer sheath for the, would become the inner and outer cladding on the tube, and some other components like end plugs that would go together. Those things would get welded up, both fuel or targets, evacuated and out-gassed by heating them up in a furnace and a vacuum pulled on them.

They'd get sealed off. And then they would go to the extrusion press and get re-heated, and co-extruded using for many years a lead oil lubricant, magic mixture of lead particles and oil. Later that was changed to tin because of the environmental concerns with using lead. And then you, when you made the extrusion then those little cores that were six or eight inches long ended up being the cores inside the fuel tube that were stretched out to twelve feet or so. And that process would metallurgically bond the cladding and the end plug, and all the components together. It was a very, very unique process from that standpoint. From then on, I guess they went, both the fuel and target tubes went, we usually processed everything in batches in the building so one week we might be making fuel, the next week we'd switch over and make targets. So the products were sort of segregated in the process.

After extrusion they went to a cleaning step where you removed all of the extrusion lubricant. Because you can't extrude very accurately to the size that you want, we processed them through a cold drawing operation where we actually drew the tube through a, using a draw bench and a die on the outside and a plug on the inside, because that was done at room temperature and you actually reduced a cross-section of the fuel or target tube and stretched it out about, I would say it was about a 10% reduction in area. Maybe not that much. Maybe 5% reduction in area. Since that was done at room temperature and the die and the plugs stayed at the same temperature, it gave you a really precise control on the diameters of the tubes that you were making. In that process you ended up putting the oil lubricant on them so they went back to the cleaning room. The basic cleaning process there was a degreaser, caustic solution and nitric acid. After the draw bench all they went through was a degreaser. And after drawing nothing was exactly straight, so they went through a straightening operation. And that from time to time varied from being a press operation, and then in the 1980s or so we bought a thing called a roll straightener which was like a rolling mill with contoured rolls that, with a little bit of magic touch you could pass the tube through there and not screw up the inner and outer surfaces on the tube. And sometimes you'd be lucky and get them straight. When that was done, I guess that was done before the, they went through that process directly after drawings. They still had the oil on them and then they would go to the cleaning process. The target tubes then went back to 320 to get finished. And we'll get to that, we'll follow that thread in a minute.

But the fuel tubes, the next thing they, in about 1970 or so we started, probably '75, we started using a process called the thermal test oven. This was a process, we took the fuel tubes and heated them up to a temperature higher than they'd ever see in a reactor. And so if there was any potential for them to blister they would do that in the oven rather than a reactor. Let's see, I guess that was actually done before we drew the tubes. The fuel tubes, and later target tubes, went through a fluoroscope to look for any non-homogeneities in the tube. Primarily looking for small inclusions that might have been in the core that could cause thin cladding on the tubes. And there were criteria for how big or how dense an inclusion could be. And all along the way, as we rejected these tubes, they became scrap that got recycled back into the UAL casting process.

Went to another device called the fuel distribution analyzer, and this was an x-ray device where, basically a fluoroscope. Well I take that back. It was an x-ray, transmission x-ray device where a detector was held inside the tube and the x-ray beam was directed through the tube. Then basically the tube was rotated and translated, and you were able to look at the entire surface of the tube that way. And by measuring the amount of attenuation that took place from the uranium, you could make an assessment of how well the uranium was distributed in that. And we had a spec of how much variation you could see from, there were small areas of the tube and this was looking at a one inch long by quarter inch wide window in the tube. So there was a spec on how much variation could be inside that size of an area.

From there the fuel went down to the nuclear test guage, and that was eventually replaced by the new NTG that was sub-critical, deeply sub-critical, and that was actually built up in 321. So we didn't have to transfer the tubes back and forth. And somewhere along the line in there, I guess before they went to that fuel distribution analyzer, the tubes were final machined after we had used the fluoroscope to find the ends of the cores in the tube. The tube was machined so that the center of the core would be at a certain elevation in the reactor. We would cut the ends of the tubes off and machine those. So after you'd accumulate enough tubes to put a whole reactor charge together, you went through a process called matching where you looked at the individual tubes that you had and selected which ones would go together best in a fuel assembly. Typically there was three fuel tubes in each fuel assembly, and the fuel content varied. If we'd make 300 fuel tubes they all weren't exactly the same.

So you did a mix and match process to pick which ones would be best to go together. And they were physically assembled together. The concentric tubes slid inside one another. The ends were attached, were held together with fittings that went on the end. And we used a joining process called magneforming, which was an electromagnetic forming process which actually puts a crimp on a tube and holds the fittings in place. And then they were packaged and either stored in that .... concrete storage rack that we had, or put in the shipping containers that went out to the reactor areas as needed. On the target tube side of the business, the core ends and ...... were located with an eddy current device. You could distinguish where the lithium aluminum ended in the tubes with that. They went through a final machining operation similar to what the fuel tube did. This was all in building 320. They were final machined. And when the finished tubes ended up, most of the finished tubes ended up coming over to 321 because they were assembled with, in some fuel assemblies we had a mixture of fuel and target tubes. Some of the targets were separately dischargeable from the fuel assembly, so those were completed in 320 with the magniforming process by adding end fittings and those sort of things.

MS: Yeah I think we went back to the target tubes. They are pretty well covered. What about, I heard that fuel tubes and target tubes, after they were made but before they were assembled, they had to be stored separately or transported separately.

FR: We, well from the criticality standpoint, when the tubes were in building, tubes and billets were in building 321 we treated them as if they were fuel tubes, just from a criticality perspective. We processed everything in batches. As I said we might make a, spend a week making fuel tubes and the next week making target tubes. So they tended to go through the building in discreet batches of fuel or target tubes, but I mean you could be in one side of the aisle and there would be target tubes, and one side of the aisle there would be fuel tubes.

MS: So it wasn't like there had to be a fire wall between them.

FR: Right. No intent to do that.

MS: What about the development of rib fuel in targets? Is that anything special?

FR: That's a process near and dear to my heart.

MS: Good, I asked the right question.

FR: Some of the tubes had ribs, let's see. I'm not sure if, maybe somebody told you this part of the story.

MS: No I really didn't get too much feedback on that.

FR: I don't know if we went through a period when there weren't ribs on fuel tubes.

MS: I think very early on, and they pretty quickly determined they needed to have something.

FR: Right. I guess we had fuel tubes and then these targets were still the pins that went inside of them, and it was just awkward to handle.

MS: Yeah they needed something to keep the fuel and target stuff separate from each other?

FR: Well that was done initially by housing tubes that were in there.

MS: And also to make sure that the water was able to flow evenly.

FR: Right. There were ribbed housing tubes that were simple to make, and we used to buy those from vendors. So at some point in time somebody got the idea to put ribs on them. And the undesirable thing, and you can do that with the co-extrusion process. But when they first started out doing it they used just a cylindrical billet. And when you'd form the rib on the tube you'd get, the core material would flow up inside the rib which was undesirable from a couple of aspects. One, it put more fuel in that area so it became a hot spot in the tube and actually became power limiting on the tube in the reactor. And it also thinned the cladding because you were stretching all that material out to form the rib.

MS: So you're saying the rib itself had to be formed from the outlying material that was at the cladding.

FR: Right. And it would flow up, yeah. The vendor we worked with, I guess a fellow named Roger, it'll come back to me, Roger Leband, I know he is the patent holder on the rib billet. And he was an SRL employee at the time. And that press in SRL I believe was used to make the first demonstration of the rib billet concept. And that's where you took, instead of having a cylindrical outer sheath, we had a special extrusion that had four ribs theoretically with the, do you want all the technical stuff on this?

MS: Sure, go ahead. We got tape, I just got to check.

FR: Okay. What you'd do is you'd look at the tube you wanted to make and you looked at the extrusion ratio that you had, and typically you made, we used an extrusion ratio of about 25 to 1, but each tube had a unique extrusion ratio because of its geometry and that sort of thing. So you'd look at the size of rib that you wanted on the tube and you'd multiply that cross-sectional area by the extrusion ratio. And you provide that much greater area on the billet. So theoretically when you'd extrude that you'd have enough metal that would flow down to form the rib on the tube. And it did work much better. And that's about the time I arrived on the plant site. But the process, my claim to fame at Savannah River Plant was I believe I'm the guy responsible for optimizing that design of dies to make the ribs where we had very little upset in that area. And that was just a matter of controlling the contours inside the die cone so that this little rib portion got reduced at the same rate as everything else. And that was pretty well done by, about 1975 we figured out how to do that pretty well. And we used that basic design for all of the rib core extrusion dies.

MS: And that was used from then on out, right? As long as they made fuel targets?

FR: Yes.

MS: What about, we've talked some about this already, but as far as the 305-M test pile? And then it was replaced, or at least augmented by the NTG. How did that all come about? Or that may have been before you got there

FR: Yeah the test pile was originally built when we were still making slug fuel. And one shortcoming of that is that when you put the, you could put a small slug in the, first of all slugs were pretty homogenous because they were a machined piece of uranium metal of given dimensions. So there wasn't much variation that could take place between slug to slug to slug. And you didn't worry about variation up and down the length of the short slug. When you made the fuel, because we were using a casting process and you could get segregation occurring in the casting it would get propagated through the process when you extruded it, you could have a target tube or fuel tube that might have twice as much uranium at one end as the other. And this big test pile was insensitive to that because it was basically looking at sixteen feet of stuff all the time. It was a huge thing. Okay? Now I'm assuming that we decided that we needed, the nuclear test guage was better because it only interrogated a short section of the tube at one time. So it could actually see differences along the actual length of the tube. I think that's why that was done.

MS: I think you're correct, from what I've heard. That makes sense.

End tape side.

MS: What about, we were talking about the NTGs, and I guess we've kind of covered that, when they started doing the small NTGs and they put those in the individual buildings.

FR: Right, there was like, I think it was an original driver to go from the test pile to the original NTGs, to be able to interrogate the tube over a smaller length. And then the motivation for going to the, I think you want to call the smaller NTG, I think we called it the low-K NTG, was mainly to get a deeply subcritical facility where there was no potential for criticality. And the reactor tech folks would not have to administrate that facility as a reactor. And it got rid of a lot of administrative baggage that went along with having a reactor.

MS: Okay. So that was one, that was certainly one reason to do it.

FR: Well, safety.

MS: Safety and bureaucratic sort of considerations as well. What about the special programs they did, like the transplutonium programs they did in the late sixties or mid sixties, late sixties? Did they have any special fuel and targets that were generated in 300 area to support that?

FR: Yeah.

MS: I know they did neptunium.

FR: The neptunium business.

MS: For support of that plutonium 238 heat source?

FR: Right. Yeah, the neptunium, the Mark 53s were the target that we used to produce the plutonium 238. The one story that I started telling you about the plutonium fuel that we made, the plan there I guess was we made the fuel, we'd burn it as fuel, we burnt the 239 out of it, and made plutonium 240. Now I guess that might have been on a different program. It might be these original plutonium tubes I was telling you ended up being where we produced the curium americium and those kind of things. Does that ring any bells?

MS: Yeah I know they did, one of the curium programs they had, if I remember correctly a Mark 6C?

FR: Oh that was way before my time.

MS: It was like a driver for the curium program or something? Or they had the californium as well. I think they discontinued the californium program in 1970.

FR: Right. I was there when that was going on.

MS: Okay. The cobalt 60?

FR: That was done before I was there.

MS: That may have been in the fifties. What about slotted septifoils? What that something that was done in the 300 area?

FR: Slotted septifoils.

MS: I know they had different, I don't know the difference but they had different slotted designations. One was like an E type? And then a J type, slotted septifoil? I think that was just for extra water circulation.

FR: Okay. Septifoil is the thing that held the control rods in the reactor.

MS: Yeah like a little seven chamber things, yeah.

FR: It may be that they were initially not slotted, and then as reactor power went up they had discovered a need for greater flow or something and the slots were put in there. But I guess throughout my history they were, as far as I know they were always slotted.

MS: Okay, right. So in other words you weren't involved in any of that. Nothing unusual, no change.

FR: No.

MS: Okay.

FR: And at some point in time we went from, and I guess this would have been probably in the 1980s or so, this was another thing, another piece of hardware that initially was made off-plant and the vendor elected not to make those, and we began making those on-site.

MS: Okay. What about like the development of the semi-permanent sleeve and the universal sleeve housing? Was any of that work done at M area?

FR: Probably not. Probably those were, number one the universal sleeve housing I think came along when we were still buying all that stuff from vendors. The work on physically developing the design of that was probably done at SRTC. And there's a hydraulics and heat transfer lab there where they probably looked at those designs. But again I'm fairly certain that the actual manufacture of those was done off-site before the vendor shut that business down and we had to get into it. Now you know the difference between, you know what a universal sleeve housing was and all of that.

MS: Yeah.

FR: Turns out they aren't quite so universal.

MS: It's just, for me it's more like a name and I know what it's function was, what it was supposed to do. As to how it actually operated, no.

FR: Well in the reactor you need a housing that goes around the outside of the fuel target to…

MS: To get it into the reactor.

FR: Well get it into the reactor and also maintain the cooling channel immediately around the fuel. Because that water is going at a pretty high velocity. Then there's a bulk moderator that's around that, so you need to separate. I mean it's just a physical barrier that provides the flow channel around the fuel and separates it from the rest of the bulk moderator. It must be in early times we had different sleeve housings for different kinds of assembly, and finally somebody got the bright idea, why don't we make one kind of sleeve housing that we can put both fuel and targets in. And that showed, when that came along you could use the same sleeve housing to put the Mark 31 slug assemblies in, and the same that you use the fuel. But there actually was a difference. There was a, let's see what were the differences there. I guess there was actually a separate, oh I guess they were the same and then somebody at some point in time, about the eighties, said gee we could have a reactor accident if we erroneously put fuel into a target position. So we ended up changing that so we had a universal sleeve housing that was for fuel and one was for targets. So they weren't quite as universal.

MS: Right, yeah. What about the use of computers in M area? Was that a big thing?

FR: Well it certainly was for us that struggled with it. I don't know how, in 321 I don't know how we ever kept track of accountability. It was all done on a piece of paper and people, I mean there was little cards filled out, numbers entered and all kinds of errors made. I don't know how we ever kept track of that stuff. And it was really a nightmare from the, I mean like I said half of what we cast ended up as scrap, and its composition got changed because some of it had cladding on it, some of it was bare. There were different enrichments. Some scrap from early campaigns would have a different enrichment than other campaigns. And it was, I don't know how those folks ever kept that straight. And I guess about 1980 or so they put, we put our process monitor in the building that really started out as it was going to be a process monitor and collect process data, temperatures, times and all that stuff. But it turned out that it was really a blessing from the accountability perspective, and that's probably where most of the effort went to develop it. So it kept track of the composition of each little piece of material, and also collections and process data.

MS: Yeah, right. What about the powder metallurgy technique? I know they did a lot of work on that, but it was never actually implemented.

FR: Yeah, actually there was another building that's probably gone from your map. As you recycle uranium the 235 gets burned out in it so that the concentration of the 236 and 238 and 234 increases. So to keep the same amount of 235 in the fuel tube as you make use of this recycled inventory, you have to put more and more total uranium in the fuel. Well the co-extrusion process doesn't work, back up even to the casting process. That requires higher casting temperatures because you put more uranium in and the melting temperature goes up. So you're challenging your materials and the process, the casting process. And then the ductility of the UAL alloy goes down because you're putting so much uranium in it. All the uranium bonds, when you melt uranium and it solidifies it, uranium forms compounds with aluminum UAL3 and UAL4 particles. And they are not very ductile. So the more uranium you put in there the more aluminum it eats up, and the material just doesn't want to extrude like metal. It will break and crack and everything.

FR: I guess the lab for many years promoted the use of powder metallurgy. And probably if you're going to build a plant that made aluminum based fuel these days you would do it with powder metallurgy. I think the big, one of the reasons we didn't do it was it's expensive to make that change. But the benefit is that the outside is very stable and you can put more uranium oxide in the aluminum than you can just as pure metal. So it's the, when you make the compact and extrude it, it's more ductal and you can actually put more total uranium in the fuel and make use of the recycle.

MS: Yeah I'd heard that one reason they didn't go with powder metallurgy was if they perfected the technique it would have just been too expensive to re-tool everything to work it.

FR: Well that, and there was so much enriched uranium out there in the world that nobody really, I mean it was already made. And although it is a national resource, you know it was just, if you, I mean if you needed more uranium to maintain the alloy process you just went off to the uranium warehouse at Oak Ridge and got more uranium and put it in. That was one of the false economies of that process I think was nobody was willing to admit there was more uranium out there than anybody would know what to do with. But anyway, let's see, so that was that. How about the, did anyone ever tell you about the UAL shot program?

MS: No.

FR: Before I got to the plant site one of the problems they had with the fuel was in the casting process maintaining, getting a nice homogenous UAL alloy. If you don't control the solidification process very well, the uranium will segregate in it. So one way to get around that is to, and this is sort of a pre-runner of the powder metallurgy process, was you take the UAL and you melt it and you make shot out of it. And because these particles are very small, you don't care too much about any segregation that occurs within an individual particle. So you can take two pounds of these particles and compact them into a, make a compact out of it, and make your cores that way. And there's also some other benefits in that you don't, in the casting process you have scrap that the casting process generates, and then all those castings have to be machined and all that scrap has to be recycled, so you could make the shot process more economical for materials.

MS: Okay.

FR: So somebody took the ball on this and they went out and bought, they found, we don't want to name names here do we? I think the guy's dead anyway. Somehow he took the ball in the process and went out and got an extrusion press. Well I guess he actually went and bought this extrusion press. A brand new extrusion press that was actually bigger than the press, more capacity than the press, it was a vertical press, but it was a, forcewise it was a bigger press than the 321 press. And they installed that in a building on the west side of 321. I don't know if that building even shows because it's gone. And then they had to build a building back there. And they spent a whole lot of money on it, like millions of dollars on this, at least a couple of million dollars. And then somebody discovered they neglected to fund the facility to make this UAL shot. And I think some people's careers got adversely affected at that point. The press was never used. I mean they played around with it trying to find uses for it, but eventually we sold the press and moved it out. And I don't know the number of that building. I think it's a warehouse back there now, or after the press was removed it turned into a ….

MS: It wasn't that building back here around 315?

FR: Yeah it was right in back of this thing.

MS: So it's behind 321.

FR: It was on the west side of 321.

MS: Okay, right. When was this?

FR: Well the press was there when I got here in '68, and it didn't get removed until 1990 or so, '80 or '90. It kind of just sat back there. So people would go back and run it to make sure it was still operating.

MS: Interesting.

FR: But it was just unbelievable that they built that, and the building had no real ventilation for containment. I mean it was just a stupid idea from the beginning, a stupid $2,000,000.00 idea.

MS: Well that can happen. What about security in M area? How did that change over time?

FR: I can recall when I walked over and went through a guard gate at the front of like where the cafeteria is. And then there was nothing else inside the area. You could just walk in and walk through the building, or walk, I used to always walk in at the big overhead door where the extrusion press was when I'd come over there. And then whenever all the security craziness started, it turned into a very hardened, well it wasn't a very hardened facility. It had a lot of fences and stuff around it. The building, as far as, the building itself did not offer much security. It was an asbestos sided, transite building that you could pound a hole through in ten seconds and then walk right in. But they put in a lot of fences and security systems.

MS: I heard something about there was even a machine gun emplacement up on top of 321.

FR: There was a posted guard up there. I don't doubt that he had, no doubt in my mind that he had a machine gun up there. There were battle stations around the building that were hardened facilities.

MS: In fact I think, one person I've interviewed said that security was relatively tight at the beginning, and then they slacked off in the middle years, and then it got tight again in the eighties.

FR: Well when I got here we…

MS: Largely as a result of like external things going on, you know.

FR: Yeah. I think when the plant started the Army was based out there. I mean there were Army facilities out there. And they had anti-aircraft guns and all sorts of stuff. When I got here, Dupont had their own security force and they were a bunch, by that time they were a bunch of old guys that, you know too old to run and do everything. And I'm not sure they gave them real bullets.

MS: Yeah. I know Dupont was not particularly interested in doing that aspect of it, and that's where the Wachenhut force came in.

FR: Right.

MS: Okay. Well that covers all the things that I can think of as far as my questions go. Is there anything else that you want to add? Or is there anything else that I might have missed, which is certainly a possibility.

FR: No I can't, I mean I'm sure we could cover things in more detail, and make it prettier.

MS: I can't think of any other major questions to ask. How many people worked there in M area? Ballpark figure.

FR: I'm thinking that the highest I ever saw in there, and that's probably when all the facilities were working three shifts, there were probably about 500 people total.

MS: In all of M area.

FR: In all of M area.

MS: Which one of the buildings would have had the most people?

FR: Probably I guess it's a draw between 313 and 321. 321 might have had some more people, but there were quite a few people in 313.

MS: And did all those people have clearances?

FR: I'm pretty sure at one, yeah at one time you had to have, I mean when I first came to the site you could not go anywhere without a Q clearance.

MS: Okay. Let's see, one more additional question. As far as the raw material that came into M area, they had, like what came into building 313? Would that have been natural uranium?

FR: Well initially it was probably some enriched uranium came in there, low enriched 234 weight percent, or percent 235. Then we probably went to natural, well it may have been natural to start with. There's been a combination of natural and low enriched. There was a campaign, the Mark 15 campaign, that used an enriched slug and I'm not, I think that enrichment was something like 7% or 10% or something like that. It was not a highly enriched fuel. Then in the end it was just all depleted uranium that was processed in there.

MS: Okay. What about building 321?

FR: 321, as far as I know all of used enriched uranium, either being a combination of the recycled or the, I mean it was all pretty highly enriched uranium. You know a little neptunium, a little plutonium.

MS: What about lithium?

FR: In 320, I think they started out using natural lithium and then when Oak Ridge had, when the enriched lithium became available in large quantities from Oak Ridge, that's when we started using that.

MS: Okay.

FR: And that's another reason why the vacuum furnace I guess, when we started out the process it was designed to use natural uranium so you needed to have a lot of it in there because there's only like 7% lithium 6 in that. But later we had the higher enrichments and so then you could reduce the total lithium content in the fuel and targets. And that's probably what a better explanation of why the uranium, why the lithium concentration went down and in time we were able to not have to have the vacuum furnace.

MS: What about, now autoclaves, they were found like in 313.

FR: Right.

MS: And they were simply to test the slugs or

FR: Right. Expose it to an environment that it would see in the reactor. So if you had a failure

MS: .... so it would fail in the autoclave before it got in the reactor.

FR: Right.

MS: And those were in 313 from the beginning, right?

FR: I assume they were. I don't know.

MS: I think that's correct. That's just what people have said. I just wanted to double check. Okay. I think that's about all I can think of to ask.

FR: Okay.

MS: Well thank you very much, I appreciate it.

FR: Okay.

End of tape.