Proving the Principle

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by Susan M. Stacy

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Idaho Falls, Idaho
DOE/ID-10799

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Published 2000
Printed in the United States of America
DOE/ID-10799

ISBN 0-16-059185-6

Prepared under contract by Jason Associates Corporation for the
U.S. Department of Energy, Idaho Operations Office.

Contract Number DE-AM07-97ID13472,
Task Order Number DE-AT07-98ID60300 (Task 14)

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Stacy, Susan M., 1943-
Proving the Principle: a history of the Idaho National Engineering and Environmental Laboratory, 1949-1999 / Susan M. Stacy.
p. cm.
Includes index.
ISBN: 0-16-059185-6 (pbk:alk. paper)
1. Stacy, Susan M., 1943- 2. Nuclear reactors—History.
3. Nuclear energy—Research laboratories—Idaho. 4. Radioactive waste disposal—Idaho. I. Idaho National Engineering and Environmental Laboratory (INEEL). II. Title.

TK9202.S73 P76 2000
621.483—dc21 CIP

For sale by the Superintendent of Documents, Mail Stop SSOP,Washington, D.C., 20402-9328

Dedication

To the pioneers of the NRTS who were part of the nuclear science adventure, and to the employees of the INEEL who continue the adventure of science.

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Introduction

"What did they actually do there?" This question has come my way frequently while researching and writing this history. Idahoans seem to have a sense of continuity with their mining and timber roots, their agricultural heritage, and the great themes of the West—Lewis and Clark, the Oregon Trail, Reclamation. But when it comes to their nuclear heritage, connections seem vague. The Idaho National Engineering and Environmental Laboratory (INEEL) was set up deliberately in a remote area. Fifty years later, it still is remote, in more ways than one.

I became curious about the INEEL after hearing a lecture about Hanford, the government's other nuclear facility in the Pacific Northwest. The speaker described Hanford's secret war-time mission to manufacture plutonium for weapons and criticized its later environmental record. The talk made me wonder about the role of INEEL in the nuclear world, for I knew little of its history. Therefore, when I was asked in June 1998 to prepare a history of the INEEL on the occasion of its 50th anniversary in 1999, I was ready with questions to ask of the past.

The story of the INEEL, originally named the National Reactor Testing Station (NRTS), is really a thousand stories. Sadly, not all could be in this book. Among those not here are certain defense research topics—the Centaurus laser-pumping experiments, for example—and medical topics like the campaign to recycle the Power Burst Facility for Boron Neutron Capture Therapy, a potential treatment for a deadly type of brain tumor. The accomplishments of the Radiological and Environmental Sciences Laboratory and a kaleidoscopic array of recent non-nuclear research are likewise missing. Recent decades in general receive less attention than the early days. But then, recent decades are full of programs and issues that continue to evolve, so perhaps it is better to let them mellow before a historian tries to characterize them.

This book is neither a technical report nor a scientific assessment. It is intended for the general reader with no background in physics, chemistry, or any other science. It aims to trace the changing relationship between a federal nuclear laboratory and its home state. Nuclear science is a character in the story, however, but not dressed in all its technical finery. A glossary and acronym list are available at the back of the book for those who wish an occasional reminder.

It is the question "What did they do?" that produces the thousand stories. The INEEL was the scene of thousands of scientific experiments. I learned to correct my notion of an "experiment." The word brought up vague memories of high school chemistry class—pouring a liquid of one color into a glass filled with a liquid of another color. The result was a third color, and that was it. In nuclear matters, however, an experiment may require acres of land, huge buildings, hundreds of people, and millions of dollars. It may take years to conceive, design, and build. After all that, the action phase of an experiment might take about the same time it took to pour liquid A into liquid B.

Large-scale laboratory work requires the well-orchestrated efforts of teams. Nevertheless, a historian, particularly when commissioned for a golden anniversary, looks for insight by talking to individuals. Who can interview a team that existed and dissolved forty-five years ago? Yet accomplishments are so often the product of teams, working groups, task forces, and committees, that it is hard to identify the individual who might have flashed the first break-through light on a problem. Team work is a fact of life in Big Science, perhaps most science. People demonstrate creativity and imagination in ways not often recognized. This book does not mention all the times that someone said of another, "He was the most brilliant physicist I've ever known," "We had superb back-up from our radiochemists," "The weather service sent their best meteorologists to the NRTS," "Our welders were the best in the business." I heard that sort of thing frequently.

Therefore, I regret the many stories not recorded here, the many exceptional individuals not acknowledged, the many discoveries and engineered systems not mentioned, the many ingenious experiments not described. I hope that the all-too-few names and episodes that do appear in the book will be understood partly as stand-ins for the many others that could just as well have been included—and stand-ins, as well, for the teams that made it possible for individuals to have stories to tell.

All historians of the Atomic Energy Commission or the Department of Energy (DOE) and its laboratories have had to cope with the multiple-arena aspect of their subjects: activity moves on several fronts at the same time. At the INEEL this is notably the case. Major programs were under different contractors and progressed simultaneously, sometimes having little more in common than the desert scenery and the landlord. Rather than chart INEEL history using internal bench marks such as the change in DOE secretaries or the five-year increments of operating contracts, I tried to keep in mind the general reader and the non-scientist, for most of whom this book will be an introduction to the INEEL.

As this manuscript neared completion, a criticality accident occurred in Tokaimura, Japan, in a plant fabricating highly enriched nuclear fuel. Having learned some basic nuclear language, I saw how carelessly many journalists reported this news. They used the word "contaminated," for example, when they meant "irradiated." The Idaho Chemical Processing Plant (renamed Idaho Nuclear

Technology and Engineering Center, INTEC, in 1998) at the INEEL has been the scene of three accidental criticalities. These episodes, although as grave as any unintentional criticality, were not germane to the general flow of the history and were piled on the stack of untold stories. Lest anyone believe that these were deliberately omitted, information about them is supplied in the appendix.

Associates have asked if my research exposed any "secrets" at the INEEL. DOE supplied me with no security clearance. Considering the broad scope of the history—and the time given in which to complete it—this was not a concern. I consulted many documents that were at one time classified and subsequently declassified. Nevertheless, the manuscript managed (inadvertently) to arouse classification concerns in connection with certain activities at the Chem Plant in the 1950s. For the rest, the selection of material, its interpretation, and any errors it may contain are entirely my own responsibility.

It was a special privilege to become acquainted with dozens of retired and current employees at the INEEL. Selected excerpts from some of these conversations appear in the book. If these in any way encourage INEEL people to record their own memories and their own explanation of why things were done the way they were, I say, "Get busy." The tons of scientific reports on the shelves omit all too well the flavors of human experience, be they disappointment, tedium, or exhilaration.

Now at the end of the project, I reflect once more on the lecture about Hanford and consider what I learned about the INEEL. In trying to understand environmental and other events within the context of their time and place, it seems to me that the managers and scientists of the INEEL were neither careless nor casual about the disposition of hazardous materials, radioactive waste, or radioactive releases. Some people account for this by remarking, "This was not a weapons production site." This explanation, expressed as a negative, gives insufficient credit to more positive themes in INEEL history. A research mentality, the daily use of the scientific method, the safety traditions established by the founders, and the integration of Site employees into surrounding communities—all of these must count for something.

Environmental concerns are surely important, but it is possible that when future generations consider the impact of the INEEL on the environment, they will find that impact to be far outweighed and outlived by the laboratory's remarkable legacy of scientific discovery and engineering achievement.

Susan M. Stacy

Acknowledgments

The one-year horizon for preparing this book required some serious help from a lot of people. Greg Hula, the DOE/ID project manager, asked DOE/ID's contractor Jason Associates to supply a lot of it. Nelson Soucek managed the project for Jason, sensitive always to the tension between the deadlines that crowd and the space required to do work. I appreciate the many quiet ways he kept these contending forces in a productive balance. Greg Hula was on the other side of that coin, and I thank him for the many ways his kind patience, guidance, and astuteness helped to improve the manuscript.

Jason placed Lori McNamara on the project as research assistant and photo researcher. Lori and Kris Burnham compiled the information on historic NRTS reactors found in Appendix B. Assisted by Terese Nield, she located most of the photos appearing in the book. This task took her into many private homes, and we thank all of those generous people, including Bertie Lee Marvel, Pat Gibson, the Thomas Sutton family, the Ada Marcia Porter family, Orville and Margaret Larsen, and William Holden, Jr., who permitted the use of their photos.

Kris Burnham also designed the book and cover. She, along with others at Jason, also undertook the task of preparing the index. In addition to her talent, Kris brought her own considerable knowledge of NRTS/INEEL resources to bear on many details of the book, for all of which I thank her.

The INEEL Photo Lab was a major partner in this project. We are grateful to Joyce Lowman and the rest of the Photo Lab crew: Cindy Copeland, Mike Crane, and Ron Paarmann. My personal thanks to Joyce for giving me access to the special treasures she preserved over the years because she thought they might be useful someday. Her encouragement meant a lot to me.

Thanks also to Jerry Russell of the Rock Island office of the U.S. Army Corps of Engineers, Ed Hahn at Argonne-West, Dave Baurack of Argonne-East, Mary Jane Fritzen of the Bonneville Historical Society, Kirk Clawson of the National Oceanic and Atmospheric Administration, Marie Hallion of DOE Headquarters, who rendered additional help with photos, Clarence Mike of the Idaho Transportation Department, and Pixanna Walker of the Lost River Visitors Center for help locating people and pictures.

Acknowledgements

Librarians sometimes take their helping work for granted, but the researchers they help don't. I thank Teresa Oh and Bernice Kunkel at the INEEL Technical Library; Judy Krieger at the Argonne-West library; Alan Virta and Mary Austin at the Boise State University Special Collections Library; Carol Silvers and all the reference librarians at the Idaho State Library; Judy Austin, Carolyn Bowler, Kathy Hodges, Linda Morton-Keithley, Angela Carney, and John Yandell at the Idaho State Historical Society Library.

I asked Greg Hula to gather a group of people willing to review the manuscript for technical accuracy. This group began small and then grew. I would like to thank especially C. Wayne Bills, Theron Bradley, Julie Braun, John Byrom, John Commander, Don Dahl, Bill Ginkel, Joe W. Henscheid, Greg Hula, Bill Jensen, Ron King, Jay Kunze, Leroy Lewis, Richard Lindsay, Brent Palmer, Bill Parmley, Paul Pugmire, Carl Robertson, Robert Stallman, Bob Starck, Harlin Summers, Tom Wichmann, and Diana Yupe. The late John Horan was the first in this group. It was my good fortune to have many hours of conversation with him. He was a person of moral discernment, common sense, and great generosity of spirit. His death occurred just as the first chapters were materializing; he left far too soon and I have missed him very much. To him and his wife, Kathy Horan, I cannot adequately express my thanks.

Talking with people connected with the Site as retirees, state officials, or current employees was the choicest part of this work. Many generously loaned me documents and reports from their own collections. I thank them all: Tony Allen, Boyd Anderson, Cecil D. Andrus, Al Anselmo, Jacqui Johnston Batie, Jerry Batie, Ray Barnes, C. Wayne Bills, Brett Bohan, J. Robb Brady, Robert Brugger, John Byrom, John Capek, David Cauffman, Terrell Carver, Jack Clark, Jack Combo, John Commander, Clay Condit, Beverly Cook, Deslonde deBoisblanc, Don Deming, Pete Dirkmaat, Kenhi Drewes, George Freund, Mary Freund, Bill Ginkel, Merle Griebenow, Clyde Hammond, Orval Hansen, Joe W. Hensheid, Kathy Horan, King House, Dennis Keiser, Larry Knight, Jay Kunze, Gloria Lambson, Kay Lambson, Margaret Larsen, Orville Larsen, Leroy Lewis, Jerry Lyle, Phil McDonald, Mary McKnight, the late Fred McMillan, Clayton Marler, Dick Meservey, Michael Moore, Clay Nichols, Warren Nyer, Don Ofte, Gordon Olsen, Hal Paige, Bernice Paige, Myrna Perry, Henry Peterson, Augustine Pitrolo, Susan Prestwich, Paul Pugmire, John Ray, Chuck Rice, Bryce Rich, Walter Sato, Bruce Schmalz, Jeff Schrade, Robert Skinner, Robert Smylie, Susan Stiger, Harlin Summers, John Taylor, Charles Till, Marvin Walker, George Wehmann, John Wilcynski, Kirby Witham, and others.

Then there were the members of the Arrowrock Group, historians Madeline Buckendorf, Barbara Perry Bauer, and Elizabeth Jacox, who provided documents from their previous research and much personal encouragement; Jeff Bryant, who introduced me to Chem Plant historical resources; Nolan Jensen, for photo interpretation and for a uranium rock sample; Eric Simpson of Bechtel BWXT's

Community Relations group, for helping make connections; Roger Anders, who sent draft manuscript chapters of an in-progress volume on the history of the Nuclear Regulatory Commission; Paul Zelos of Idaho State University for providing back issues of Site Impact studies and other valuable bibliographical materials; John Simpson, for permission to quote from his book and for putting me in touch with John Taylor; Jeanette Germain and Todd Thompson for editing; Dino Lowrey, for making certain important arrangements; James M. Stacy and John McKinley, who sent me several NRC documents; Hollie Gilbert, for help with Argonne photos and help with laughter. Thank you all.

Many others from DOE or its contractors answered questions, sent reports, or found photos. Every contact helped, and I am grateful.

The people at the Cultural Resources Department of Lockheed Martin Idaho, now Bechtel BWXT Idaho, were of special help in this project. Clayton Marler, Suzanne Miller, and Julie Braun considered years ago that a history would be a long-lasting way to commemorate INEEL's 50th anniversary. They promoted the idea beyond their department and joined others, not all of whom are known to me, who shared the same view. Along with Greg Hula and others, they look like godparents of a book. Beyond that, Julie's personal encouragement and wise counsel have been graces in my life. I'm plain lucky to have them.

At home, my husband Ralph McAdams has kept our household from becoming a proof of entropy. Assuming more than his share of chores was the least of it; I am most grateful for the island of peace, the cups of tea, the chocolate eclairs, and his constant loving support.

Chapter One

Aviator's Cave

People had to be strong to walk, for they walked in great strides... They would dehydrate roots and fruits for winter storage and put them in caches up and down the valleys or across the mountains. That was done so we would be noticed as being poor and without food. People did not know at the time that my people had caches. After the fruits were dehydrated, then they would go up into the mountains, over the summits, and into the meat world.

–Emma Dann–

Mike Atwood, the chief pilot, and his co-pilot, a sergeant with the Special Response Team, boarded their Bell 222 helicopter at Central Facilities Area (CFA) to begin a routine perimeter surveillance of the Site. The two were part of the Airborne Security Program, a system that the Department of Energy had installed in 1984 to beef up the security of America's "special nuclear materials," a phrase referring to uranium, plutonium, and a few other elements.[1]

INEEL 89-329-2-2

It was January 1985, four years before the collapse of the Berlin Wall and the beginning of the end of the Cold War. The proper name of the Site, also referred to as "the desert," was Idaho National Engineering Laboratory (INEL). The pilots flew the perimeter several times each day—and each night, equipped with night vision goggles—to check for unauthorized entry, lost hunters, or anything else unusual. Fencing for the 894-square-mile Site had never been considered necessary—despite the classified nature of much that went on there.

The pilots and their helicopters were components of a new special response team trained in counter-terrorism. In the wake of the killing of over 240 U.S. Marines in Lebanon in October 1983, this heightened level of protection now lay over more traditional security measures: passes, badges, personnel security clearances, armed guards at entry gates, secure radio channels, "Keep Out" warning signs, and a "need to know" approach to information.

Security fences topped with barbed wire did exist around several small acreages within the perimeter where the business of the Site was concentrated. Outside those fences, the land was mostly open desert. A few neighboring ranchers had privileges on the premises, enjoying concessions made during the early years when the ranchers had persuaded the Atomic Energy Commission (AEC) that there was no good reason to keep cattle and sheep from grazing the land during the few months of the year that the climate permitted.[2]

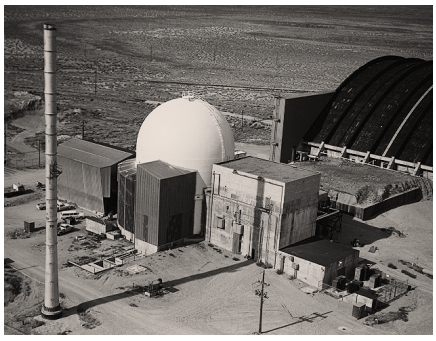
As the helicopter ascended, it hovered momentarily and then tilted eastward into forward flight about five hundred feet above the desert floor. At this low

Shoshone and Bannock encampment near Pocatello, Idaho.

Idaho State Historical Society 79-148.8

INEEL 89-582-7-1

Test Reactor Area in foreground. Idaho Chemical Processing Plant, (now Idaho Nuclear Technology Engineering Center) in middle distance. East and Middle buttes on horizon.



INEEL 75-3690

Containment dome and emission stack for Loss of Fluid Test at Test Area North.

INEEL 73-3049

Naval Reactors Facility. Building in center houses S1W, the prototype for USS Nautilus.

altitude, the landscape retained its definition of shallow swales, knolls, small ridges, an occasional crater, and low hills. Sometimes the pilots flew twice that high, and then these details dissolved, and the desert appeared as "a broad, nearly flat plain," a phrase used often to describe this part of the Snake River Plain. It was true, however, that pancake-flat floors of undrained basins—playas—were also a feature of the landscape at many places.[3]

In the sub-zero temperatures of the morning, the pilots swept over the Site, aided by the blazing blue brightness of the Idaho sky. A glance to the south always afforded a stunning view of Big Southern Butte, impressive in any season. Further east were two more buttes, named East and Middle for their relationship to Big Southern and each other. Rising over 1,400 feet from the flatness of the desert, the ancient volcanoes had been reliable landmarks for travelers through the centuries.

Below the helicopter, a carpet of snow covered the straw-toned and gray winter colors of desert grasses and low shrubs. Here and there the snowy expanse gave way to an industrial complex, its square corners and rectangular shapes contrasting sharply with the softer contours of the surrounding terrain. Approaching such a cluster from a low altitude, one might imagine an encounter with a kind of enclosed city, with towering exhaust stacks taking the place of spires and steeples, and chain-link fences surrounding the buildings instead of high stone walls.

Flying past each cluster, the pilots looked for signs of disturbance. Each area contained at least one building with a unique and unexpected shape that rose up on the horizon and drew the eye. At one, it was a large silver dome. At another, it was the dark-ribbed roof of an immense barrel-vaulted building with the doors of an airplane hangar. At another area miles away, one could see a row of round wooden cooling towers with steamy water vapor boiling into the frigid air like so many cauldrons of hot soup.

The pilots were flying a random pattern. They had observed herds of deer and elk near the eastern boundary, but no sign of poachers. They were heading back to CFA when Atwood noticed a faint wisp of steam rising from—what? Apparently nothing. The spot was several miles from one of the activity clusters, and no ribbon of road went anywhere near it. He would have known if it were the scene of some special test or experiment, so he tilted closer and circled the plume. He saw a small ridge formed by what seemed to be a lava tube. The steam drifted from a hole in the top of the tube. He decided it was merely the condensation of warm air from a void under the tube meeting the cold air outside.

Atwood noted the spot with the global positioning gear in the helicopter. He returned to base and promptly forgot about it. Something made him think of it again in 1988 and he decided to revisit the place. This time it was spring. The desert was green, almost lush-looking from the air. Again the sun was bright, but a temperature of

seventy degrees made the expedition a more pleasant outing than it would have been before. As he hovered over the hole, he noticed that the vegetation growing near it was unusual, a different color than the sage and rabbit brush so common on the desert, a brighter shade of green.

He set the helicopter down on a flat spot about thirty feet from the hole. Lava tubes are common on this part of the Snake River Plain. These were formed as recently as 200,000 years ago when basalt magma oozed quietly out of the earth from thirty miles below, filling up low stream valleys and canyons. The outer portion of the flow cooled and hardened more quickly than the inside, providing tunnels for the hot molasses-like fluid within to move long distances before it cooled. Eventually, the magma stopped erupting and the tunnels drained. Often, all or part of the roof collapsed.[4]

As they approached, Atwood and his co-pilot saw a cairn near the hole. The rocks were stacked nearly three feet high. Their first thought was that an old sheepherder had erected the marker. The Snake River Plain had been a well-used crossing beginning in the late decades of the 19th century and the early 20th. Stockmen had driven cattle and sheep to the shipping centers of Montana from Oregon, Washington, and western Idaho; and their cairns had been found elsewhere on the Site.

But then the two men noticed piles of obsidian chips, thousands of them, strewn about. Suddenly they knew they would need flashlights. Fetching them from the helicopter, they returned to the hole and beamed the light into the cavern below.

I saw buffalo skulls with horns and a lot of other bones. You can tell buffalo by the way the horns come out lower on the skull than other animals. We climbed into the hole, stepping on rocks that led you down into it. I could smell bobcat. You had to stoop a little to get into the cave, but then the cavity really opened up and we could stand up easi - ly. We saw a lot more bones and what looked like a fireplace the way the rocks were placed. There were all kinds of things in there.[5]

INEEL Cultural Resources

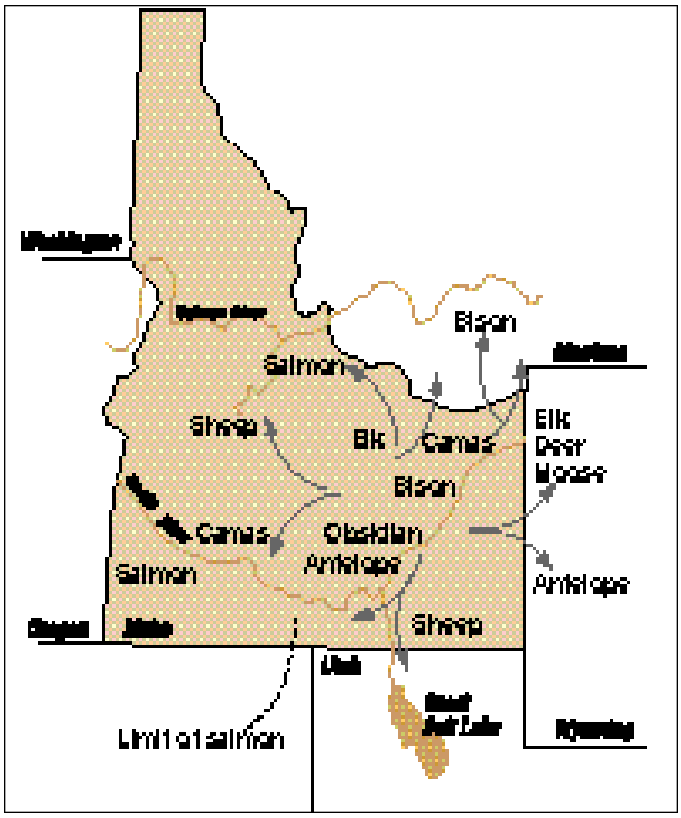
The floor of the cave contained more obsidian chips. Amidst the thick scatter, they found what many people call "arrowheads" and what archaeologists call "projectile points." The skulls and rocks and other objects on the floor were covered lightly with a thin film of dust. Upon exploring briefly, they realized that the lava tube had a large high-ceilinged central area and three arm-like extensions. Crevices in the rock walls contained mysterious objects made of twine, bone, and pieces of wood. Whoever had put them there had done so many hundreds of years before, and the pilots may have been the first to see them since then.[6]

Left. Projectile points found on the INEL site. Below. Archaeologists and members of the Shoshone-Bannock Tribe get acquainted with the interior of Aviator's Cave.

INEEL89-329-1-9

The ancestral homelands of the Shoshone and Bannock people extend across the entire length and width of the Snake River Plain, across the Site, and into the north well beyond the rugged mountains of the Bitterroot, the Lemhi, and the Lost River ranges and the valleys between them. To the south and east, they include the grassy lands around Bear Lake, the northern fringe of the Great Basin, and the bison country of Wyoming and Montana.[7]

It was a generous territory upon which they built their economy. They were hunters and gatherers, and the land supplied subsistence and more. The mountains and streams supplied sheep, deer, squirrel, salmon, fiber, grasses, watercress, fruit, obsidian, and fuel. Rabbits, marmots, small mammals, reptiles, and sage brush inhabited the dry desert. All these were useful. The river bottoms around the Snake River were rich in roots, camas, tules, grasses, hawks, and eagles. The people hunted bison and used its flesh and bone for food, tools, and clothing.



INEEL Cultural Resources

Until they began using horses in the early 1800s, Shoshone and Bannock people traveled on foot.

With these riches, the people ate and dressed well during all seasons and had choice materials with which to make the tools and goods of everyday life. They crafted baskets and pots to carry, store, and prepare food. They trapped game with snares and heated their dwellings comfortably with wood in the winter. They made spears, bows, arrows, knives, scrapers, awls, needles, and other tools with obsidian, chert, bone, and wood. The botanical variety in the region supplied a pharmacy as well as food.

To live with the rhythm of the land was to understand the seasonality of the resources, and to walk from place to place accordingly. Each direction of the compass pointed to special gifts—camas to the west, bison to the north and east. When the people walked through the arid desert between the winter villages in the Fort Hall bottomlands and the mountains to the north, they cached food and knew where to find water.

They traveled in family groups. From the winter villages, some paths took them across the Site towards the Big Lost River, one of the waterways that flowed with some reliability in the spring of the year. The desert was hot in summer and unthinkably cold in the winter. This and other caves in the area must have offered considerable comfort in either season and a useful camp for a more extended stay.

The cave contained perishable items of great age in a reasonable state of preservation. These provide some insight as to how the early travelers spent their time. When people stopped at the cave, where water from small natural basins nearby might have been available in the spring and fall, they worked. They made and repaired clothing, snares, bows and arrows, knives. Over the years, the people left rush mats, hides, rabbit-fur robes, and pottery behind. The plants growing near the mouth of the cave were saltbush, which for some reason found this spot unusually hospitable.

Charred bison bones speak of good meals. On fine days, flint knappers worked outside; on days too cold, inside near the fire. Artisans in stone, they had no idea that people of the nuclear age would give names to their

tools—Avonlea, Desert Side-notched, Rosegate—or that their sizes and shapes would tell a story about the passage of time.[8]

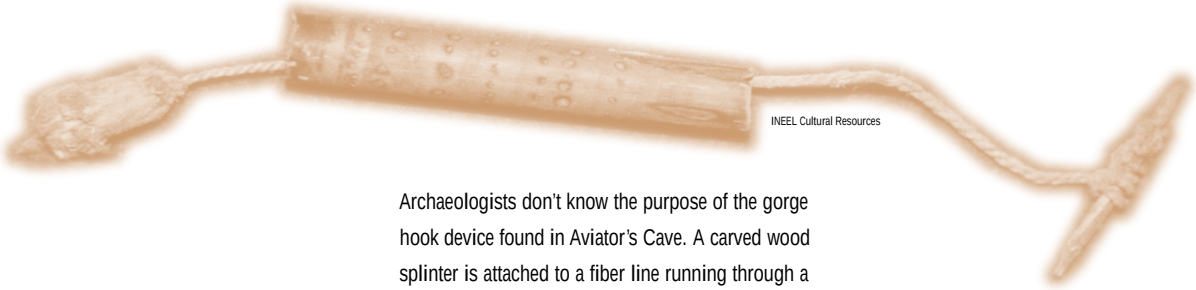
In the air once more, the pilots could see in the land below the subtle scars that marked the changing fortunes of the Shoshone and Bannock people. After the trappers had come, and after Eliza Spalding and Narcissa Whitman had proved in 1836 that families could cross the continent in wagons, the Oregon Trail brought a vast invasion of native lands. The wagon ruts of Goodale's Cutoff, one of its branches, is still recognizable at the southwestern corner of the Site. After the first waves of settlers, great herds of cattle and sheep moved along the trail.

The mountains to the north contained gold, and when prospectors discovered this in the 1880s, they stimulated a substantial freighting industry between the mining towns and supply centers at Eagle Rock (now Idaho Falls) and Blackfoot. Wagon roads began to criss-cross the Site, carrying food and dry goods, mining gear, and hopeful passengers. The desert remained primarily a corridor, as it had been for the Indians, a place for temporary camps on the way to somewhere else.[9]

Someone eventually did try, however, to homestead in the desert. The land seemed good, and all that was needed was to transport water to it. The serpentine tracings of old canals in the western region of the Site were easy to pick out from the air. It had required the resources of the federal government to make such irrigation projects feasible. The Carey Act of 1894 and the Reclamation Act of 1902 provided the legal framework to imagine that water from the Big Lost River could be dammed, diverted into a canal, and sent to transform the desert into a garden. The effort was doomed because the engineers miscalculated the amount of water available. They didn't understand the wind-blown soils of the desert and the layers of fractured basalt beneath the reservoirs and canals. Soils were too porous or contained too much clay. Disappointed, the settlers drifted away in the 1920s, having failed to find "salvation from the application of science and engineering expertise." So the Site lost the few inhabitants who had ever thought of residing permanently on the desert.[10]

Atwood reported the cave to archaeological authorities, who in turn notified members of the Shoshone-Bannock Tribe at the Fort Hall Indian Reservation in southeast Idaho. He and other pilots of the Special Response Team flew back to the place many times, carrying members of the tribe and archaeologists to the cave for visits and work trips. As the one who rediscovered the cave, he had the privilege of naming it. He chose Aviator's Cave as a gesture of acknowledgement to all the pilots in his unit.

The successive waves of trappers, pioneers, miners, and settlers in southeast Idaho had long since changed the landscape and restricted the seasonal round, although Shoshone and Bannock people continued to use some of their traditional routes. Memories of the cave live in legends. Gold had played out. Dreams of agrarian abundance had gone bankrupt. The Lost River Desert, sometimes called the Arco Desert for the village on its northern fringe, became another "remote" place in a long list of remote places in the American West. But with the coming of World War II, remoteness would prove to be its most appealing attraction.[11]



Archaeologists don't know the purpose of the gorge hook device found in Aviator's Cave. A carved wood splinter is attached to a fiber line running through a reed shaft. The opposite end of the line is tied to a tuft of fur, which plugs the end of the tube, preventing the line from pulling out.

Chapter Two

The Naval Proving Ground

They had a place where civilians could watch them fire the guns occasionally. I remember how the ground would shake; it was a terrific concussion. Your eyes sort of vibrated and your vision was blurry. After the shot, you could see a poof of dirt in the desert.

–Kay Lambson–

As tensions built toward world war in the late 1930s, the U.S. Navy hired contractors to build naval bases on the Atlantic and Pacific coasts, Hawaii, Guam, and at five Pacific atolls named Johnston, Palmyra, Samoa, Midway, and Wake. The bases were to implement a war plan named Rainbow Five. In the event of war with Japan, the five westerly bases would form a kind of defensive curtain protecting the Navy's major fleet base in Hawaii. Offensively, they were to be take-off points for bombers to hit Japanese targets in the Marshall Islands and Kwajalein.

The war started before the bases were ready. In December of 1941, Japan crippled the fleet in Pearl Harbor, attacked Midway, and captured Wake and Guam, preventing the United States from carrying out Rainbow Five. The Navy quickly expanded its West Coast bases and also looked inland for support facilities. Gun factories, for example, needed to be secure from potential enemy raids by sea.[1]

The Sixth Supplemental National Defense Appropriation Act of 1942 placed two support facilities in Idaho. One was the Farragut Naval Training Center, a training base for sailors at the southern end of Lake Pend Oreille. The other was the Naval Ordnance Plant at Pocatello, established on April 1, 1942, under the command of the Navy's Bureau of Ordnance.[2]

Built by the Morrison-Knudsen Company of Idaho, one of the Navy's major contractors, the ordnance plant was situated on 211 acres about three miles north of Pocatello. The Navy chose the site because Pocatello was home to one of the largest Union Pacific Railroad terminals in the country and on the route of a transcontinental highway. Lying east of the coastal mountain ranges, it was reasonably secure, and the plant could take delivery of steel, chemicals, ordnance, and battleship guns shipped from the West Coast.

The guns came from such fighting ships as *USS Missouri* and *USS Wisconsin* whose revolving armored turrets, studded with sixteen-inch guns, the Navy's most powerful, helped win the Pacific war. Repeated firing of the guns eroded the bore, wore out the rifling, and compromised the accuracy of the gun. The Pocatello plant removed the distorted inner sleeves of the gun barrels, relined them with fresh metal, rifled the new linings, and then tested them for

The battleship USS Missouri wears out the linings in its guns.

Naval Historical Center 80-G-421049

accuracy. In addition, the plant warehoused ordnance and manufactured new guns and gun mounts—large and small—for service on Pacific fleet battleships.[3]

As an accessory to the plant, the Navy needed a firing range on flat terrain and about thirty miles long to proof fire the guns. It first considered a site near Taber, a tiny settlement about forty miles northwest of Pocatello. But the ground there was uneven, and lava rock was too close to the surface for ease of construction. The Navy looked further north and found an ideal site: flat, remote, and unpopulated. What few acres were in private hands had to be condemned, but most of the land was in the public domain.[4]

On the southern edge of the site, a Union Pacific branch line passed by on its way from Pocatello northwest to the towns of Arco and Mackay. The place was sixty-five miles from Pocatello, and it would be easy to extend a spur line and build a siding. The Navy withdrew about 271 square miles from the public domain and built the Naval Proving Ground (NPG). Its acreage cut a jagged-edged swath into the desert roughly nine miles wide and thirty-six miles long. From the firing point at the south end, the guns had an unobstructed range toward the northeast.

The Navy intended to house some of its employees, both military and civilian, at the proving ground with their families. The facility was divided into two parts: the residential area and the proof area. As at Pocatello, the Morrison-Knudsen Company built everything at the site, subcontracting some of the work to the J.A. Terteling Company, another Idaho construction firm. The place was dedicated and ready for business on August 2, 1943.[5]

The eighty-five-acre proof area was north of the residential area and fenced; anyone entering had to pass a guardhouse. It contained a battery of gun emplacements, a concussion wall and control tower, and magazines for smokeless powder, fuzes, and charges. An office building, railroad trackage, oil storage tanks, electrical substation, and other facilities supported the operations. A locomotive hauled the guns and other loads from place to place around the proof area. Most of the buildings were made of reinforced concrete to withstand the vibration and shock from the guns and potential munitions explosions.

The concussion wall, designed to absorb blast and protect those who fired the guns, was a particularly formidable piece of architecture. Standing between the gun emplacements and the residential area to the south, it was 315 feet long, 8 feet thick, and 15 1/2 feet high. Its rebar was doubled and placed in a close eight-inch grid. Those in the control tower behind the wall could peer out of narrow window slits at the emplacements, each painted with a letter to make up the slogan "SAFETY FIRST."[6]

INEEL 2974

Residential area of the Naval Proving Ground as it looked in July 1951, view to southwest. Older section is at right near water tower.

The railroad brought the guns and other material from Pocatello to a siding dominated by a 250-ton gantry crane. A gun ready to be proofed was positioned on one of the ten emplacements and loaded with a charge, most likely prepared by a "WOW," a civilian Woman Ordnance Worker. Down the range, to the east and west of the centerline, were rows of concrete monuments, marked and placed at regular distances. To prepare for a test, spotters drove down dirt roads named Centerline, West Monument, and East Monument. From observation posts, they communicated with operators in the control tower and used the monuments to triangulate the location of impact. In this way, they evaluated and recorded the performance of the gun.[7]

INEEL 3629

Proof area in October 1951. Gantry crane at lower left. Gun emplacements in foreground. Buildings in center are behind concussion wall. Storage area at upper right.

Less than half a mile from the concussion wall was the residential area, divided into two sections by the railroad spur coming in from the Union Pacific branch. The officers and several civilian families lived on the west side of the tracks in brick houses with white shutters. The Navy built for permanence, planting the grounds with trees and shrubs. The northern-most dwelling, the one with a matching garage, was reserved for the commanding officer. The southern-most was a barracks and mess for up to fourteen enlisted marines. Beyond the barracks were a kennel for the marines' patrol dogs and a well-supplied commissary, which the civilians called "the store."[8]

After the war, the Navy built more houses, wanting to alleviate winter travel problems for employees who commuted between the site and Arco. It built a loop road on the east side of the railroad tracks and arranged nineteen white-painted wood-frame houses around it, back yards facing to the spacious interior of the loop. Most of the houses, if not all, had basements, and each had generous yard space to grow gardens. The Navy finished installing the lawns and sidewalks in October of 1946.[9]

The main landmark for "the Base" was an elevated water tank perched on a wooden tower in the residential area. Officially, the railroad siding and village were named "Scoville" after Commander John A. Scoville, the Officer in Charge of Construction of the Pocatello plant and the proving ground. The Navy named the main roads Lincoln Boulevard, Farragut Avenue, and Portland Avenue, a legacy that remained—along with the name Scoville—after the Navy left the site.[10]

In this setting, the wartime business of firing lethal weapons and detonating huge explosive charges co-existed with a small—and unique—Idaho village. The Navy shipped first-run movies to the residents twice a week. These were shown in the locomotive shed next to the spur line. On movie nights, the locomotive was parked outside, displaced by the movie projector and rows of benches. The versatile building also served as a fire station and garage.[11]

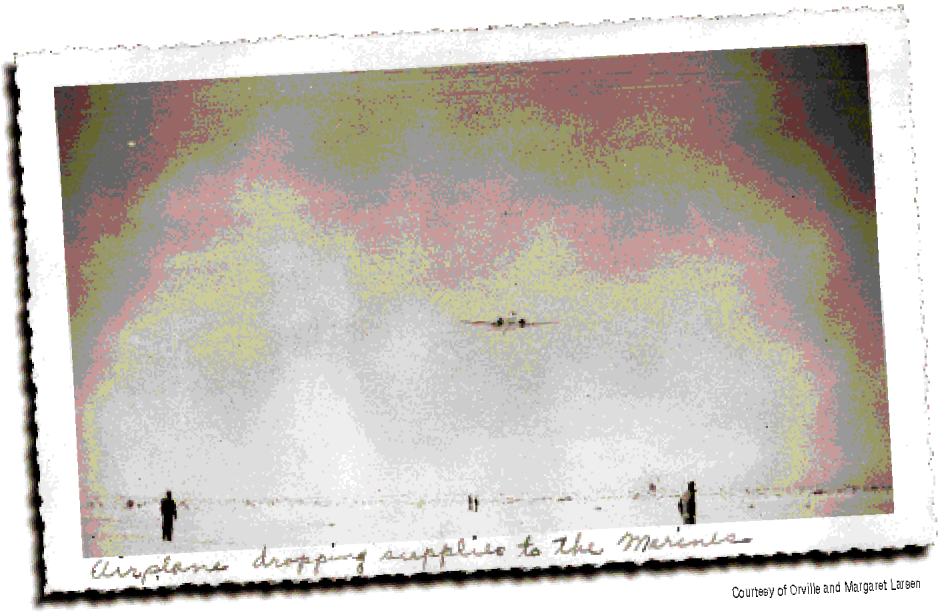
Children were an integral part of the community. The marines made skating rinks for them in the winter. Students filled up a gun-metal-gray bus and went to school at Arco seventeen miles away, sometimes accompanied by a marine when certain boys got out of hand. In typical military fashion, the bus stopped one day each year in front of the marine barracks, where no child could escape the dreaded "tick shot," a booster to prevent Rocky Mountain spotted fever.[12]

Trouble was easy for children to find, what with forbidden piles of railroad ties lying about and Navy floats and buoys awaiting repair on the dry desert ground. One year, one of the lieutenants tried to grow freshwater clams in a pond made from a gravel pit, but was thwarted when some of the children discovered them and opened every one, amazed at the beautiful purple luster inside. Another temptation was the water tower. At least one pair of enterprising young girls sneaked away from home one night, thinking it would be a good idea to climb to the top. They tripped an alarm, and the marines came after the intruders with flashlights and guns, shouting "Halt!" High in the air and giddy from excitement, the girls couldn't manage the descent, so the marines had to fetch them down.[13]

Courtesy of Orville and Margaret Larsen

Margaret Larsen, the NPG's first Woman Ordnance Worker, and her son John pose in the shadow of the water tower in 1949.

Characteristic of its civilian/military blend, the settlement found ways to deal with remoteness and isolation. One of the civilian families kept a small herd of dairy cows a mile or so northwest of the village. The father and his sons went each day to collect the milk, brought it home to the basement of their house, separated and pasteurized it, and delivered it to the other residents in a milk truck. In summers, the men organized baseball teams and played teams from Arco, Mackay, and other towns. When not otherwise working, women entertained each other at sewing circles. During one winter, an unusually heavy snow storm closed the roads to the base, isolating it for nearly a month. The residents offered refuge to travelers stranded on the road and sheltered them in their homes for the duration. The Navy dropped food bundles from airplanes into snowbanks. All were relieved when the roads opened before a woman who was pregnant had to leave for the hospital.[14]



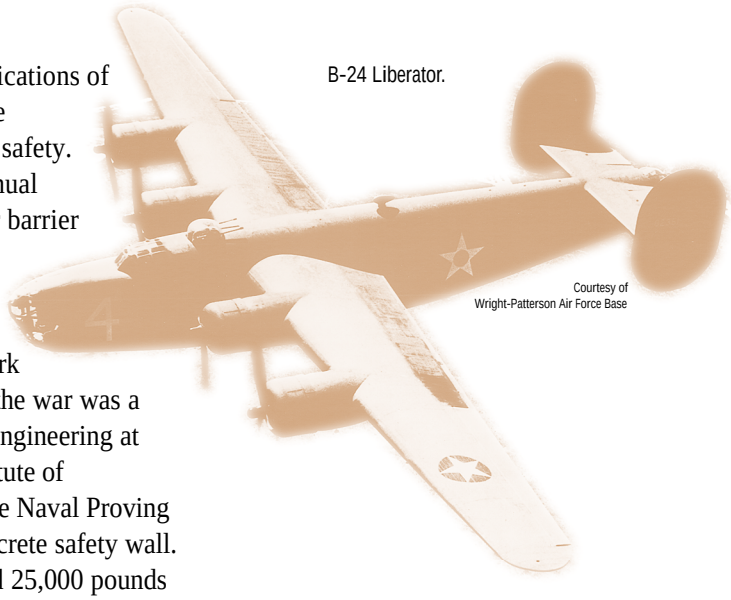
Courtesy of Orville and Margaret Larsen

The extraordinary winter of 1948. The Navy dropped food and other supplies when snow blocked roads to Arco and Blackfoot.

Meanwhile, the Bureau of Ordnance found many ways to exploit its expanse of desert. The proofing of guns commenced on November 20, 1943, with the shooting of an anti-aircraft gun high into the air. Proofing continued after the war ended in 1945; the Naval Proving Ground eventually fired 1,650 minor and major caliber gun barrels. For 1944 alone, the commander ordered over 15,000 projectiles, to be used for gun tests and target practice.[15]

Bomb groups and fighter squadrons training at the Pocatello Army Air Base regularly blasted two areas of the proving ground as they practiced high-altitude bombing techniques. Residents grew accustomed to the drone—day and night—of B-24 Liberator bombers and B-17 Flying Fortresses as they dropped hundred-pound sand-filled practice bombs with black powder spotting charges, trying to hit wooden pyramid targets.[16]

The Navy permitted the U.S. Army to use part of the grounds for detonation research. At ordnance centers elsewhere, the Army managed loading plants, where charges of TNT and other explosives were packed into their shells and cartridges. Freshly loaded projectiles were stored within safety cells separated by concrete barrier walls. Should the contents of one cell ignite or explode accidentally, the wall was supposed to prevent the contents of the adjacent cell from detonating. The Army Safety and Security Division had reason to believe in 1944 that the quantities of explosives accumulating in the safety cells of its loading plants, while within the specifications of the safety manual, were exceeding the limits of safety. Possibly the safety manual needed to be revised or barrier standards improved.



B-24 Liberator.

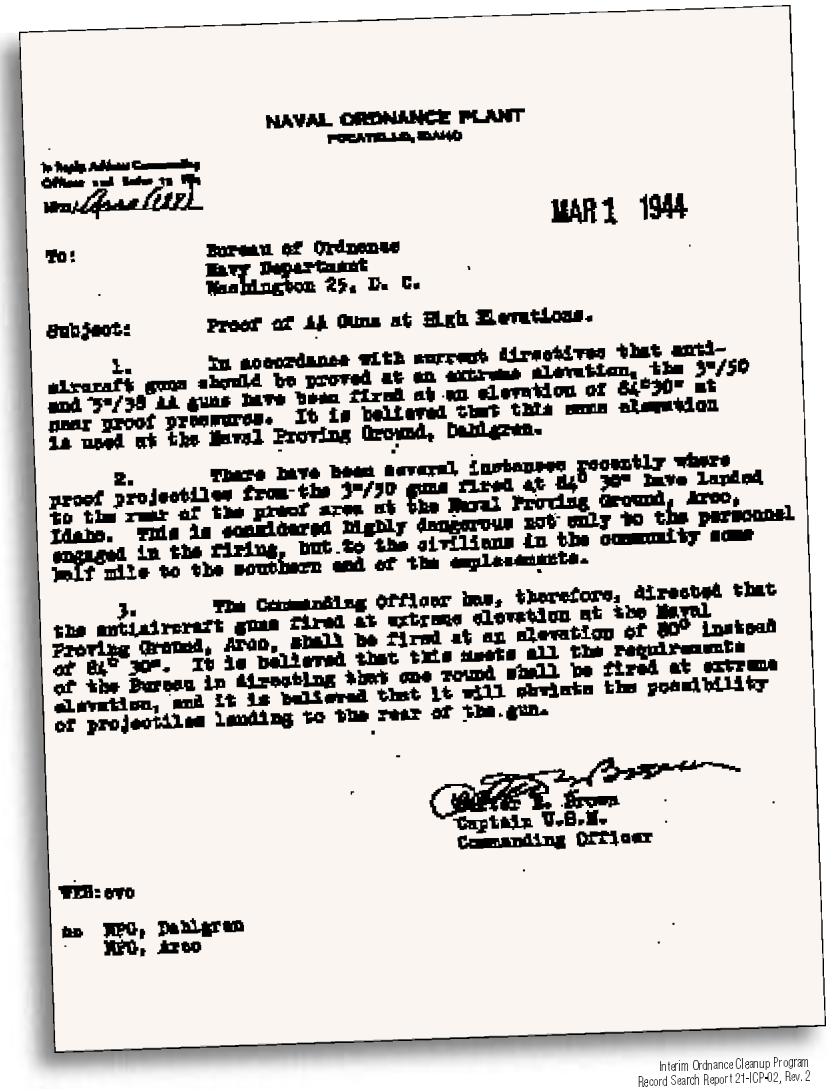
Courtesy of Wright-Patterson Air Force Base

To test this premise, Lieutenant Colonel Clark Robinson, who before the war was a professor of chemical engineering at the Massachusetts Institute of Technology, came to the Naval Proving Ground. He built a concrete safety wall. On one side, he stacked 25,000 pounds of TNT against the wall to represent fresh-loaded bombs. On the other side, he placed 5,000 more pounds of TNT. In the first test, setting off the 25,000 pounds resulted in the detonation of the small pile as expected, and the barrier wall turned to dust and very small rubble. The test confirmed that the barrier wall could not isolate the impact of a 25,000-pound explosion. He built more tests and experimented with air gaps—leaving several feet of air between the pile of TNT and the concrete wall—and different amounts of TNT. It was all to find a safer way to store bombs.

Typical of scientific experiments, the test engineers predicted how each test would perform and then compared predictions to the actual results. With each main test, Robinson used the opportunity to do side experiments. One day, he set out small token charges at varying distances from a large TNT charge, expecting the closest ones to go off by sympathetic detonation. On the day of the test, the blast went off as planned, but some of the

Courtesy of Pat Gibson

Pat Gibson, daughter of a civilian ordnance worker, and her horse, Ginger. Marine barracks in distance at right.



NAVAL ORDNANCE PLANT
POCATELLO, IDAHO

MAR 1 1944

To: Bureau of Ordnance
Navy Department
Washington 25, D. C.

Subject: Proof of AA Guns at High Elevations.

1. In accordance with current directives that anti-aircraft guns should be proved at an extreme elevation, the 3"/50 and 5"/38 AA guns have been fired at an elevation of 84°30" at near proof pressures. It is believed that this same elevation is used at the Naval Proving Ground, Dahlgren.

2. There have been several instances recently where proof projectiles from the 3"/50 guns fired at 84° 30" have landed to the rear of the proof area at the Naval Proving Ground, Arco, Idaho. This is considered highly dangerous not only to the personnel engaged in the firing, but to the civilians in the community some half mile to the southern end of the emplacements.

3. The Commanding Officer has, therefore, directed that the antiaircraft guns fired at extreme elevation at the Naval Proving Ground, Arco, shall be fired at an elevation of 80° instead of 84° 30". It is believed that this meets all the requirements of the Bureau in directing that one round shall be fired at extreme elevation, and it is believed that it will obviate the possibility of projectiles landing to the rear of the gun.

Walter E. Brown
Captain U.S.N.
Commanding Officer

WEB:ovo

cc: NPO, Dahlgren
NPO, Arco

Interim Ordnance Cleanup Program
Record Search Report 21-ICP-02, Rev. 2

Combining gun proofing and civilian habitat sometimes presented special hazards.

results were unexpected. The blast effect of the detonation was lower than he predicted.

This is presumably because of our altitude (4,950 feet) and the consequent lower density of air over that at sea level where most of the blast effects have been noted. Incidentally, this is in line with our observation obtained when firing guns at the Proving Ground... Not only were no windows broken, but the windows at the Proving Ground approximately 6 miles from the scene of the explosion were not even rattled, and at the very small settlement [Midway] some 12 miles from the scene...they barely heard the noise.

Another surprise was that none of the small token charges went off during the blast. Robinson concluded that the formula he had been using to determine safe air-gap distances, while correct at sea level, was probably not correct for a higher altitude. He concluded that it might be safe to permit closer spacing of magazines at high altitudes with the same degree of safety. He and the Navy commanding officer immediately asked for more explosives to do more air-gap tests.[17]

And so it went. The Army and Navy went on to do more barrier-wall tests, some using slabs of 3/8th-inch steel plate as part of the wall. They did boxcar tests, wanting to identify the blast characteristics of projectiles stored longitudinally on a boxcar. Results helped them advise how far from depot buildings a loaded boxcar should be parked to be safe. Later they sent up illuminating star shells and white phosphorus projectiles to find out how well they would perform as a smoke screen.[18]

Perhaps the most spectacular tests were the ones that blew up igloo-type magazines loaded with explosives. On August 29, 1945, at 9:36 a.m. Mountain Time, the Navy exploded 250,000 pounds of TNT. After the atomic bomb itself, this blast was said at the time to be the next largest deliberate detonation ever set. Seismologists, geologists, meteorologists, and ordnance depot representatives from all over the coun-

try converged at the test site to observe and take measurements. The public found perches on East and Middle buttes and along the highway. At Boise, two hundred miles away, a small group clustered atop Table Rock Mesa east of the city to watch and listen. None were disappointed. The blast produced a purple-gray cloud a mile wide and more than a mile high. It left a crater fifteen feet deep. The group on Table Rock Mesa heard the report fifteen minutes after the blast. None of the other igloos constructed as close as two hundred feet away ignited, but the windows blew out of a test barracks erected a half mile away.[19]

Other experiments tested the performance of different kinds of projectiles, fuzes, and explosive loads. The engineers and chemists tested smokeless powder and amitol charges, and tested for fragmentation of projectiles. They sought ways to store large quantities of projectiles—or redesign the projectiles—to prevent all of them from detonating at once in case of an accident aboard a ship or other place where they had to be stored "in intimate contact" with each other. Test by test, they refined their understanding of how explosives might safely be stored and transported.[20]

Although technicians tried to collect unexploded ordnance after each test, they often failed to find it all. Occasionally a projectile was "initiated by desert heat," as someone wrote in 1949. "It is possible that some [unexploded projectiles] may be lying loose in the area." To the cairns and dry irrigation canals already in the landscape, the years of explosives experimentation added huge craters, piles of shattered concrete and twisted metal, and bomb shells.[21]

After the American victory over Japan, naval vessels were quickly decommissioned. Coastal bases started shipping to Pocatello one trainload after another of guns, armor plate, gun housings, and "miscellaneous" materials for storage. Much of this material—nets, floats, anchors, mooring rings, buoys—went to the Naval Proving Ground to await sandblasting and repainting. Experiments continued into 1947 and 1948, but at a slower pace than before and no longer in association with the Pocatello gun plant, which curtailed its operations in late 1949.[22]

Some of the later tests were classified. Project Elsie is thought to have tested the performance of sixteen-inch shells made with depleted uranium. The purpose of Project Marsh is still generally unknown. In 1947, the Naval Proving Ground was designated a depot for stockpiling surplus manganese for the United States Treasury—starting with nearly twenty-five tons. In 1948 there were tests of influence fuzes and countermeasures for guided missiles.[23]

U.S. Army Corps of Engineers, Rock Island District

One of ten craters in Mass Detonation Area, where an igloo-type magazine containing up to 500,000 pounds of TNT was detonated in October 1946.

INEEL Cultural Resources 4A-18

The Atomic Energy Commission adapted one of the Navy's ordnance storage bunkers as a laboratory for calibrating dosimetry equipment.

U.S. Army Corps of Engineers, Rock Island District

This 500-pound semi-armor-piercing bomb was found near the Experimental Dairy Farm during the ordnance cleanup of the 1990s.

Huge Powder Blast Rocked Wide Area

from Arco Advertiser, *August 31, 1945*

A huge chocolate colored cloud of dust, shaped like a mushroom, followed by two muffled thuds, was what a large group of navy and army officials, scientists, photographers and others experienced Wednesday morning when a cache of 250,000 pounds of TNT were exploded on the desert near the gunnery range. For several days all of Eastern Idaho excitedly awaited the blast, as this was the largest collection of powder ever set off by man.

On the desert area about 10 miles east of the gunnery range the navy had constructed four igloos. Two were of a design approved by the army and two were of a navy design. They were in proximity of about 500 yards. Each was built of reinforced concrete and stored 250 thousand pounds of powder. The one exploded was the army type, and the purpose of the experiment was to determine the strength of the igloos and how far the earth would be shaken. Seismographs had been placed at various places in the surrounding area, and a series of blast meters, like spokes in a wheel, extended from the igloo area to a distance of approximately one-half mile.

Within close proximity of the blasted igloo were installed concrete shelter proofs for military photographers, and about a quarter of a mile distant was the dug-out where the men who set off the charge were housed. The dug-out was of reinforced concrete, and sandbags protected the entrance-way.

Promptly at 9:30 the signal to touch off the explosion was radioed to the control dug-out and the first sight was a huge, billowing cloud of dust which resembled an enormous mushroom. In approximately 15 seconds the explosion was heard—two muffled reports. Capt. Walter Brown, commandant, was certain that the second blast heard was an echo.

Courtesy of Orville and Margaret Larsen

U.S. Army Corps of Engineers, Rock Island District

U.S. Army Corps of Engineers, Rock Island District

The huge cloud of dust seemed to hover over the spot for about ten minutes and gradually moved westward toward the Arco community, as the air currents destroyed the symmetry of the cloud and it began to resemble a huge dust storm.

An inspection of the spot where the igloo stood showed a pit approximately 15 feet deep which was strewn with large chunks of reinforced concrete, steel and wire reinforcing material. Most of the steel surrounding the bombs of TNT seemed to have been completely destroyed, although small fragments were found a half mile distant.

Above. Cloud from one of the mass detonation experiments. Middle. Largest of the craters in Mass Detonation Area was later enlarged and graded by IDO for use as a demolition range. Photo circa 1995. Below. Ruptured and empty cans of smokeless powder partially fill a crater. Photo circa 1995.

Although another war would bring large Navy guns back to the old Proving Ground in the late 1960s, the Navy would no longer own the facility. By that time, the original firing range was dotted with laboratories and other buildings, so guns could no longer be fired to the north and had to be pointed south. A new federal agency had acquired the Navy's desert property and was using this remote region of Idaho for an altogether different kind of scientific "proofing."

INEEL 70-59

From 1968 to 1970, during the Vietnam War, the Navy test-fired sixteen-inch guns from the battleship USS New Jersey. The firing point, named the Naval Ordnance Test Facility, was south of the Experimental Breeder Reactor-I complex, and the target was the northern flank of Big Southern Butte. Sixteen-inch guns were the only World War II-era naval weapons used during the Vietnam War. The Navy moved the old gantry crane (photo left) from its original location and used it again to unload guns brought from Pocatello by rail. The purpose in reworking the guns was to extend their range for use in clearing 200-yard-diameter landing zones in the heavily canopied jungles of Vietnam.

CHAPTER THREE

THE URANIUM TRAIL LEADS TO IDAHO

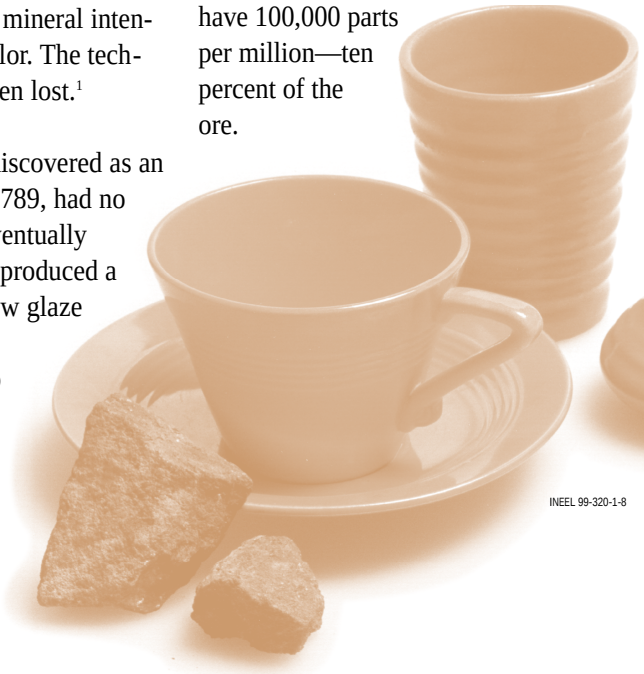
Uranium: a heavy, slightly radioactive metallic element...

–Encyclopedia Britannica–

Archaeologists excavated the Imperial Roman Villa near Naples in 1910. In a first-century A.D. mosaic mural, they found pale yellow-green glass containing one percent uranium. Roman artisans probably used a uranium-bearing mineral intentionally to obtain the color. The technique may then have been lost.[1]

Uranium, when it was discovered as an element and named in 1789, had no known use. Someone eventually learned—again—that it produced a pleasant orange or yellow glaze on ceramic goods. Photographers used it to tint photographs. For such aesthetic uses, the world required only a few hundred tons of ore a year. Mines in Bohemia, Portugal, and Colorado supplied the modest demand. Then Henri Becquerel discovered its property of radioactivity. In 1898 Marie Curie, investigating further, discovered radium in uranium ore and began to elucidate its decay products. Everything changed.

Uranium is dispersed widely over the earth; the soil in the average backyard has 2.7 parts per million. It is more common than tin. But backyard concentrations are hardly worth mining. A good uranium mine might have 30,000 parts of uranium per million, but a bonanza-class uranium mine would have 100,000 parts per million—ten percent of the ore.



INEEL 99-320-1-8

The Homer Laughlin Company, maker of Fiesta Ware, used uranium to obtain the bright orange glaze known as "Fiesta Red." In 1943, the company obtained a license from the Manhattan District and used depleted uranium until 1972.

Such a mine was discovered in Zaire (formerly, the Belgian Congo) about the time that the world was learning that radium might have wonderful curative properties. Because of its richly concentrated ore, the Shinkolobwe mine produced uranium far more cheaply than anywhere else. Other uranium mines closed, and the Shinkolobwe satisfied most world demand until well after World War II.[2]

The discovery of radioactivity was a prelude to other discoveries that led to a new twentieth century market for uranium. First, the world learned that atoms definitely are not the smallest particles of matter—rather, atoms are built of electrons, protons, and neutrons, with most of the weight in the protons and neutrons.

Next, uranium, like most elements, has more than one isotope. Some atoms contain more neutrons than others and weigh slightly more. Uranium-235 weighs less than uranium-238, for example, and more than uranium-233. Although different isotopes act and react the same way when combining

The Trinity fireball, fifteen seconds after detonation on July 16, 1945, rises above the New Mexico desert. The bomb was an implosion device using plutonium made by the reactors at the Hanford Engineering Works.

U.S. Department of Energy

chemically with other elements, the protons and neutrons in their nuclei can behave very differently upon being provoked in certain ways.

Scientists soon found that they could strip the electrons or neutrons from certain atoms and bombard other elements with them. In the 1930s they built great machines—atom smashers—to find out what would happen when they fired streams of neutrons into various elements at high speeds.

Upon bombarding uranium with neutrons moving at a certain speed, they found that some of the uranium atoms break apart (fission). The debris arranges itself into pairs of elements with roughly half the mass of uranium, such as (but not always) barium and krypton. Energy is released in the form of two—sometimes three—neutrons, heat, and other leftover particles. Many of the fission products are themselves radioactive. Of all the uranium isotopes, it appeared that only uranium-235 fissioned.

The ancient quest for some sorcery that would transmute one kind of matter into another was over. Traditionally the quest had been to make gold. Perhaps ironically, however, it turned out that the nuclear sorcerers could turn gold into mercury, but couldn't turn mercury (or lead) into gold.

Playing Marbles with Atomic Particles

After physicists had sorted out the kinds of particles that made up an atom, they learned that they could separate electrons or neutrons or protons from certain atoms. Then they invented ways to shoot the particles at samples of other elements.

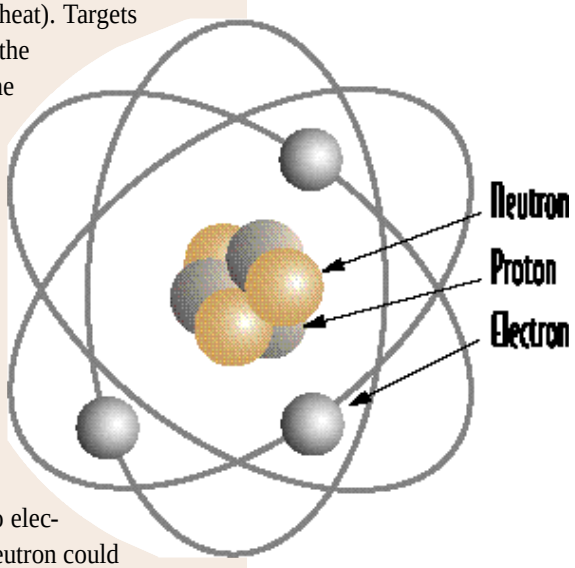
The faster a beam could travel, the more energy it had when it struck the target, and the more interesting the results. Most of what we have learned about energy and matter in the twentieth century, we have learned by bombarding samples of matter with atomic particles.

Particle accelerators, also called "atom smashers," shoot streams of electrons, protons, deuterons, alpha particles, or heavy ions at their targets. The machines that create these fast-moving streams rely on the application of an electric field, which either attracts or repels particles of like charge.

Van de Graaff generators, cyclotrons, synchrotrons, and betatrons are types of particle accelerators.

Nuclear reactors split atoms apart, producing streams of neutrons (and large amounts of heat). Targets are placed inside the reactor close to the flow of neutrons.

The neutron was discovered in the 1930s, the last of the trio of electrons, protons, and neutrons to be found out. Because it had no electric charge, the neutron could penetrate the nucleus of atoms, something other particle accelerators had not been able to do. The big surprise in the 1930s was to learn that shooting a neutron at uranium-235 atoms caused them to split apart.



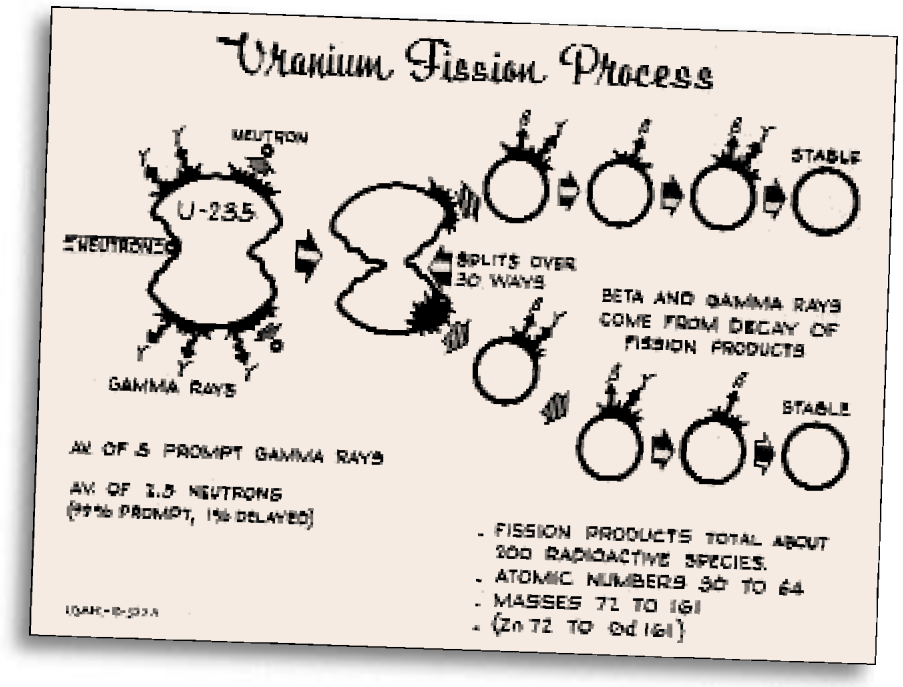
The central portion of the atom depicts the nucleus, consisting of protons and neutrons, which give the atom most of its weight. Electrons orbit the nucleus and are considered weightless.

With the discovery that a neutron could split uranium and generate more neutrons, a new demand for uranium was inevitable. Provided that enough uranium-235 is packaged in just the right way, the liberated neutrons are likely to hit one or two other atoms and cause them to fission also. This was the phenomenon of the chain reaction. Fission released an amount of energy far larger than the energy obtained from chemical reactions of the same mass. Scientists learned that it is possible to create an environment in which to start such a reaction, whereupon nature—and skilled operators—keep the reaction going.

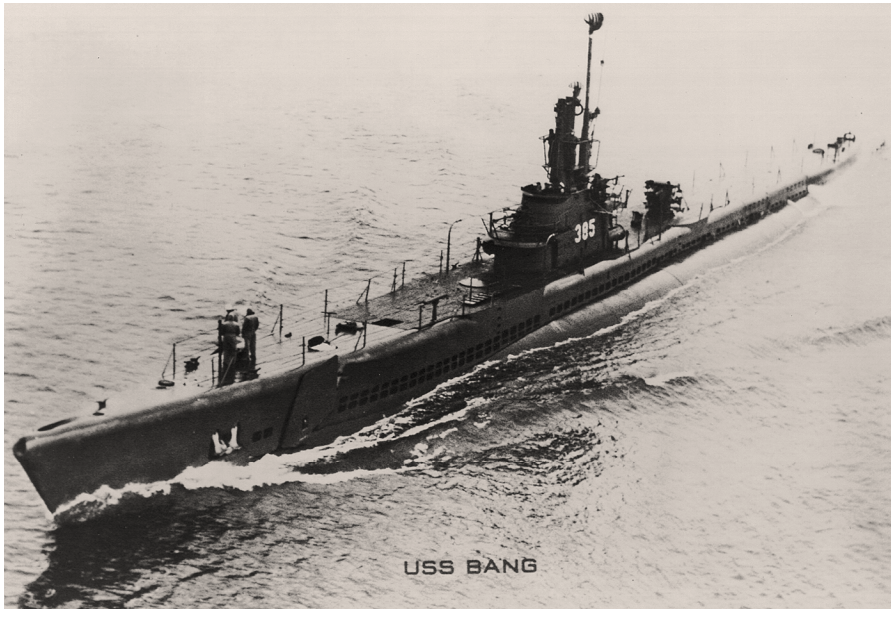
In the late 1930s, events in Europe were pointing to a German war of conquest. It required no great leap of imagination to realize that a chain reaction initiated in a well-engineered container could explode as a bomb. If chain reactions could be controlled, on the other hand, they could produce electricity or help build canals and harbors.

Developing any of these ideas would require a great deal of uranium. One of the inconvenient things about natural uranium is that 99.3 percent of it is uranium-238, an isotope that resists splitting apart under neutron bombardment. For every 140 atoms of U-238, there is only one atom of U-235.[3]

Early in 1939, scientists of the United States Naval Research Laboratory in Washington, D.C., met with scientists from Columbia University and Enrico Fermi, Nobel laureate nuclear physicist. They discussed how the heat of fission might produce steam for a turbine and propel a ship or submarine. Navy scien-



INEEL Cultural Resources



Courtesy of Department of the Navy, Submarine Force Museum

Above. In the 1950s, the AEC published films and booklets to help American citizens understand nuclear energy. Left. The USS Bang, a pre-nuclear U.S. Navy submarine built in 1943, used diesel fuel to generate electricity. When submerged, it ran on battery power and had to surface every 48 hours.

tists Ross Gunn and Philip Abelson concluded that the Navy should pursue the idea. The fission reaction needed no oxygen, which all other fuels need to burn. The benefit of such a fuel in a submarine was obvious. The two realized that the lighter fissionable isotope of uranium would have to be separated from the heavier one in order to create a mass that would fit in a submarine—or a bomb—and begin a chain reaction. They considered how this might be done.[4]

As Adolph Hitler's war grew more menacing in 1939, the scientists in America who had fled Europe grew more fearful that German scientists might produce an atomic bomb. Albert Einstein wrote a letter to President Franklin Roosevelt urging upon him the importance of securing a supply of uranium. "The United States has only poor ores of uranium in moderate quantities," he wrote.

The government should secure a supply of the ore for the United States. He continued:

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German undersecretary of state, Von Weizsacker, is attached to the Kaiser-Wilhelm-Institut in Berlin, where some of the American work on uranium is now being repeated.[5]

Roosevelt understood the threat and authorized secret research work to begin. By 1942, production seemed feasible, and the job went to the U.S. Army, which created the Manhattan District of its Corps of Engineers. General Leslie Groves took charge of the project and monopolized most of the uranium then in the United States. The Manhattan District bought 1,250 tons of uranium ore from the Belgian owner of the Shinkolobwe mine for $1.60 a pound. As the war progressed, Groves bought more, placing annual orders amounting to $200 million. Scientists Gunn and Abelson had no further access to uranium, so Navy studies of ship propulsion had to pause for the duration of the war.[6]

The Manhattan Project was a success. Enrico Fermi and others built the world's first nuclear reactor in Chicago

No one took photographs when Enrico Fermi and the Met Lab brought Chicago Pile Number One (CP-1) to criticality on December 2, 1942. Artist Gary Sheehan shows the cramped quarters in the squash court underneath the stadium at the University of Chicago. Fermi and the others concentrate on instruments indicating the increasing rate of neutron fission. Three young physicists stationed on the right were the "suicide squad," prepared to pour jugs of cadmium-sulfate, a neutron absorber, onto the pile and kill the chain reaction if the control rods didn't work for some reason. The person below the balcony is prepared to operate a control rod by hand, another precaution. Some employees who participated in the creation of CP-1, not necessarily in the painting, eventually moved to Idaho to become pioneers at the National Reactor Testing Station.

in December 1942. After that, an unprecedented collaboration of military, scientific, and corporate resources managed to build a weapon. A version of the Navy scientists'idea for separating the light from the heavy isotope of uranium was built at Oak Ridge, Tennessee. The technique produced the few pounds of "enriched" uranium needed for one bomb.

Chicago Historical Society P&S-1964.0521

Uranium had another useful quality. In a chain reaction, it could manufacture another fissionable element. Some of the liberated neutrons entered the nuclei of uranium-238, not splitting it but eventually changing it into plutonium, a new element not found, it was thought at the time, in nature. This plutonium activation product, upon being bombarded with neutrons, proved to be fissionable. Therefore, a bomb might also be made with plutonium.

The government built huge "atomic piles" (later called reactors) of uranium and graphite at Hanford, Washington, to manufacture plutonium. The procedure was extremely costly. Despite the massive size of the Hanford reactors, their daily output of plutonium was rarely enough to fill a shot glass. Once plutonium atoms had been created, they had to be separated from the uranium matrix in which they had originated—and from the fission and other activation products. Chemists devised ways to do this. The Manhattan District built two bomb designs, each using one of the two fuels. On July 16, 1945, the team at Los Alamos, New Mexico, tested a plutonium device. On August 6 and 9, 1945, respectively, the United States dropped Little Boy, a uranium-charged bomb on Hiroshima and Fat Man, containing plutonium, on Nagasaki. Hiroshima received the destructive power equivalent to 12,500 tons of TNT; Nagasaki, 22,000 tons.[7]

During the war and immediately afterward, the assumption that uranium was scarce continued to influence the way governments and scientists regarded it. The scarcity was felt to be so serious that General Groves, who continued to administer the Manhattan District after the war, approved a proposal in 1946 to build a reactor that would help solve the uranium shortage.[8]

The proposal came from Walter Zinn, one of the physicists who had been with Enrico Fermi in Chicago. The Manhattan District had organized a "Metallurgical Laboratory" there, a name intended to disguise its true purpose. After the war, the government assigned weapons work to other laboratories, and the Met Lab ceased to exist. Its assets were reorganized as the Argonne National Laboratory with a mission to develop reactors, supported by research in chemistry, physics, metallurgy, and other fields. Zinn became its first director.[9]

Zinn could see that the nation's first priority for uranium would continue to be for weapons. Any use of it for other purposes would have to promote defense goals or make extremely efficient use of uranium. He proposed therefore to design and build at Argonne an experiment to prove that a reactor could generate electricity and manufacture plutonium at the same time.

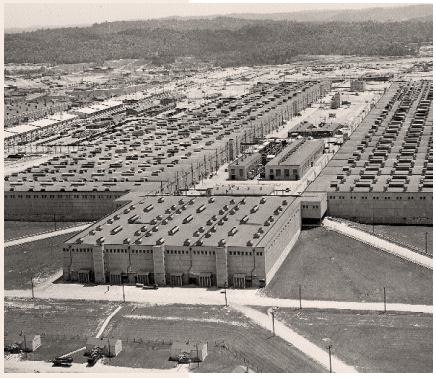
It was an astonishing idea. The reactor would be built so that the non-fissioning U-238 would be tucked in close to fissioning U-235 fuel rods and also surround them like a blanket. During the chain reaction, one liberated neutron would keep the chain reaction going and another one or two would hit the U-238 and create new atoms of plutonium fuel. It would solve the scarcity of

Making Enriched Uranium

Throughout the Cold War, gaseous diffusion was a reliable way to make enriched uranium. The first step was to change the solid uranium oxide into a gas called uranium hexafluoride. The gas was then circulated thousands of times through fine filters with tiny openings. The lighter U-235 atoms passed through the filters slightly more easily than U-238.

U.S Department of Energy 094 054 001

Gradually the percentage of U-235 in the gas increased, and it was said to be "enriched." The gas was then converted back to a solid form and shaped into rods or pellets. These were placed in tubes made of aluminum, zirconium, or stainless steel. These cladding metals do not interfere with the passage of neutrons, but they do protect the uranium from air and water corrosion and provide a path for the heat to leave the fuel.



Oak Ridge National Laboratory

Above. Worker holding simulated nuclear fuel pellets. Below. Exterior of the Gaseous Diffusion Plant in Oak Ridge, Tennessee.

Depending on its intended use, uranium can be enriched to any percentage desired. The uranium in bombs is one hundred percent enriched. Test reactors, which require a rich flow of neutrons, need uranium enriched up to ninety-five percent. Uranium in commercial power reactors is typically two percent to four percent enriched.

uranium, because now the abundant non-fissioning isotope could become fuel. More profoundly, it would provide a revolutionary abundance of energy in a world constantly craving more. That a fuel could replace itself in the very process of consuming itself, perhaps "breed" even more than the original amount, was a fabulous possibility.

General Groves approved Zinn's proposal, observing that independent reviewers would have to agree the reactor could safely operate near Chicago. As it turned out, the decision would not be Groves' to make, and Zinn's idea—along with many others—had to wait a few years while Congress rearranged the nuclear enterprise as a peace-time institution. Those years brought a more pessimistic outlook for world peace and many other changes, but none of them challenged Zinn's logic. Uranium remained costly, and the breeder project remained high on any list of proposed experiments.[10]

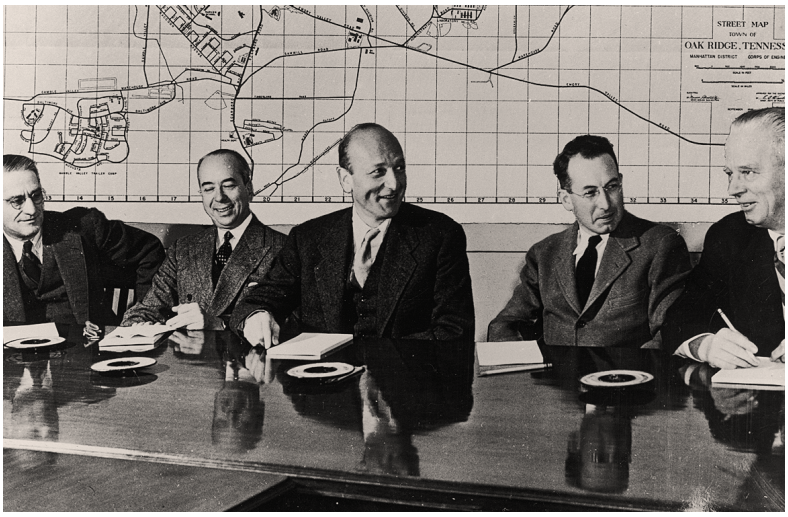
Congress passed the Atomic Energy Act in August 1946. The government continued to monopolize uranium and plutonium. The military handed control of atomic weapons factories and laboratories to a new civilian agency, the Atomic Energy Commission (AEC), headed by five commissioners. Advisory committees assured that the military would influence the distribution of uranium for defense purposes—and help decide on the allocation of resources for defense research.

The Act created a special committee in Congress called the Joint Committee on Atomic Energy (JCAE) to prepare budgets and approve AEC policy directions. The committee was unique. House and Senate members typically created committees as convenient ways to divide their work; this one was mandated by law. Nine members from each chamber sat on the JCAE, concentrating a great deal of authority among very few legislators.[11]

In due course, the new commissioners took their seats, hired their staff, and decided on a plan of action. Everyone—President Harry S. Truman, the scientists who had developed the bombs, and the corporations that had helped build them—desired to develop peaceful uses of nuclear energy. Congress hoped that research and development would eventually show that a civilian nuclear power industry could generate electrical power economically enough to compete with coal and gas fuels.[12]

But such peaceable sentiments were not to dominate the early years of the AEC. Instead, the United States and the Union of Soviet Socialist Republics (USSR), allies in World War II, became antagonists in a tense ideological and geo-political conflict that came to be called the Cold War. One of its major battlegrounds was nuclear weapons technology. The two nations raced to be first to possess and command the most destructive possible power against the other.[13]

When David Lilienthal became the first AEC chairman, he learned how little destructive atomic power the United States actually possessed. The world, including President Truman, assumed that the nation had a sizeable stockpile of atomic bombs. But on April 3, 1947, it was Lilienthal's duty to tell the president that the United States had exactly zero atomic bombs ready for use and that it would be several months before that number could improve. Not surprisingly, the production of bombs became the AEC's most urgent priority.[14]



U.S. Department of Energy

President Harry S. Truman appointed the first five AEC commissioners. From left to right, William W. Waymack, Lewis Strauss, Chairman David E. Lilienthal, Robert F. Bacher, and Sumner T. Pike.

The U.S. Air Force became interested in uranium. Colonel Donald J. Keirn, a visionary in the field of jet aircraft propulsion, realized that if nuclear power could be linked with jet engine technology, the country would have an unparalleled offensive weapon. Uranium fuel would occupy less space in an airplane than a baseball. A pound of enriched uranium could replace the energy in 1.7 million pounds of standard chemical fuel. A nuclear-powered airplane could stay aloft for days at a time, ending flight-distance limits. In 1945 J. Carlton Ward, Jr., president of Fairchild Engine and Airplane Corporation, told a senate committee that the range of an atomic plane would be limited only by its ability to carry enough "sandwiches and coffee for the crew." It could deliver bombs anywhere in the world, approach a target from any direction, and never have to rely on a refueling base outside the United States. A bomber combining jet speed with long range would be a useful weapon indeed.[15]

The U.S. Army was similarly tantalized by the idea that a handful of fuel could end the logistical headache of transporting fuel to remote locations. Perhaps nuclear power plants could be mobile, able to travel with a field hospital or command center. If so, a power plant could be mounted on a barge and towed from one port to another,

supplying emergency electrical power to on-shore operations after earthquakes or other disasters. Reactors could be small, medium, or large, depending on the need. Perhaps they could be loaded into trucks or airplanes and then reassembled in the Arctic or in a desert.[16]

The Navy and the Air Force were first to mobilize their interests. They asserted themselves as the AEC struggled to get organized. The growing fear of communism contributed to their causes. But before the AEC could apply nuclear energy to the goals of either service, it had to accomplish a huge backlog of preliminary research.

Leaders to Conduct Arco Desert Tests

"You treat us fine,' 'atomic energy commission officials Thursday told Idahoans an dU. S. Rep. John Sanborn, standing, as they opened four-day eastern Idaho tour. From left, Roger Warner, A E C engineer; Leonard E. Johnston, to manage A E C's $500,000,000 atomic reactor station in Arco desert, and Bion Phillipson, program director. Officials seek employes' homes in present towns.

Courtesy of the Thomas Sutton Family

Once the announcement was made that the atomic reactor station would be in Idaho, the AEC had to decide where to locate its headquarters.

The central fact was that the scientists had produced only a bomb, a sudden explosion finished in seconds. Making electricity had little in common with making bombs. Could a reactor be reliably controlled for long periods of time? What metals and materials could withstand the corrosive forces of heat and radiation for long periods of time? What form should uranium fuel take? What was the best way to carry heat away from the reactor? Could power plants be safe enough to operate near populated areas? Could uranium produce electricity cheaper than coal or natural gas? In sum, the science of nuclear reactors had to be developed nearly from scratch.

The new AEC began to set priorities for experimental reactors and assign projects to its laboratories. These tasks confounded the commissioners for more than two years. They seemed unable to settle on a program. Finally, the AEC's Reactor Safeguards Committee advised that, for safety reasons, the AEC should build proposed reactor experiments at a remote location, not at any existing laboratory. Nuclear research would bring with it nuclear waste and chemical processing, neither of which were suitable by-products for heavily populated areas. Most importantly, if an accident were to occur, it should not endanger large numbers of people. Walter Zinn himself agreed with this:

I am inclined to the opinion that for a nation with the land space of ours and with the financial resources of ours, adopting a very conservative attitude on safety is not an unnecessary luxury.[17]

Or, as AEC Commissioner Sumner Pike put it, "We didn't want to put work like this next to a high school." The decision to build a "testing station" for reactors seemed to liberate the AEC, unsticking it from a two-year habit of talk and no firm decisions. In January 1949 the commissioners created a

Division of Reactor Development and hired Lawrence R. Hafstad to be its director. Lilienthal gave him his first assignment: recommend a site for the testing station.[18]

The site had to meet safety criteria. Fewer than 10,000 people should reside in the nearby area. No other national defense sites should be in the vicinity. The AEC must have complete control of the property. Fuel, water, and electrical power should be plentiful. Weather and geological conditions should prevent contamination of lakes and waterways. Earthquake-prone sites were out.[19]

By the time Hafstad was on board, a list of some twenty sites had shrunk to two candidates: Ft. Peck, Montana, and the Naval Proving Ground in southeast Idaho. Sentiment seemed to favor Ft. Peck. By this time, frustration over inaction was palpable. Still, the AEC paused and asked an engineering firm from Detroit to compare the virtues of the two sites.[20]

The Detroit firm quickly rounded up an impressive array of facts on climate, geology, labor, land, and construction materials. They evaluated rail and highway connections and assessed the socio-economic characteristics of nearby towns. The analysts even took the trouble to ask the commanding officer at the Naval Proving Ground if there was much fog at the site during the winter.

With all the data gathered, the bottom line was that the Montana site would cost the AEC $50 million more than if it built in Idaho. After that, annual operating expenditures in Montana would cost a significant premium. Furthermore, the Idaho location had a far superior socio-economic profile; nearby towns could provide a better base to absorb new population.[21]

The AEC decided on the Idaho site on February 18, 1949, and called it the National Reactor Testing Station (NRTS). The local press called it the "atom plant." Lewis Strauss, one of the commissioners, had old friends at the Navy's Bureau of Ordnance and felt that the Navy would surrender its investment peacefully. He was mistaken; the Navy resisted. It demanded that the AEC support a congressional authorization for funds the Navy could use elsewhere.[22]

Despite the secrecy of AEC deliberations, Montana and Idaho interests both knew that their territory was in the running for something big. The Idaho Falls and Pocatello chambers of commerce had retained former senator D. Worth Clark and his law partner Thomas Corcoran to represent them in Washington and find out if any influence could be exerted, and if so, how. The Montana congressional delegation had been aware of the early tilt toward Ft. Peck and thought the deal was set. Suddenly news leaked out that Idaho was the "top favorite."[23]

Upon the uproar that arose when Montana discovered its loss, Chairman Lilienthal tried to quiet the ruckus by explaining the decision to Montana Governor John Bonner and making the announcement public, which he did on March 22. Montana kicked for another two months, appealing fruitlessly to President Truman and to the JCAE at hearings in April and May.[24]

On April 4, the AEC named Leonard E. Johnston as the man to open and manage an AEC field office near the testing station. His mission was to adapt the Naval Proving Ground for scientific experiments involving nuclear reactors and using uranium.[25]

Chapter Four

The Party Plan

There is nothing to get excited about.

–J.S. Gardner, Blackfoot legislator–

It must be at least humorous, if not pathetic, to the engineers in charge...to observe so much falderol," wrote the editor of the *Arco Advertiser*. His scorn was aimed at the Idaho Falls Chamber of Commerce, which had created a presumptuous new letterhead for its stationery. A map of the state showed Idaho Falls, designated with a heart, as the only city in the region and named "The Atomic City." The town was going too far in its campaign to headquarter the AEC's new atom plant. The AEC could not possibly be influenced, the editor felt, "by the bowing and scraping of two-bit bigwigs in any of the prospective towns of the area."[1]

If Leonard E. Johnston, the chief engineer-in-charge, felt either amusement or pathos as he surveyed the towns of southeast Idaho, he never revealed it. He was supremely a diplomat, and this quality was to serve him often in the next five years. He had to invent a reactor testing station—an entirely new concept in the history of the world—out of nearly nothing. Soon construction workers would be flooding into the desert by the thousands and looking for places to live. The Manhattan Project had built government towns at its isolated nuclear sites, but this time the AEC planned to let the private market provide housing. Johnston needed all the nearby towns as allies.[2]

Courtesy of the Winfield Marvel Family

Bill Johnston, his wife, and their two children along with the children of Arco's Mayor Winfield Marvel.

and five AEC colleagues arrived Idaho in mid-April. They had a of exploring to do. Besides surying their hoped-for inheritance om the Navy, they had to figure it where they were going to ouse people—and where they ould settle their own Idaho perations field office, officially bbreviated as IDO.[3]

Leonard Johnston, born in South Dakota in 1911, cared little for his given name and liked to be called Bill, after his father. He was a visionary and completely unflappable, intense without being provocative. He had been associated with very large projects for most of his career. He had worked on the U.S. Army Corps of Engineers' Ft. Peck Dam in Montana during the 1930s, eventually becoming executive officer of the Corps' Ft. Peck District. During the war, the Corps sent him to Oak

E.F. McDermott, Mayor Tom Sutton and Bill Holden (left to right) congratulated each other after the AEC chose Idaho Falls as the headquarters for the NRTS.

Courtesy of the William Holden Family

Ridge, Tennessee, where he was assistant unit chief of the Gaseous Diffusion Plant K-25, a giant facility of over two million square feet. Later, he became deputy director of operations for the Manhattan District. In 1946, as a civilian, he opened up and managed the new Schenectady Operations office for the AEC in New York, the site of the Knolls Atomic Power Laboratory (KAPL), an experience that proved, among other things, that he could survive face-to-face contact with the Navy's formidable Captain Hyman Rickover. As an ex-military employee of the Manhattan Project, Johnston was typical of the executives in the managerial ranks of the AEC.[4]

As soon as he was named, Johnston became the focus of great interest from the communities of southeast Idaho. All of them were wide open to the opportunities about to come their way. Like many regions of the American West, the history of the area was a tale of economic booms brought about by outside investment in mining, railroads, or irrigation. It had been some time since the last good boom in southeast Idaho, but no one had forgotten how to hustle.

Johnston toured the towns east, west, and south of the site. Community leaders everywhere welcomed him with gratifying enthusiasm. If warmth and good will could build houses, the government would have no trouble at all. The business people in the region had plenty of energy and ambition.[5]

The town of Arco flung itself into a festive celebration only hours after it heard that the AEC had selected the "Arco site." State Senator E.J. Soelberg deployed the Arco High School band for a torchlight parade down the main street of the town. *En masse*, the citizens had themselves a dance in the recreation hall. Someone had calculated that the $500 million that the AEC said it would spend on the site was greater than the assessed valuation of the entire state of Idaho. Arco saw the AEC project as a boom to outclass all other booms. Being the town closest to the site, it felt sure that good fortune was on the way. No longer would the *Idaho State Encyclopedia* say of Arco: "Points of Interest—There are none of note in the town."[6]

Arco had fewer assets than Idaho Falls but nevertheless felt that it could remedy its deficiencies. Arco mayor Winfield Marvel and others flew to Hanford to look around and solicit advice. Soelberg went to the state capitol at Boise to meet with Governor

Courtesy of the Winfield Marvel Family

Courtesy of the Ada Marcia Porter Family

Above. Torchlight parade in Arco. Left. Arco and Butte County leaders undertook a comprehensive planning process to prepare for growth.

Courtesy of the Winfield Marvel Family

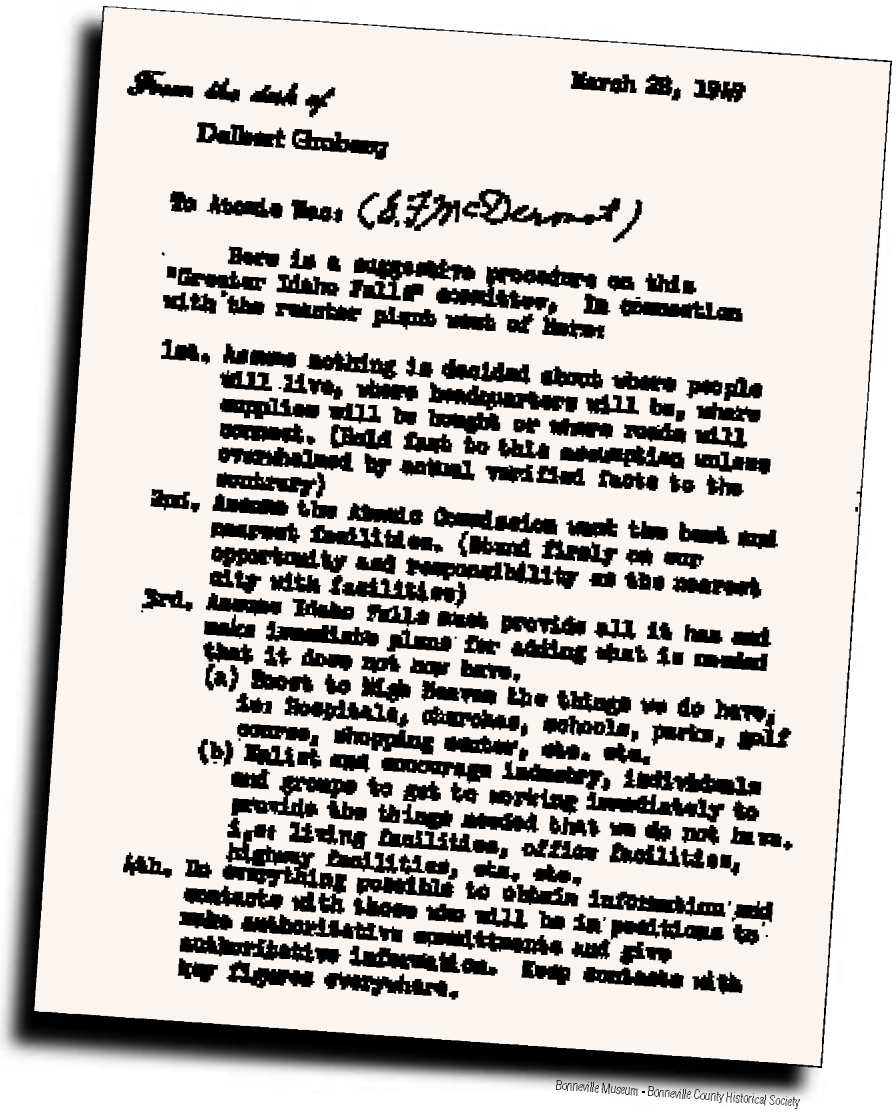
Mayor Winfield Marvel on his way to Hanford, Washington, to learn what Arco might expect with the NRTS as a neighbor.

C.A. Robins and the state's Director of Aeronautics, Chet Moulton, to discuss airport development. Later Arco welcomed an urban planner from the Federal Housing Administration to help prepare a comprehensive land use and utility expansion plan. Despite the small size of the town (548 inhabitants, according to the AEC's Detroit consultant), its citizens were ready for action. They started swapping real estate and expanding their businesses within days of the announcement.[7]

The leaders of the Idaho Falls Chamber of Commerce, particularly Bill Holden, an attorney, and E.F. McDermott, the publisher of the Idaho Falls *Post-Register*, were equally quick to react, but not by dancing. They started organizing themselves and their regional allies. Making the most of the prized opportunity at hand was going to require careful attention to detail. They knew that it would "probably take super-human efforts on the part of everyone to digest this large assignment which has been served to us." They focused quickly on the target of landing the operations field office in Idaho Falls. One of the barriers to that goal was the unhappy fact that no proper road connected Idaho Falls to the Site.[8]

The chamber organized a special Atomic Energy Plant Committee consisting of sixteen past chamber presidents "to work with and for the orderly and complete integration of our community in the overall development." Within days of the AEC announcement,

The Idaho Falls plan to win the IDO took shape early. Delbert Groberg, a past president of the Idaho Falls Chamber of Commerce, offered his advice for attracting the AEC to Idaho Falls.



From the desk of

March 28, 1949

Delbert Groberg

To Atomic Men: (E.F. McDermott)

Here is a suggestive procedure on this "Greater Idaho Falls" committee. In connection with the retainer plank week of later:

1st. Assume nothing is decided about where people will live, where headquarters will be, where supplies will be bought or where roads will connect. (Hold fast to this assumption unless overwhelmed by actual verified facts to the contrary)

2nd. Assume the Atomic Commission want the best and nearest facilities. (Stand firmly on our opportunity and responsibility as the nearest city with facilities)

3rd. Assume Idaho Falls must provide all it has and make immediate plans for adding what is needed that it does not now have.

(a) Short to High Heaven the things we do have, i.e. hospitals, churches, schools, parks, golf course, shopping center, etc. etc.

(b) Enlist and encourage industry, individuals and groups to get to working immediately to provide the things needed that we do not have, i.e. living facilities, office facilities, highway facilities, etc. etc.

4th. Do everything possible to obtain information and contacts with those who will be in positions to make authoritative commitments and give authoritative information. Keep contacts with key figures everywhere.

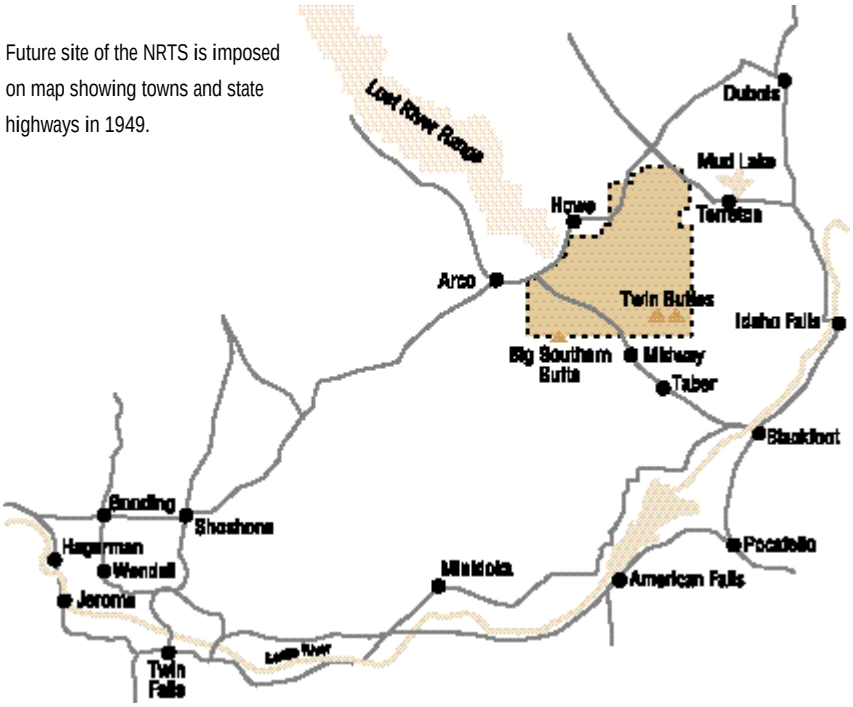
Bonneville Museum - Bonneville County Historical Society

Idaho Falls sent a delegation from the towns north of Idaho Falls to meet with the governor. These towns were on the route between Idaho Falls and the west entry to Yellowstone National Park. They had for some time desired a direct highway connection to Arco, and this obviously was the time to renew the campaign. Urgent and unanimous, the towns petitioned Robins to enlist the State Highway Department in the task of building the new road.[9]

The town of Blackfoot was only thirty-six miles from the site—and connected to it by a paved, albeit primitive, road. With a population of 5,500, the agricultural center also was home to the Idaho State Hospital South, originally named the Blackfoot Asylum for the Insane, and thus had a good-sized commercial center.

Pocatello was larger than Idaho Falls' 19,000 people by a few thousand, and was home to the growing Idaho State College. The Naval Ordnance Plant complex included office space, transfer warehouses, and other facilities that could serve the IDO immediately despite being sixty-five miles from the testing station. The town leaders welcomed the prospect.

So the four contenders for the IDO's home town were Arco, Idaho Falls, Blackfoot, and Pocatello. The winner could look forward to a multitude of commercial opportunities, not to mention heightened prestige and a general boost in the cultural evolution of the town. The AEC officially activated the IDO on April 4, but it was up to Johnston to choose its permanent home.



Future site of the NRTS is imposed on map showing towns and state highways in 1949.

By the time Johnston arrived for his first visit, competition among the four cities already was getting rough. On April 6 the mayors and newspaper publishers of the four towns met together to "overcome the selfishness which seems to abound in all our communities." Together they sent a telegram to Johnston to say they had all united to work with him on the project he was to supervise. It would help, they said, if he could tell them what to expect. An AEC news release followed, indicating that in all of 1949, only fifty people were expected to arrive for work. Growth would be gradual and there was time to get organized. Once more, a delegation went off to Boise for another planning session with the governor.[10]

Despite the official declaration of amity, each town did its best to win the headquarters. As Johnston and his small entourage made their first round of visits during the week of April 18 (beginning respectfully with Governor Robins), the towns prepared to make their welcomes and their first impressions.[11]

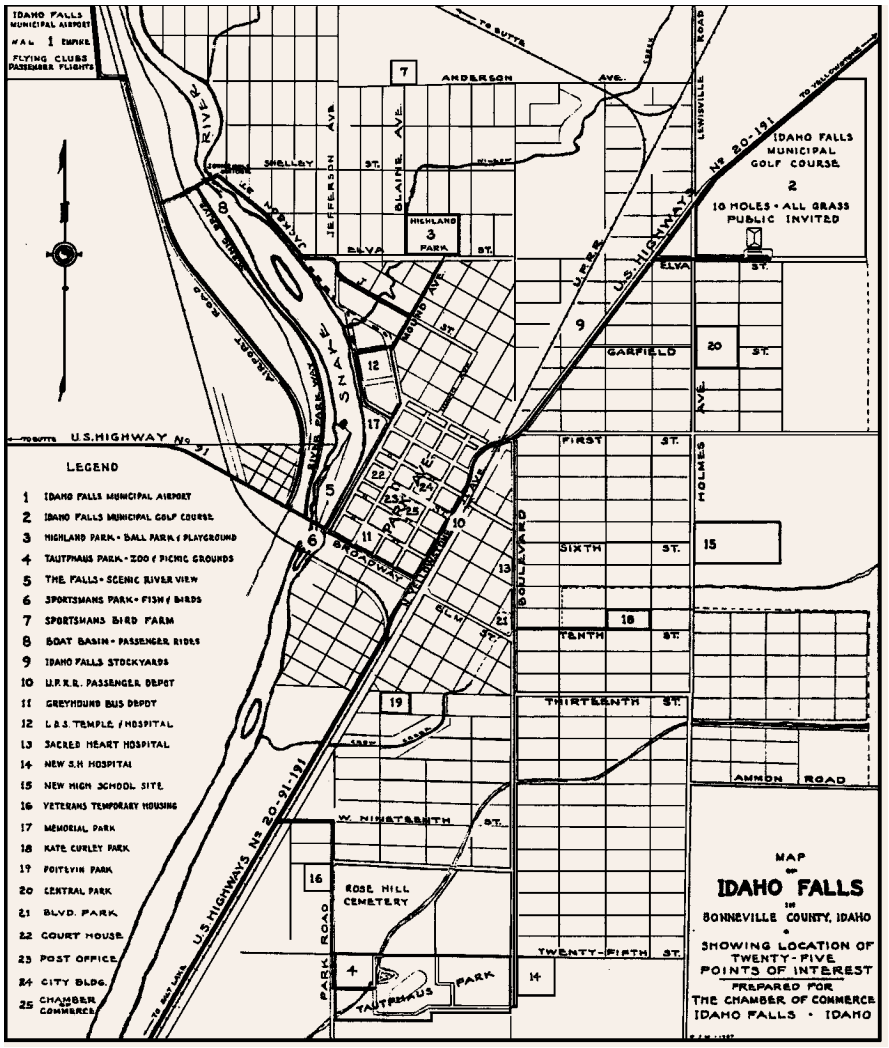
Arco took the approach that its proximity to the site was so self-evident that the plum would have to fall on its side of the fence. The committee rounded up old college friends of Johnston who happened to live in Arco and deployed the town's most distinguished citizens, Idaho's former governor Clarence A. Bottolfson and his wife, Elizabeth. They prepared an evening's dinner and the next day a cordial breakfast gathering for the visitors.[12]

The Idaho Falls Chamber busied itself creating happy memories and magical illusions for the visitors. Some called it "the party plan," as it included rounds of luncheons, cocktail parties, dinners, and tours showing the sunniest and most appealing features of the city.

Guest lists were carefully crafted to include the young wives in town who were "as winsome as possible." The visitors were shown the site of the new civic auditorium, where 2,500 people could be seated. The high school art teacher, a talented artist and the nucleus of a group of mature artists, organized an art exhibit, to which the guests were adroitly exposed. "Yes, we absolutely can and will build new houses fast," was the consistent message. The men from the AEC heard good things about the schools, saw the city's parks, and had a look at the spectacular Yellowstone country just up the road. In Idaho Falls, AEC scientists would not be destitute denizens of a cultural desert, but would be eagerly embraced by a friendly and hospitable town with everything going for it.[13]

Idaho Falls'most important illusion concerned the existence of a road to the Proving Ground. To weave that magic, the chamber arranged for Bonneville County road grading vehicles to go to the western edge of town where they moved sufficient dirt around to give a convincing impression that the road to Arco already was under construction, at least to the county line. Activity was particularly heavy on the day that the visitors were brought to see for themselves. The road seemed, for all practical purposes, a *fait accompli*. Holden's orchestration was so thorough that some of the vehicles appeared to be regular daily traffic already using the road for routine business.[14]

Blackfoot's Chamber of Commerce held a public meeting (which was covered thoroughly by a reporter from the Idaho Falls paper) more to persuade the populace that little further needed to be done than to rouse them to action. "There was no dither," said the reporter of the meeting. Blackfoot felt confident that its sewer and water planning, which pre-dated the AEC announcement, and a school system with a capacity for three hundred more children meant that it already was prepared for growth. But the road to the site was its ace in the hole. It would take Idaho Falls and the state too much time to build a new road to the site. Pocatello too would require a more direct road, and it would have to bridge the wide Snake River, another project that would take too much time and money before it could meet AEC needs. Therefore, the Blackfoot chamber concluded, "Blackfoot, willy nilly, looked like the port of entry."[15]



Street map of Idaho Falls circa 1949.

At Pocatello, the obvious attractions, aside from its size, were the facilities of the Naval Ordnance Plant and the college. The Pocatello leadership, however, was reluctant to make any guarantees about housing or expanding urban infrastructure for the rapid population growth sure to come. And, it was said, Pocatello parties tended to exclude women and were, as a result, "rather stiff" affairs.[16]

The AEC must have noticed a missing airport in Blackfoot, a too-small hospital under construction, and too few business services in the little town. Arco's wholehearted commitment and desire, with its rational approach to sound planning, could not overcome its small size, even with the state's

The party plan worked, or at least it did not fail. On May 18, 1949, after circumspect deliberations, Johnston announced that the field office would locate in Idaho Falls, leasing office space at the Rogers Hotel downtown. A new road to the site would improve travel time, and construction workers could live conveniently at Arco and Blackfoot. Rail connections would be handled from Pocatello.[17]

The craftsmanlike execution of a clever strategy in Idaho Falls contrasted sharply with the serene, perhaps passive, attitude at Idaho's Statehouse. Chairman Lilienthal also had been one of Robins' mid-April visitors. Writing of the encounter in his journal, Lilienthal said Robins impressed him as a "relaxed, governor ters to . He ecide , and he hy the egation, at that noment

was "trying to raise enough Ned" to get the testing site relocated to Ft. Peck, couldn't see that. Montana's governor had even telephoned Robins to ask him what Idaho's angle had been. Then he refused to believe Robins'denial that there had been any angle at all.[18]

With no evidence to the contrary, the AEC had every reason to believe that it could continue its tradition of independent operations in Idaho. No opposition appeared anywhere. The government's habit of secrecy in atomic matters had originated during a patriotic war. With the growing threat of a communist enemy, secrecy would have to continue. Johnston told one of the Rotary clubs in August that employees "must at all times be checked and double-checked on our loyalty standing." Citizens seemed content to accept details about the testing station whenever Johnston felt free to provide them.[19]

Scientists had produced the awesome bombs that ended the war, and they enjoyed an image as being far above the daily play of political persuasion—at least in southeast Idaho. Bill Johnston's conduct did nothing to dispel that notion. People instinctively trusted him as soon as they met him. He didn't fit the stereotype of an engineer with a single-faceted personality. He was stylish in dress—even the frames around his eyeglasses were *au courant*. He and his equally popular wife Helene enjoyed entertaining Idaho Falls associates and the many political and industrial visitors who came through the city. His friendly and candid

This logo appeared on the cover of the Idaho Falls Chamber of Commerce's 1949 Annual Report.

manner, easy sense of humor, and the absence of anything officious about him all went a long way to creating a promising start for the AEC in Idaho Falls. He felt that IDO employees should become part of the fabric of town life, so he set that example and encouraged it in others.[20]

Leaders in Idaho Falls, for their part, turned from parties to the sobering duties of development. The editor of the *Post-Register* wrote:

But once the flush of excitement has given way to sane analysis it becomes increasingly apparent that the first phase of the program was by all odds the easi - est. Now that we have the headquarters of this mammoth project located here we are confronted with the greatest civic project that we have undertaken. To house all the people who are bound to come here to live, to see that our school facilities are quickly expanded, that water and sewer lines are extended into new areas, that sidewalks and roads are built... The city—and in fact, this entire area—is on the threshold of its greatest era of development.[21]

It was clear that Idaho Falls and the other nearby towns viewed the AEC as the region's next source of growth. In fact, Idaho Falls delivered on its promises, building 1,648 new houses between 1949 and 1951. With this beginning, town leaders hoped that the momentum would carry farther than previous booms that had gone bust, and they were eager to nurture this promising sprout in their midst. Besides, developing atomic power for peaceful uses was a worthy adventure for patriotic citizens.[22]

Hiring On at the NRTS

In 1949 the Navy put its civilian employees on notice that the AEC was coming and that they would lose their ordnance jobs. One of them was Al Anselmo.

Around September 1949, the [Ordnance Plant] boss asked if I had a job yet. I said, "No." He had met a man named A.R. Tuttle, who worked with the AEC. "They are taking over the Site soon and they have problems because they will be shipping things into the Site right away. I volunteered you."

Tuttle rode with me a few times out to the Site. One time I asked him if he would need a traffic manager or warehouse manager. "I can't talk to you. You have to have Q clearance," he said, and he handed me some forms. By the time the job opened, the paperwork was done. I started on October 10, 1949.

At first we had no badges. Then they issued badges numbered 1 to 99 for the Idaho Falls employees. Numbers 100 and up were for the Site employees. Mine was 100.

After I was hired, I said to Tuttle, "I don't have a job title." He told me I had six jobs—property management, surplus, excessing, warehouse, traffic, and receiving. He said when I got too busy to do them all, I should let him know so we could hire people to do them, and to keep the one I wanted. So I kept traffic and receiving and assisted him in hiring the rest.

The first time I had to deal with a shipment of radioactive materials, I was scared—not of the stuff, but of violating the regulations unintentionally. Even then, there were lots of regulations. In those days, the AEC sent security escorts with the truckdrivers. We shipped stuff all over the United States—to Chicago, New York, Oak Ridge, Hanford.

As the years went on—especially during the ten years we shipped Three Mile Island debris to Idaho—I developed contacts in the governor's office of each state our shipments went through. I had good rapport with all of them. We trained the various state police departments in how to handle an accident if there were any.

Al Anselmo

Chapter Five

Inventing the Testing Station

The desert is starting to show some small signs of activity.

–Bill Johnston, July 1949–

Settling into the fourth floor of the Rogers Hotel on July 16, 1949, the IDO staff, now grown to twenty-five members, suddenly found themselves needing to execute some sort of "party plan" of their own. They had to reassure a number of eastern visitors with second thoughts about Idaho. A rumor had surfaced in Oak Ridge that "bubbles in the lava beds" made it unsound for the reactor building's foundation. John Huffman, one of the Oak Ridge scientists responsible for one of the proposed reactors, came to have a look. The Idaho group took him to the reactor site, where a careful examination alleviated his concerns. They also made sure he understood the nature of the superb fishing country just up the road past Arco, a trick they may have learned from the Idaho Falls Chamber of Commerce.[1]

Aside from bursting bubble rumors, Johnston had to deal with waves of doubt coming from AEC Headquarters in Washington. Despite the AEC's apparently irrevocable decision in February, resistance to the idea of a testing station was growing: it would cost too much money, the Navy wanted to keep its property, the estimates of safety hazards were overblown and a testing site really wasn't needed. Scientists continued to propose that reactors be built at their Argonne or Oak Ridge labs.[2]

Worse, a turf war had erupted. Walter Zinn learned that Hafstad intended for Johnston and other AEC field managers to wield a controlling amount of authority. They would select the contractors to design and build the reactors, thereby retaining direct AEC control over reactor research. Zinn cared little for this idea. Not one to say diplomatically what he could say bluntly, he wrote Hafstad, "I believe it would be unsatisfactory to ask unqualified people to take responsibility for approvals." In the ensuing tussle, Zinn threatened to withdraw the breeder reactor, but Hafstad made compromises favoring Argonne's choice of contractors and calmed the waters.[3]

Courtesy of the Winfield Marvel Family

Leonard "Bill" Johnston

Zinn vs. AEC Managers was only the first eruption to set the ideals of scientists at odds with the ideals of administrators at the NRTS. Scientists thought administrators had little appreciation for scientific sensibilities or the creative process; managers thought scientists had no public relations moxie and an insufficient devotion to budgets and schedules.

The conflict played out strictly within the AEC family, but it delayed firm decisions about the Idaho reactor program. It had seemed in April that three reactors were slated for the proving ground, but in June the number was up in the air again. With Washington in a shuffle, Johnston used his podium time before Rotary clubs and other local groups to provide general updates on the purpose of the Site, but couldn't announce a construction start on the first project until September. Eventually, the hash and rehash in Washington at last dissolved into decisions to build four major pro-

The excavation for EBR-I began in 1949.

INEEL 225

A Memoir of the Rogers Hotel

In the early years, the fourth floor of the Rogers Hotel provided an unusual environment for an office. The available rooms were generally small with an adjoining bathroom. The toilets were of the noisier power-flush rather than the gravity type. This made for embarrassing incidents, such as when you were on a long distance call and the unknowing caller would comment about the sound of a flushing toilet. In the summer when windows and doors were open you could hear even more flushing sounds from adjoining rooms, across the hallway, and across the narrow break between building sections.

Since filing space was at a premium, the secretaries put file cabinets and boxes in the bathtubs, which sometimes produced complicated traffic problems. Sometimes you'd have to go, and you'd find blueprints and plans spread out all over the fixtures. Window screens weren't tight, and the secretaries didn't appreciate the dead flies that greeted them in the tub every morning. The downtown eateries were overwhelmed at lunch hour, so many employees brought lunches, and that certainly helped attract the flies.

Air conditioning was very limited, so the major saving feature of the place during the very hot days of summer was the existence of the White Horse Bar in the lower level of the hotel, where a cool beer was always available at the end of a long hard day.

Anonymous

INEEL 0133

Drill rig crew takes core sample from spillway on an old irrigation canal.

jects: Zinn's Experimental Breeder Reactor (EBR, later called EBR-I), the Materials Testing Reactor (MTR), the Idaho Chemical Processing Plant (ICPP, or Chem Plant), and the Submarine Thermal Reactor (STR, later named S1W).[4]

Johnston pressed forward, even though the Navy continued to occupy the site through most of 1949. The Naval Proving Ground families gradually moved away, but the last one didn't leave until the night before the Navy's last official day of possession on December 1, 1949. Johnston carried on as though the testing station were a going concern. He moved his staff into the Rogers Hotel and moved his family to Idaho Falls from Schenectady.[5]

Johnston's effort to secure a dependable supply of electricity brought him into the middle of a regional struggle between public and private suppliers of power. The Idaho Power Company was willing to cooperate only if the AEC paid for every bit of the investment and guaranteed a ten-year contract. The company feared that the Bonneville Power Administration (BPA) would step in and offer public power at cheaper rates, wiping out Idaho Power investments. The negotiation, which also included Utah Power and Light (UP&L), extended well into 1950. Before it was over, Johnston's and AEC's legal counsel, Bigelow Boysen, went so far as to prepare a case against the two private companies condemning all or part of each company's properties.

But before the AEC carried out that unfriendly step, it compromised by paying for new transmission lines and capitulating to a ten-year contract.[6]

Finding satisfactory reactor sites was the immediate priority. Each would need water, electricity, access, and security. As many as ten reactors might be built eventually. Although the desert seemed vast, the reactors couldn't go just anywhere. Above all else, reactor buildings would be dense and weighty. Each needed a rock-solid earthquake-proof foundation for reinforced concrete basements, lead and concrete shields, and heavy steel frames. Some of the desert's windblown soils lay rather thinly on the lava rock, and no one wanted to spend a lot of money blasting basalt.[7]

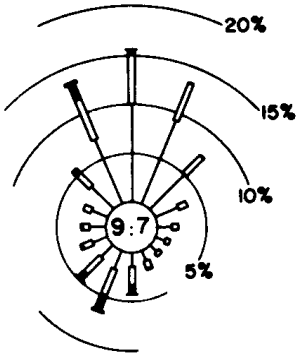
The U.S. Army Corps of Engineers sent two core drilling crews to Idaho, one from each of its Sacramento and Walla Walla district offices. The Navy had not needed to explore below the surface at the proving ground, so it was uncharted territory. Core samples revealed the depth of the soils overlying the lava rock and profiled the alternating layers of sediments, basalt, and water-bearing gravels. The crews also evaluated spillway and bridge structures already on the Site.[8]

When they tested the land east of the Big Lost River, the drillers discovered that the depth to bedrock was greatest near the creekbed and diminished with distance. Therefore, once the architects had decided on the desired depth of a basement, they could put the building where the depth of overlying gravels matched the basement depth, minimizing the blasting of lava rock. The civil engineers bragged for years about how this procedure had helped to save money. Other areas proved suitable as well, including one near the place where the new highway from Idaho Falls was expected to intersect with the road from Blackfoot.[9]

The reactor sites had to meet safety criteria. The Reactor Safeguards Committee, which had recommended the remote testing station in the first place, required that two concentric zones surround any reactor site. The near zone would be a controlled-access area where an accident might pose severe danger. The radius of this area was determined by a formula based on the reactor's power level. The second zone would be determined by a combination of reactor type, meteorology, hydrology, and seismology. Danger within this zone was low, but nevertheless should contain only a limited population. To make sure this secondary zone was large enough, the AEC arranged to buy additional land east and west of what the Navy had withdrawn from the public domain. Finally, an informal practice had evolved during the Manhattan Project of siting reactors no closer than five miles from one another when this was feasible. This may explain why the MTR and the S1W were located five miles apart.[10]

The safety principle of isolation applied to all future reactor experiments (if not always at five-mile increments), establishing the testing station's characteristic land-use pattern of widely separated clusters of buildings. Each project settled into its own "desert island," connected to central services by roads and utility lines.

A site was good only if water could be brought to it. Idaho geologists familiar with the desert area of which the proving ground was only a small part had told the Detroit consultants that a few dry wells had been drilled here and there along with some productive ones but the data was scant. They spoke of an "underground stream" flowing between



Courtesy of National Oceanic and Atmospheric Administration/INEEL 60-1100

Above. National Oceanic and Atmospheric Administration wind rose depicts wind patterns at the north end of the Site. Right. In the early years, U.S. Weather Bureau employees launched helium-filled balloons twice a day to measure the upper level wind speed, direction, temperature, pressure, and humidity.

the mountains to the north and the Snake River to the southwest and told the Detroit consultants that water would be plentiful if the wells tapped the stream.[11]

In May Johnston announced that the first civilian contract would go to A.J. Schoonover and Sons of Burley, Idaho, to drill a well at the site selected for Zinn's breeder reactor. Johnston had told local business leaders that most of the IDO contracts would be for amounts less than $100,000, intentionally within the capability of Idaho's small businesses, and he was as good as his word. The well was exploratory but, if successful, would convert to a production well. By August, it had proven itself. Johnston was pleased. "Each new development to date," he said, "has indicated that the Idaho site will meet every expectation of the AEC as an ideal location for the reactor testing station."[12]

Finding water was far easier than anyone had imagined. The "underground stream" proved to be more like an underground ocean, and the IDO was never at a loss to find water for building sites. It did, however, have to blast lava rock at times. Bill Johnston along with his driver, Marvin Walker, witnessed one of them at the Chem Plant:

I was still Johnston's driver and document courier when they started the basement for the Chem Plant. They flew an expert in from somewhere to oversee the blasting of the rock. There must have been a carload of explosives in that blast. Just placing the charges had taken several days, and when it was ready to go, Johnston and I watched. We were directed to a spot quite a distance away, and Johnston's AEC car, a black 1950 Buick, was parked between us and the blast. We were at least 50 yards beyond the car. The expert hadn't expected much to come up, and all that did come up was dust and small debris and one very large surprise boulder that must have been encased in the lava. It flew towards the Buick. "Another hundred yards, and you'd have made a direct hit on my car," said Johnston to the expert. Later, when we examined the results, the lava looked as clean as if a saw had cut it. He did a beautiful job.[13]

In August 1949, the USSR detonated an atomic device. The news shocked the citizens of the United States. At AEC Headquarters, a sense of urgency infused the reactor program. Priorities clearly had to favor defense goals. President Truman ordered the AEC to develop a hydrogen bomb, also known as the Superbomb. With 1950 came the Korean War. The U.S. Army sent military advisors to the NRTS to facilitate procurement and otherwise move the construction schedule as rapidly as possible. The MTR and the Chem Plant, aside from their major research missions for peaceful purposes, also had subsidiary defense-related missions of urgent interest to Los Alamos weapons researchers.[14]

Johnston continued master planning the Site, enlisting other federal agencies for help. The U.S. Soil Conservation Service advised on the re-seeding of disturbed construction sites. The U.S. Weather Bureau studied wind and weather patterns across the Site. Exhaust stacks would soon become part of the landscape, and the architects would need to know how high to build them and which directions were downwind and upwind. The winds would play a major role in diluting the gases and particulates that would exit the stacks.[15]

The U.S. Geological Survey (USGS) analyzed the structure of the Snake River Plain aquifer and layers of lava rock beneath the site, drilling thirty-three test wells. At a meeting of the Rotary club in Pocatello, someone asked Johnston about the projected use of water and if the wastes might contaminate the underground supply. He replied, "Waste water returned to the desert drainage will be clear and [as] free of foreign matter as pure spring water." It was the thinking at the time that the soils would absorb "atom waste" long before the water that might contain it could reach the aquifer.[16]

The U.S. Army Corps of Engineers, with the Bureau of Land Management, helped with the purchase of surrounding state and private lands. With new acquisitions, the AEC would control a total of 400,000 acres, more than doubling the Navy's holding.[17]

In October Johnston reported to his various Idaho audiences that three reactor sites had been selected. Hanford was dismantling its concrete batch plant and shipping it to Idaho. The engineers had found good sources of sand and gravel not far from the Navy's circle of small white houses. Cement would arrive by rail and be conveyed conveniently to the mixing vats. The pace began to quicken. Johnston hired another local firm to excavate the basement for Zinn's breeder, even before Bechtel had been selected as the construction contractor.[18]

INEEL 0111

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INEEL 4116

Above. The batch plant from Hanford is reassembled at the NRTS and nearly ready for action in November 1949. Middle. Inherited from the Navy, houses like CFA 609 were later used as offices. Below. By January 1952, a new cafeteria was operating at Central. The kitchen included a pastry section.

When the Navy handed over the proving ground on December 1, they left it mostly as it had been, and the AEC reaped the cost savings that the Detroit consultants had predicted. The Navy buildings became the staging area for the construction that began in earnest in 1950. The area continued to expand as a central service area for the NRTS. Eventually it acquired the name "Central," or more officially, "Central Facilities Area (CFA)." Its functions grew to include a fire station, dispensary, technical library, cafeteria, warehouses, offices, laboratories, and a maintenance shop for the fleet of buses that would take workers to and from the Site. The contractors quickly appropriated the houses, marine barracks, magazines, cranes, roads, and utilities for service. The industrial odds and ends lying about the Navy's storage yards supplied treasures for scrounging scientists for many years to come.[19]

Whether Johnston ever was under any illusions about the true status of the road from Idaho Falls to the Site is lost to history. One day in the spring, not long after he had arrived, he had his driver take the Buick past the point where the county's roadwork had ended. The car bumped along on an old stock trail that wound westward through the mix of lava fields and grazing lands. Johnston met one of the ranchers, and they talked about the road. "Just tell the engineers to fill, don't cut," warned the rancher. Snow drifted badly in the winter and would fill low spots. Johnston kept it in mind.[20]

First, the road had to be financed. Johnston told the Governor Robbins that the project would be handicapped without good roads. He needed a new road to connect the Site to what Bonneville County had already graded and graveled west of Idaho Falls. Also, the shoulderless road between Blackfoot and Arco, which probably followed the meandering path of an old wagon road, needed to be upgraded to a standard, two-lane condition. Robins replied that Idaho would devote some money to the roads if the federal government would accept them into the Federal Aid Primary System and help with federal funds. Johnston pressed, "I will appreciate any special expediting methods your staff can use..."[21]

Johnston's program director, J. Bion Philipson, took over the conversation with the governor. The road had to be available by the end of summer in 1950, he said. If the state would prepare bid specifications in the winter of 1949, this would be possible. Philipson suggested that the state hire several contractors, each to build one section of the road. In that way the job would get done faster than if only one contractor were hired to do the entire job. He offered the AEC's own survey parties to work under state supervision, and he said the AEC would supply at least $700,000 from its own funds for the road, over-matching Idaho's $500,000.[22]

But the negotiation between the AEC and the State of Idaho was only beginning. Governor Robins became far less easy-going than the gentleman Lilienthal had met. He complained that the AEC schedule "makes a stiff demand" on the state. It would upset previous budget plans and "will certainly strain us to the limit" and "expose us to considerable maneuvering in the

handling of funds and arouse some community criticisms." The highway department had obligations in other parts of the state, and "can't go higher than $300,000." The state intended to relocate most of the Blackfoot road and thought the actual cost of all the work would exceed early estimates. Still, the governor asserted that the state would do its best to meet "reasonable" demands.[23]

INEEL 0695

The dickering continued through 1950 and into 1951 and beyond, engulfing the three counties through which the roads would pass (Bonneville, Bingham, and Butte), Idaho's congressional delegation, the federal Bureau of Public Roads, and a host of chamber of commerce committee members, the Idaho highway commissioners, contractors, and others. Resentment flared in Blackfoot as the IDO seemed to favor the Idaho Falls road at the expense of the Blackfoot road, on which ninety percent of the freight to the site was hauled. "They wined and dined those [AEC/IDO] people," accused Blackfoot, hinting of legal lapses.[24]

Struggles over right-of-way and who would pay what and when strained the political skills of the Idaho Falls civic leaders to the utmost. When the winter of 1950-51 arrived, the new road was not ready, and the Blackfoot road had not been improved. Site employees from Idaho Falls had to travel south to Blackfoot and then dogleg west on the Blackfoot road to get to the Site. The road opened finally on October 8, 1951.[25]

The AEC ended up spending $1,141,000 for the road from Idaho Falls, while the State of Idaho's share was $337,000 and a promise to improve the Blackfoot road. The federal Bureau of Public Roads contributed $563,000, an amount widely perceived as a "higher-than-usual percentage in relationship to Idaho's portion." In 1952 the state managed to grade about twenty miles of the new Blackfoot road but announced that if Idaho funds were the only ones brought to bear on the problem, the state would have to piece the repairs over the next three years, and even then not necessarily get the job done by 1955. Meanwhile, the road continued to deteriorate dramatically under heavy Site traffic.[26]

Prodded by an indignant Blackfoot, which wondered all over again why the AEC had chosen Idaho Falls as its home city, Johnston promised to persuade AEC headquarters to support a special federal appropriation through the Bureau of Public Roads. This he did, with the Idaho congressional delegation backing the proposal "to the hilt."[27]

INEEL 99-344-10-14

Above. Excavation for MTR in October 1950 shows concrete work in progress and location of future fuel-storage canal. Left. The CFA in 1999 was the home of Site support services such as environmental monitoring and calibration laboratories, communication systems, security, fire protection, medical services, warehouses, cafeteria and laundry services, vehicle and equipment pools, and bus operations.

By early 1953 a more comprehensive approach to road planning was evident. The IDO was getting ready to open a new reactor complex at the northern edge of the Site. State and federal road authorities prepared to extend a new road west from Rexburg towards the Terreton and Mud Lake area, as well as make other improvements to the connections from the Site to Arco, Idaho Falls, and Blackfoot.[28]

Although anticipating new roads, the IDO decided early that it would bus employees to the Site from surrounding towns. Considering the thousands of employees on the way—and the narrow condition even of new roads—it was the safest alternative. Bus service began early and continued, the fare always set so low that most employees would find the buses far more attractive than carpooling. Although Johnston had passed along to the engineers the rancher's warning about snow drifts, the message was lost. During the first winter of the new road, drifting snow closed it, forcing employees to go the long way once more.[29]

Thus, the first transactions between the AEC and the State of Idaho involved long haggles over who would pay the cost of infrastructure. The accommodation from Boise was reserved, perhaps unavoidably stinting. Equally, the AEC made clear that it intended to avoid as much off-site expense as possible, and not only for roads. Asked if the AEC could help impacted school districts cope with rapidly rising enrollments, the answer was an unequivocal "No."[30]

Johnston, however firm his private demeanor during negotiations, often emphasized more harmonic chords in public. "We have here in our western country," he would say, "a project which is destined to bring to life some of the great things that the atomic age holds for the world."[31]

Idaho State Historical Society G2-20.28827 Box 5

Right. Governor C.A. Robins. Below. On October 8, 1951, the road linking Idaho Falls to the Site was officially opened, ending long months of negotiations.

Idaho State Historical Society MS326 Box 5

Chapter Six

Neutrons: Fast Flux, High Flux and Rickover's Flux

Pile research is not for us'ums, Fa la...
Leave it for our Argonne cousins, Fa la...
Engineering is for us'ums, Fa la...
We're a bunch of dirty peons. Fa la...

–Ditty sung by Oak Ridge physicists to the tune of Deck the Halls, Christmas 1947–

As director of the Argonne Lab in Chicago, Walter Zinn ran weekly seminars for his scientists, assigning topics such as, "If you were going to cool a reactor with an organic substance, what substance would you use?" It wasn't academic; Zinn was looking for real answers. Reactor designers in the late 1940s all had more questions than answers.

A few years later, Zinn's staff had an opportunity to run an experiment subjecting a certain promising organic (a diphenyl) to irradiation to see what would happen. They noticed right away that the material started to break down. The hydrogen in the compound turned into a gas and formed little bubbles, each of which stole neutrons and made it harder for the reactor to continue its chain reaction. Then the stuff turned from its original clear liquid into something gummy and black. Conclusion: if you had a ship reactor using this particular material as a coolant, you couldn't put enough barges behind the ship to tow away the tar.[1]

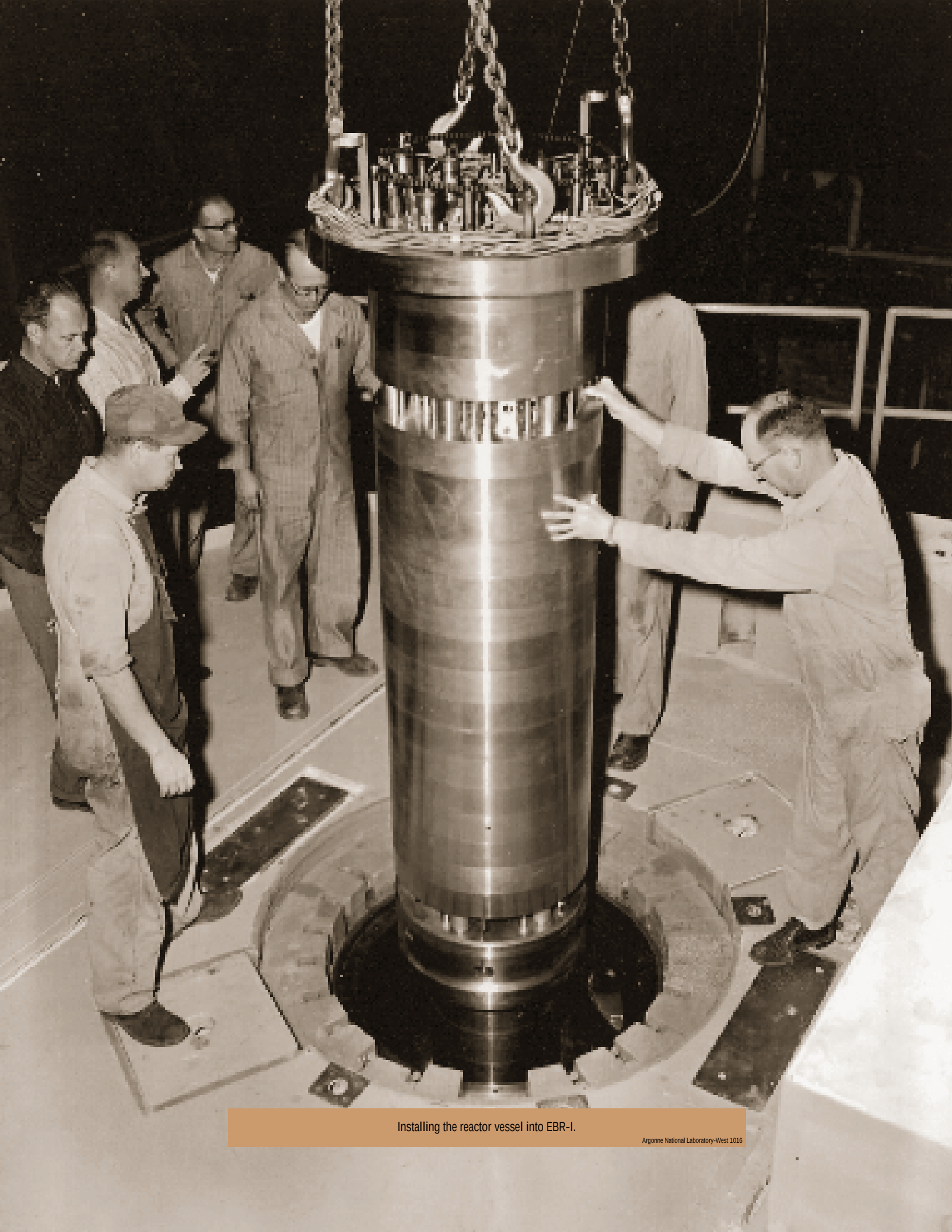
U.S. Department of Energy 201-23

Walter Zinn

The experiment ruled out one option for cooling a reactor. Therefore, the scientists chalked it up as a success. In science, identifying a weak idea is often a move closer to finding a better one.

A reactor is a machine that produces neutrons and makes heat. In reactor design, much depends on just what kind of work—or research—the neutrons and heat are expected to do. The first three reactors at the NRTS each emphasized a different kind of work. The Navy wanted to make heat. Walter Zinn and the incipient nuclear power industry wanted to make heat and new fuel at the same time. Just about everyone wanted to bombard something with neutrons.

And everyone was impatient. After AEC Headquarters finally made firm decisions about what reactors would go to Idaho, the IDO was ready. Infrastructure planning was under control, and Johnston's group was ready with management procedures that would govern the testing station. Unlike the field offices for other AEC facilities, where operations were under the guiding vision of one contrac-



Installing the reactor vessel into EBR-I.

Argonne National Laboratory-West 1016

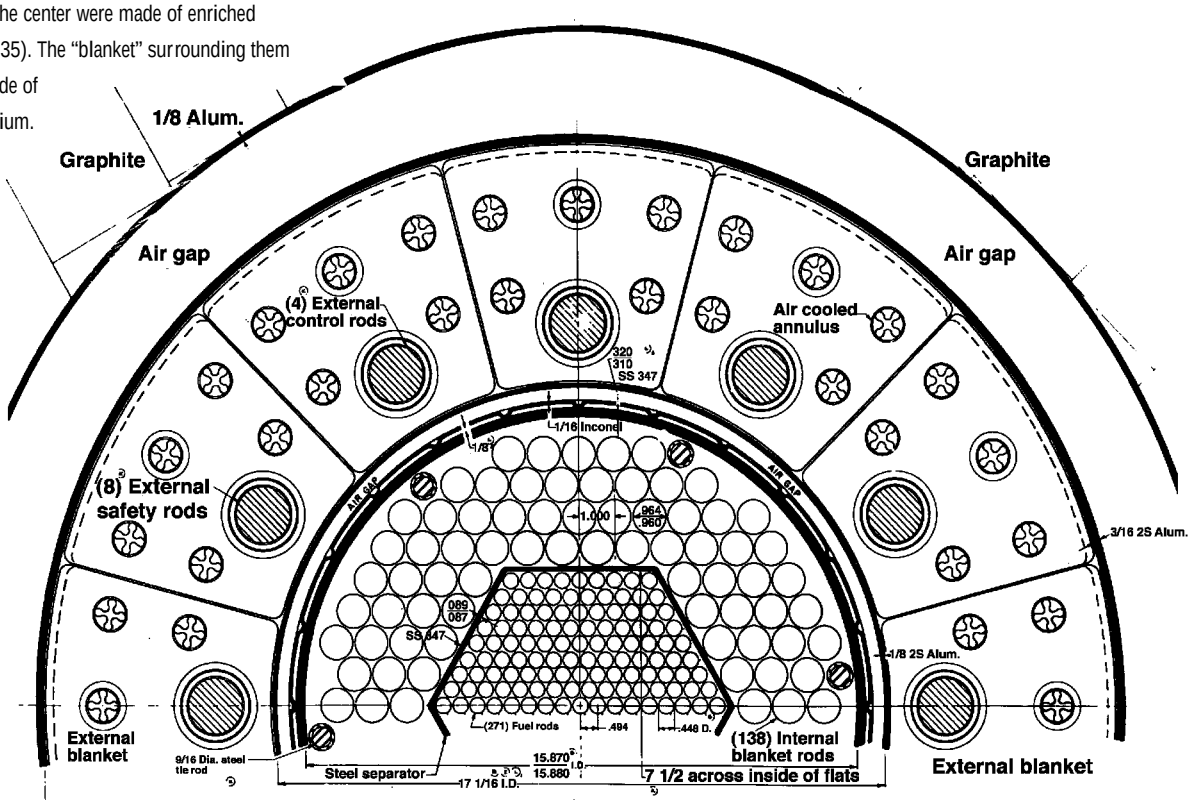
tor, the IDO had to supply central services to many laboratories and contractors simultaneously. To make things even more complicated, other AEC field offices actually had cognizance over a number of NRTS activities.

For example, an AEC field office in Chicago managed the AEC's relationship with the Argonne National Laboratory, including its Idaho experiments. The Navy's submarine projects had a similar relationship with the AEC office in Pittsburgh. Thus, in addition to coordinating the activities of its own contractors, the IDO had to coordinate with a whole cocktail of sister field offices, other laboratories and their directors and contractors. Johnston had to develop a consistent approach to labor relations and cope with differentials in the benefits each contractor offered its NRTS employees. The daily task of IDO management was to define and refine the nature of all these relationships and determine who would do what inside *vs.* outside the contractors' fences. This was a thoroughly impossible job, but it was done.[2]

Over time, an accumulation of loyalties to a home lab and small frictions over how the Idaho "landlord" preferred to handle things tended to produce separate cultures among the separate complexes that grew up on the desert. But common experiences among all employees—such as being neighbors in town and riding the bus together to work—tended to overlay separate loyalties with a site-wide sensibility. Many an employee found, for example, that a career stalled with one contractor could be reinvigorated by a transfer to another—without the employee having to pull up roots and move the family to another state.

In 1950 the builders were busy—at least trying to be busy, for they often were ahead of blueprints. Laborers began filling up barracks in Arco and Atomic City (the new name for Midway), and union halls were busy. The first reactor, Argonne's, already was under construction. As would be the pattern for most of the reactors to come, the complicated work began with a team of physicists and others at the home lab, who designed the reactor and the support buildings it would need. When the AEC approved the project, it selected an architect/engineering (A/E) firm to

Cross-section schematic of the EBR-I reactor core. Fuel rods in the center were made of enriched uranium (U-235). The "blanket" surrounding them were rods made of ordinary uranium.



design the reactor building and associated buildings in the complex. Then a construction contractor, usually different than the A/E firm, built the project and hired local labor. The home-lab scientists designed and often fabricated the reactor itself. Typically, they disassembled the reactor and shipped it in pieces for reassembly in Idaho.

The Argonne team had spent years considering every detail of the breeder reactor. Their main goal was to prove that the reactor could produce new fuel from the abundant isotope U-238. All design decisions promoted this goal. A secondary goal was to produce electrical power, since that was the ultimate economic mission of the breeder. This wasn't expected to be hard to do, because conversion technology for reactor-generated power (turbines and generators) already existed.

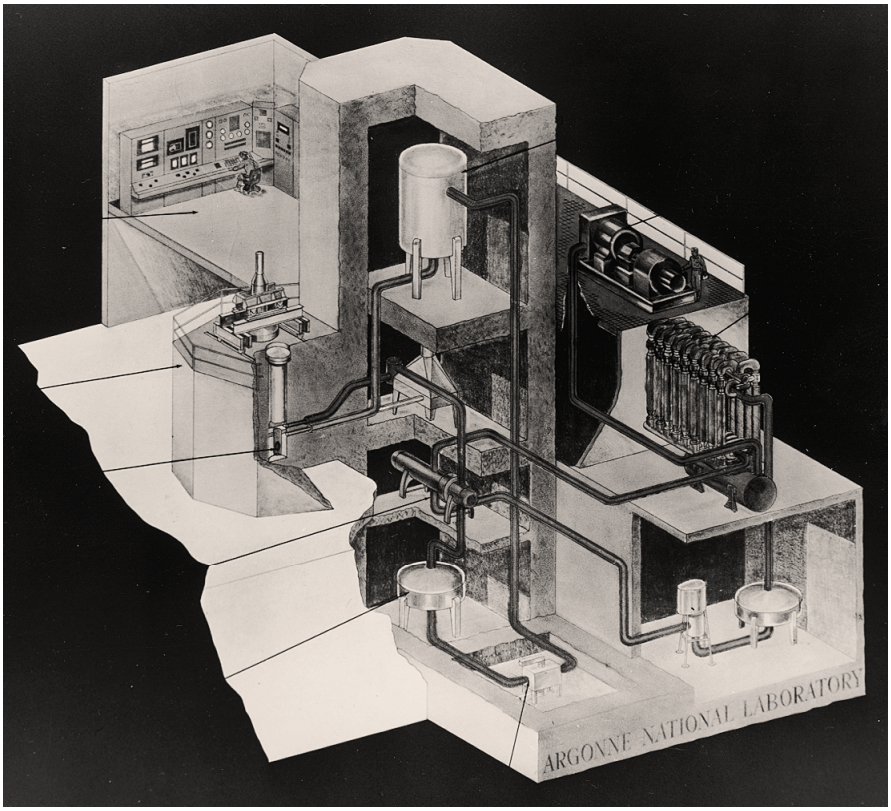
The reactor would have pencil-thin rods of fuel enriched to more than 90 percent U-235. These would be arranged close together in the core of the reactor. Similarly shaped rods of U-238 would surround them. Each neutron would have to count; none could be wasted. Either the neutron fissioned another U-235 atom to keep the chain reaction alive or it penetrated a U-238 atom and changed that into plutonium.[3]

By this time, physicists knew that if nothing slowed down the neutrons during the chain reaction, each fissioned atom was a little more likely to produce three neutrons than two. The natural speed of the neutrons is almost beyond imagination. They sprint away at 44 million miles per hour. Physicists call them "fast." Until the reactor acquired its official name, the AEC community called it "the fast flux," flux being the word to describe the flow of neutrons.[4]

Unfortunately, it was all too easy to waste or lose neutrons. The cladding surrounding the fuel could absorb neutrons. So could the coolant and the structural metal holding the rods in place. Neutrons could leak from the core into the container surrounding the reactor. Obviously, the materials of which these items were made had to be chosen for their reluctance to absorb neutrons—or their willingness to reflect them back into the core. The designers chose stainless steel for the cladding. They surrounded the core with a "blanket" made of natural uranium to catch the neutrons that would leak from the core. Any neutrons that shot past the U-238 rods within the core would have another chance to hit U-238 atoms in the blanket.

With the fuel rods close together and the neutrons moving fast, the core would generate a lot of heat. A coolant would have to flow through the small spaces between the rods and carry this heat

Cutaway view of EBR-I power plant.



INEEL 13185

EBR-I building at photo right, with supporting Reactor Test Facility to left. November 1954.

away to keep the fuel from melting. It couldn't be a material such as water or graphite that stole neutrons or slowed them down. Rather, a liquid metal was chosen, a eutectic alloy of sodium (chemical symbol: Na) and potassium (K) called NaK (pronounced "nack").

NaK was liquid at room temperature. It could easily pass between the fuel rods and collect the heat efficiently, and it didn't absorb many neutrons. But it wasn't perfect. NaK tended to burn when it came into contact with air. The pipes containing the NaK—and the pumps moving it—would have to work perfectly for a long time. In case the pipes did fail, the atmosphere into which the NaK leaked should not contain air.[5]

And on it went. Physicists chose each feature of the reactor for a reason based in physics, whereupon each feature inevitably handed an engineer a major challenge. For example, what specific kind of pump should circulate the NaK? The liquid would flow at very high temperatures. Traditional mechanical pumps would not hold up. The EBR used them, but Argonne engineers eventually invented an electromagnetic pump as well. This pump had no moving parts, was completely sealed, and was made entirely of metal.[6]

But that wasn't all. Eventually the NaK would absorb enough neutrons to become radioactive. What if a pipe did break or the NaK had to be replaced? How could people do the work without exposing themselves to danger? What kind of container should store the old NaK?

Every feature of the reactor had a cascade of consequences, each of which had to be confronted and solved. In the end, each reactor was the creation not only of a presumed brilliant physicist, but of a team of engineers with many different specialties. As the purported "dirty peons" at the low end of the scientific pecking order, engineers had thousands of opportunities to be brilliant at the NRTS.

The Bechtel Company announced it would finish erecting the EBR buildings in February of 1951. Zinn, recalled chemist Kirby Witham, had chosen the EBR site to be near the anticipated junction of the new road and the old road from Blackfoot, cutting travel time as short as possible.[7]

[Zinn] didn't want to travel past Central. The [IDO] had several sites available, mostly along the Big Lost River north of Central... Zinn picked a place where we wouldn't have local traffic passing us all the time. He wanted to be regarded strictly as a land renter. It would cause less friction.[8]

Unfortunately, the highway department changed the highway route, leaving Zinn a little more isolated than he had intended—and obliging him to explain for years why the EBR was left "hanging out there away from everybody."[9]

The designers of the MTR, the second reactor, were content with their site five miles north of Central despite the longer ride from town. It was as flat as a floor—no rolling hills or low ridges here. They had thought that some of their experiments might involve the projection of a neutron beam from the reactor across distances of up to a quarter mile. The ground needed to be flat in at least one direction from the reactor building.[10]

Chapter 6 - Neutrons: Fast Flux, High Flux, and Rickover's Flux

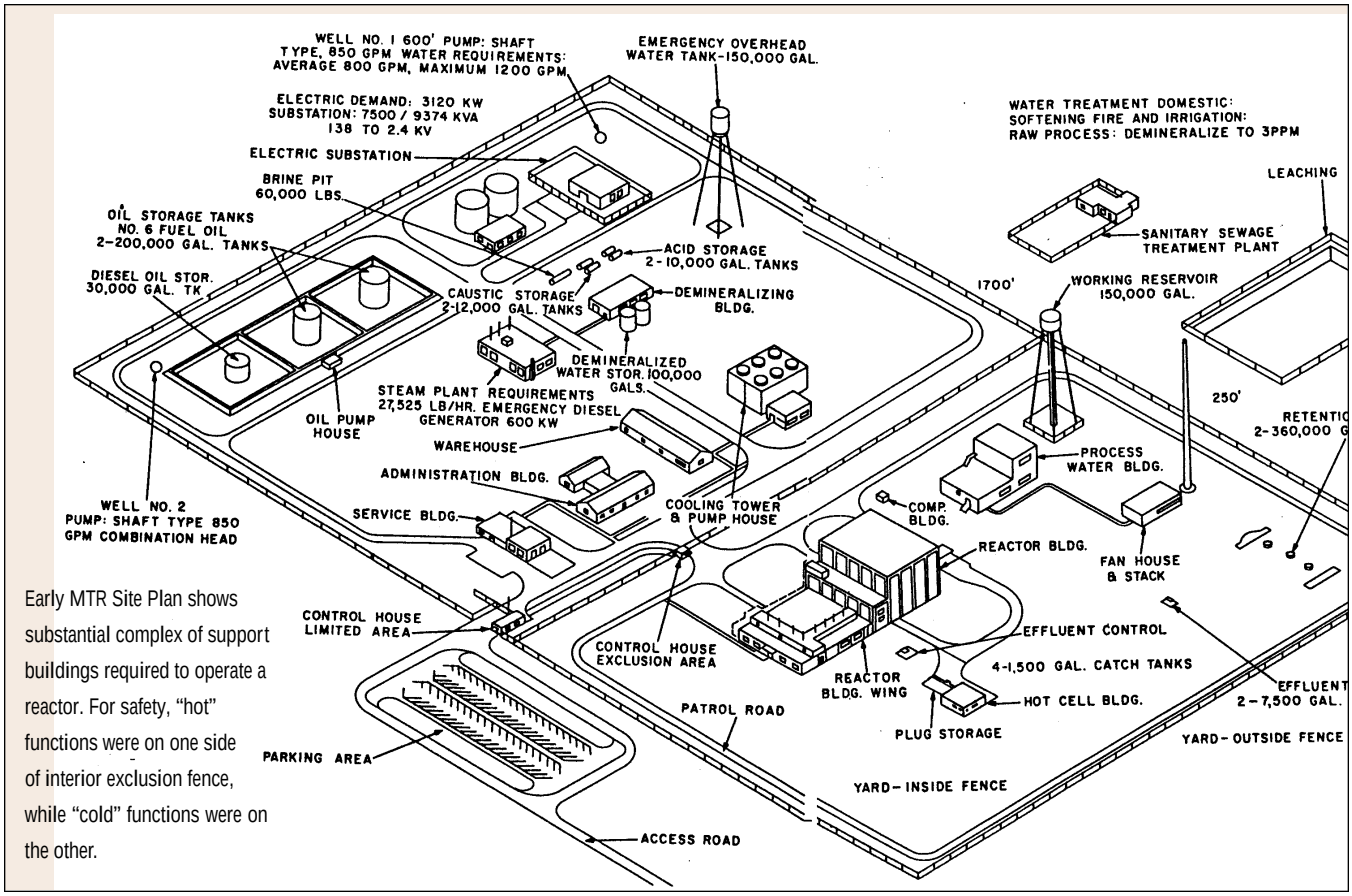
The majority of the MTR's experiments would be more like Argonne's tar-making investigation. The nuclear community needed to learn a great deal more about how the fission environment would affect the materials of which the reactor was made, including the uranium fuel. The work of its neutrons was to bombard and irradiate.

Uranium could take the form of a solid, gas, or liquid. Which would be the best? How long would a fuel element last before it lost its reactivity? How would fission-product build-up affect the ability of the fuel to do its work? What kind of beta or gamma radiation would result from the decay of fission products? What was the best shape for fuel elements? Rods? Flat plates? Curved plates? Over time would the fuel element shrink or stretch? Bend inward or outward? Crumble? The cladding had to protect the fuel and prevent the fission products—the radioactive krypton and barium and other elements—from escaping into the coolant or the environment.

Then there were endless questions about coolants and piping. Was there a liquid metal more convenient and safer than NaK? Advancing the art and science of nuclear reactors required answering one question after another, building a whole new body of knowledge.

The way to start was to bombard candidate materials with neutrons in the MTR, and the more neutrons the better. If they could tuck the sample near the core of the reactor and subject it to as many neutrons in a week as it would otherwise receive in a year in a regular reactor, physicists could learn quickly if radiation would damage the material, and if so how soon and how badly. If they irradiated a sample fuel element, they would learn exactly how a curved fuel plate made of a certain alloy would shrink or expand or bend. Aside from its generous neutron flux, the defining characteristic of the MTR was the fact that it had about a hundred sample holes.[11]

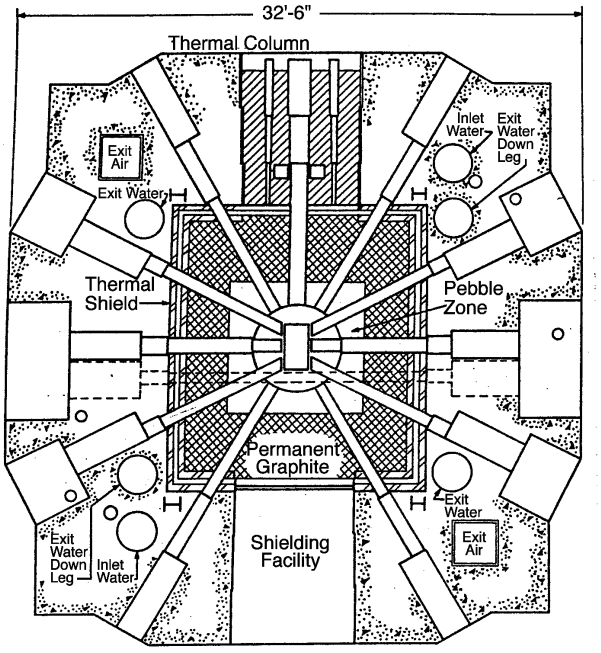
Scientists at the Clinton Laboratory at Oak Ridge had been working on the "high-flux" reactor since 1944. It called for highly enriched uranium fuel and an operating power level of 30 megawatts.

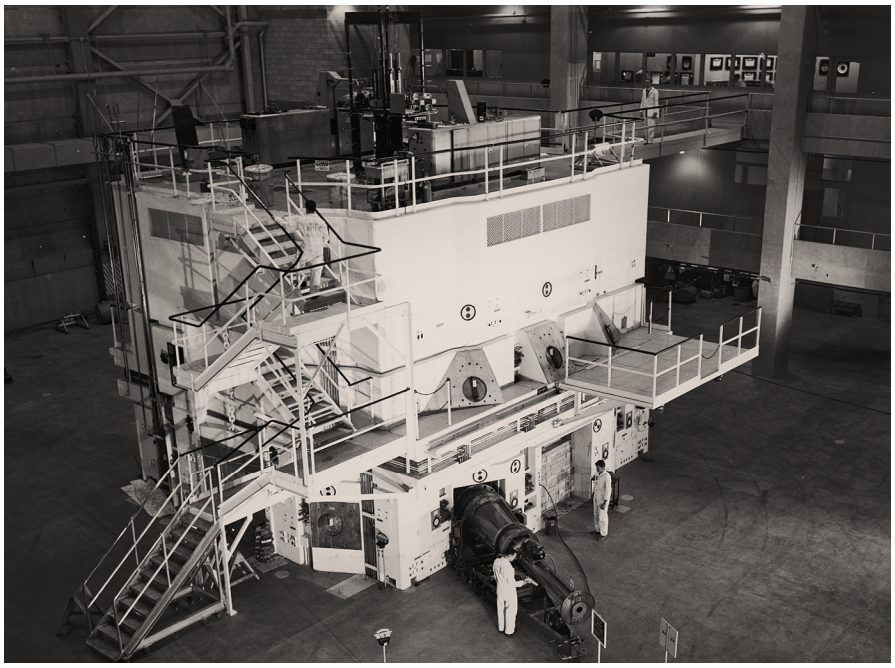


Early MTR Site Plan shows substantial complex of support buildings required to operate a reactor. For safety, "hot" functions were on one side of interior exclusion fence, while "cold" functions were on the other.

At this power level, the fuel would have to be replaced fairly often—about every seventeen days—because fission products would build up in the fuel and dampen the chain reaction. A "spent" fuel element would consume only five percent of its U-235 atoms.[12]

Compared to the EBR, the MTR's neutrons needed to be slowed down. The slower it traveled, the bigger a neutron looked to a target nucleus, and the easier to grab. The MTR required a feature not present in the EBR—a moderator to slow the neutrons. The designers chose water, which could do double duty and carry away heat as well. Neutrons would strike the lightweight water molecules, bounce around, and lose energy with each little bounce.[13]





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In 1946 the Clinton Lab, directed by Alvin Weinberg, proposed that the AEC build the MTR along with a companion chemical processing plant to recover the enriched uranium from the reactor's spent fuel. The AEC approved, and by Christmas 1947 both projects were at an advanced stage of design. Naturally, the Clinton scientists expected to build the entire complex at Oak Ridge. When the AEC announced that it intended to centralize all reactor development at Argonne, the angry Oak Ridgers felt demoted and complained bitterly that the AEC "stole all our reactors."[14]

The decision to centralize reactor development at Argonne soon weakened. By 1949, the Reactor Safeguards Committee deemed it best that the MTR neither go to Argonne nor Oak Ridge. It was better suited to the remoteness of the Idaho proving ground, chiefly because of its 30-megawatt operating level. Zinn was just as glad the complex didn't end up at Argonne because he didn't relish

Above. Horizontal section of the MTR (bird's eye view). Beam holes provide access for test samples near the reactor core. Left. The MTR before it went critical and before experiments began. The "coffin" at center floor level is a shielded device for loading a test sample into the beam hole. It replaced the hole's plug, which was stored during the experiment in a special building. The MTR had three working levels. Note control room at upper right.

having the MTR's chemical processing plant on the Argonne premises. The plant would separate unfissioned U-235 from spent fuel elements and send it off to be recycled into new fuel elements. It would be a heavy industrial complex, and it would generate a great deal of waste, radioactive and otherwise.[15]

The Fluor Corporation, hired to build the MTR, broke ground about five miles north of Central in May 1950. The site for the Chem Plant was about one and a half miles away on the opposite side of the access highway. The two complexes were situated so that neither the MTR nor the Chem Plant were downwind of each other in the prevailing daytime wind, which came from the southwest. If an accident were to occur at either place, any release of airborne fission products would be less likely to harm workers elsewhere.[16]

Progress on all Site construction—including excavation work by the F. H. McGraw Company for the NRTS's third reactor—was interrupted by an unusually cold winter in 1950-51, a great disappointment because this was the Navy's submarine reactor and the Korean War had begun. Bechtel had to postpone its work on the Chem Plant, and both projects waited until spring.[17]

The Navy's reactor complex was five miles north of the MTR. Guided and dominated by the energy and vision of Captain Hyman Rickover (Rear Admiral after July 1953), the Navy had asked the Westinghouse Company to apply nuclear fission to the "steady, well-regulated release of energy to run an engine—safely." The engine was to run a submarine at a certain speed and use two propellers. John Simpson, assistant manager for technical operations at Westinghouse, described the problem:

The concept of a nuclear propulsion plant was disarmingly simple. Just put enough uranium, enriched to the proper amount of the uranium-235 isotope, into fuel elements; the fissioning of the uranium will produce heat. Then flow a coolant over these hot fuel elements to generate steam that will then drive a turbine. The turbine turns the propeller shaft...Sounds easy, doesn't it? The trouble was, none of this theory was well enough advanced to know precisely how much or how many, or how big or how small... Most of the hardware we needed didn't exist. Some of the materials we needed didn't exist either. They had to be improved or developed from scratch. They had to be tested.[18]

Many of the hardware components were tested in the MTR. One problem was the choice of coolant. Each of the major possibilities—water, helium gas, or liquid metal—had the familiar cascade of implications and drawbacks. Water would have to be kept under pressure to keep it from boiling in the core of the reactor. Helium was hard to procure and hard to contain. Liquid metal conducted heat well, but it would take longer to develop into a safe system.[19]

Rickover, who felt that corporate competition served the Navy well, assigned General Electric (GE) to develop a liquid metal concept; Westinghouse, pressurized water. Each company built an AEC-owned and -financed nuclear development laboratory. Westinghouse purchased the original site of the Allegheny County Airport in a suburb of Pittsburgh for what became known as the Bettis Atomic Power Laboratory. GE built Knolls Atomic Power Laboratory in New York.[20]

As expected, the Westinghouse program produced results first. In a daring depar-

Naval Historical Center 80-G-K-18497

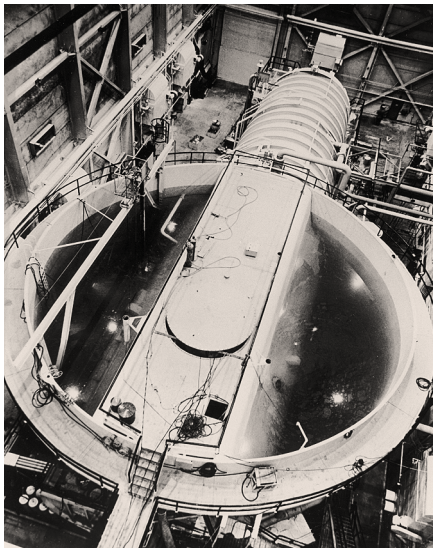
Rear Admiral Hyman Rickover

Getting Heat from Neutrons

The work of the Submarine Thermal Reactor was to make heat. It takes thirty trillion fissions (3×10^{13}) to release 1 Btu of heat. The fissioning of one pound of U-235 can produce the Btu equivalent of burning 1,400 tons of coal or 260,000 gallons of oil.

ture from standard practice, Rickover insisted on skipping certain steps in transforming the idea into a finished product. Traditionally, scientists tested a new idea to "prove the principle" that it would work. Then they built a prototype, usually not full size, to test fuels and components. Next came a demonstration plant, large enough to establish the economics of operation and to put the components to a long-term test. If the idea still had vitality, the sponsor finally built a full-scale operating plant. The process usually took years.

But Rickover wanted to buy time. "The nation that first develops nuclear engines," he said, "will rule the oceans of the world; our enemies are working on such engines; we *must* be first." He discarded the neat sequential view of research and development and ordered a full-scale "proof of principle" reactor to be built in tandem with a full-scale submarine, *USS Nautilus*.[21]



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Above right. Officers enter hull of Nautilus prototype. Note rim of sea tank at upper left. Above. Reactor is in hull section surrounded by water.

INEEL 56-2744

The project was spread out all over the country. The Argonne reactor designers were in Chicago; Westinghouse and Bettis were in Pittsburgh; the reactor prototype was in Idaho; and the *Nautilus* shipyard was in Connecticut. To make sure the mate to the Idaho-tested reactor would fit into the Connecticut hull, Rickover required that each have identical dimensions. The sizes and shapes of parts, the piping, pump and control connections, shielding, the maintenance routines, and the training of the crew—if they worked in the Idaho prototype, they would work in Connecticut. So the Idaho reactor was cocooned in a full-sized replica of two *Nautilus* hull sections, those containing the engineering room and the reactor compartment.

On the matter of perfect congruence between Idaho and Connecticut, Rickover reinforced the principle over and over. During one of his inspections in Idaho, he stopped in his tracks.

"What's that equipment over there by the bulkhead?" he asked, although he obviously knew what it was.

"That's a coffee maker we use during work," a supervisor assured him.

"Get it out of here," the Admiral insisted. "You know the rules. Move it outside the hull."[22]

The hull section containing the reactor rested in a "sea tank" (originally called McGaraghan's Sea after Commander Jack McGaraghan, the Navy's executive officer in Idaho) of water forty feet deep and fifty feet in diameter. The purpose of the water was to help shielding specialists study "backscatter," radiation that might escape the hull, bounce off water molecules, and reflect back into the living quarters of the ship. The tests

began with careful monitoring and measuring of various radiation sources while the reactor operated at low power. Then full-power operation allowed for measuring the levels outside the hull shielding. By this method, the sea tank helped *Nautilus* engineers design the shielding and arrangement of equipment that would best protect the crew.[23]

In the cramped quarters of a submarine, shielding should occupy just enough precious space, but not a square foot too much. Most shielding—and human activity—aboard submarines is fore and aft the reactor, not along the sides. Years later, the Navy's orientation handbook for sailors, *The Bluejacket's Manual*, would say, "Heavy shielding protects the crew so that they receive less radiation than they would from natural sources ashore."[24]

Not surprisingly, using pressurized water as the coolant handed another set of engineers opportunities to be brilliant. At the time, no one understood just how corrosive hot water could be on the metal cladding surrounding the fuel. In dealing with the problem, Westinghouse discovered that pure zirconium resisted such corrosion. No one supplied the material, so Westinghouse built its own facility to produce it. The pure metal formed the cladding for the fuel elements in the Idaho prototype reactor. Later, Westinghouse developed a zirconium alloy that improved its performance further.[25]

The rectangular buildings at the Navy's prototype complex and at all the other reactor sites at the NRTS were representations of the low bid and had no kinship with aesthetics or high-style architecture. Buildings were basic shells of reinforced concrete, pumice block, wood, or metal. Excitement and value resided entirely inside, in reactor rooms, laboratories, and operating corridors. These places were full of the best, the newest, the first, and the only. It fit the times, for as so many people would later recall, "Everything we did was new."

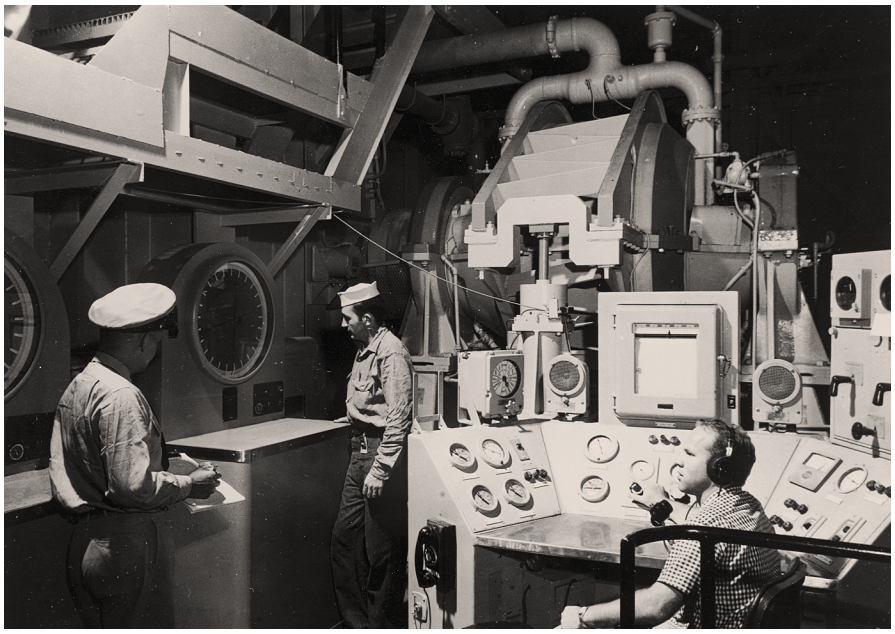
The Mail Goes Through

The dedication of those Idaho people was amazing. Once, we needed to get some data to Pittsburgh by the next morning. Remember, this was before fax machines. The last plane for Salt Lake City had already left Idaho Falls, so we sent the data to Salt Lake City by a driver, who could still make the connection with the midnight plane for Pittsburgh. Unfortunately he ran out of gas while still in Idaho. But he was undaunted.

The state police came by, and he persuaded them to drive him to the state line and to radio ahead for the Utah state police to meet him and take him on to the airport. He reached the airport just in time and found the Westinghouse courier. The pony express had nothing on these guys.

John Simpson[26]

The testing station was about to go into business. Argonne would operate the breeder; Bettis, the *Nautilus* prototype reactor. For the MTR, the AEC intended to select the company that employed the best industrial research manager in the nation.



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Naval personnel operating S1W equipment.

Chapter Seven

Safety Inside and Outside the Fences

Was it dangerous? Against today's climate of 'guaranteed safe, predicted, nuclear operation' we would have to be judged somewhat open loop. Dick [Dr. Richard Doan] must have realized that the key to safe operation in a game still subject to surprises was to tap that insatiable desire of some people to explain even the most trivial departure from the known and understood norm.

–Marion E. Thomas–

On a fall day in 1950, a research physicist named Deslonde deBoisblanc picked up the Bartlesville, Oklahoma, morning paper and read that the AEC had chosen his employer, the Phillips Petroleum Company, to manage a classified government project. He went off to work contemplating this news with great interest.

When I reached the laboratory there was a note that I was to attend a 10:00 a.m. meeting in Dr. Doan's conference room. That meeting was unlike anything that I had ever experienced before, or have since. About thirty people, not all from the Research Division, were seated, wondering why they were there, some having guessed that it was related to the announcement, but still puzzled.

At ten o'clock sharp, Doan strode into the room, went to the head of the table, and delivered what might have been the shortest briefing in history. He supposed by now everyone knew that something was going on in Idaho and that Phillips had been chosen to be part of it. He said that each of us had been selected but that until we received Secret clearances, the nature of the project couldn't be revealed. Furthermore, arrangements had been made for the lot of us to go to Oak Ridge, Tennessee, without spouses, for an accelerated course in nuclear technology as well as specialized training tailored to our individual assignments.[1]

Bonneville Museum - Bonneville County Historical Society, March 1963, Philtron

Dr. Richard Doan

Others of the chosen group were on field trips, and to these Doan placed phone calls and said, "I've got news for you. You're going to Idaho." They soon learned that their mission was to run the MTR reactor.[2]

Doan, a man apt to be seen in his off-hours wearing blue jeans, western-style shirts with scalloped pockets, and a ten-gallon hat pushed back on his head, told

A portal personnel radiation monitor. Detector searches from head to foot. “Counting” equipment is overhead and alarms if count exceeds background level of radiation. Employees were monitored upon entering and leaving work areas.

U.S. Department of Energy 74-10537 Photo for AEC by Milt Holmes

his group that housing for them and their families might be a problem, although an Idaho Falls developer was building a subdivision that would contain enough affordable homes for each of them.[3]

Idaho State Historical Society/INEEL 57-1216

Ponderosa Drive, Idaho Falls. New subdivisions around Idaho Falls kept pace with the growth in employment at the NRTS.

Despite their unfamiliarity with Idaho, the mystery about the project, and the promised difficulty with housing, no one whom Doan beckoned chose to decline. To a man, they trooped to Oak Ridge, where they slept in barracks by night and hovered around a mock-up of the MTR by day. Architects from Idaho Falls came to consult each man about the kind of house his family would need. When they got to Idaho Falls, the city gave them its usual warm welcome, printing their names in the paper along with necessary social data about club memberships and street of residence.[4]

Richard Doan, a fully matured scientist and administrator at fifty-two years old, arrived early in January 1951. Born and raised in Indiana by a family with Quaker roots, he taught high-school and college physics while earning a doctorate at the University of Chicago. It was the right place to be for a young physicist in the 1930s. He worked with Dr. Arthur Holly Compton on X-ray and cosmic ray research. Doan built, calibrated, and tested cosmic-ray meters destined for Peru, Greenland, and other exotic places around the globe. He made his reputation as a scientist by developing useful methods of measuring X-ray wavelengths. In 1936 he went to work for Phillips' research division.[5]

Compton, a Nobel laureate, was a member of the Manhattan Project's S-1 Committee, the group that guided the program. When Compton organized the secret Metallurgical Laboratory in Chicago, he asked Doan to leave Oklahoma and direct the lab. One of Doan's unique managerial duties was to hunt for any pure uranium that might be found in the industrial closets of the country, a pursuit that was said to have turned his hair gray. In 1943 he moved to Oak Ridge to direct the scientists developing the Hanford plutonium-separation process.[6]

After the war, Doan returned to Phillips and became director of research over the company's work on geophysics, hydrocarbon conversion, chemicals, and rubber. Phillips aimed to be a new-products leader in the energy industry, which in the early 1950s meant getting a foothold in nuclear energy. When Phillips bid for the AEC contract to operate the MTR—one of thirty-four firms to do so—Doan was, perhaps, the single most important asset in Phillips' package. The company expected to benefit from the broad exposure and invaluable training the experience would provide its scientists.[7]

Once in Idaho, Doan proceeded to set the standards for test-reactor operations and Phillips' employees. If Bill Johnston had invented the testing station, Doan transformed it into a genuine scientific laboratory. Running reactors was still a profoundly new and potentially dangerous enterprise, and Doan felt that safety had to be institutionalized at every level. He insisted that engineers and physicists be on-line at the MTR twenty-four hours a day. Excellence in every part of the operation, he felt, was the only sure way to safety.[8]

Doan's interest in safety, combined with his status as a Manhattan District alumnus and wide-ranging connections in the AEC and industry, led to new projects and new missions. Many of them had to do with reactor safety, but others were in the realm of pure research. He set the NRTS on a trajectory of growth far beyond the AEC's original vision for the place.[9]

Doan, sometimes referred to as "Pappy" by employees, had acquired a certain charm and a talent for persuasion, but that veneer was rarely mistaken for softness. He was willing to be unpopular for his decisions, and this quality made him seem either "aloof" or "tough, but fair." He understood the tension between logical scientific development and the role of individual

initiative. Eventually he had over 2,000 people working for him. He had to balance the practical facts of business with the unbusiness-like fact that virtually everything the 2,000 people were doing had never been done before.[10]

Doan insisted that Phillips employees integrate themselves into the communities in which they lived. He bought a house as soon as he could and joined the Presbyterian Church, the Kiwanis Club, the Idaho Falls Chamber of Commerce, the country club, and civic life in general. He expected other Phillips people to follow his example.

Equally, Doan committed himself to the Phillips corporate culture, which regarded every employee as part of the far-flung Phillips "family." The company practiced a brand of welfare capitalism it had inherited from its founder, Frank Phillips. In addition to pension, health-care, and education benefits, the company sponsored intramural athletic teams, company picnics, a monthly magazine promoting *esprit d'corps*, and memberships in athletic and self-improvement clubs called the Frank Phillips Men's Club and the Jane Phillips Sorority for women, Jane having been the founder's wife.[11]

A Phillips Woman

My secretarial career began with Phillips Petroleum Company the summer of 1960. All new secretaries were trained at Central Facilities as a group, learning the "Phillips" procedures of office work.

My first permanent assignment was in the Project Engineering Department of the MTR reactor project. The facility was housed in an abandoned temporary construction barracks covered with tar paper, thus its nickname, the Tarpaper Palace. Temperatures rose to well over a hundred degrees in the summer, and winter found us freezing in this single-walled structure using only tar paper to cover the cracks. The Palace was the farthest distance from the guard house/bus stop. Foot travel was over gravel roads and through the MTR reactor building. The dress code for female workers was dresses, heels, and hose. This made the walk doubly hard. The wind blew mightily on the desert, and since full skirts and crinolines were the style, many of us would wrap masking tape around the bottom of our skirts to keep them down when walking out-of-doors between buildings.

Pregnant women were not allowed to work near the reactor areas because of the radiation. When a woman reported she was pregnant, termination occurred the same day.

The Jane Phillips Sorority was a women's group named after the wife of the founder of Phillips Petroleum Company. Monthly business/social meetings were held at the Bonneville Hotel in Idaho Falls. Yearly convention meetings were held throughout the country, two of which I attended as a delegate. One trip was by bus to Odessa, Texas, and the other was by car to Bartlesville, Oklahoma, the home office of Phillips. Because the company helped to finance these trips, we stopped at Phillips gas stations and charged our gas to Phillips credit cards. These conventions were to educate us on company history and progress as well as provide helpful training. We returned to our jobs with enthusiasm and more enlightened.

Myrna Perry

A Jane Phillips Society social.

Bonneville Museum - Bonneville County Historical Society, Dec. 1956, Philtron

One method that Phillips used to promote a family feeling among employees was to sponsor intramural athletic competitions. The August 1960 issue of the *Phillips Philtron* reports the current progress of the teams.

NRTS Intramural Softball League Standings as of August 1960

	Won	Lost	Pct.
MTR Robins	10	1	.910
CF Canaries	8	3	.728
MTR Pelicans	6	5	.700
CPP Eagles	6	5	.546
ETR Seagulls	4	6	.400
SPERT Bluejays	3	7	.300
Hdqrts. Cardinals	3	7	.222
CPP Orioles	1	9	.100

As the contractor for the MTR, Phillips was responsible for hazard management and safety operations within the fence of the MTR complex. Outside the fence, the IDO took over. Bill Johnston had decided early that safety outside the contractor fences would be a direct IDO responsibility. Safety, assigned to the Health and Safety Branch, was a broad concept and included employee health, operational safety, radiological protection, and environmental protection.

One of the first tasks of the Health and Safety Branch was to discover the pre-reactor level of background radioactivity in the Site's environment. The operation of reactors and the Chem Plant would certainly release radioactivity into the air, soil, and water. It was necessary to survey the desert before the first reactor went critical and establish a baseline for future comparisons. The Branch asked biophysicists and biologists from Hanford, who had done a similar survey at that site, for help.[12]

Ateam from Hanford's Radiological Sciences Department went to the Rogers Hotel in May 1950 to work out the details of the survey. As yet, the NRTS had no laboratories, so samples had to go to Hanford for analysis. In the next few months, a truck was sent from Idaho to Hanford every two weeks loaded with tapes of data, vials of water, and cardboard ice-cream cartons filled with plant and animal samples.

The scientists in charge handed several students from Idaho State College at Pocatello excellent summer jobs collecting samples and classifying plant and animal species populating the site. They adapted one of the Navy's white clapboard houses as a field station, and students were seen all summer entering with armloads of sagebrush and other plants. The little kitchen now contained autoclaves and other lab-like gadgetry used to prepare samples. The refrigerator held packets of animal parts awaiting the next truck to Hanford.

The samples came from 107 plots of ground, staked at intervals of a quarter of a mile in two perpendicular transects across the testing station. In the kitchen, the students weighed out a twenty-gram specimen of each plant, put it into a fresh carton, daubed it with a drop or two of formaldehyde, and labeled the carton. Elsewhere in the house were stores of air filters, air-monitoring equipment, X-ray film, and instruments to record the amount of radiation in the air.

With the help of IDO and USGS employees, samples came from locations far beyond the boundaries of the testing station. Air samples came from Dubois, sixty miles away, as well as from the EBR- and MTR- construction sites. Water samples came from every well at the Site and from wells in Pocatello, Blackfoot, Atomic City, and Idaho Falls; from wells at farm homes between the Site and the Snake River; and from the Thousand Springs gushing from vertical lava-rock walls into the Snake River Canyon down-gradient more than a hundred miles away.

The Hanford laboratories counted and dissected and measured. Sampling continued from May to November because of the cyclic presence of some isotopes. The findings were published in a report much consulted in succeeding years.[13]

The first increase in the level of background radiation at the Site came not from NRTS experiments but from the detonations of nuclear weapon tests at the AEC's new Nevada Test Site in 1951. The NRTS and other air monitoring stations in southern Idaho detected the fallout from these tests. One secret Nevada test generated readings so high at the Idaho Falls airport that an airport official, as yet unaware of the test, decided that the detection equipment was malfunctioning. On another occasion, a truck loaded with spent fuel from Hanford was headed for the NRTS and passed through a rainstorm between Boise and Twin Falls. The rain

washed radioactive particulates out of the fallout cloud and contaminated the truck. The truck arrived at the NRTS with a detectable radiation field on all of its exterior surfaces, up to 10 millirem per hour in spots. It took some time before the puzzled analysts figured out what had occurred.[14]

The AEC kept the tests secret in an effort to deceive the USSR, whose physicists, it was feared, could learn the size and other features of a detonation from the fallout that reached its own atmosphere. If the AEC had made public announcements before the tests, it would have made Soviet work easier. But by keeping the secret from the NRTS as well, it presented the Site's environmental monitoring personnel with similar challenges.

The IDO continued an active program of sampling, regularly testing the air (using film badges located on perimeter fences and other areas), on- and off-site wells, dairy milk from cows at nearby farms, and tissue from trapped or road-killed jack rabbits and other animals on the Site. After 1959 the IDO distributed quarterly tabulations of the monitoring results to the press, the Idaho Department of Health, and members of the Idaho congressional delegation.[15]

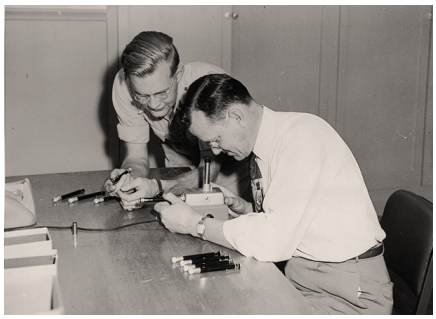
Questions of safety interested nearby towns as well, and southeast Idaho news reporters covered the story of the background radiation survey with great interest. Reporters wrote several articles about radioactivity, teaching themselves and their readers how to understand the special hazards associated with "atom work," and the difference between alpha, beta, and gamma radiation. They described various methods of shielding and how remote-controlled devices manipulated hazardous materials while the operator stood behind thick panels of leaded glass.[16]

Reporters described the job of the health physicist (HP), who regularly measured the doses of radiation each worker received. The HPs issued everyone a small ionization chamber resembling a pen that was carried in a shirt pocket. Together with a badge lined with special film, the HP could determine and record the radiation each employee had been exposed to in a day, a week, a quarter, or a year. The AEC issued regulations providing maximum exposure limits for given periods of time, and each contractor was obligated to protect its workers and its safety record accordingly. In 1955 the National Committee on Radiation Protection, whose advice guided the AEC, adopted exposure standards for the general public for the first time. These were an arbitrary ten percent of the permissible occupational exposure level. The IDO philosophy was that the NRTS was not engaged in weapons production and should operate as a model for civilian and peaceful operations, so the Site used exposure standards that were more restrictive than those permitted by the AEC. Another reason for preventing workers from exceeding exposure limits was to avoid having to transfer them to non-nuclear work, a significant administrative annoyance.[17]

The public read about emergency evacuation plans, new microwave communications technology, the use of air filters, and the large ionization cham-

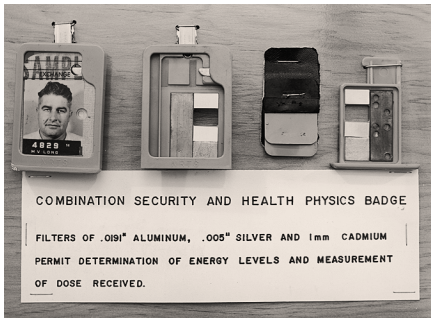
IDO 21221

A house in the former residential part of the Naval Proving Ground became a field station, its kitchen a laboratory for the 1950 radiation survey.



Idaho State Historical Society MS 326 Box 5/INEEL 3479

Calibration technicians check ionization chambers of a minometer. Site employees wore them in their pockets. The devices were checked daily for possible exposure to radiation.



INEEL 59-1619

Film badges measured personal radiation dose levels.

People and Radioactivity

If a lump of radioactive material sits on a dish on a table, a person nearby would want to measure, first, just how radioactive is the material? and second, if the person walks or stays too near it, what "dose" of radioactivity might be received?

"Curies" measure the rate at which atoms in the lump are decaying. "Rems" measure the dose that a person might receive from exposure to it. Much depends on whether the person eats, drinks, breathes the material or simply walks past it.

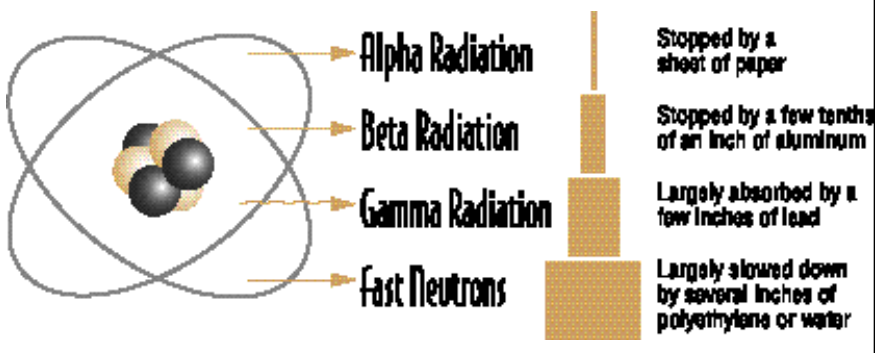
People in the United States receive an average yearly dose of radiation of 360 thousandths of a rem, or millirem. About 82 percent of it is from natural sources like radon, cosmic rays, rocks, soil, and food. Radiation has been part of the natural environment for millions of years. Many foods contain radioactive isotopes. The amount is so small that it is measured in trillionths of a curie, or picocuries.

Beer	390 pCi/liter	Whiskey	1,200 pCi/liter
Tap water	20 pCi/liter	Brazil nuts	4 pCi/gram
Milk	1,400 pCi/liter	Bananas	3 pCi/gram
Salad oil	4,900 pCi/liter	Flour	.14 pCi/gram

We receive doses from other sources:

Cigarettes, 2 packs/day	8,000 mrem/year	polonium-210
Living in Salt Lake City	46 mrem/year	cosmic radiation
Living at sea level	26 mrem/year	cosmic radiation
Dental bite-wing X-ray	2-4 mrem	
Chest X-ray	6 mrem	
U.S. Capitol Building	20 mrem/working year	granite
Base of Statue of Liberty	325 mrem/year	granite
The Vatican	800 mrem/year	granite

Source: DOE/EM-0065P and other



Penetrating power of various types of radiation.

bers being set up in the region's airports to monitor radiation. In addition, the U.S. Weather Bureau, which set up a permanent weather station at the Site, was studying every breeze that blew, launching balloons and setting up permanent instrumentation. Some of the first gauges went up on the Navy's old wooden water tower, for example, and measured air movements at 75-foot and 150-foot elevations.[18]

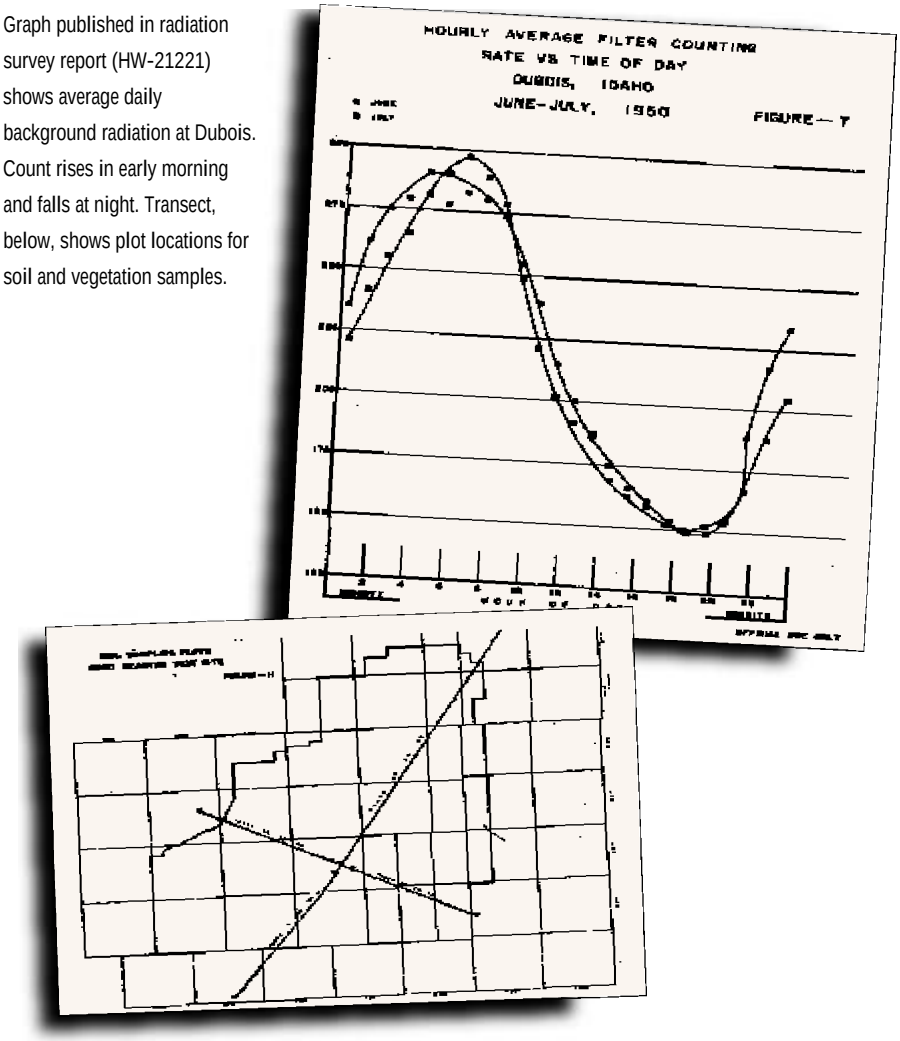
The State of Idaho also had early concerns about safety, and these had to do with construction workers. The Idaho legislature had created a Department of Labor early in 1949 with a tiny staff of three: a commissioner, a safety advisor, and an office secretary.[19]

When W.L. Robison, the first commissioner, realized the impending size of the construction program, he and his safety advisor made their own trek from Boise to the Rogers Hotel for a briefing. "After being identified by a formidable array of guards," Robison wrote later to Governor Robins, "we were ushered into Mr. Hostetter's office." Using a large map showing proposed buildings, G.M. Hostetter, chief of the IDO Safety Division, explained how the work would progress. He showed Robison where the first-aid station was located, and how it soon would be enlarged, a full-time nurse and doctor hired, and two emergency ambulances purchased. Until the road to Idaho Falls was finished, emergencies would go to the hospital in Blackfoot. One of the big dangers was lead poisoning. "All walls are to be lined with heavy sheet lead," said Robison of one project. Workers

handling it would have medical examinations before they started and "proper [safe] guards" to prevent them from being poisoned. The IDO would send the state monthly reports of accidents, first-aid treatment, and hours worked.[20]

Hostetter's initial reports were good. From the start of the work to September 1950, the IDO reported 15.06 accidents per million man hours worked. This compared favorably to a national average of 36 per million hours and very favorably to an Idaho average of 70 accidents per million hours. The Site continued to break Idaho safety records. Robison reported that on July 3, 1954, Phillips employees had worked one million man-hours without any disabling injuries. This was a first in the history of Idaho, and it was duly celebrated with visiting dignitaries and ceremony a few weeks later.[21]

Johnston created an Idaho Environmental Advisory Committee to advise him on matters regarding public health. The members—who included the Idaho Director of Public Health and other state health officers, a USGS geologist, a meteorologist stationed with the U.S. Weather Bureau in Boise, the Idaho State Reclamation Engineer, and a private physician—met for the first time in March 1954. They received an introductory tour of the NRTS and the activities that potentially involved public health. Their first impressions were favorable, and after the meeting, committee members told the press that "controls enforced by the NRTS appear adequate to prevent exposure of the surrounding area to health hazards."



Graph published in radiation survey report (HW-21221) shows average daily background radiation at Dubois. Count rises in early morning and falls at night. Transect, below, shows plot locations for soil and vegetation samples.

The group met quarterly after that, usually in two-day meetings, typically reporting afterwards to the press on their commendations and critiques.[22]

Before the advent of the AEC, the State of Idaho had little reason to become interested in radioactivity. Throughout the 1950s, few hospitals in the state, if any, used radioisotopes for the treatment or detection of disease. The Idaho Department of Health's first regulations pertaining to radioactivity were adopted in 1954 when it set standards for X-ray machines used in shoe stores. A parent or sales clerk could fit a child with shoes, place the child's feet into an opening at the bottom of the machine, and then look through a viewer to see if the shoes crowded the bones. The machines became notorious for exposing children's feet to alarmingly-large doses of radiation. Through the department's educational efforts, Idaho shoe stores discontinued the use of the machines.[23]

INEEL 59-3091

The IDO ambulance in 1959, fully loaded with emergency equipment when ready to roll.

In 1955 the Idaho Department of Health was reorganized as a Board of Health, giving it more authority in watershed protection, sewage collection and disposal. Dr. Terrell O. Carver, the administrator for the Board of Health after 1958, began to promulgate the Board's policies formally, holding hearings on a spectrum of issues, including crematoria, nursing homes, water pollution, cleaning of septic tanks, and radiation protection.[24]

The Board of Health adopted radiation protection rules in August 1958 after a few industrial users elsewhere in the state accidentally spilled radioactive materials into the environment. Such users were henceforth obliged to register themselves with the Board. The brief set of rules prohibited discharging radioactive wastes to the environment without prior approval of the Board and required that the board be informed in the event of an accident. After 1961, by which time hospitals were more involved with radioactive source materials (nuclear medicine), the Idaho legislature directed the Board to establish more-comprehensive standards. That was also the year that the Board of Health purchased its first equipment for conducting a few basic types of radiological analyses.[25]

The managers of the NRTS spent the 1950s being cordial to the succeeding governors who entered and left the Statehouse. Len B. Jordan followed Robins, and after him came Robert Smylie, elected in 1954. New governors were routinely congratulated on their elections and invited to tour the Site. They presented awards and attended ceremonial functions at the NRTS. Governor Smylie in particular was an advocate of industrial safety and recognized the unprecedented safety record maintained at the NRTS. At times, the IDO and the AEC in Washington informed the governor and Dr. Carver when spent fuel was being shipped into Idaho.[26]

When Smylie created a Governor's Committee on the Use of Atomic Energy and Radiation Hazards in 1959, the IDO supplied three of its high-level staff specialists in health physics and waste disposal to serve on the committee along with his other appointees from state agencies and industries. Smylie asked the committee to examine how other states set radiation standards and then to recommend improved control measures for Idaho. With input from this committee, the Board of Health adopted a more detailed set of standards and regulations in 1964. These refined the earlier rules and exempted federal agencies and their contractors from having to register with the state. The committee discussed the states' rights issue and concluded that the state should not restrict the AEC because federal rules already governed it. According to committee minutes, the members were "not disposed to enact regulations that might discourage industrial development within this state."[27]

Although the relationship between the governor's office and the NRTS was courteous, it was also distant. The issue of waste disposal did arouse states' rights sentiments in government circles.

Dr. Carver was well aware that "underground waters" were receiving radioactive waste at the Site. He wrote in 1959 to Senator Clinton P. Anderson, the chair of the JCAE, "In our relationship with the AEC we have been led to believe that the state need not concern itself with atomic energy installations nor their operation. We think that is wrong."[28]

Governor Smylie likewise did not care for AEC policies excluding the state from a role in water pollution control. In November 1963, he said as much before a hearing by Congress'Natural Resources and Power Subcommittee of the Committee on Government Operations. He described the state's recent progress—and the role of federal funds—in reducing sewage and other wastes going into the state's waterways but then cited problems that remained. One of them was the continuing practice by the AEC and the Bureau of Reclamation of discharging wastes directly to underground water tables. These agencies, he said, operated "in opposition to state policies" and handicapped the state's efforts.[29]

Clearly, the IDO had allowed no one to doubt that federal authorities alone were responsible for operating practices and standards governing the NRTS. The State of Idaho was outside the fence.

Phillips campaigns promoted safety in construction and shop settings. Philtron magazine published this 1957 reminder.

Bonneville Museum - Bonneville County Historical Society, March 1957, The Philtron

CHAPTER EIGHT

THE REACTOR ZOO GOES CRITICAL

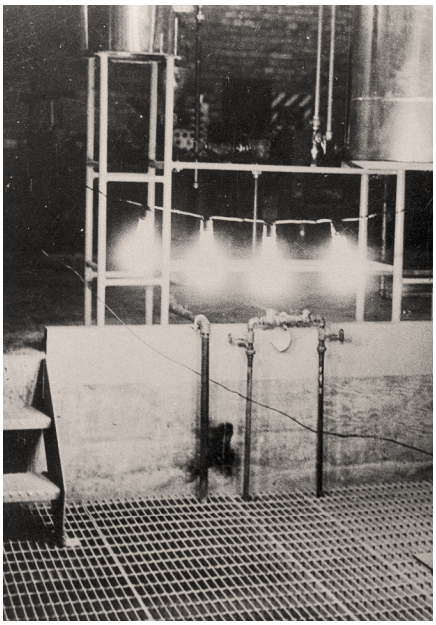
Then gradually construction workers were replaced by operations people.

–Idaho Department of Labor, 1951–

Walter Zinn's estimate was too low. He thought the breeder reactor was ready for action in late May 1951. He had ordered forty kilograms of enriched uranium packed into 179 fuel rods and some extras as a margin for error. His crew placed them into the core one after the other, measuring reactivity effects each time. As the supply of rods dwindled, dignified guests and visitors waited expectantly in the control room, watching needles trace ink on scrolls of data paper. The extra rods went into the reactor. With the last one inserted, the reactor remained calm.

Any reactor has several milestone moments in its early life. The first is the day and the hour it attains criticality for the first time. After that, the operators pass mini-milestones as they gradually step up the power levels, calibrate instruments, and run safety tests. A final moment of truth arrives when it runs under perfect control at its maximum-rated power level.

Going critical for the first time is significant because it shows that the physicists have loaded the reactor with enough fuel and arranged it suitably. The first criticality runs at a "zero power" state, meaning that the reaction produces just enough neutrons to keep the chain reaction alive. This generates very little heat. In the early 1950s, when every reactor—along with its fuel—was a first of its kind, reactor designers could only estimate how much uranium would form a critical mass.



INEEL 4053

The four famous lightbulbs at EBR-I were strung up between the generator (out of picture) and the handrail.

Zinn figured he needed seven and a half more kilograms of enriched uranium and asked the AEC to release it from military supplies. The material went to the Argonne Laboratory in Chicago where the engineers fabricated more fuel rods. These procedures cost him three months.[1]

The deed was done. Finally, on August 24, 1951, the EBR went into history as the first reactor to go critical at the NRTS, the first to use U-235 fuel, and the first to use a liquid-metal coolant. The physics measurements indicated that the arrangement and shape of the fuel rods needed improvement before the reactor could be connected to an electrical generator. Two-thirds of the fuel rods were shipped back to Chicago where the fuel was removed from its stainless-steel cladding, placed in a hydraulic press and die, and made slightly shorter and fatter. Returned to Idaho, the rods were arranged in a belt around the original rods. The new massing of uranium allowed the reactor to produce the core temperatures required to power the generator.[2]

On December 20 the reactor was connected *via* the generator to a string of four lightbulbs. At 1:23 p.m. the bulbs glowed brightly, and Zinn wrote in the

Electricity was first generated here
from Atomic Energy on Dec. 20, 1951.
On Dec. 21, 1951—all of the electrical
power in this building was supplied from
Atomic Energy —
Those Present
W. H. Zinn
M. Nesta
F. M. Tetteti
R. Cameron
B. C. Cerutti
E. J. Barrow
L. E. Loftin
C. R. Gibson
H. V. Lichtenberger
L. J. Koch
G. K. Whitham
M. L. King
M. Wilket
G. H. Stonehocker
K. Johnsen
D. F. McGinnis

log book, "Electricity flows from atomic energy. Rough estimate indicates 45 kw." After a second experiment the next day, Zinn took up a piece of chalk and wrote his name on the concrete wall of the reactor building and invited the crew present to follow, one by one.[3]

Atomic power was a reality. The NRTS had its first stunning success. The first nuclear reactor in the world to generate a useable amount of electrical power would forever be linked to Idaho and the NRTS. A few days later, the excitement over, the reactor began producing the electricity needed for routine operation of the EBR complex.

INEEL 04517

The MTR went critical for the first time on March 31, 1952, the first of many milestones. Visitors from Oak Ridge and Argonne, who had cooperatively built the project, along with Bill Johnston, Richard Doan, Bion Philipson, and others crowded together to listen to the clicking of an instrument counting the fissions taking place inside the core. Physicist Fred McMillan operated the reactor's control rods. This time, the reactor didn't disappoint. Johnston said, "Well, we got us a reactor." And that was that—no chalk, no champagne. The newspaper reporter was more effusive, recognizing the "new atomic egg they were hatching" as a historic event: mankind's first materials testing reactor. The weary team that had been working nineteen-hour days after months of preparation simply went home to their beds.[4]

But they were back soon. Doan demanded that the stepped-up progress to full-power operation must also prove that the people working near the reactor would be safe from radiation. This work was the province of five HPs. Doan had them report directly to his office and not to the reactor manager. Their sole mission was to prevent all workers, including absent-minded scientists whom the HPs sometimes referred to as "squirrels," from suffering the potentially harmful effects of radiation. For this, they had the power to evacuate work areas and scram (shut down instantly) the reactor if they thought it necessary.[5]

One of many safety tasks was to test the shielding around the MTR. This assignment fell to HP John Byrom, a new Phillips employee in 1952. He had trained in radiological physics in a special class of twelve people at Oak Ridge and then moved to Idaho Falls with his family. Like most other NRTS employees, he began the daily habit of traveling to work on a Site bus.

INEEL 4502

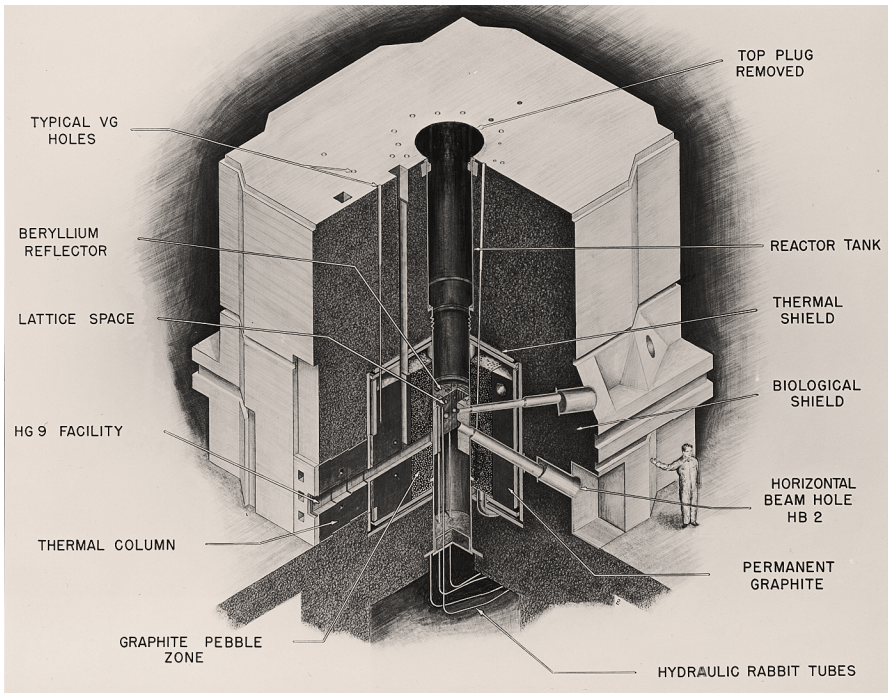
Above. MTR control room as reactor goes critical on March 31, 1952. Below. The top of the MTR, as seen from catwalk above it. A crane (unseen) lowers the top plug over the reactor core. Taken on March 31, 1952, engineers were making a final check of the control rod drive. Apparatus above round plate is the control rod mechanism that ensures the control rods are attached to the drive mechanism.

Getting to the MTR operating floor required passing several safety and security barriers. The MTR complex was enclosed behind a chain-link fence studded with night lights and further defended by a ten-foot-wide patrol road. The bus dropped him at the MTR gatehouse, where a guard checked his security badge each day. If anyone cared to notice, they could see that the 250-foot MTR exhaust stack stood on the downwind side of the complex and, for security reasons, showed no aircraft warning lights. To get to the reactor, Byrom passed into the "exclusion" area that contained the MTR building with its laboratory wing and fuel storage "canal," along with other special labs and storage buildings. The building was about 130-feet square and made of prefabricated concrete slabs.[6]

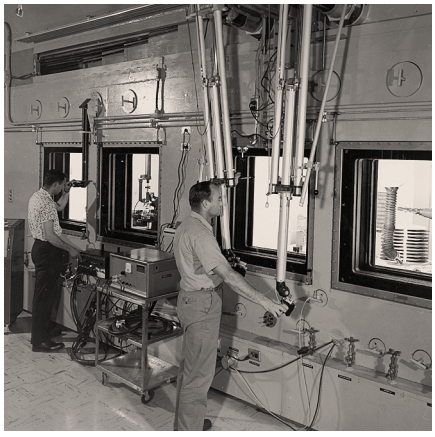
Inside, the enriched uranium core of the reactor was like a small jewel wrapped in successively thicker layers of wrapping. Surrounding the fuel was a steel tank thirty-feet deep and six feet in diameter. A steel lid fit over the top. Pumps forced cooling water through the tank under pressure to keep it from boiling. Two types of reflectors surrounded the tank to bounce neutrons back toward the core. The closest to the fuel was made of beryllium metal. Just beyond was an outer zone of graphite, cooled by forced air. Then came ten feet of dense concrete and gravel—the main biological shield. A casing of steel enclosed the whole contraption, which looked like an oversized cube thirty-two feet to the side.[7]

It was the one hundred holes piercing the reactor that were Byrom's special concern. Acomplicated plug stoppered each hole, made up of the same sequence of materials as those adjacent to it in the reactor cabinet. While the reactor was shut down, operators removed a plug and inserted a test sample toward the core. Overhead, a thirty-ton crane helped maneuver the heavy plugs into and out of shielded containers called "coffins." The plugs were supposed to prevent neutrons from straying to the outer edge of the plug openings. But would they?

Byrom used X-ray film to check for leaks, the same 14x17 inch size that physicians used for chest X-rays. He ordered dozens of boxes. In the MTR's photographic darkroom, one of several labs in the MTR laboratory wing, he loaded each sheet into a light-tight holder containing a thin lead foil backing. He matched the film to grid marks on the cabinet and numbered each grid cell. When the reactor operators started "noodling" the control rods, moving them up and down to get familiar with the MTR as they advanced toward full power, Byrom was ready.



INEEL 55-432



INEEL 61-4707

Above. The thickest wrapping around the MTR is the biological shield. Right. The MTR hot cells. Behind viewing windows three feet thick, operators examine test samples. Note shield plugs above and below windows for electrical leads, instrument air, oxygen, or other requirements.

We had already surveyed to see if we had any heavy leaks. For that we used several kinds of meters—GM meters, cutie pies, and something we called a rudolf. The barytes concrete in the shield, which had been packed in there pretty well to eliminate bubbles, did a pretty good job. Still, neutrons can squirt around corners and come out the holes, so we had to check those very carefully.

I plastered that reactor. We marked it off and pasted these films all over the reactor—holes, every place that was designed to give access into the reactor core. We used a lot of duct tape.

Then we ran the reactor at low power with the reactor holes closed up tight. Any radiation coming through the openings would produce an image on the film, black rings or dots, or whatever the shape of the leak. It took months of the physicists playing around with the reactor to give all of the film an equal amount of time. They were making their own tests of reactor fluxes in the different parts of the reactor, so on any given day, one side of the reactor might get more neutron flux than the others.

We found many places where the design was a little bit inadequate. I turned over this data to the engineers, and they designed better, more efficient plugs. But we still had to add extra shielding against some of the bigger openings. We stacked boxes of paraffin and sheets of cadmium, which absorb neutrons, and then blocks of lead and concrete in front of that. That was a lot of weight, and it had to be moved away whenever it was time to load or unload the experiments.[8]

Paraffin itself was a hazard. Someone occasionally left a box near a hot water pipe, where it would get too warm and combust. Word of one too many paraf-

INEEL 13405

Radiochemist loads an irradiated MTR flux wire into a scanner. The machine will "count" how many of the wire's atoms absorbed neutrons while in the reactor.

Reactor Power!

Power is the time rate at which energy is converted from one form to another; it is commonly measured in "watts." Reactor power is the rate at which work can be done by the heat that the reactor generates. It is measured in "thermal" watts. If the reactor produces steam to drive generators, the output is measured in "electric" watts.

A related concept is the "reactor period," once called the "doubling period." This is the amount of time it takes for the neutron flux to double (approximately). The art of reactor start-up and control is to keep the chain reaction from doubling at too rapid a rate. The operator adroitly moves regulating (control) rods in and out of the core to maintain a constant power level. If the neutrons multiply too fast, they will outpace the ability of the coolant to carry away heat. Therefore, it is not desirable to allow the neutrons to multiply at an ever-smaller doubling time.

A reactor operator is concerned with three basic measurements of neutron flux: the doubling period, the water temperature, and the water flow. The reactor is set to shut itself down automatically if any of these reaches certain previously established values.

Someone coined the dainty term "excursion" to describe a sudden and unplanned rapid rise in the power level. Many experiments at the Site involved deliberately planned excursions, one purpose of which was to learn the safe operating limits of nuclear reactors.

fin fires reached the ears of Dr. Doan, who reportedly issued a terse memorandum stating, "There will be no more paraffin box fires." And apparently, there were none.[9]

Another aspect of safety was for reactor operators to understand exactly how neutrons moved about inside the reactor. The one hundred openings led to different positions near the core or in the graphite around it. Flux differed at every spot, which was desirable because not all experiments would need the same exposure. The scientists could tailor an experiment to the most appropriate flow of neutrons. The reactor designers at Oak Ridge had predicted where the flux would be weak or intense. Now their work had to be tested.

Technicians placed tiny strands of cobalt wire in hundreds of locations in the graphite and inside the core, gaining access *via* small holes in the beryllium reflector. The reactor was made to go critical for a few minutes to irradiate the cobalt. The cobalt wires were withdrawn and sent to a laboratory down the hall for counting. Measuring instruments could detect how many atoms in each wire had absorbed neutrons. After months of doing this, the physicists plotted a map of the MTR's neutron flux. It pleased the Oak Ridge designers to learn that their predictions had been reliable.[10]

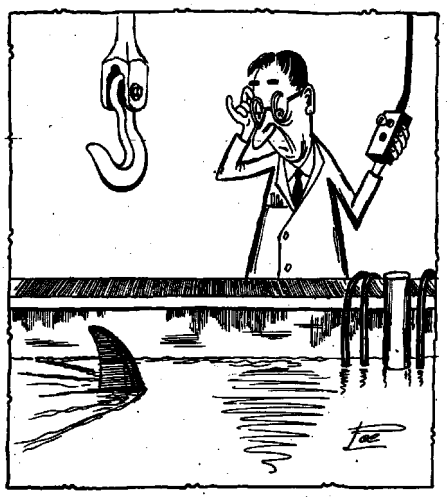
Handling spent fuel also required safety procedures. When the reactor was fully in business, the operators shut down to replace the fuel about every seventeen days. Using remotely-controlled equipment, operators opened the lid of the reactor and transferred the hot fuel into lead-lined containers. These were lowered into a water-filled trough, called a canal, where the containers ejected their fuel elements under cover of sixteen feet of water. Workers, shielded by the water, leaned over the canal with long-handled tools and moved the fuel to its resting place. The fuel, referred to as "green" because it was fresh from the reactor, emitted gamma radiation and lit up the water with the soft glow of Cerenkov radiation.

After about three months in the canal, the fission products with short half lives lost their radioactivity, leaving the fuel safer to handle. Workers loaded the fuel into a special cask and trundled it over to the Chem Plant, which recovered its unused U-235.

INEEL 57-5342

Phillips took the MTR up to its full power of 30 megawatts on May 22, 1952, another landmark day at the NRTS. The MTR was ready in August for its mission to assist other reactor designers by testing the materials of which their reactors would be composed.

The first reactor the MTR assisted was the Rickover reactor five miles up the road, the S1W (S for submarine, 1 for first prototype, W for Westinghouse). Westinghouse physicists had determined that the predominant source of



NRTS News, August 1968

Two versions of the MTR canal. Above, as depicted in Site newspaper; left, a technician poses with "cutie pie," a beta and gamma radiation detector. His colleague withdraws capsule of cobalt-60. Lights and tools dangle down side of canal.

gamma radiation from the reactor was nitrogen-16, which was generated in the reactor cooling water when a stray neutron struck an atom of oxygen-16. What they didn't know was how likely it was for any given number of nitrogen atoms to capture neutrons and therefore how big a problem nitrogen-16 would be. Dr. John Taylor, responsible for the *Nautilus* shielding studies, recalled:

Because the half-life of nitrogen-16 is only 7.35 seconds, the capture cross-section [probability of capture] could not be measured by the normal accelerator methods. Without that information there was no way to design the major components of the shielding for the submarine. Thus, a closed loop was installed in the MTR to circulate water through the MTR neutron flux so as to be able to measure the nitrogen-16 activity generated in the water. The inferred cross section was used to design the shielding. The facilities at the NRTS were essential to solving this key question bearing on the radiation safety of the Navy crew.[11]

Another issue for the Navy was the long life of the reactor and its fuel. Changing fuel in the cramped spaces of a submarine was extremely inconvenient, not to mention hazardous. Replacing the entire core was worse.

INEEL 64-2056

INEEL 55-973

The boat had be dry docked while welders cut open the skin of the boat and removed the reactor the same way a surgeon might remove a bad appendix. The procedure would tie up the boat for up to two years, hardly the place for a weapon system during war or an international crisis.

The Navy's Westinghouse team sent sample capsules to the MTR for irradiation for the requisite number of weeks or months, whatever would duplicate the capsules'lifetime radiation in a ship. The team sent fuel alloys, control rod materials, and structural metals. The work was highly classified; MTR workers sometimes did not know what was inside the test capsules.

Westinghouse scientists took the capsules back to their own labs, dismantled them, and studied them in minute detail—weigh, X-ray, measure, count. Little by little, they learned which materials would hold up and which would not. The scientific habits of making predictions, observing closely, and keeping detailed records were the same as those so recently practiced by the Bureau of Ordnance. Every experiment at the MTR—and everywhere else at the NRTS—began with the sponsor's prediction and ended with some increment to the world's store of knowledge, however large or small.

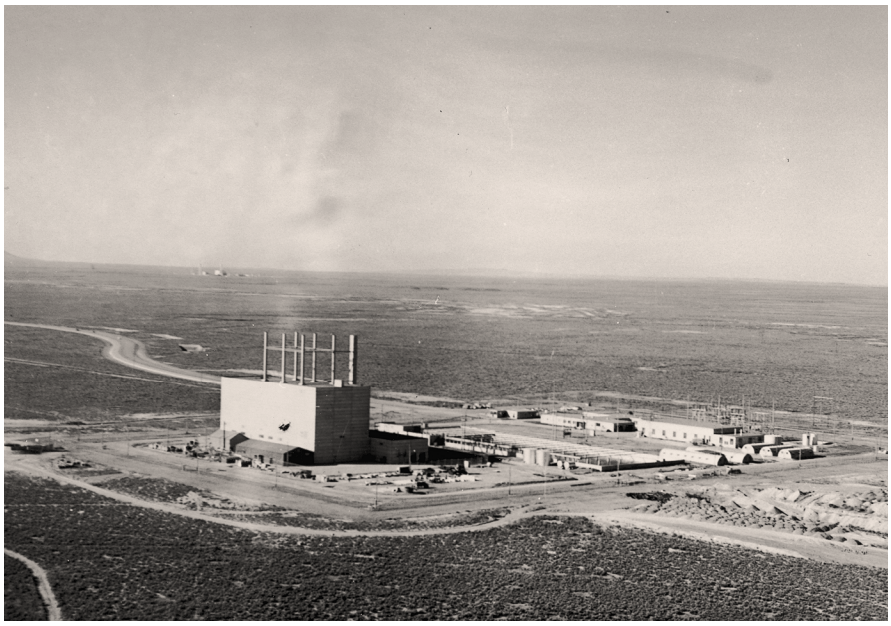
Above. A straddle carrier transported spent fuel elements from the MTR to the Chem Plant. Left. Fuel elements cool in the MTR canal. As a side experiment, a can of food rotates in a special rig so that contents get equal exposure to gamma radiation.

The Navy experiments were costly because the conditions in the capsule duplicated the effect of pressurized water on the sample. One of the Navy's useful early findings was to discover that radiation affected stainless-steel welds by making them stronger, but also made the metal more brittle.[12]

The S1W had gone through the same kinds of start-up and safety procedures as the EBR and the MTR. It was scheduled to go critical on March 29, 1953, but Rickover's approach to milestone moments was rather more calculating than either Phillips'or Argonne's. He felt the occasion to be of extreme importance. Certain people who should have been there were not. Some of those who were present should not have been. So he postponed the procedure for a day and adjusted the mix of people in the control room. The reactor first went critical shortly before midnight on March 30, 1953.[13]

Two months later it was time to prove that the high-temperature reactor could produce enough power to turn a propeller shaft. Rickover was again in the control room, along with AEC commissioner Thomas Murray. At the epochal moment, Rickover instructed Murray to open a certain valve. John Simpson later wrote:

The commissioner was thrilled at the chance to play an active role in making history. Murray stepped forward, grasped the valve handle, and slowly turned it.



INEEL 6477

In the adjoining area, inside the hull of this submarine-on-land, steam hissed against the turbine blades. A propeller shaft began to turn.[14]

The heat of the reactor was doing muscle work. A hasty champagne made of alcohol from the chemistry lab and soda water from a soft drink dispenser was mixed for a toast.[15]

When Westinghouse was ready in June to take the reactor to its next milestone, full operating power, it began a 24-hour endurance run. Again Rickover intervened. He was anxious to convince skeptics that nuclear-powered propulsion was truly reliable—that a boat could remain submerged for a protracted run and the crew come safely home. He decided suddenly to extend the run and simulate a crossing of the Atlantic Ocean. This would take nearly a hundred hours at full power.[16]

Above. The S1W building, camera facing southwest. Note MTR area in background. Below. Inside the S1W hull during construction.

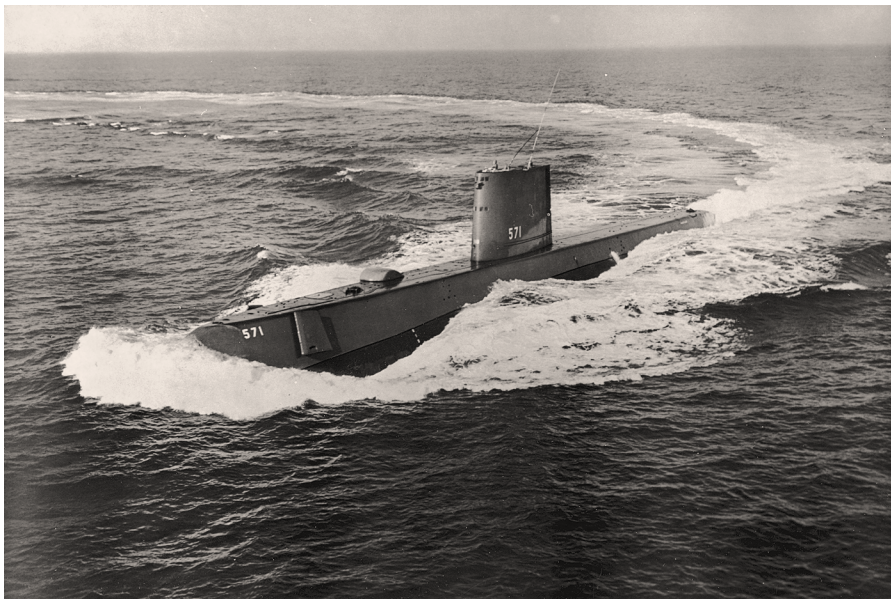
Naval Reactor Facilities

Charts went up on the wall of the reactor control room for plotting a 2,500-mile route from Nova Scotia to Ireland, and the Navy men who happened to be there for training began four-hour watches. For sixty hours, the run went well. Then a condenser tube began to leak, and radiation was soon detected near it. Next a steam generator sprung a few small leaks. The Westinghouse people argued among themselves: should they shut down the reactor? Given the location of the leaks, neither public nor personnel safety was at stake. The run continued.[17]

Department of the Navy, Submarine Force Museum

Then the control for one of the steam generators failed, causing the water level to drop and the reactor power level to become erratic. Debate about shut-down became more heated. The crew reduced the power level to half and restored the water level. In the end, the reactor "crossed the Atlantic" in ninety-six hours, but not entirely at full power. The crew had resourcefully fixed emerging problems and kept the reactor running. Had there been an accident, the nuclear navy might have become a political impossibility.[18]

But there was no accident, and there would be none. Rickover was well aware of the engineering work yet to be done. "We are having trouble with valves and with controls," he wrote soon after the run, "but we are solving every one of them, and as fast as we learn anything that needs modification, we are incorporating it into the *Nautilus*."[19]



Naval Reactor Facilities

The success of the S1W led to the launch of *USS Nautilus* on January 21, 1954, five years after design had started. The Navy was proud of its innovation, and the public eagerly consumed news of its many "firsts." One of them occurred in 1958 when the submarine became the first to travel beneath the ice at the North Pole. After the ship's celebrated return, skipper William Anderson sent a telegram to Idaho, paying tribute to those who had engineered the S1W prototype.

... during Nautilus*' North Pole sub - merged transit from Pacific to Atlantic the performance of our engineering plant exceeded all expectations. To the first manufacturer of naval nuclear propulsion our sincere thanks for pro - viding the plant that made possible this first transpolar crossing.*[20]

In the roster of reactor concepts "proved" for the first time at the NRTS, the S1W was the first to use water under high pressure as a coolant. Because it succeeded so well, Rickover and the AEC chose the same technology to demonstrate that the concept could support a civilian power industry. In December 1957, the Shippingport Atomic Power Station went critical in Pennsylvania, operated by the Duquesne Light Company. Rickover invested in it the same attention to detail he had with the submarine. He obliged the company to allow his own representative access to the control room at any time with full authority to

Above. The launching of USS Nautilus, January 1954. Left. USS Nautilus at sea and at speed.

shut down the plant if he thought it was not operating safely. Rickover explained himself clearly: the "whole reactor game hangs on a much more slender thread than most people are aware. There are a lot of things that can go wrong and it requires eternal vigilance."[21]

In 1956 Congress proceeded with the construction in Idaho of the prototype reactor for the aircraft carrier *USS Enterprise*. Thereafter, an entire nuclear-powered fleet slid down the shipyard ways into the sea.[22]

Cerenkov Radiation

In 1934, a Russian physicist named P.A. Cerenkov placed some radium in a flask of water. He saw a bluish-white glow in the water.

Cerenkov learned that this glow was caused when the gamma rays hit electrons in the water. The energy of the gamma rays was so great that the electrons moved through the water faster than light moves through water.

This beautiful blue light was a common sight around the NRTS. Whenever an irradiated fuel slug was removed from a reactor and placed into a water-filled storage canal, the diffuse blue glow surrounded the slug. Cobalt-60, which also emits gamma rays, also produces the light when it is stored in water. The most brilliant display of "Cerenkov radiation" appeared when a reactor operated within a tank of water. NRTS photographers prized certain photographs of this effect and used them frequently in pamphlets and public information brochures.

Argonne National Laboratory-West 9112

Humorous road sign, erected by an Idaho business owner on Highway 20 near the Site, entertained tourists and Site workers alike.

Chapter Nine

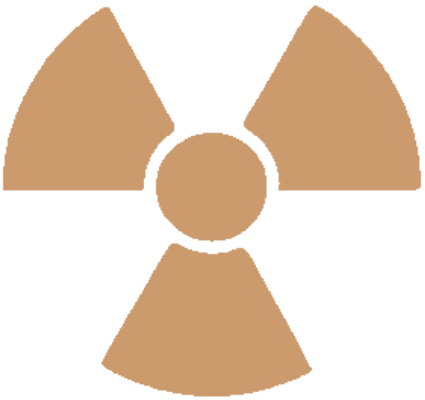
Hot Stuff

Heck, we weren't afraid of it. You just had to be schooled in it. I knew the HPs were looking out for us.

–Clyde Hammond–

Dr. Richard Doan and John Horan, director of the Health and Safety Branch of IDO, were in Washington, D.C., to address a JCAE subcommittee studying industrial radioactive waste disposal. Representatives from the AEC's national laboratories and from private industries described for the committee the practices and standards prevailing at their sites. It was 1959. The hearings were part of a series that had begun two years earlier with inquiries on the effects of fallout from nuclear weapons testing. Judging by their questions, the committee was interested in the growing volume of waste, the consequently growing costs of managing it, and its impacts on the environment.[1]

The disposal of radioactive waste already was a subject the public knew something about. During the Manhattan Project days, Hanford had committed solid and liquid waste to the ground, a practice that relied on the ion-exchange capacity of the soil to hold radionuclides and keep them from migrating more than a few inches from their source. The practice continued during the 1950s and was reported freely to the public. *Popular Mechanics* magazine, for example, described Hanford's "hot garbage" in one of its 1955 issues. Using the sort of exaggeration that dismayed scientists, the article tried to get the point across: "Desert soil soaks up the deadly wastes with sponge-like rapidity, and earth particles trap and filter much of the radioactive material on the way down." In the late 1940s, Argonne scientists in Illinois packed waste into special containers and thought about placing these in abandoned salt mines or rocketing them into outer space.[2]



The AEC in its early years took little interest in waste disposal and declined to establish uniform policies for its laboratories. In 1948 the AEC asked its laboratory directors to meet together and suggest something. Upon taking a vote at the end of this discussion, the majority decided that each lab should solve waste disposal problems in its own way. The AEC went along with this democratic idea. By the time Bill Johnston took charge of the Idaho station, nothing had changed, so the NRTS evaluated its options without reference to prescriptions emanating from Washington.[3]

With reactors going critical at the NRTS, radioactivity became a part of daily life and had to be understood, controlled, and minimized. Radioactive waste of various kinds was going to be generated. It would come in the form of solids, liquids, and gases. Like any other hazard, it could be managed safely if it was respected. The task of inventing the testing station wasn't finished until all waste had a destination. Not only did workers have to be protected, but also the nearby population and the environment they all shared.

For solids, the IDO decided to employ a landfill. IDO's Division of Engineering and Construction developed a set of criteria and asked the USGS to find a good spot. It should be at least ten acres. Fifteen to twenty feet of sedimentary overburden should lie over the lava

When needed for protection in radiologically contaminated areas, workers wore anti-contamination (anti-C) clothing including taped shoe covers and gloves, hair coverings, respirators, and Scott Air-Paks.

Argonne National Laboratory-West 9079

Radioactive Half-Life

Radioactivity is a natural characteristic of elements like radium and uranium. It also is a characteristic of many elements that have absorbed neutrons while in a nuclear reactor.

The nuclei within radioactive atoms are unstable. They disintegrate (decay) by throwing off one or more of their constituent particles spontaneously. As time passes, the material actually changes from one element or isotope into another, one atom at a time.

No one can predict when a specific atom will decay, only the probability that a certain percentage of atoms will disintegrate within a certain period of time.

Physicists decided that the "half-life" of a radioisotope would be a convenient way to describe the decay of a substance: the time required for one half of the atoms to disintegrate.

The process of decay takes place regardless of the temperature, the pressure, or chemical conditions surrounding the substance. Different authorities identify slight differences in half-life depending on the method used to count. The number following the name of the element identifies a specific isotope that is radioactive. It is the combined number of neutrons and protons in the nucleus of each atom.

Radioisotope	Half-life	Radioisotope	Half-life
Silver-110	24.6 seconds	Krypton-85	10.73 years
Indium-114	1.198 minutes	Hydrogen-3 (Tritium)	12.32 years
Barium-137	2.6 minutes	Strontium-90	25 years
Lanthanum-140	1.687 days	Cesium-137	30 years
Cadmium-115	2.228 days	Americium-241	432.2 years
Ruthenium-97	2.44 days	Radium-226	1599 years
Iodine-131	8.040 days	Carbon-14	5715 years
Niobium-95	34.97 days	Plutonium-239	24,400 years
Hafnium-181	45 days	Iodine-129	1.72×10^7 years
Polonium-210	138.38 days	Uranium-238	4.46×10^9 years
Cobalt-60	5.271 years	Uranium-235	7.04×10^8 years

rock, and it should contain plenty of clay. Workers should be able to dig vertical-walled trenches and not have them collapse. Naturally, the area needed good surface drainage and couldn't be upstream of any reactor sites. The IDO wanted to be able to get to the landfill without having to build a long, expensive road.[4]

The USGS suggested a one-hundred-acre area about two miles southwest of EBR-I and five miles west of Central Facilities. The site met most of the criteria. The depth of sediment above the lava rock, having been blown by the wind for thousands of years, was not uniformly twenty feet. However, the soil contained clay, which provided good ion-exchange and absorptive capacity. Any moisture that managed to saturate the waste and suspend radioactive isotopes would travel into the soil, where chemical reactions would tend to remove radionuclides from the water and bind them to the soil. The water would move on, albeit slowly, because fissures in the lava rock had filled with sediments, and this too would retard the movement of contaminants. The desert climate, which contributed about eight inches of precipitation per year over the Site, was an ally of the landfill plan, as very little moisture sank deeply into the soil. The geologists noted that it was unlikely, but possible, that water reaching the soil could carry contamination downward to the water table (of the Snake River Plain Aquifer).[5]

The IDO accepted the USGS recommendation and in May 1952 fenced off the first thirteen acres of the controlled access area that soon became known as the NRTS Burial Ground. In July work-

ers opened the first trench, six feet wide and nine hundred feet long. The place was in business. Waste disposal became another of the central services provided to contractors doing experiments in the desert.[6]

Solid items came from daily routines as well as one-of-a-kind experiments. They ranged from tiny scraps of paper to heavy pieces of equipment. Around the reactor sites, the simplest wastes resulted from the very work of trying to prevent the spread of radioactivity in work areas. HPs made daily rounds of reactor areas and laboratories to check for leaks, hot spots, and radioactive dust. Using thin sheets of filter paper, they took hundreds of "swipes" every day. They also went beyond the reactor areas. One of the HPs, Henry Peterson, recalled:

Once a week at the Test Reactor Area [TRA, site of the MTR], we also surveyed the areas that were supposed to be clean. We swiped the cafeteria and all the offices. We swiped desks, drawer handles, any place where people were and the things they touched. You'd put the swipe in a little envelope, label it, and put it in your shirt pocket until you went to the lab and put it in the counter. It was no big deal—these were microcuries we're talking about. Then you'd do the floor with a wide-area detector and look for hot spots. If you found one, you used masking tape to pick it up. If that didn't do it, you'd rope off the area for cleaning later. We had to prove every week that a place was clean.

I remember one time we had to rope off the entire MTR lab wing because an analyst was sloppy. He crapped up [contaminated] a hallway by spilling something on the floor and then walked around with it on his shoe.

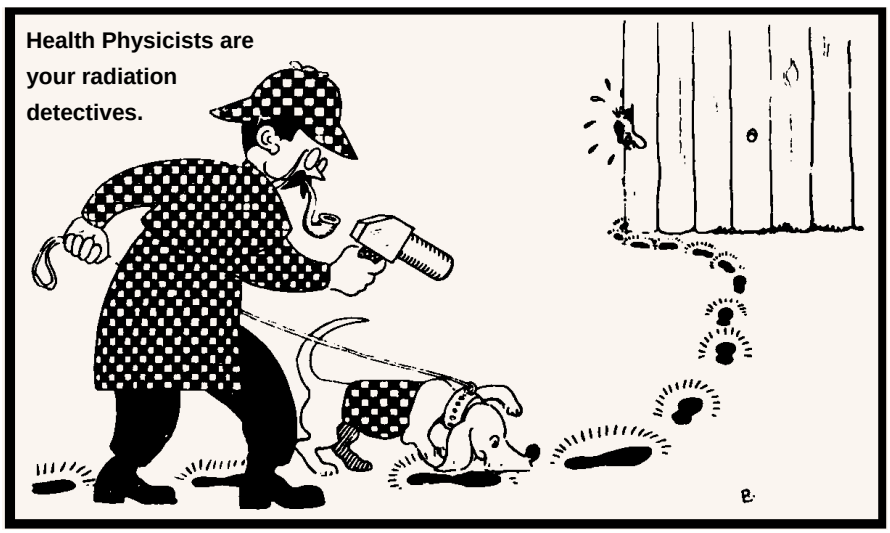
We also checked dust mops. Maintenance people were pretty thorough. Most of the time, we'd find nothing, but occasionally we did. Those kinds of practices were effective [in controlling radioactivity]. HPs didn't have a head-hunter mentality. We tried to do critiques that helped reactor operators solve problems.[7]

To find some radioactive speck was to contaminate the smear paper, however slightly. The same was true of mopheads that had done their intended job after a spill. Hot-cell work produced waste: beginners as well as experienced operators sometimes spilled a radioactive sample or broke glassware. Some items, even unbroken, were not reused once they had been contaminated. The Navy used disposable baby diapers as soak-up rags, although at other hot cells, technicians preferred women's sanitary napkins and ordered them by the gross. These, along with smear papers, gloves and glass shards, were tossed into waste bins marked with the standard yellow and magenta warning symbol and posted for radioactive waste.[8]

Larger objects included particulate filters. Having trapped radioactive dust from gases sent up laboratory vents and process stacks, these were regularly

INEEL 73-1552

Above. Aerial view of the Burial Ground in 1973. Triangular shaped area is the Subsurface Disposal Area, where transuranic (TRU) wastes were buried before 1970. Foreground shows the above-ground Transuranic Storage Area, where TRU wastes were stored after 1970. Below. Reminders such as this were placed in Site publications to make employees aware of the responsibilities associated with radioactive materials.



removed and replaced. Nuclear experiments generated contaminated debris and machinery, some of it in large and awkward shapes. Discarded pipe fittings resulted from the repair of lines that had carried contaminated fluids. Structural metal that once had been part of an irradiated fuel assembly had to be discarded. It all went to the Burial Ground.[9]

INEEL 62-2132

Above. Open trenches occasionally became susceptible to flooding from rapid snowmelt or heavy rains. Below. Workers check radioactivity at a long-tongued trailer.

Twice a week, someone went to all of the reactor buildings and labs, emptied the radioactive waste bins, boxed the contents, and trucked the load to the Burial Ground. Cardboard was sufficient for regular items, but wooden crating was used for bulky larger items. An HP went with the truck driver and took radiation readings near the waste containers and in the cab of the truck. Like everyone else, trash haulers were not allowed to exceed daily radiation dose limits. If a load, such as one containing metal parts that had become radioactive in the neutron environment of a reactor, had too high a reading, the driver used shielded containers and hauled them behind his pick-up truck on a long-tongued trailer. These loads were then transferred from the truck to their burial place with the help of cranes. Depending on how strong the radiation, workers covered the load with earth immediately or waited until the end of the week. The Burial Ground was designated for solids only, but a few sealed containers of liquid apparently found their way into the first trench.[10]

When the first trench was full, a cover of earth went over it and it was planted with native grasses. Another was opened, and then another, each location identified with the help of tags placed on the perimeter fence. The first trench served until October 1954.[11]

One trench every one or two years might have met local needs at the NRTS, but the AEC had a problem elsewhere that intruded into IDO plans. In 1951 President Truman and the defense establishment decided that the nation's security required enlarging its stockpile of nuclear weapons. They began building new weapons production plants around the country, one of them the AEC's Rocky Flats Fuel Fabricating Facility near Golden, Colorado, about sixteen miles northwest of Denver.

The plant went under construction in 1951 and began operating in 1952. Here the AEC manufactured hollow plutonium spheres that served as trigger devices for nuclear warheads. Rocky Flats machine shops also made other weapon

INEEL 09768

parts from stainless-steel, beryllium, depleted uranium, and other metals. Waste materials were contaminated with plutonium, solvents, and other industrial chemicals. Although Rocky Flats operated no nuclear power reactors, its scientists conducted criticality experiments in connection with weapons development.[12]

At the time, the Rocky Flats plant occupied only four square miles. The water table beneath the surface was high and known not to be isolated. Furthermore, a civilian population resided near the plant. Burial of waste on-site obviously was a poor option.[13]

The AEC calculated the cost of land burial at the NRTS and at the Nevada Test Site, another AEC facility. Of the two, the NRTS was closer. In April 1954 Rocky Flats shipped several drums of low-level plutonium waste to the NRTS in a trial run. The shipment went well, the costs were reasonable, and the decision stuck. It was the first in a steady stream of shipments that flowed into the Burial Ground for decades to come. Like it or not, the IDO accommodated Rocky Flats deliveries. John Horan said later that the IDO did not like it. Rocky Flats was never consistent in how it characterized its shipments and refused to identify the contents in any meaningful detail.[14]

Some of our people got rather ornery about that, dug their heels in, and threatened not to accept it at one point. We didn't always feel they were honest about what they were sending us. We had criteria for the Burial Ground, such as "no liquids." But they did send liquids—trichloroethylene [was one of them].[15]

Rocky Flats justified keeping secrets from IDO managers as a matter of national security. The NRTS was not considered a weapons laboratory and did not have access to many of the details concerning the waste or how it was generated. After considerable haggling between IDO and Rocky Flats over this, Rocky Flats finally agreed to supply IDO with an annual memorandum summarizing the waste that had been shipped during the previous year.[16]

The fact that waste shipments came to Idaho from Rocky Flats, however, was a matter of public record. At the 1959 hearing, which was public, the chairman of the subcommittee, Carl T. Durham, interrupted a discussion on the cost of waste disposal to ask Horan:

Chairman Durham: Are you receiving any material from any other operations except what is going on at Idaho?

Mr. Horan: Yes, sir; we do. We receive a large volume of waste from the Rocky Flats plant near Denver, Colorado, but this is the only other contributor of waste at our location.

Representative [Chet] Holified: Is that a processing plant?

Mr. Horan: It is a weapons fabrication facility.[17]

Plutonium and other human-made elements have an atomic number greater than that of uranium, which is 92, and are thus referred to as "transuranic" elements, or TRU. All are radioactive, and many have extremely long half-lives. Plutonium emits alpha particles, for which a piece of paper or three inches

Dumpster waste included boxed items, metal containers, and other scraps.

INEEL 61-1824

of air is sufficient shielding. This characteristic differentiated Rocky Flats waste from fission- or activation-product waste producing beta particles or gamma rays, which required stronger shielding. When the sealed drums of TRU waste arrived at the Burial Ground, workers handled them with nothing more than a gloved hand. Typically drums were taken off the back of the truck and hand stacked in rows in the center of a pit. Material that arrived in wooden crates went around the edge of the pit. Sometimes, workers handled unusual volumes—and packages—of waste, as labor foreman Clyde Hammond recalled:[18]

Courtesy U.S. Department of Energy-Rocky Flats 26568-02

Once we got a bunch of stuff from a California contractor who buried waste at sea. He had it all ready to bury and then he went broke. He had it already loaded, so it came out to the Site, and they were all concrete barrels. Some of those barrels weighed more than a ton apiece. So we buried them out here.

They had a big spill at Rocky Flats, Colorado, and we got their whole plant out there, lathes even. It was a big mess. Truck after truckloads of stuff.[19]

The "big spill" at Rocky Flats was caused by a fire in September 1957. A small pile of plutonium shavings ignited spontaneously in a glove box. Inexplicably, the glove box was made of acutely flammable plexiglas, and the fire raced out of control through the building. The fire blew out or burned hundreds of ventilation filters and melted the top of an exhaust stack. The bulky clean-up debris went to the NRTS Burial Ground packed in thousands of barrels.[20]

By the time of the fire, the Burial Ground's first thirteen acres—and ten trenches—had been filled up. In November 1957, two months after the fire, the IDO opened up new acreage. Workers began digging pits for the bulky post-fire increase of TRU waste. They continued using trenches for the NRTS's own fission- and activation-product waste. However, when someone at the NRTS generated an item too bulky for the narrow trenches, the practical thing to do was to place it in one of the Rocky Flats pits. Thus, different waste types were mixed together in some areas. The main difference between a trench and a pit was the shape of the excavation. Pits were of varying sizes. Some of the large ones were up to 300 feet wide and 1,100 feet long. Others were as small as 50 feet wide by 250 feet long. The work presented certain challenges to equipment operators. Hammond recalled how they solved one of them:[21]

U.S. Department of Energy 350 074 001

Above. Work stations inside the Rocky Flats fabrication plant had numerous glove ports. Below. Sealed enclosures called glove boxes allowed for workers to handle plutonium without direct exposure to it.

We had to keep two feet of dirt between the solid rock and the barrels. Well, nobody knew how to do that, since we didn't know where the rock was and whether it laid evenly beneath the sur - face. So we drilled holes down to the rock... We'd measure the hole and then pour corn seed in the hole to fill the bottom two feet. Then when we dug the pits, the equipment operators would come in with cats and cans [tractors equipped with scrapers]. We took all that dirt off. When we hit the corn, we knew we had two feet left to the rock. That's how we dug the pits and kept our two feet of dirt on top of the rock. It worked. It was an HP's idea.[22]

This application of Yankee ingenuity eventually changed. Later excavations were made to bedrock and then backfilled with soil and clay. Another once-practical technique that flourished during the 1960s also gave way. In 1963, some combination of labor shortages (caused by strikes) and funding problems led Burial Ground operators to start rolling waste drums off the backs of trucks and let them lay in the pits where they landed. With Rocky Flats barrels coming in by the thousands, tipping them out was faster and cheaper than manhandling every barrel. The practice, which continued until 1969, was further justified by the fact that it reduced potential exposure of workers to radiation. The barrels, regarded as settled in their final resting place, were expected to deteriorate eventually, so the environmental impact of the procedure, which damaged or dented some of the barrels, was regarded as of no serious consequence.[23]

Between 1960 and 1963 the AEC designated the NRTS, along with Oak Ridge, as a disposal area for commercial radioactive wastes from such places as hospitals and universities. Previously, commercial businesses had placed this material in the oceans, but the practice was too costly to continue. No commercial landfill sites were available anywhere else in the country at the time. The designation resulted in relatively little new waste for the Burial Ground, but it provoked NRTS managers to remind the AEC that the NRTS facility lay over an aquifer. Even though the NRTS was taking no undue risks, the AEC should look for permanent waste disposal sites elsewhere.[24]

Gradually, improvements and changes occurred over the years. Different types of waste were segregated, record keeping methods grew more sophisticated, procedures and requirements became more formal. Upper limits on the level of radioactivity handled at the Burial Ground went into effect after 1957. In February 1962 nearly two inches of rain fell on snow and frozen ground, causing localized flooding. One pit and two trenches were open at the time, allowing pools to form, overflow, and carry dumped items beyond the excavated area. After this, a diversion drainage system was constructed in hopes of preventing another such episode. Guidelines were established for fissionable material (U-235, Plutonium-239) to prevent the possibility of accidental criticalities. Decades later, analysts studying the waste regretted that standardization had not arrived earlier; they could have used better information about early waste types and their specific locations. Early records of what went into the trenches were not complete. But

A crane helps workers unload Rocky Flats barrels in 1961.

INEEL 61-1650

INEEL58-1450

INEEL 69-6138

Above. Workers unload and stack drums of Rocky Flats waste in 1958. Delivery truck required no shielding. Below. A load of drums containing 1969 fire debris tumbles into a burial pit.

the Burial Ground was intended to be a permanent facility. No one at the time imagined that someone would ever wish to disturb it.[25] As John Horan said to the JCAE at the hearing:

Senator [John O.] Pastore: For how long will that burial ground be consid - ered quarantined?

Mr. Horan: Indefinitely.[26]

Likewise, environmental monitoring improvements came gradually to the Burial Ground. The USGS drilled a system of ten monitoring holes west of the burial trenches in 1960 so that the progress of any subsurface moisture could be detected. Film badges went up around the perimeter fence to monitor direct radiation levels at the boundary of the Burial Ground. Later years brought additional monitoring holes, test wells, and more sophisticated monitoring techniques, particularly after the public became more concerned about the possible migration of contaminants to the aquifer.[27]

With respect to the liquid wastes generated at the NRTS, Doan and Horan described for the JCAE the NRTS strategy. The philosophy was similar to that followed at AEC facilities elsewhere. It depended on whether the waste was contaminated with radioactivity or not, and if so, whether the hazard was "high-level" or "low-level." If it were low-level, the strategy was to dilute it and disperse it to nature—into the air, water table, or soil. High-level wastes were those for which such dispersion would endanger the environment. Here, the strategy was to hold onto the material, typically in stainless-steel tanks at the Chem Plant, concentrating it if possible to reduce the cost of managing it.[28]

Water was by far the major constituent of most low-level liquid radioactive (and non-radioactive) waste. Reactor operations used water by the billions of gallons every year as a reactor coolant and in canals to store irradiated fuel. Water was used in decontamination. At the Chem Plant water was used in a variety of ways—for cooling, to make up chemical reagents, for dilution, and to clean up process equipment. Evaporator condensate at the Chem Plant produced large volumes of water.

Depending on how it had been used, a stream of waste water might be contaminated by virtue of irradiation, as when it passed through a reactor, or because it had picked up particles in the clean-up of spills or equipment. To determine what level of dilution, if any, were needed before a watery waste could be dispersed

to the environment, the IDO used as its guide a National Bureau of Standards handbook known as *Handbook 52.* This book identified the maximum allowable concentrations of each radioisotope that could be permitted in public water supplies. In lieu of any other guidance from AEC Headquarters, the NRTS used this handbook in its own way, as Horan described for the JCAE:[29]

Liquid radioactive wastes discharged to the ground are maintained at such levels that the concentration in water at the nearest point of use down gradient will not exceed one-tenth of the maximum permissible concentration... Solutions which are within the prescribed limits may be discharged to the groundwater table through wells, pits, or ponds. Adsorption, dilution, and decay factors determined by IDO may be used in establishing allowable concentrations at points of discharge in order to comply with our basic guide...[30]

The USGS had advised the IDO that water flowed through the aquifer at a rate of thirty-five feet per day. Horan continued:

Since this cannot be a precise determination, and recognizing that there are variations from location to location, a safety factor of 10 has been incorporated into our calculations. Therefore, we have assumed a linear velocity of 350 feet per day.[31]

Thus, the IDO had evaluated the risk inherent in discharging above an aquifer and developed formulas containing several safety factors. The formulas exaggerated the rate of flow by ten times and reduced the allowable maximums (at the point of use) by ten times. Against these factors, the half-life of each isotope was considered. The IDO Health and Safety Division then translated all of these factors into a set of disposal guidelines for each radioisotope and obliged all of its contractors to follow them when sending any liquids into the environment.[32]

To reduce the uncertainties pertaining to water flow in the aquifer, Horan stepped up environmental research. He hired, among other specialists, soils scientist Bruce Schmalz to work with the USGS on further investigations of the interplay between the waste, the soils, and the aquifer. Early research was conducted at a 600-foot-deep low-level waste injection well at the Chem Plant, into which went water that had been treated with sodium chloride—salt. The USGS drilled fifteen monitoring wells down-gradient from the injection well, thinking that the salt in the injected water would act as a convenient tracer. Each day, the Chem Plant discharge contained up to two tons of salt. When normal sampling methods repeatedly failed to detect any salt in the monitoring wells, Schmaltz tried something else:

One of the first things I did was to decide that something different needed to be done. We weren't getting anywhere, so to speak. I'd heard about the use of a florescent dye. So I and another fellow mixed up a fifty-gallon drum of this fluorescent dye and put it down the well together with a big slug of salt. The slug was, I think about fifteen tons all at once. We never did find the salt, but we found the fluorescent dye... This started the analysis of the rate of movement [of water in the aquifer] and the diminution of concentrations as a function of distance.[33]

INEEL 67-5191

Settling pond at the Test Reactor Area in 1967.

INEEL 56-3203

Sodium potassium (NaK) waste is flammable and potentially explosive in contact with water or moist air. Shooting the barrels containing it introduced air in the container, causing combustion. A fire hose was used to complete the burn of any waste not initially burned. This Nak disposal took place in Trench 7 in 1956.

Elsewhere at the NRTS, settling ponds or disposal to a drain were used instead of injection wells. This was done mainly to prevent accidental discharges of concentrations above the allowed concentrations. The ponds worked in concert with holding tanks and monitoring routines. Horan described the early system used at the Naval Reactors Facility (NRF):

The NRF had two waste tanks, 125,000 gallons each, into which all of the liq - uid drainage of the reactor building were collected. The liquid was then sampled when a tank was filled and analyzed in the health physics counting room...[The analysis determined what radioactive constituents were in the water.] After measurement, the waste could be pumped out in a pipe that ran underground until it reached a French drain in the southeastern area outside the fence. The Navy reactors that came after the STR [S1W] were held to a zero-leakage design standard. Little radioactive material appeared in the waste holding tanks from those plants.[34]

At TRA, Phillips used retention basins. MTR operations used demineralized water to cool the reactor and to shield the spent fuel in the canals. Despite this pretreatment to remove impurities, the water contained traces of sodium that were activated while passing through the reactor core and had a half-life of about fifteen hours. This then became part of the waste stream, but had to be held until the sodium had time to decay, about a week. In the canal, the cladding on a spent fuel element occasionally developed a pinhole leak. Fission products within the element then leached into the canal water. The water was constantly bled off and replaced with fresh water, so after such a leak, it contained traces of fission products. The water went to a soil-lined pond after passing through a filtration system. Solids settled to the bottom of the pond, the smaller particles adsorbed or absorbed by the clay. The particles continued their radioactive decay while the water evaporated. These procedures were part of the general routine, although unofficial side experiments were not unknown, according to HP John Byrom.[35]

Some interested fisherman conducted his own experiment by dumping a few fertilized trout eggs into one of the hot settlement ponds. We noticed a few large healthy(?) trout swimming around in the pond for several years after. These ponds were sampled monthly for many years—or more frequently when an incident indicated that radioactive material greater than normal had been accidentally released to the ponds.[36]

The IDO operated a hot laundry to wash coveralls and other protective clothing that had served its mission in the course of someone's work. Located at Central Facilities, the laundry drain went to a septic tank and drainfield with other sanitary waste.[37]

Also at Central was a landfill for non-radioactive waste. As a fully equipped industrial complex, the NRTS supported machine shops, carpentry shops, fabricating centers, paint shops, automotive and bus garages, electric

substations, and every conceivable kind of non-radioactive laboratory—chemical, metallurgical, photographic, and dosimetry. All of these activities generated their own typical wastes—metal and wood scraps, solvents, resins, acids, caustics, broken tools, empty containers, and the like. Depending on the material, it was disposed of in the vicinity of the particular work area or it went to the landfill at Central. Sanitary waste went into sewage lagoons at each reactor complex. Even paper products had a treatment protocol. Some was shredded and incinerated; in later years, some of it was compressed, made into pellets, and sent to fuel the coal-fired power plant at the south end of the Chem Plant.[38]

Some varieties of chemical waste posed explosive hazards, and these were stored or treated by methods unique to the substance. Sodium potassium alloy (NaK), for example, could react explosively when placed in contact with water. Occasionally, small flasks of NaK had to be discarded. On one occasion, five such flasks went into a container which was then isolated in a trench at the Burial Ground. A security officer fired upon the container with a charge intended to ignite the contents and burn it. A small water supply and a hose stood by to give the NaK further encouragement to burn.[39]

Finally, wastes could take the form of gases. Procedures for releasing gases with radioactive elements, most of which were relatively short-lived, followed a similar logic as that for liquids. The dilution medium was air rather than water. These releases were subject to continuous study and research conducted jointly by the IDO and the Weather Bureau. Mechanical measures for holding, filtering, and scrubbing paralleled the measures used for aqueous wastes, as did the monitoring activities that accompanied all releases.

In the 1990s, the National Center for Disease Control undertook to identify the radiation dose to a hypothetical individual located off-site at a point of maximal exposure to Site releases between 1952 and 1989. To do this meant identifying the possible pathways by which radiation might have traveled away from the Site. The analysts who performed the retrospective study concluded that of all the potential pathways by which radiation might have reached off-site citizens, only the gaseous releases were of potential interest, and even those had been small. Solid and liquid waste disposal practices had not, at least until that time, provided a pathway to human populations, and were therefore of no consequence to the study. Solid and liquid waste practices had produced no measurable exposure to anyone beyond the boundaries of the Site.[40]

Chapter Ten

Cores and Competencies

With atomic energy in the engine room, guided missiles in the hangars to topside, and the target-seeking homing weapons in the torpedo tubes, the submarine of the future figures to be the instrument of war most benefitted by atomic era science.

–All Hands, Oct. 13, 1951–

By February 1957, *USS Nautilus* had run as far as her first loading of fuel would allow. The boat had traveled 62,562 miles, more than half of them submerged. She had hosted royalty, entertained political leaders, and convincingly played the role of a high-speed enemy submarine in Navy war games. Now she sailed home to Groton, Connecticut, for the delicate process of removing the reactor core and replacing it with a new and better one.

Fuel in the unshielded core emitted gamma radiation so intense that a few moments of close exposure would cause death. The procedure to remove the core from the boat was pre-planned in endless detail. The objective was to move the core into a shielded transport cask and hoist the cask onto a truck. This conceptually simple—but highly complex—task took two months to accomplish. *Nautilus* then sailed away to the Pacific Ocean, and the old core was sent across the country to Idaho.[1]

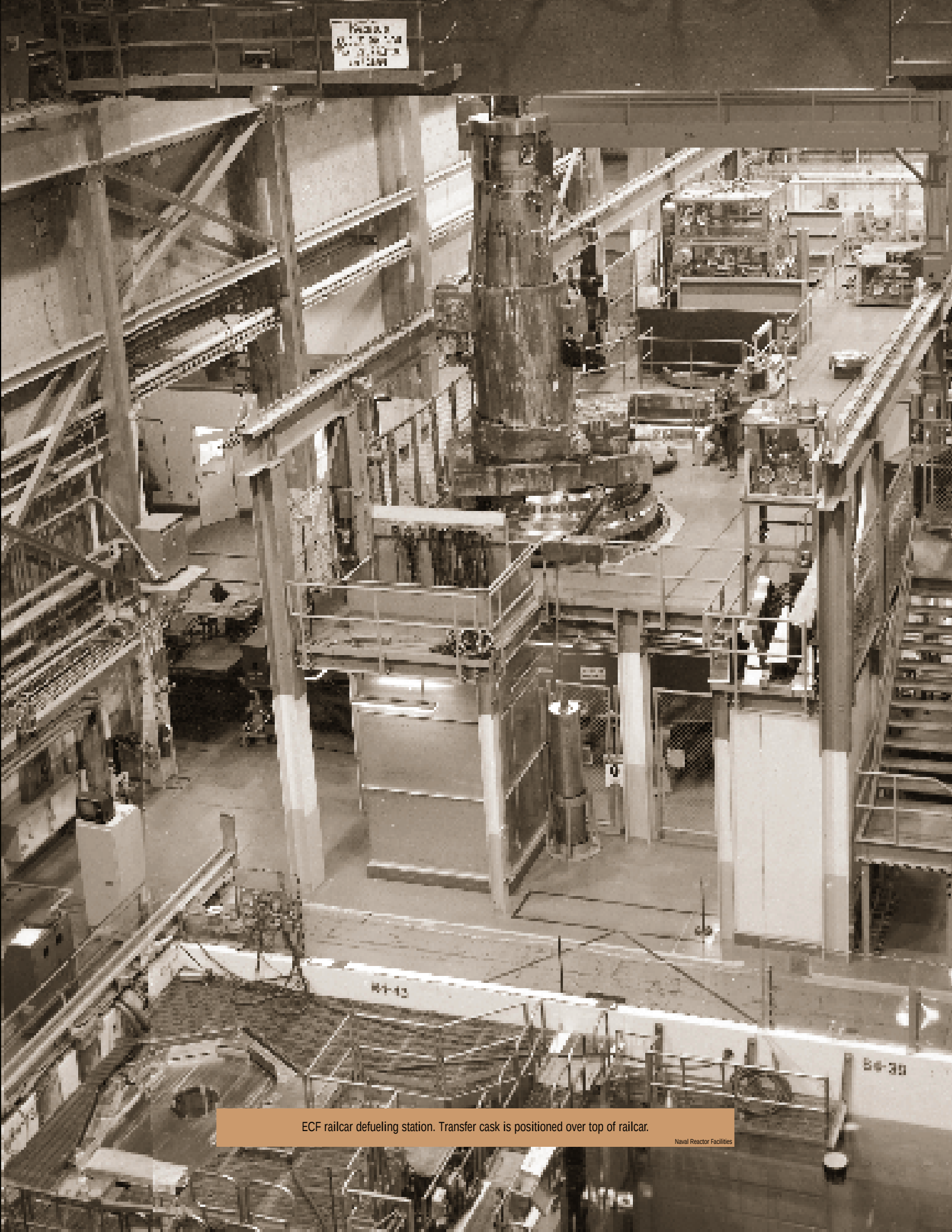
A brand new facility, the Expended Core Facility (ECF), was being readied at the NRTS to undertake the equally delicate task of unloading the cask and placing it safely in a deep pool of water, a procedure that took about three days.

Naval Reactor Facilities 10024

The ECF under construction, looking east toward S1W. Equipment and water pits take shape.

Within the Navy's complex, the ECF was located near the north fence. It began as a building 340 feet long, although its designers expected it to expand as the workload grew. They considered the facility an important continuation of the research and development phase of the nuclear industry. Here were complete reactor cores that had served their missions, not merely sample elements tested in the MTR. Did the fuel operate as predicted? How well did the cladding hold up? How much beyond its design life might the core have lasted? By no means would the Navy rest on the performance of the first cores.[2]

Nor would a commercial power industry, once it had begun. The designers visited Hanford and other places to study how they handled irradiated cores. They hoped the ECF would become a model system, a sound demonstration for the industry sure to come in the future.[3]



ECF railcar defueling station. Transfer cask is positioned over top of railcar.

Naval Reactor Facilities

The action was definitely underwater within the ECF. The safest way to store the cores and have access to them was to place them in "water pits," the Navy equivalent to the MTR "canals." The basic problem was getting close enough to the fuel to handle or study it. When a truck or train car arrived with a load, the first move was to hoist the entire transport cask into the water of a receiving pit and set it down on the (heavily reinforced) concrete floor. After that, subsequent manipulations extracted the fuel from the cask and moved it from one water-pit work station to the next.[4]

Engineers constantly invented or adapted gadgets and machines to do underwater what was taken for granted in the dry, non-radioactive world. Because working with a whole core or fuel element was too dangerous or bulky, they would shear a piece off or punch a piece out. Hack saws and band saws cut and chopped to obtain representative samples. Other instruments measured and weighed them. Periscope ports and observation windows with shielding power equal to the concrete walls of the pits gave visual access into the water. Workers guided the remote manipulators by the light of standard diving lamps. They were quick to try new ways to see through the water. When television cameras were commercially available, they bought one from the local Farnsworth Electric Company, encased it in a stainless-steel can, installed a window in one end, and dipped it into the water. Experimentation was a part of daily work:

Naval Reactor Facilities

ECF workers on the defueling platform above an M-140 railcar prepare to receive fuel into a transfer cask.

ECF Engineering designed an underwater core-component de-scale system [to remove hardened incrustation on metal parts] in late 1962. This included an inner vessel ...encased in an outer vessel, [each] with a bolt-on top and seal. The void space between the vessels was pressurized with air to displace the water after the component was loaded; then the inner vessel was pumped full of de-scale solution and circulated while being heated... It operated for a time with moderate success...until the inevitable happened, the top cover seals failed. Water pits #1 and #2 were "deep purple" for a week, and it was several months before all trace of purple color was gone. That event ended the underwater de-scale operation.[5]

And unusual events occasionally produced a "lesson learned."

A rail car container crashed through the closed west-end roll-up door number 6 one morning during car switching operations. The rail car uncoupled from the switch engine and slowly rolled through the closed gate and the closed door. The surprised craftsmen and others threw tools and wood blocks in front of the wheels to bring the railcar to a stop before it ran off the end of the rails and into the water pit. One immediate corrective action was to install rail stops at the end of the tracks by the craft offices, and of course the other actions were to replace the fence gate and the roll-up door.[6]

After the shearing and milling operations, the portions of fuel that would not be examined further were moved through the pits and out of the building to the Chemical Processing Plant. Other non-fuel solids went to the NRTS Burial Ground.

The ECF inspected and analyzed the fuels from S1W and the other Idaho prototype reactors in addition to fuel from *Nautilus*, *USS Seawolf*, and other vessels. The original plant was designed to process three cores a year

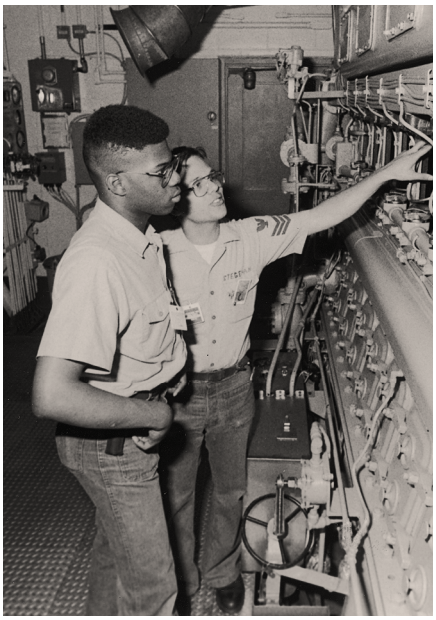
Right. Rickover at hull entrance to S1W prototype. Below. Navy students in training onboard S1W prototype.

Naval Reactor Facilities

per shift, but new business required expansion. In addition to fuel from the vessels of the growing Nuclear Navy, MTR-irradiated specimens came to ECF scientists. Spent fuel from the Shippingport reactor was shipped to the ECF from Pennsylvania for examination. The detailed examination of nuclear fuels accomplished its purpose. Reactor fuel improved. Structural alloys and cladding improved. Over time, inspections grew more precise and more exacting. The life of a ship core eventually matched the design life of the ship itself, twenty years or more. By 1989, the ECF building had grown to a length of a thousand feet.[7]

Greater work loads—and larger cores—generated more risk of exposure to radiation, and protection strategies grew ever more sophisticated. In the earliest days, people leaving work areas—not only at the Navy facility but elsewhere at the NRTS—submitted themselves to "friskers," hand-held probes that scanned hands, shoes, and perhaps the whole body for radioactivity. Nearby were rolls of tape, so that a worker could remove a hot particle by a press of the tape and leave it in a collection can. But experience and innovation produced ever cleaner work areas.

It was not uncommon to press off a hot [particle] almost every time one left the high bay. Next came shoe covers for entry into the high bay. Then came the requirement to cover the hot spot with tape and proceed to the radcon [radiation control] field office, where the rad techs removed the particle and saved it for isotope identification and foot trail mapping for possible pickup location. Better radiological work practices, deck oil mopping, and improved anti-C[ontamination] clothing and laundering all contributed to significant reductions in particle spread.[8]



Naval Reactor Facilities

Elsewhere in the Navy complex, the reactor prototype program also was growing. Admiral Rickover had sent the first crew of the *Nautilus* to train at S1W in Idaho. After that, training seemed an obvious mission for the reactor, to the lifelong gratitude of generations of young women in the neighboring towns. When each trainee arrived in Idaho, he had a few days to find and settle a place to live. One in four of the trainees married before his six months of training were over, and it wasn't unheard of for a man to meet, court, and marry, all in his first two weeks.[9]

Rickover's ideas about the training of nuclear plant operators were controversial within the Navy. He wanted to train a new type of naval officer, unfettered by what Rickover saw as the useless traditions embedded in regular Navy training. On the basis that assuring safety aboard ship required that all ship personnel be able to evaluate potential hazards, Rickover had his way. He

Some of Admiral Rickover's Favorite Aphorisms

Employees at the NRF used to hang plaques around the place to remind themselves of the Admiral's philosophy on Life and Time.

Heaven is blessed with perfect rest. The blessing of earth is toil.

Every hour has sixty golden min - utes, each studded with sixty dia - mond seconds.

When you waste your time, remem - ber even God cannot undo the past.

In this school, the smartest work as hard as those who must struggle to pass.

The secret of success: late to bed, early to rise, work like hell and you'll be wise.

Hal Paige

established a system of nuclear training schools, and the desert prototype was an essential part of it. Rickover supervised the preparation of textbooks and ordered that no examinations contain multiple-choice or true-false questions. Tests required essays, definitions, statements of fact, or calculations. Homework was required, and since it often involved classified material, trainees had to do it on the premises, not at home.[10]

The controlling philosophy was self-responsibility. Rickover rejected simulations in favor of real reactors. "You have to train people to react to the real situation at all times. But if they are trained with a simulator, they tend to expect there will be no consequences," he said. Rickover didn't want to train the wrong instincts by using a machine that could not mimic a real nuclear power plant under real-time conditions, including casualties. Computers capable of doing this were not available at the time. Cross-training also was important. Electricians should know mechanical systems, for example. Trainees came to the desert after six months of theoretical instruction from a specialty school elsewhere in the system. In Idaho a trainee began by picking up—or trying to—a "triple-hernia-sized" crate of operating manuals, instructions, and schematics.[11]

Using the books and seeking the instructors he needed, the trainee traced every system, component by component. Enlisted men, no less than officers, learned and used technically accurate vocabulary, no nicknames or shortcuts. Common language tended to level everyone; it wasn't unusual for a petty officer 3rd class to be instructing an officer. Due to the prevailing Idaho practice—at least in the early years—of wearing civilian clothes, visiting Navy brass from the regular Navy were in for

A1W under construction. Photo, circa 1956, shows S1W spray pond in foreground.

Naval Reactor Facilities

new experiences. An admiral once toured the S1W prototype and then stayed for lunch with his guides. Later he learned who the men were. "Enlisted men! I thought they were college physicists!"[12]

When he felt competent in a system, the trainee sought an instructor to examine him and sign his checklist. Mastery gradually produced a long list of signatures. The trainee then stood watch at one of the operating stations in the hull. At first, he was paired with a more experienced mate, but then he himself was in charge. Learn one station, move to the next. The trainees started the reactor plant, took it up to full power, maneuvered, shut it down, repaired it, maintained it. Although the nuclear program attracted the top two percent of the Navy's enlistees, some men wiped out, usually because of a failure of self-initiative, not academic insufficiency. There were few second chances. The story is told that one hot summer day, a few sailors took a refreshing but forbidden dip in a cooling-water pond on their way home. Caught, they were dismissed.[13]

The training program grew more complicated as nuclear fuel evolved and as the Navy adapted nuclear power to surface vessels. In 1958 a second prototype, A1W (Afor aircraft carrier), went critical in a new building west of S1W. The prototype actually consisted of two reactors, "A" and "B," which powered one propeller shaft, a "first" that the NRF quickly added to its list of credits. The arrangement simulated Engine Room Number Three of an aircraft carrier, the first of which was *USS*

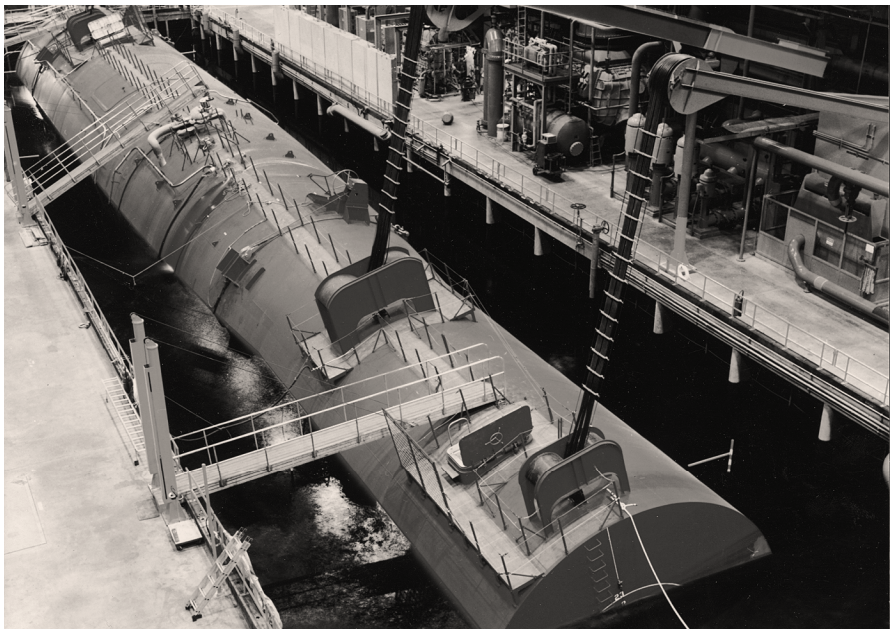
Naval Reactor Facilities

1950s photo showing A1W in center view. Round-top structure on roof is an all-weather shelter for a crane.

Enterprise, a mammoth ship containing eight reactors and four engine rooms. On aircraft carriers, there is room outboard of the reactor compartments to put other equipment or offices. To make those areas habitable without stay-time restrictions, the compartments needed to be shielded on the sides. The A1W prototype, therefore, did not require testing in a tank of water.[14]

The conventional steam plant aboard non-nuclear aircraft carriers supplied energy to catapult airplanes off the decks. When nuclear reactors took their place, they operated at temperatures not as high as conventional plants. Producing a sufficiently powerful head of steam for the catapult therefore required some adaptation of operations. A series of experiments at A1W simulated catapult launches using steam draw-down from the reactor. Each test produced a terrific boom that rolled across the desert and might have reminded Naval Proving Ground veterans of the good old days at the gunnery range.[15]

Then in 1961 came the S5G prototype (the 5th submarine design, made by General Electric). As the Cold War intensified, the United States and the USSR poured their latest technology into the theory and practice of undersea warfare. They wired the ocean floors with sound detectors. These called forth technology to quiet the submarines. One source of noise came from the pumps that circulated the coolant through the reactor and kept it under pressure. The art of sound detection became so refined that skilled listeners could identify the unique sound patterns of individual boats. So the mission of S5G was to eliminate noise.[16]



Naval Reactor Facilities

The S5G prototype floating in its basin.

S5G, like S1W, was built in a huge box of a building, its roof presenting an inscrutable flat surface to satellite cameras passing overhead. The reactor went critical for the first time in September 1965. The hull section floated in a "basin" of water. Operators inside the hull used equipment to make the hull rock back and forth, adding more realism to the simulation. In this setting, the Navy developed a method of circulating the reactor's cooling water without using a pump and exploiting the principle that warm water rises. *USS Narwhal* was the first boat equipped with the system. At high speeds, pumps were still needed, so the controller could move the coolant either by so-called "forced" or "natural" methods.[17]

Rickover made sure that the thousands of Navy trainees who came through the program at Idaho—and the contractors who designed and built the Navy's reactors—were exposed to his philosophy of safety. The men in a nuclear-powered submarine had no avenue of escape in the event of an accident. Therefore, safety engineering and training had to guarantee that accidents would not happen. Every feature of the machine, beginning with its design, had to be completely free of error. Safety lay in the perfection of parts, components, and assemblies. Ultimately, the most important safeguard was human competence—trained, tested, reliable.[18]

This approach contrasted somewhat with the general philosophy employed by the AEC in creating the reactor testing station in a remote location. If accidents were to occur, then a combination of isolation and engineering safeguards would reduce the consequences. Later, when the AEC began to license commercial reactors, its approach to the public's safety continued to rely on

Rickover on Responsibility

Responsibility is a unique concept: It can only reside and inhere in a single individual. You may share it with others, but your portion is not diminished. You may delegate it, but it is still with you. You may disclaim it, but you cannot divest yourself of it. Even if you do not recognize it or admit its presence, you cannot escape it. If responsibility is rightfully yours, no evasion or ignorance or passing the blame can shift the burden to someone else. Unless you can point your finger at the person who is responsible when something goes wrong, then you have never had anyone really responsible.[19]

Admiral Hyman Rickover

Naval Reactor Facilities

S1W on the day of Admiral Rickover's death, July 8, 1986.

remoteness and engineering safeguards. Rickover, by instituting management systems for "quality," was considerably ahead of the rest of American industry.[20]

Rickover preferred to visit the NRF with little or no advance notice, partly to avoid wasteful ceremony and partly to observe conditions as they were, unvarnished and unpolished. However, this didn't mean that his hosts preferred to be surprised. People did what they could to predict his trips to the NRTS so they could be as well-prepared as possible.[21]

Whether he was expected or not, Rickover visits left memorable impressions on the people who met him. Stories about the man were passed on to a new generation of NRF workers who had not known him. Secretaries from steno pools recalled standing by to take dictation while he waited for airplanes. He liked to collect silver dollars, commonly in circulation in the 1950s, so office cashiers checked their supplies and polished them up. Outdoors, groundskeepers gathered up cigarette butts and repainted fire hydrants if they didn't look bright enough. One story (among many others) is retold with many variations in it:

Admiral James D. Watkins, Chief of Naval Operations, came to the NRF to speak at an officer graduation ceremo - ny [or for a visit.] On his way to the NRF, a guard stopped him for speeding [or for not having a security badge]. "Do you know who I am?" Watkins asked the guard. The guard said, "No sir, but you're not short and you don't have white hair, so you're not Admiral Rickover."

"What would you say if I told you I were Rickover's boss?" said Watkins. "Then I'd know you were lying, sir. Rickover ain't got no boss."[22]

The stories celebrate a man who by the sheer force of his brilliance, wit, and dedication created an institution as complex and world-changing as the Nuclear Navy. An abiding respect continues for Rickover's simple belief that there was no room for error aboard nuclear-powered submarines.

CHAPTER ELEVEN

THE CHEM PLANT

The crew is versatile, processing various types of fuel at different times...

–Phillips Petroleum Company–

It was 1950. Chemist Don Reid and others at Oak Ridge were nearing the end of four years' work to invent and design a pilot chemical processing plant for MTR fuel. They had found a work place in what Reid called "a little bit of a shed" on a hill overlooking the Oak Ridge plant and next door to the shed commandeered by Captain Rickover for his early studies in naval nuclear propulsion. Reid recalled how they got started.

After looking around the laboratory and other areas in Oak Ridge...and seeing what was available in the way of material, it was decided to use old bismuth-phosphate plant equipment stored in the field west of the laboratory... We found some old...columbium-stabilized stainless-steel plates out in the field and this was to be used for the dissolver. This was taken by R.M. "Murph" Jones, later of MTR Engineering, to Nooter Engineering Works in St. Louis, a fabricator for Monsanto. Jones followed the fabrication of this special piece of equipment, and it was a very successful prototype of the [Chem Plant] dissolvers.[1]

The group patched the equipment together and began their experiments. The goal was to design a process for dissolving MTR fuel and extracting from it the substantial percentage of U-235 that had not fissioned during its seventeen days in the reactor. The huge expense of gaseous diffusion was invested in the fuel, so the effort to recover and recycle unused fuel was well justified.

INEEL 64-1808

Dissolver vessel for zirconium-alloyed fuels is in the foreground in this view inside a processing cell. The cells were entered rarely, and only after thorough decontamination.

The dissolver vessel was important. It had to contain the powerful acids that would dissolve sturdy metal alloys and not itself dissolve. Also it had to be small enough that the uranium inside it could not accidentally form a critical mass. Engineering was at least as important as the chemistry.

Dealing with the waste that the dissolution process would produce also occupied the group. They experimented with evaporators to reduce the volume of waste, much of which would be water. They articulated the principle of "holding the concentrate and discharging the condensate," a philosophy consistent with the AEC facilities' general approach to waste management—retaining high-level waste and dispersing low-level waste.

The group erected a pilot plant and after considerable experimentation, decided on the chemicals, the design of vessels and pipes, and the sequence of steps that would separate the uranium from the dissolved solution. They tested valves and instrumentation in a series of "cold run" tests using natural uranium and "warm runs" using low levels of irradiated uranium. Then they asked the AEC for five kilograms of irradiated U-235 from an Oak Ridge reactor.

Chem Plant technician demonstrates use of master-slave manipulator. Photographer entered hot cell before cell became “hot.”

INEEL 68-1275

We were down in the cells one day when Miles Leverett brought in David Lilienthal, the chairman of the AEC. He looked around and said, "You are moving along pretty well." We said, "Yes, but we want to get five kilograms of U-235 irradiated, but we can't get it through the bureaucracy. He went back to Washington and three days later we had approval...

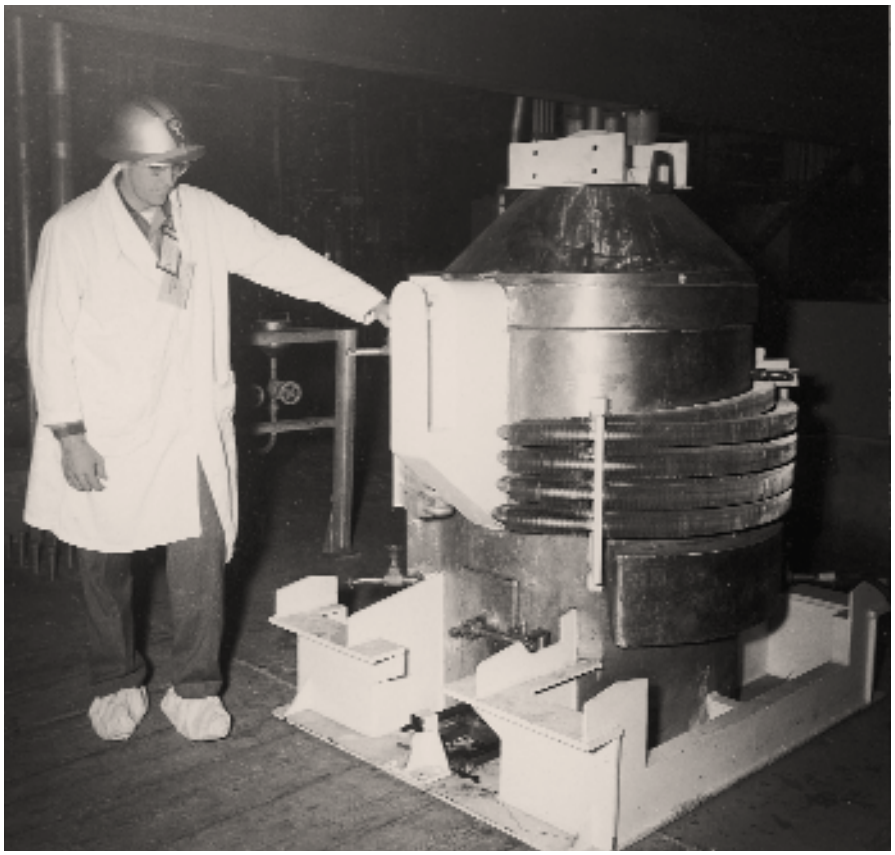
Somebody got the idea that if we could get this material irradiated in a Hanford production reactor where the flux was ten to fifty times higher than Oak Ridge's, we would get a bigger burn-up and a better demonstration. I made a trip to Hanford to look into this, but Hanford was not interested in doing outside irradiation. They had to use all their neutrons for the production of plutonium. It was brought out that we were not asking for neutrons but giving them. They took a new look at it and pretty soon we had approval to go into the Hanford reactor.[2]

Upon seeding the reactor with enriched U-235 fuel elements, called slugs, Hanford happily discovered that the slugs helped increase the production of tritium. Tritium was a radioactive isotope of hydrogen used in bombs to boost the explosive power of the plutonium chain reaction. The AEC was building a reactor plant at Savannah River, South Carolina, to produce tritium, but until it was completed, the AEC was counting on Hanford. Thus it was decided that the Chem Plant, when it was completed, would recover the unfissioned U-235 in the Hanford slugs.[3]

At AEC Headquarters, meanwhile, the staff concerned with weapons research was thinking about the Chem Plant in connection with an altogether different issue. It was trying to decide which of the AEC facilities should produce radioactive lanthanum-140, called RaLa for short, a material needed at Los Alamos for weapons experiments. Oak Ridge had been producing RaLa, but its equipment was hard to decontaminate, couldn't keep a predictable schedule, and was exposing workers to too much radiation. The bomb scientists at Los Alamos needed a more reliable source. The AEC had initially decided to build a new RaLa facility at Hanford, but with the MTR and the Chem Plant materializing in Idaho, they had another option to consider.[4]

RaLa is a fission product. After uranium atoms split and form (among others) isotopes of barium, the barium-140 isotope continues to decay into other isotopes, one of which is lanthanum-140. The problem with RaLa was that its mother isotope had a short half-life, and the half-life of RaLa also was short—about forty hours.

Spent MTR fuel fresh out of the reactor would contain RaLa. Up to this time, AEC Headquarters had not considered harvesting RaLa from the MTR. The plan was just the opposite. Spent nuclear fuel from the MTR would sit



INEEL 55-3549

Shipping cask used to transport "green" MTR fuel elements. Note cooling coils.

quietly in the storage canal for a few months just so that short-lived isotopes like RaLa could decay out of existence. After that, the fuel could go to the Chem Plant less hazardous to handle.

But the Korean War began in 1950. The AEC needed RaLa for weapons development. During World War II, scientists at Los Alamos had perfected the plutonium bomb as an implosion device. Explosive pressure from outside the small plutonium-239 core pushed the not-yet-critical mass into a critical mass. The bomb worked only if the sphere were compressed at the same instant from all sides. This was a problem solved with much trial and error and hundreds of (non-nuclear) test explosions. The experimenters used RaLa in test cores to help diagnose the efficacy of their gradually improving techniques. Work at Los Alamos now focused on creating thermonuclear weapons, and the scientists still required RaLa.[5]

Because RaLa decayed so quickly, the supplier and the user had to coordinate closely. When Los Alamos needed a quantity of RaLa for a pending experiment, it would inform Oak Ridge (or later, Idaho). Oak Ridge would remove fuel elements from a reactor, cool them a day or two, and drop them into a caustic bath. The caustic dissolved the cladding and the fuel, releasing the

Support

In a typical office setting in the middle of a city, "support" means the administrative functions provided by the personnel, legal, accounting, payroll, and similar departments. In an industrial plant like the CPP, "support" meant a variety of laboratories with special equipment and functions.

"Process" support meant working out ways to improve the chemical processes that are the main mission of the plant. This group designed bench-scale pilot experiments and tests to evaluate and compare with current practices.

"Analytical" support meant taking a sample of waste, water, or other substance and determining exactly what was in it and how much and what concentration. Laboratories were loaded with X-ray equipment, shielded boxes, spectrometry, and chromatography instruments.

"Radiochemical" support could identify alpha, beta, and gamma-emitting radionuclides in any solid, liquid, or gas substance. People in these and other labs had to use alpha-tight containment cells and learn to use glove boxes and remote manipulators to protect themselves from radiation.

Another form of support peculiar to an environment with radioactivity came from safety specialists, who not only examined the accumulation of exposure on personnel badges, but evaluated techniques and procedures for safe operation of equipment and processes. They reviewed construction plans to see what the safety impacts would be when parts had to repaired or replaced in case of an accident.

INEEL 62-6349

Samples were drawn from all stages of the uranium extraction process and sent to the Remote Analytical Facility (until 1986). Here, technicians and scientists examined the hot samples to help determine the effectiveness of the process and ways to improve it.

lanthanum and (about 250) other fission products into the soup. The lanthanum was then recovered in a centrifuging process and shipped quickly to Los Alamos.

The dissolving process also liberated gases, among them radioactive iodine-131. The gas went through a filter and up a stack into the environment. It was the filtration system at Oak Ridge that was so ineffective. With a half-life of about eight days, iodine could settle onto blades of grass and eventually contaminate the milk of cows that ate the grass. Hanford's virtue, aside from its ready supply of fuel, was its isolation.[6]

Oak Ridge scientists persuaded AEC Headquarters that it would be more economical to produce RaLa in Idaho. They could add a RaLa capability to the Chem Plant for perhaps $20 million less than building a plant at Hanford. The MTR could supply spent fuel every seventeen days. So it was done. The AEC assigned the RaLa operation to the Chem Plant, adding a small subsidiary defense mission to its original peaceful purpose.[7]

The Chem Plant might be thought of as a kitchen-in-reverse. Instead of putting ingredients together to make bread or cookies, the system was designed to begin with a finished product and recover only one of the original ingredients, say the sugar, and refine it so it could be used again. As in the case of RaLa, a secondary ingredient might also be retrieved. The rest of the ingredients and whatever chemicals it took to recover the prized ones would become wastes.

The Chem Plant removed the U-235 in a sequence of steps. Upon dissolving the fuel and its cladding in an acid, the next steps, called extraction cycles, introduced a chemical solvent that would form a compound only with the uranium. Then the compound was extracted and refined. Along the way, water was added to dilute the solutions to a composition suitable for extraction and to help prevent accidental criticalities. Later in the process, some of the water was evaporated. At first the solvent was hexone (methylisobutyl ketone), a chemical cousin of acetone (used in nailpolish remover). In 1955, the Chem Plant was modified and the extraction process improved with the use of tributyl phosphate in the first extraction cycle. Among other effects of this new process, the changes expanded the capacity of the plant.[8]

The Foster Wheeler Company designed the origianl plant. The Bechtel Corporation built it. The first operator, American Cyanamid, managed construction, hired operating personnel, and developed the first safety procedures and operating manuals. It took thirty-one months to build and cold-test the plant, making it ready for the first hot run. The designers had borrowed freely from existing technology, as Don Reid recalled.[9]

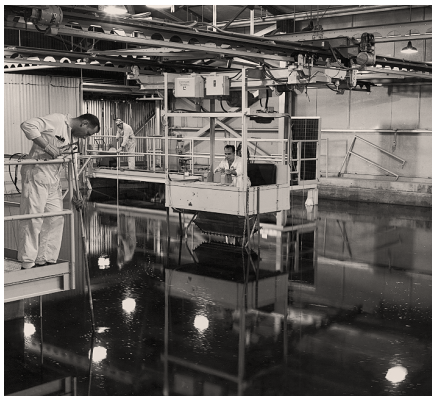
Foster Wheeler...took the flow sheets developed by Oak Ridge and, using their oil refinery knowledge, converted these flow sheets to a commercial plant. Their nomenclature and drawings are still in use at ICPP. It was started in haste because it was a war plant—the Korean War was on...

The Chem Plant in 1956 with Big Southern Butte to the south. The process building is at center right; the storage basins, at the southern edge of the complex.

INEEL 56-112

The plant construction started, but the design was done in New York City. It was a conglomeration of problems because most of the Foster Wheeler people were not security-cleared. We had to do everything unclassified, resulting in numerous trips back and forth between Oak Ridge, Washington, and New York.

...we had to use existing techniques and knowledge. The stack [design] was lifted right out of Hanford specifications and installed without change. The waste evaporator was a development at KAPL [Knolls Atomic Power Laboratory] for their waste evaporator and was just lifted in total and fabricated as such. The storage basin was a take-off from the storage basins at Hanford, even the buckets and monorail system. We bought an absolute duplicate of the original Hanford crane...The high priority of the CPP overrode all opposition.[10]



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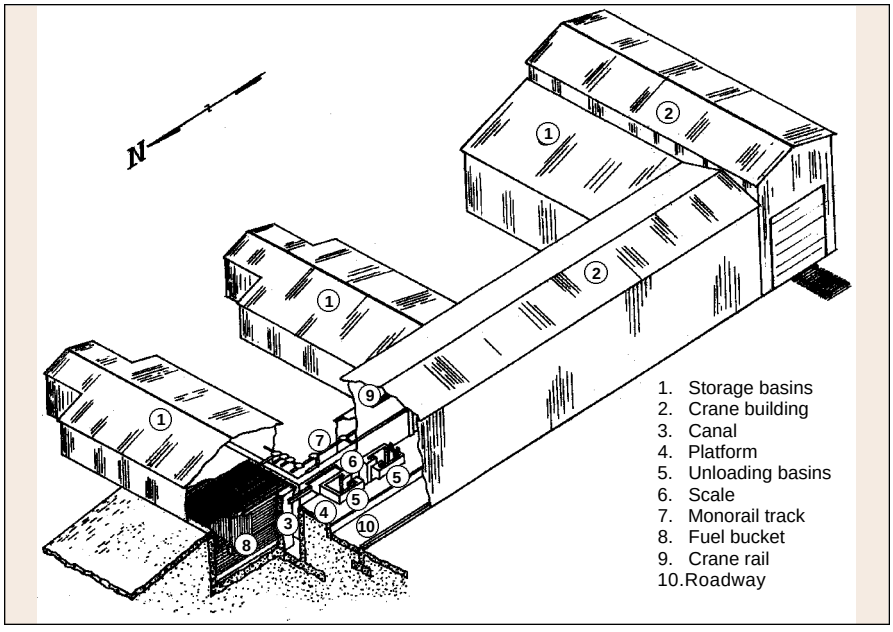
The plant was expected to process fuels with different types of cladding—aluminum, zirconium, stainless steel. Each type called for a different process formula, and the fuels of different types could not be mixed. Therefore, the operators had to accumulate enough of each type to make it worthwhile to run a batch through. This meant that fuel arriving at the Chem Plant had to be stored someplace until enough had accumulated for a run.

So, part of the Chem Plant complex included a special fuel-storage building housing basins of water twenty feet deep. On the Chem Plant's 82-acre site, the basins were located about a third of a mile south of the main processing building. A year's accumulation of fuel was needed for the first production run, so the basin was finished first and opened for business while the rest of the plant was still under construction. The first shipment arrived in November 1951. Security was heavy. Said Reid, "None of the construction people could be allowed anywhere near the vicinity." One of the first security guards at the Chem Plant was Mark L. Sutton (later an Operator Helper), who recalled:

I was often assigned to the ICPP area for patrol and exit/entry control at the guard house or gates. The whole ICPP area seemed to be a maze of pipe trenches, cement pours, worker's tools and office shacks. The [fuel storage building] was perhaps already complete and had some Hanford "J" slug fuel elements stored under water in it, but at that time I was not acquainted with the intended activities and the terms describing them.[11]



Above. Storage pool at the Fuel Storage Building. At center is a transfer crane with a riding cab. The fuel is stored in cadmium-lined racks under 20 feet of water. Left. Schematic view shows unloading pools, canal, and other features of the Fuel Storage Building.

Memories of an Operator Helper at the Chem Plant

I recall reporting to Shift Supervisor Archie Larson on a Sunday day shift. He gave me an orientation in the works of the Process Makeup area, where non-radioactive chemicals were measured and mixed for use...

...Operator Helpers were shown how to air sparge [agitate a liquid by pumping air into it] solutions in vessels so as to mix the chemicals into a homogenous solution, and then where and how to draw samples and to take them to the Shift Lab for analysis. This work was considered entry-level, and training was "on the job," usually by experienced helpers and/or Operators. Experienced personnel were most always anxious to be relieved of this type of work because of the tedium [and] ever-present risk of radioactive contamination—analogous to "dirty work."

One other usual job for Operator Helpers was to mop up radioactive materials when they were inadvertently released from the intended confines of the process piping, vessels, sample garages, sample bottles, and cell vent systems. There was a sort of unwritten code that whoever caused a "spill" or release of radioactive material, thus creating radioactive contamination of an area, should be the one to clean it up. This, often as not, fell to the lowly Helper because he was the one delegated to do that "dirty radioactive sampling" work, but whenever the Helper could pin the cause on an Operator, he did get some help.

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Water and mopheads were basic aids for decontaminating spills.

...I was also assigned [to] the Waste Processing building. This work, of course, included the usual sampling, mopping, and routine shift readings. Waste collection was an on-going continuous operation, if not the surveillance of filling vessels or pump-outs, then periodically the operation of the low-level liquid waste evaporator...with the attendant collection of "clean" non-radioactive condensate...and disposal to the service waste well—or re-run, if it was not within specifications as ascertained from the samples submitted by the Helper to the Shift Lab.

Most plant work was done on a 24-hour day coverage by three crews working eight-hour shifts... [rotating shift work was less desirable than straight day work but better than [straight evening or straight midnight shifts].

I also worked as an Operator Helper on an aluminum-clad radioactive fuel element processing campaign...I helped charge fuel elements to the dissolvers for batch-wise dissolution, pulled input feed samples, helped with routine readings, and made some of the acid or base feed adjustment additions...

Vessels, pumps, etc, in each cell or Process Makeup area were titled/labeled with those respective area designations and followed by three-digit numbers, the first digit...designating the type of equipment as follows: 1-vessel, 2-pump, 3-heat exchanger, 4-agitator, 5-jet, 6-sampler, 7-burrette, 8-funnel, 9-special. Thus C-101 was a vessel in C Cell, D-301 was a heat exchanger in D Cell.

Mark L. Sutton

Cask-heavy trucks rumbled past the security gate at the Chem Plant's west fence and disappeared into special entry bays at the storage building. Cranes removed the casks from the trucks and deposited them underwater, where mechanical hands removed the fuel and placed it into stainless-steel buckets suspended from overhead tracks. The fuel moved along to its assigned resting space. The shielding water carried away heat and was recirculated and refreshed daily, the overflow injected to a disposal well just south of the building. To the water had been added chlorine to prevent the growth of algae. Sodium nitrate was added to prevent the chloride from dissolving the stainless-steel cladding or accelerating the corrosion of the aluminum cladding. The building had its own motor generator set for an emergency power supply.[12]

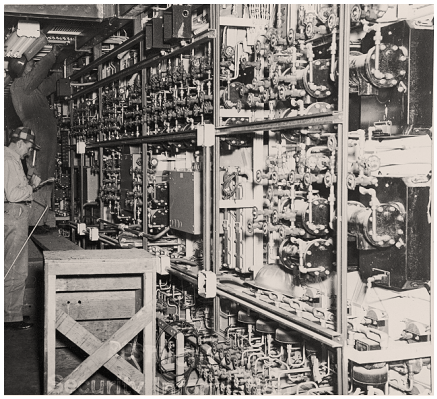
In February 1953 the operators were ready for their first hot run. They had test-run the plant using non-irradiated uranium, and by trial and error, calibrated all of the instrumentation. They had checked out the plant's fifty-plus miles of piping and tubing. Using magnets and nitric acid, they made sure all the pipe fittings were made of stainless steel. Despite previous inspections and controls, they found a few fittings made of the wrong material, and the pipe fitters had to cut them out and replace them.[13]

After the AEC decided to equip the Chem Plant with a RaLa facility, military officers arrived on the scene to help expedite procurement and otherwise remove barriers to early completion. They proposed that government

INEEL 56-34

employees run the plant instead of contractors. Despite the country's wartime footing, the AEC rejected the idea because the recycling of uranium was intended eventually to be a component of the commercial power industry, and civilian companies would have to learn how to do it. Besides, contractors had a good war record, having produced the atom bomb.[14]

American Cyanamid thus recruited engineers, chemists, and mechanics from industries all over the United States. The recruits went to a special school at Oak Ridge to learn basic nuclear technology and how to handle radioactive material. Arriving in Idaho in 1951 with the plant still under construction, they set up their first offices at the Central Facilities Area in the Navy's handy white houses. They prepared to train others, writing safety manuals, operating procedures, and process specifications. Someone decided the Chem Plant would use the metric system, which was somewhat unusual



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Above. Shipping cask arrives at the CPP. Below. Pneumatic instrument tubing is installed behind the facade of the operating corridor where operators will control process.

for American chemical companies at the time, so that became part of the training, too.[15]

Straddle-carriers, long-legged transporters adapted from timber industry lumber-handlers, brought casks loaded with the first fuel elements from the storage basin to the head end of the process building, where fuel was dropped remotely into the dissolver in the first cell. Remotely operated cutters at the basin had trimmed as much structural metal from the fuel as practical before the fuel headed down the chute into the dissolver vessel.

The work with the highly radioactive material was mostly below ground level, so that the earth formed part of the shielding. Each vessel was isolated in its own shielded room, or cell, typically about twenty feet square. During a run, operators stood attentively in an operating corridor between the banks of cells, facing gauges and other instruments, their hands on levers that would open or shut pertinent valves by remote control, heat up certain solutions and cool down others. Pumps, steam jets, or airlifts advanced the feed from one vessel to the next. The pipes penetrated the dense concrete walls, five feet thick around each cell. Piping also brought the water, air, or chemical additives to the cells from upper-level storage tanks. Certain reactions produced gases, and pipes carried it away. Each of the original twenty-four cells had a name, beginning with A Cell and proceeding through the alphabet (skipping I and O). As the Chem Plant opened, several spare cells awaited future developments.[16]

The first run dissolved Hanford slugs. It lasted six months and recovered over 240 kilograms of U-235 in the form of uranyl nitrate, a thin yellow liquid. The Chem Plant shipped it unshielded to Oak Ridge, although it was packaged in ten-liter stainless-steel bottles encased in a "birdcage" framework designed to prevent accidental criticalities.[17]

The liquid waste, of course, remained at the Chem Plant. As in so many other corners of the NRTS, this was one more place where scientists and engineers could say they were doing something new. Pipes conveyed the waste underground into a 300,000-gallon stainless-steel storage tank (nested within a concrete vault) east of the process building. Stainless steel had become more available after World War II. Hanford had used carbon steel, having no other choice, and then neutralized its acidic waste with caustic. This increased its volume, caused solids to form a sludge,

INEEL 57-112

Chemist Bernice Paige was the first woman to win a lifetime achievement award from the American Nuclear Society for her technical contributions to nuclear science.

INEEL 06940

Lowering slug charger over the slug chute above a dissolver.

INEEL 06971

November 1952. CPP operators transfer a filled bottle of concentrated uranyl nitrate product into a "bird cage" for shipment to Oak Ridge.

and made future retrieval hazardous and costly. The Chem Plant spared itself from these particular problems, perhaps because its research mission generated different decisions. The stainless steel tanks allowed the storage of waste in acidic form and resisted corrosion. Scientists assumed that disposal to the environment was "out of the question," that tanks were not the final resting place for the waste, that isotopes in the waste might have further use and should be retrievable, and that nothing should preclude the option of transforming the liquid into a safer, more stable, solid form.[18]

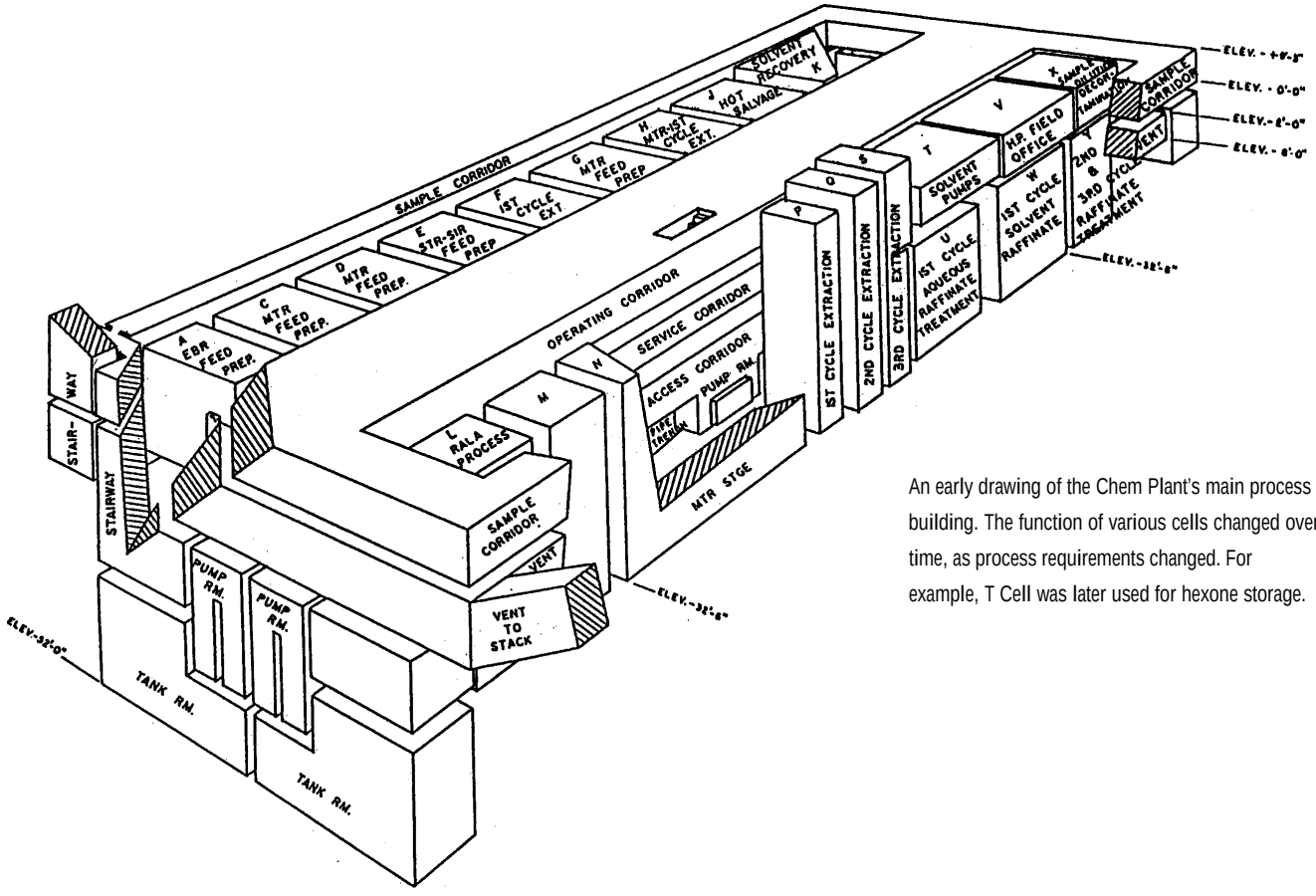
When the run was over, the operating crew decontaminated cells, vessels, and pipes and prepared for the second run, slated for MTR fuel. The plant was partly an experiment in direct maintenance;

with stainless steel. Then crews entered the cells from the access corridor to repair valves and other fixtures *via* direct physical contact. For the benefit of future commercial plants, the AEC hoped to demonstrate that this method could potentially reduce operating costs and not overexpose employees.[19]

Subsequent runs filled the first storage tank with liquid waste. Ten more were built; one of them always stood empty in case of a leak. Operators could transfer the liquid either from a leaking tank or the concrete vault into which the liquid had accumulated. When full, each tank contained only a few gallons of pure radioactive fission products. The rest of the solution was dissolved cladding-metal ions, process additives, and water. The tanks

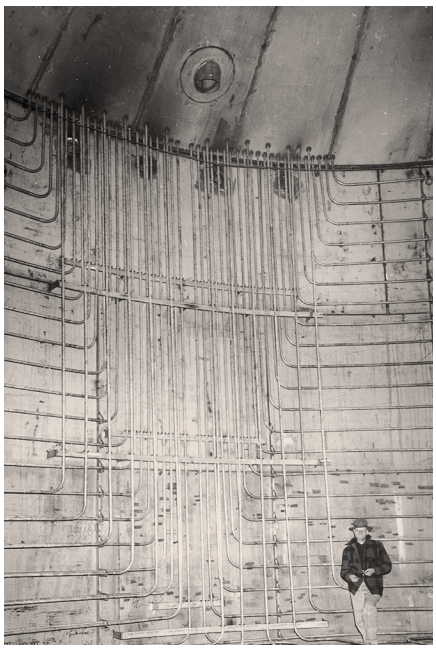
first cycle extraction, which accumulated most of the fission products, had cooling systems to carry away decay heat to minimize corrosion. Other liquid wastes included condensate (containing low levels of radioactivity), and those went into a disposal well.[20]

The Chem Plant was launched. Over time, the plant recovered U-235 from many new types of fuel. Each had unique cladding and fuel chemistry, challenging the chemists and engineers to develop new formulas in small-scale pilot plant workshops, most of which also required modifications in the physical plant. Process development became a regular Chem Plant activity.[21]



An early drawing of the Chem Plant's main process building. The function of various cells changed over time, as process requirements changed. For example, T Cell was later used for hexone storage.

Sometimes the task seemed deceptively simple, such as a request later in the 1950s to process spent fuel from Savannah River reactors. The fourteen-foot-long elements were clad in aluminum and had to be cut to eighteen-inch lengths to fit into the dissolver vessel. The engineers practiced the cutting procedures with non-irradiated elements and built a special cutting machine to do the job. As they began preparing for the hot run, said Don Reid,



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...we soon found out that we had exceeded the technical knowledge of the materials. We found that the Savannah tubes, while being irradiated, had changed metallurgical characteristics. Instead of cutting like regular aluminum—on which the cutters had been tested—they crumbled like graham crackers, so a whole new technique and procedure had to be developed. Maintenance was extremely difficult because of the crumbling, and a very extensive complete modification [of the process was] required.[22]

But the requisite persistence and ingenuity were available, and the Chem Plant crew eventually conducted another successful run. Such accomplishments helped move the Chem Plant beyond its original mission to recover just two or three types of fuel. It became a permanent fixture—and a revenue generator—at the NRTS. The plant processed at least a hundred varieties of spent nuclear fuel. It came from university and test reactors all over the world, from commercial power plants, from most of the reactors at the NRTS, and from Navy ships.

The RaLa program lasted from 1956 to 1963, the province of the complicated L Cell, which had a remote viewing window and several miles of piping. In the early days, each time green MTR fuel clattered into the vessel to be dissolved in acid, a puff of radioactive iodine blew out the Chem Plant stack. The way to control a release was to time it in concert with benign weather conditions. Managers evacuated outdoor construction workers who might be around the area. The IDO Health and Safety Branch required that iodine releases occur only when the weather—wind direction and speed—fit a certain profile to promote dilution and movement towards unpopulated areas. Later, activated charcoal scrubbers absorbed iodine, and a special tank was installed to retain the gas for later release.[23]

INEEL 55-610

Above. Cooling pipes inside 300,000-gallon waste tank. Left. "Pillar and panel" vault under construction in 1955 for one of the Chem Plant's eleven 300,000-gallon waste tanks. Concrete components were precast.

Monitoring the iodine releases to make sure operating contractors kept within IDO-set guidelines was the task of health physicists. Monitoring teams carried radiation detectors and patrolled site roads and the public highway near Mud Lake during a release. When their meters detected a radioactive cloud, they took the highest reading and collected air samples. They collected jack rabbits and analyzed their thyroids, often finding these to be better indicators of off-site exposure to iodine than were their meters. Of course, collecting the jack rabbits also required special techniques, as HP John Byrom recalled later:

One method used was with a seat anchored to the front fender of a truck and a gunner with a shotgun strapped to the seat...The driver would head out across the sagebrush until the rabbit was flushed. Then it was up to the gunner to harvest the bunny. Much powder was probably burned before the gunners got very good at this sport. Talks with the gunners indicated it was... rather hard on the seat of understanding. All in all, the method was quite successful and many specimens were collected, whether in self-protection or skill I could never learn.[24]

The march of progress eventually made bunny gunners obsolete. Like much else at the Site, pioneering methods gave way to more economical or more effective improvements. To detect the iodine cloud as it exited the Chem Plant stack, for example, someone devised a "scintillation sky scanner." The device used a pivoting gun barrel as a shield. It was erected just outside the Chem Plant fence and trained on the top of the stack. The RaLa operators were in radio contact with an HP at the scanner. "We dropped it!" they would say. The scanner detected the iodine cloud the moment it exited the stack. This device was also responsible for revealing that the stack released iodine while process vessels inside L Cell were being decontaminated. Learning this, the RaLa operators changed the decontamination schedule, doing it just before the next run, giving the iodine more time to decay.[26]

Iodine-131 (I-131) was potentially the most hazardous of the isotopes released to the atmosphere by any of the operations at the NRTS, and the RaLa program was the major contributor. However, the releases were not a secret. When the IDO began distributing quarterly environmental reports in 1959, the reports identified the curies of iodine released by these runs and maximum levels that had been observed.[26]

None of the iodine releases at the Chem Plant (or anywhere else at the NRTS) crossed the boundaries of the Site exceeding the radiation protection standards applicable at the time. In the RaLa days, the highest dose to drift offsite may have been nine percent of the allowable concentration.[27]

Chapter Twelve

Reactors Beget Reactors

You couldn't move forty bright people to Idaho and expect them to quit thinking for themselves or stop being bright.

–Deslonde deBoisblanc–

Bill Johnston got an offer he chose not to refuse. After twenty years with the government, he went to Duluth, Minnesota, in 1954 to work for the Taconite Contracting Corporation. Taconite was preparing to build a pelletizer plant, an undertaking of such size that the company needed to build a town to go with it. The construction phase at the NRTS had by no means ended, but the organization itself was well rooted and on the verge of shifting into an expansive operational mode. Some of Johnston's colleagues felt that he left because he had done what he came to do and that his background, after all, was civil engineering. Others added that the offer was extraordinarily sweet.[1]

Johnston had spent a good part of his energies in 1953 simplifying the management of the testing station. The IDO had set up a technical library, document control systems, and a print shop. Procurement, warehousing, and maintenance systems were in place. The Lost Rivers Transportation Company ran the buses under an IDO contract. Instead of managing these functions itself, the IDO decided to consolidate and place all these activities under the responsibility of Phillips.

The Argonne and Navy programs were under the aegis of AEC offices in Chicago or Pittsburgh, and if the IDO moved to consolidate them under its own jurisdiction, it did not succeed. The Chem Plant was an IDO project, however, and fell into the Phillips net. Chem Plant employees noticed that Phillips' benefits were better than American Cyanamid's, and the transition went fairly smoothly. NRTS employees numbered 1,700 by this time, and the consolidation affected a thousand of them. Dr. Doan assured them that Phillips would "fill job assignments...as far as practicable from applications by present employees." The IDO announced that the change, to take effect in October 1953, would save the government $250,000 a year. Thus streamlined, the NRTS was ready for the changes coming in 1954.[2]

The industrial leaders in the electrical utility business were impatient to develop a nuclear power industry. The spectacular success of the NRTS's first four projects had awakened considerable optimism that nuclear energy, with federal support of nuclear research, would someday mature into a commercial proposition. Largely because of military requirements for nuclear applications, such research funds were plentiful. Companies that wished to enter the nuclear field had many opportunities to do so.

President Dwight D. Eisenhower dominated the formulation of nuclear military policy during the 1950s. Truman before him had felt that atomic weapons would help keep peace, and

President Dwight D. Eisenhower before the General Assembly of the United Nations delivering his address on Peaceful Uses of Atomic Energy, New York City, December 8, 1953.

Dwight D. Eisenhower Library

had committed the country to the development of a hydrogen bomb. He felt that the Soviet Union aspired to dominate the world and regarded the United States as an enemy to be destroyed. In Truman's last three years, annual defense spending went from $13.5 billion to $50 billion. Eisenhower, assuming office in 1953, felt that such huge defense budgets would weaken the economy. "Long-term security required a sound economy," he wrote in his memoirs. His New Look for defense emphasized a military capability to inflict "massive retaliatory damage" on anyone initiating an offensive strike on the United States. The policy lowered the total expenditure on defense but changed the allocation of resources from conventional to nuclear force. The shift fattened the budgets of the U.S. Air Force in particular, because it was the service that would inflict the retaliatory damage.[3]

Eisenhower did not wish to "scare the country to death" by sharing with the public the gruesome scenarios that would come of a nuclear war. He was sensitive to growing business pressure and shared the hopes of scientists for the peaceful atom. The AEC recognized economic nuclear power as a national objective and discussed it with the JCAE in May 1953. Then in December, Eisenhower proposed that the United States and other nations surrender some of the uranium in their stockpiles to international control, thus "dedicating some of their strength to serve the needs rather than the fears of mankind." The Soviet Union didn't agree to the scheme, and it never materialized. Nevertheless, Eisenhower affirmed "Atoms for Peace" as a banner for nuclear commerce.[4]

So the country had two urges, atoms for peace and atoms for war. Both helped grow the NRTS. For the next thirty years, the question of whether nuclear power would eventually produce electricity more cheaply than coal or oil was rarely in doubt; the political debate, rather, was when it would happen and whether AEC policy was helping or hindering the process.

Courtesy of Oak Ridge National Laboratory 55-515

Delegates at the United Nations Conference on the Peaceful Uses of Atomic Energy (1955, Geneva) admire Cerenkov radiation from the small reactor operated by Oak Ridge National Laboratory.

Congress's major step toward a nuclear power industry was to replace the Atomic Energy Act of 1946. The original act had emphasized secrecy and government control of scientific information. It forbade the private ownership or use of nuclear fuel. Clearly, this did not encourage private enterprise. The government's monopoly on nuclear power was once described as "an island of socialism in the midst of a free enterprise economy."[5]

The AEC needed a new legal framework for the federal licensing of power plants and for promulgating safety standards—and for maintaining the United States as a world leader in these areas. As a matter of prestige, it was important that the nation maintain a technological lead in peaceful arenas as well as military. The state of American technology was believed to reflect the superiority of American democracy and capitalism over communism. The new Atomic Energy Act of 1954 shifted American policy and the AEC in this direction.[6]

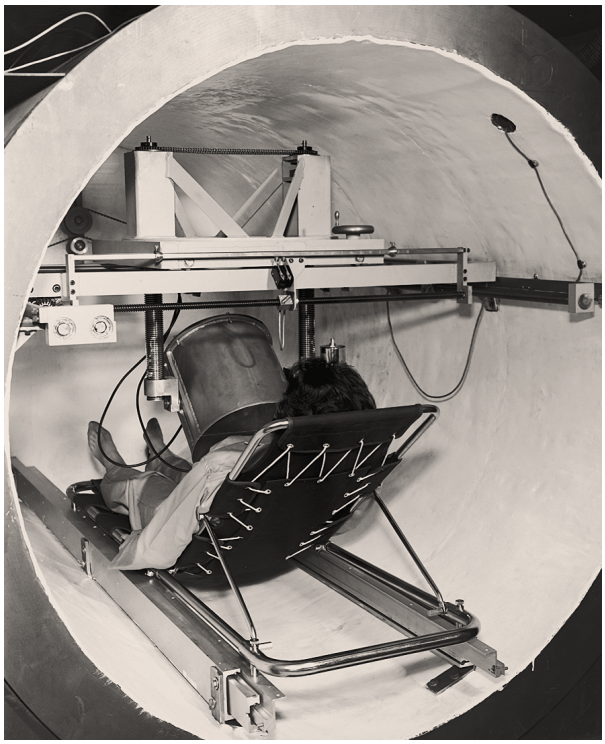
The NRTS already was on a growth trajectory partly driven by creative impulses from within its work groups. At the Test Reactor Area (TRA), the MTR was an instant hit. Like Sun Valley, another Idaho landmark with a global identity, the MTR became so essential and so famous that nuclear literature in the 1950s and 1960s often didn't bother to mention its country or state.

Being at the leading edge of a new industry was impressive enough, but the sheer search for knowledge was the reason Phillips people went to work every day—and stayed all night if a result or reactor startup was expected at midnight or two a.m. For such devotees, there was a bunkhouse at Central, and if those beds were full, it was well known that women's restrooms contained cots.[7]

The pioneering work at the MTR influenced reactor design all over the free world. The Sylvania Electric Products Company was typical of the MTR's many commercial customers. Sylvania wished to manufacture fuel elements. Using two different techniques, the company made eighteen fuel elements using natural uranium. The MTR subjected them to prolonged high-flux exposure—and the scientists observed how both types gradually increased in diameter and decreased in length. Findings such as these helped Sylvania design fuel assemblies that allowed for swelling, which otherwise would choke off the flow of coolant.[8]

If the AEC or home lab scientists at Oak Ridge and Argonne had thought that the Idaho desert would be a passive slate on which experiments would be built, run, and shut down, the Phillips group soon corrected this notion. Opportunities had to be created, problems had to be solved. Innovation was the only answer, and it brought growth, as Deslonde deBoisblanc recalled.

We had a problem at the MTR canal. Apparently the cladding on one of the fuel elements stored there had failed. The fuel was leaching radionuclides into the canal water, but we had no way of determining which element was the bad one. We needed what we didn't have, which was instruments that were sensitive enough to detect a mixture of minute quantities of radioactive elements and tell us what they were. We found a way to solve this problem, and in doing so initiated a program to study the "decay schemes" of the radioactive isotopes which put nuclear spectroscopy on a firm basis.



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Health physicists scrounged the lining of an old Navy gun barrel and invented a whole body counter. Employees were examined regularly.

The AEC Division of Reactor Development funded a special laboratory and a staff for it. This program was very broad and permitted theoretical and experimental studies of the fission products as well as the neutron deficient isotopes produced by bombarding samples in the MTR. This access to the world's highest continuous source of neutrons was just too tempting to resist. But background radiation from weapons tests was a constant annoyance. The solution of that problem was found to be lying on the ground at Central Facilities Area.

We found some thick steel plate that the Navy had left behind from its proving ground days. That stuff was an absolute treasure. It was pre-war steel manufactured before any bomb tests and completely free of man-made radiation. With that we built a special room in which background radiation was reduced to an absolute minimum.[9]

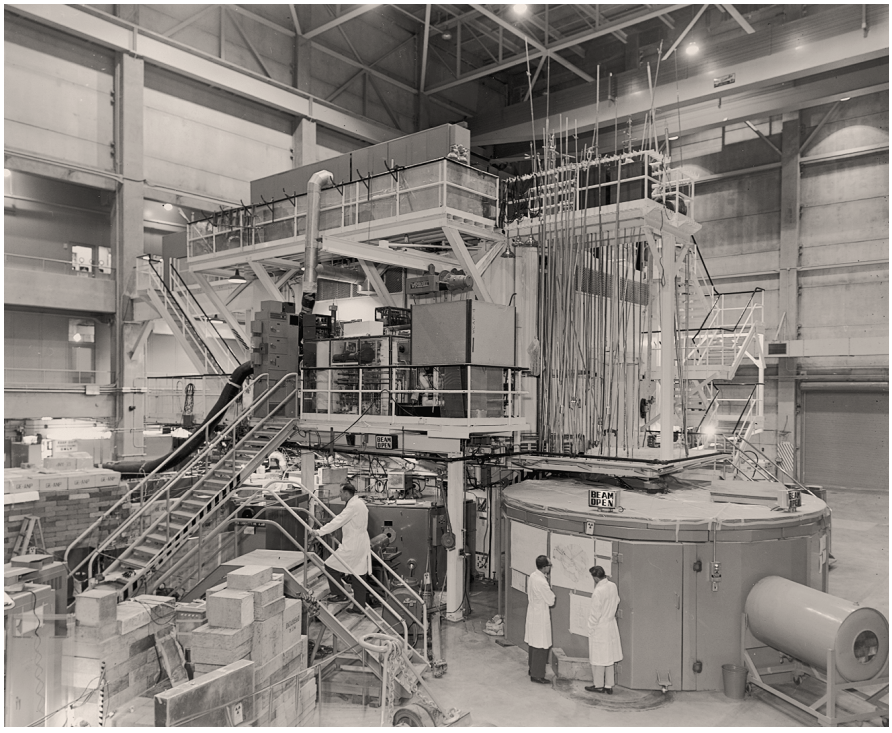
In that special room, physicist Russell Heath led a team of scientists who learned to discriminate among the different energy levels in the radiation being emitted by the several isotopes in the MTR canal water. They also learned the half-life for each and were able then to determine when the damaged fuel element had been placed in the storage canal. Thus, they were able to retrieve it.

Heath went on to standardize the way measurements were made. He prepared a catalog containing the gamma energy spectrum and half-lives of hundreds of radionuclides. Phillips published the first edition in 1958 and several thereafter. The "Blue Book," as the catalog was known, made it possible for researchers elsewhere to profile and identify mysterious elements without spending tedious weeks or months doing so. It was a valuable contribution to the world's store of information about the nature of matter. The catalog continued in use over forty years later.[10]

Another group of physicists under the leadership of Dr. Robert Brugger took full advantage of the MTR's high neutron flux and its beam holes. When unobstructed by shielding, a beam of neutrons streaming out of the reactor was a tool useful for exploring the nature of matter at the level of the nucleus. Although scientists elsewhere had access to spectrometers and other instruments, they did not have access to the neutron flux of the MTR or the availability of hot samples produced within the MTR. The basic idea was to bombard isotopes with neutrons. The atomic nuclei sometimes absorb these neutrons, sometimes bounce them off. Brugger's group studied these interactions and calculated the probabilities for each reaction. This was called "measuring cross-sections," a term originating from the graphic method used to depict the process.

To complicate matters, the probabilities of absorption or scattering are different depending on the energy of the neutrons. The group selected the neutron energy with an instrument called a neutron crystal spectrometer. Another instrument was the fast neutron chopper and time-of-flight spectrometer. Here, it was possible to "chop" the beam of neutrons into pulses as short as a millionth of a second. These pulses would then spread out in time as the neutrons, with different velocities, traveled down a long flight path to the detector array. Whenever the scientists put a sample in the beam, some of the neutrons were removed. From the ratio of the sample-in to sample-out detector signals, the scientists could calculate the total cross section as a function of neutron energy. (This "total" cross section is the sum of the absorption and scattering cross sections.) In the case of samples that scatter the neutrons, the scientists measured the angular distribution of the neutrons and the energy difference between incident and scattered neutrons with a slow neutron velocity selector developed by Dr. Brugger. Brugger also developed a technique to expose samples under millions of atmospheres of pressure to the neutron beams of the MTR.[11]

The work opened a new frontier. No one previously had such access to the exotic radioactive nuclides that the scientists studied at the MTR—or such a team of chemists and physicists making the most of the opportunity. The findings were of incalculable value in the design of reactors. If fertile uranium (or thorium) were to be packed around the



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The MTR is all but hidden by experimental apparatus. Samples are being irradiated through beam port at right. Another port is being prepared for an experiment near stile-like stairway. Boxes contain paraffin and other shielding materials. Rack of handling tools stands ready at balcony level.

core of a reactor, it was essential to know whether the reactor would create more fuel than it consumed and how long the "doubling time" would be. If the process were to take forty years or more, the commercial economics were far less attractive than if the process took, say, fifteen years. Brugger's work meant that reactor designers could select fuels and other materials with some confidence that the reactor would be economically viable. Consequently, scientists from all over the world beat a path to the door of the NRTS.

Phillips scientists made many other moves to expand the capabilities of the MTR. Engineers added a "hydraulic rabbit," which allowed them to run specimens into the reactor without shutting it down. Argonne installed a high-temperature, high-pressure circulating water loop in position HB-2 of the reactor. This permitted a specimen to be exposed to neutron flux along with high-temperature circulating water. The complex apparatus included a heat exchanger, pumps for circulating the water, and the means of regulating temperature, pressure, and other parameters in the water. A Hot Cell Building went into use in the summer of 1954. Operators, shielded behind thick concrete walls and special viewing windows, could handle, photograph, mill, measure, and weigh radioactive samples using remotely operated manipulators.[12]

The AEC authorized Phillips to build a second reactor at the MTR site, the Reactivity Measurement Facility (RMF). Started up in February 1954, this was a small, very low-power reactor located in the east end of the MTR canal. Water was its moderator, reflector, and shield. The RMF used the same kind of fuel assembly as the MTR, but operated only at power levels of one or two hundred watts.

The small reactor, the first of many low-power reactors at the Site, complemented the MTR in that it had a high sensitivity to subtle changes in reactivity. The RMF functioned as a "detector" of neutrons, whereas the large MTR functioned as a "source" of neutrons. The two functions could not be maximized in the same reactor. The RMF enabled analysts to assay new and spent

Right. Technician demonstrates removal of a fuel element from cask. Crane holds lid while worker uses special tool to remove element. Cask held six to eight elements. Below. The MTR canal contained the small Reactivity Measurement Facility, a low-power reactor. The flat plate in front is a boron-aluminum control element. Samples to be measured went into a "water hole," here filled with a plug.

INEEL 55-1989

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fuel and to study reactivity changes in hafnium, zirconium, and other fuel materials as a function of their total irradiation. One of its first operators, Joe W. Henscheid, recalled:[13]

We'd irradiate a small piece of uranium fuel for several days in the MTR, then take it out and quickly insert it in the RMF. Some of the fission products in the hot fuel sample, although relatively short lived, would decay into very high-cross-section neutron absorbers (so-called "neutron poisons"). Reactor designers, especially in the Navy nuclear program, were interested in knowing more about the adverse effect these neutrons could have in power reactors. In the RMF, as these poisons built up, we had to withdraw control rods to keep the reactor critical. This provided a very precise way to track and measure the effect of these poisons. Recall that this was all being done before we had high-speed computers and elaborate computational modeling that now replace such experimental programs.[14]

The spent fuel cooling off in the MTR canal opened up other research opportunities. The fuel emitted gamma rays—the fresher the fuel the stronger the radiation. They had a penetrating power similar to X-rays and could, among other things, kill pathogens. Many industries in America wanted to know if gamma radiation could do something beneficial for their products. The U.S. Army hoped irradiation would improve the safety and shelf life of food. Phillips built a special Gamma Facility and opened it in 1955. The building was placed outside the MTR exclusion area so that industrial scientists without security clearances, who were not allowed near the MTR, could enter the building and do work.[15]

The spent MTR fuel went to the Gamma building in 26,000-pound carriers shielded with lead, steel, concrete, and water. In the Gamma canal, six feet wide and about sixteen feet deep, the fuel rested near the bottom. Operators placed the elements, now referred to as "gamma sources," into cadmium boxes and parked them at safe distances from each other. Experimenters then dipped their samples into the canal at a preselected distance from the fuel element. Depending on how long the sample was to be exposed, its package could be a plastic bag, a can, or a special container with a corrosion-resistant coating. An experimenter could specify the degree of "aging" or "freshness" in the fuel needed for a given test.

Sponsors paid non-profit rates (40 cents per million roentgens plus shipping; $10 minimum charge) and waited their turn on a first-come, first-served basis. They subjected nearly everything imaginable to gamma radiation—meat, grain, fruit, plastics, drugs, coal, gold, diamonds. Hawaii wanted to know if it could improve the shelf life of papayas and mangos and build its export trade. Restless visitors were always on the scene, anxious to learn how gamma rays had changed their product. Typically, the canal contained forty to fifty fuel elements and scores of samples.[16]

INEEL 55-1672

Typical 1955 scene at the Gamma Facility. Sacks of potatoes await experimental irradiation in the canal.

The pressing question in Idaho concerned potatoes. Could irradiation prevent stored potatoes from sprouting? Idaho growers had built their mega-million-dollar industry by learning how to store potatoes for several months, keeping frozen-food plants open profitably long after the glut of the harvest. By the late 1940s, scientists had developed chemical inhibitors to suppress sprouting and other problems for up to nine months. But the goal was a twelve-month industry.[17]

INEEL 57-2619

The University of Idaho owned its own "column" at the Gamma Facility. Walter C. Sparks, one of the researchers at the university's Research and Extension Center at Aberdeen, Idaho, would take ten-pound lots of potatoes, confined in nothing more than open mesh sacks, to the Gamma Facility canal. In an hour's work, he would lean over the railing and lower each sack into the water by means of a long cord. Distance between fuel and potatoes was adjusted for the selected exposure. Some sacks got five minutes, others ten or fifteen. Elsewhere in the canal people might be dunking strawberries or bacon. Sometimes a potato got loose from the sack. Long-handled forceps were handy, and someone would grab the tool and fish for the potato.[18]

INEEL 55-1672

These early experiments demonstrated that irradiation did inhibit sprouting. Another round of experiments in 1963 by the Potato Processors of Idaho demonstrated that irradiated potatoes could be used for satisfactory frozen french fries and some other processed products. However, parallel research with chemical inhibitors had demonstrated that a chemical called CIPC was relatively more simple, required less handling of the potatoes, and presented fewer complications in protecting workers. So the Idaho industry discarded irradiation as the more costly of the two methods despite continuing investigations by competing growers in Canada and Japan into the possibilities of irradiation.[19]

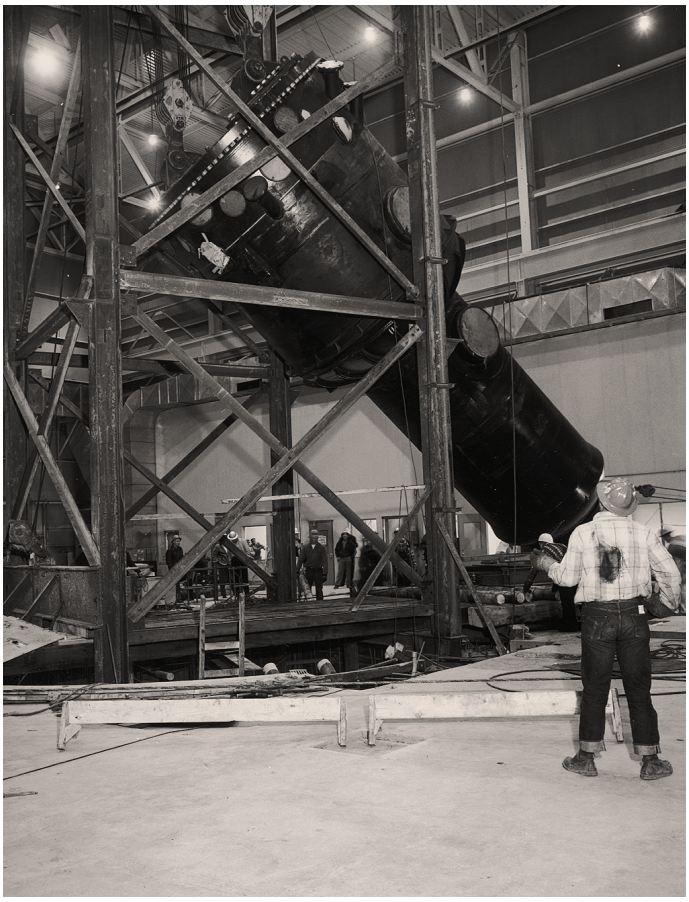
Back at the MTR, the constant cry from customers was "More neutrons! More flux! Faster results!" In response, Phillips modified the reactor to operate safely at forty megawatts. The barrage of questions continued. Will irradiation melt fuel pellets made of this aluminum-uranium alloy? Can we use thulium-170 as a source in medical radiography? Will neutron and gamma radiation improve the coking characteristics of Sewickly coal? How can we design our reactor so it will operate at temperatures of 650 degrees? How will twenty-percent-enriched fuel perform in a high-flux reactor?[20]

Above . A rack of canned food is ready to plunge into a "water column," a rectangular shaft of metal. Air columns also were available. Left. Walter Sparks (in truck) loads up the afternoon's experiment.

Because the MTR itself was an experiment, Phillips tested how well the MTR's own components were holding up. Had the high flux of neutrons caused any structural weakness in the materials within the core area? Using its findings on this and other accumulated experience, Phillips was ready to design the next generation test reactor.[21]

Phillips wanted the next reactor building to have more room on the reactor's operating floor. The MTR work area was crowded with gear, equipment for experiments, and blocks of extra shielding. Office space was in short supply, and people set up desks and work space squatter-like in odd corners, hallways, and at the edges of precious assembly space. The next reactor would have a more generous floor plan.

As for the reactor itself, two of the MTR's chief features—the power level and the test space—were too small. The power level of forty megawatts was too low, unable to produce the concentrated neutron flux required by the military, which was typically on an accelerated schedule. Proposed military applications were pointing in the direction of fuel elements much larger in diameter than the early ones. The test holes in the MTR were no larger than one inch in diameter. "Advanced" research was calling for test holes and loops for thicker and longer elements, more exotic metal alloys, and fuel that would be cooled by gas or air, not only liquid metal or water. These items were simply not going to fit into the MTR. Also, it was difficult in the MTR, if not impossible, to expose the entire length of longer samples to a uniform flux.



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ETR reactor vessel being raised to vertical position during construction in 1956.

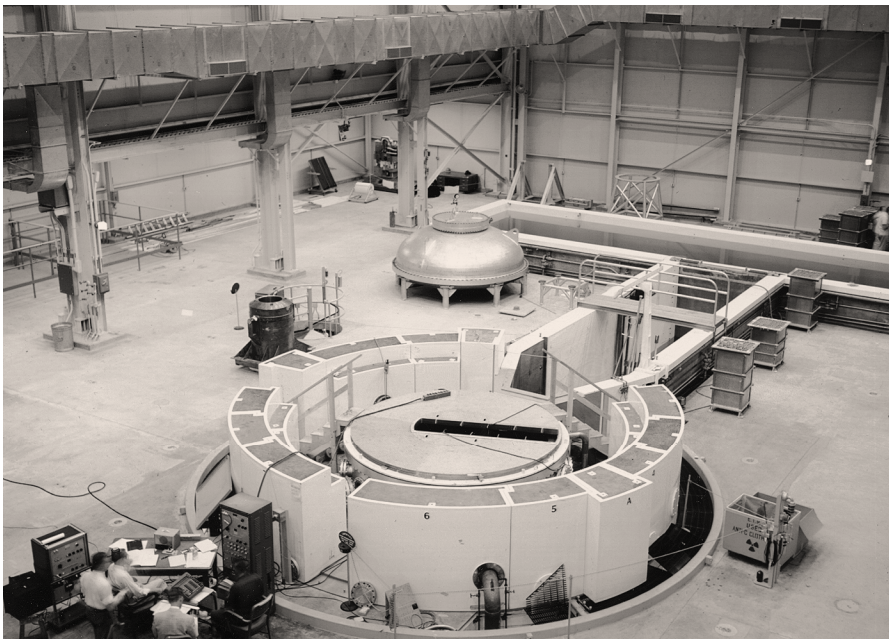
At the same time, demands for low-flux irradiation in the MTR's graphite zone were in less and less demand. That part of the reactor was becoming obsolete. By the end of the 1950s, these zones were used mainly as a place to park cobalt and other isotopes requested for medical uses, a function that reactors elsewhere in the country could perform as well as the MTR.[22]

Thus in 1954, the Phillips team was developing the next test reactor, named the Engineering Test Reactor (ETR). After the AEC approved Phillips' concept, Kaiser Engineers finished the design and built it. General Electric designed the reactor core and its controls. From design to completion, the project took only two years. Like the MTR, the ETR reactor was water-cooled. Unlike the MTR, its control rods were driven through the core from below the reactor, not from above. This arrangement left the area above the reactor available for experiments.[23]

Aside from its higher power level of 175 megawatts, the big change with the ETR was that the samples could be placed directly into the core of the reactor, not just next to it, as with the MTR. The MTR operating experience had indicated that this would be safe and effective.

The ETR fuel was arranged in a rectangular grid with holes here and there for insertion of loops and capsules. Many of the ETR holes were large enough to contain entire fuel elements, not just samples, and the experiments could operate with their own cooling systems independent of the reactor's own cooling system. Like the MTR, the ETR had a companion low-power reactor, the ETR Critical Facility (ETRC), in which the power-perturbing qualities of proposed experiments could be measured safely in advance before being tested in the ETR.

The ETR generated a neutron flux four times greater than the MTR. It went critical for the first time on September 19, 1957. It would serve many of the MTR's old customers, including the U.S. Navy, but the new kid on the NRTS block was the U.S. Air Force, and many of the special ETR loops had been designed to test the fuels required for a special airplane.[24]



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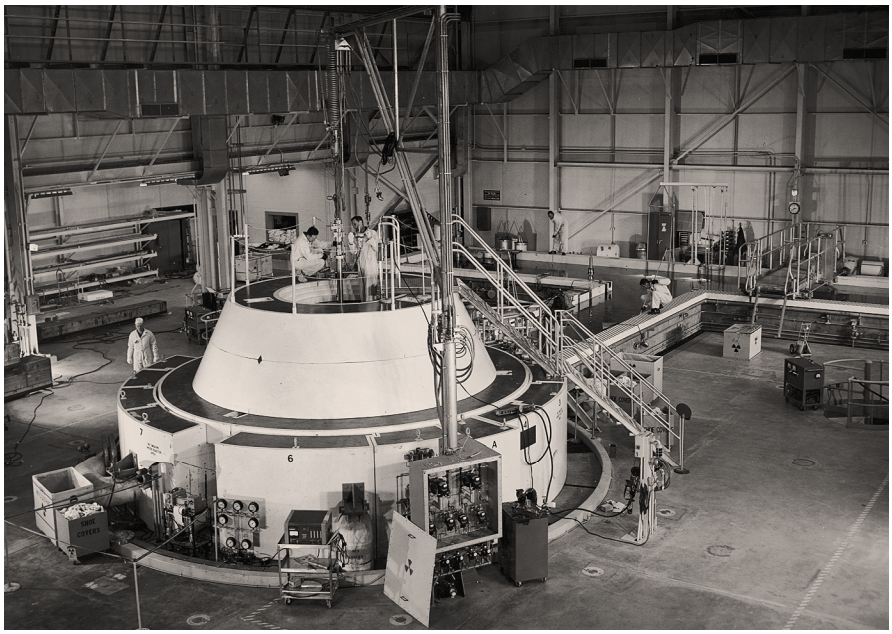

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Above. The ETR being assembled, top removed. Fuel elements were lifted from reactor core and sent through a chute into the canal—all under shielding water. This improved safety and convenience over MTR methods.
Below. The ETR with experiments in progress.

The Noble Sky

Oh come with me
to watch the first RADON
When the stars ARGON
As the day KRYPTON
And if the morn be cloudy
You won't ZENON.

MTR shift supervisor's log:
May 6, 1952

Chapter Thirteen

The Triumph of Political Gravity Over Nuclear Flight

If everything had worked out perfectly, it still would have been a bum airplane.

–Charles Wilson, Secretary of Defense–

When IDO HPs understood that the NRTS was going to be home base for a nuclear-powered airplane, they researched the hazards this might bring to the desert. Test aircraft, they found, crashed most typically on takeoff or landing. What would happen to the nuclear fuel in a crash involving fire, and what kind of emergency response would be needed? In 1957 Dr. Victor Beard, IDO director of Health and Safety at the time, organized a pair of Fuel Element Burn Tests, soon dubbed by the participants as Operation Wiener Roast. John Horan, Beard's successor, was then working at the NRF and observed the tests. He recalled how Beard obtained a well-aged MTR fuel element for an experiment.

The key idea was to burn it. For the first test, a pool of [jet fuel] was used (500 gallons, I think) and part of an aluminum fuselage...The element was suspended directly over the center of the fuel and then [the fuel was] ignited. This was done at Test Grid No. III out on Lincoln Boulevard...The Y axis was a few miles east of NRF...and highly instrumented.

Movie cameras were operating [when] they set the thing on fire. Basically, there was no release. That was Wiener Roast No. 1...[The fuel reached a temperature of 2,250 degrees F., but after the fire burned two hours, the element was essentially intact.]

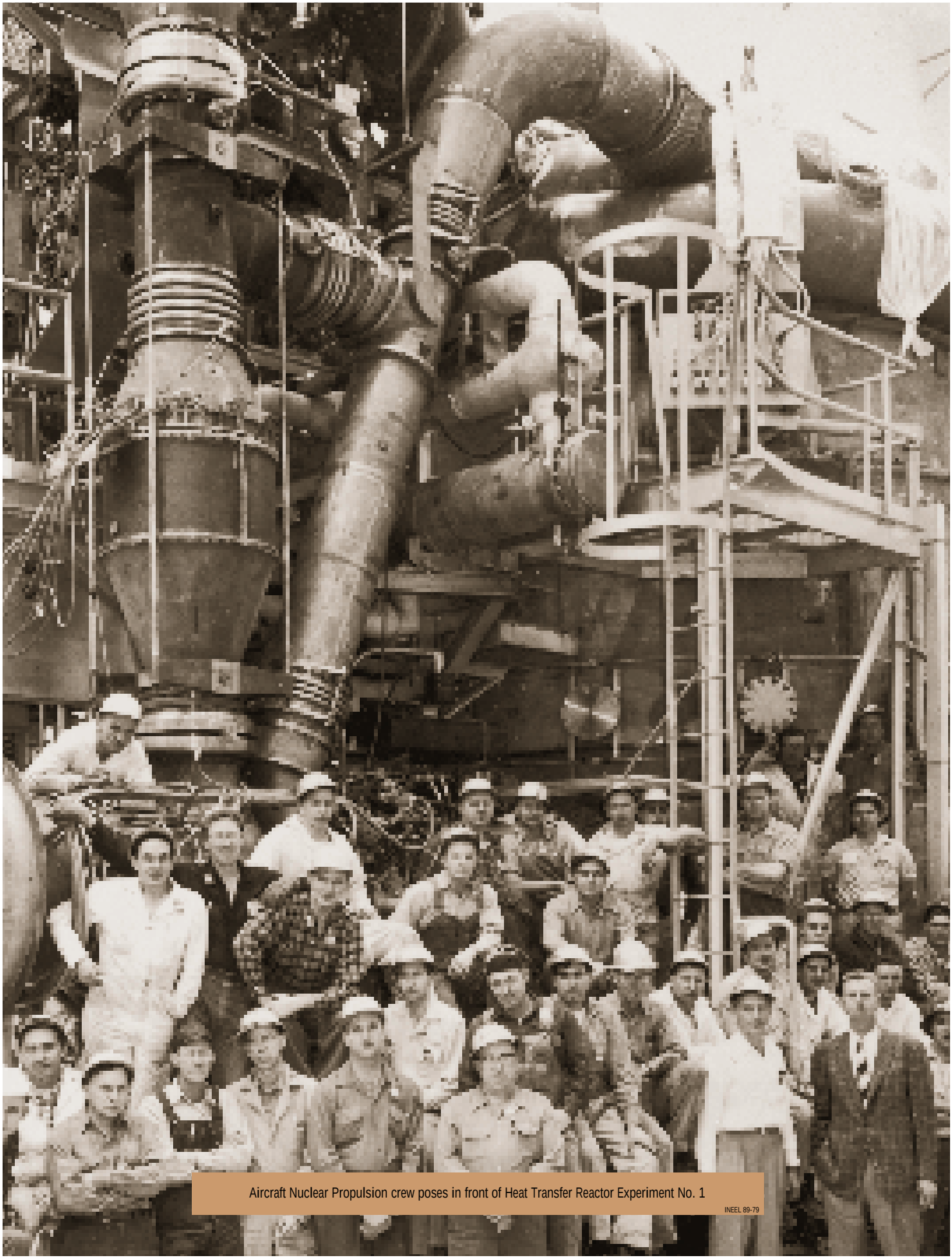
INEEL 57-1305

Operation Wiener Roast

The second time, they used an induction furnace to supply higher heat to the fuel element. This time, success. A release [was attained. The fuel melted within ninety seconds.] When I returned to NRF, the security guard told me we had an alarm on the portal monitor. I associated it with the Wiener Roast release. I took a sample from our continuous air monitor. It turned out to be cesium-137. At eight p.m. I called Beard at home and told him the cloud came over the NRF. He said, "Impossible."

The cloud had gone out on the grid. The weather changed, a shear had come in and it went back over NRF. It was barely detectable over background, so there were no health concerns.[1]

Elsewhere at the NRTS, preparations for the project were somewhat more prosaic. Bill Johnston had informed



Aircraft Nuclear Propulsion crew poses in front of Heat Transfer Reactor Experiment No. 1

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INEEL 57-4927

Allan C. Johnson

southeast Idaho in July 1952 that a nuclear airplane station was coming. Soon he and his staff, particularly Allan C. Johnson, his director of Engineering and Construction, were calling for bids on new roads, wells, power lines, a substation, and finally for construction of a huge assembly complex and a test pad. The project was called the Aircraft Nuclear Propulsion (ANP) Program.[2]

The program brought a substantial burst of growth to the NRTS, occurring just as construction payrolls for the first three reactors and the CPP had diminished. The airplane station would employ a thousand laborers. When Bill Johnston left the NRTS in the spring of 1954, the AEC appointed Allan Johnson, who was well into the swing of things, as the new manager.

Allan Johnson had been an NRTS pioneer, in charge of construction since July 1949. An architect by training, he had earned a year of post-graduate work at Princeton University by winning a national design competition in 1937. With the Corps of Engineers during the war, he had run the Washington office of the Manhattan District. After that he joined a New York company primarily concerned with the design of hospitals.[3]

Johnson had been recruited to Idaho, done well, and now it was his turn to cope with a see-saw situation in Washington. Fortunately, he could be just as smooth with Congressional representatives as was his predecessor Bill Johnston. This time, the waffling about policy wasn't confined within the AEC family but involved a huge array of conflicting interests at the center of national power.[4]

The main issue was the timing and structure of the project. The Air Force even in 1947 insisted that it would take only five years to transform paper plans into an actual demonstration of nuclear flight. "Fly early!" was its theme. The physicists who knew what there was to know about reactor development at the time, including J. Robert Oppenheimer, felt that such a schedule—and perhaps the idea of nuclear flight itself—bordered on lunacy. They proposed that an orderly technical program be integrated into the rest of the AEC's reactor research, where high-temperature materials would evolve in due course. The state of reactor physics and materials science was then far too primitive. Applied research should come before any flight plans.[5]

To help settle the matter, a group of experts convened at MIT in 1948 to evaluate the feasibility of the airplane project. Known as the Lexington Project, the group predicted that the project would consume at least a billion dollars and fifteen years before all of the theoretical problems were solved and an airplane flew. It also noted that in fifteen years guided missiles might make an atom-powered bomber obsolete.

Instead of drawing together, the antagonists each emphasized different parts of the Lexington Report. The Air Force liked the sentence saying there was "a strong probability that some version of nuclear-powered flight can be achieved." The scientists and budget managers pointed out the report's warning: "It is to be expected that crashes may occur, and the site of a crash will be uninhabitable."[6]

The Air Force forged the political alliances needed to overrule the scientists. It was a poor start for a complicated project, because the scientists also had their allies, and the two sides remained in a state of tension throughout the 1950s. The Air Force team included the airplane manufacturers and the members of the JCAE. The scientists'allies were the Bureau of the Budget and Eisenhower's Secretary of Defense, each of which, for its own reasons, tried to keep military budgets under control.

Throughout the 1950s, one or the other side in this conflict was ascendant in Washington, and neither side remained in the saddle for long. Therefore, the specific objectives of the ANP mission

changed frequently. In the field, scientists complained that this was no way to run a technical program. Money either flowed copiously from Washington or it dribbled out, choked and stinted. Idaho supporters of the NRTS observed this and learned a valuable lesson.

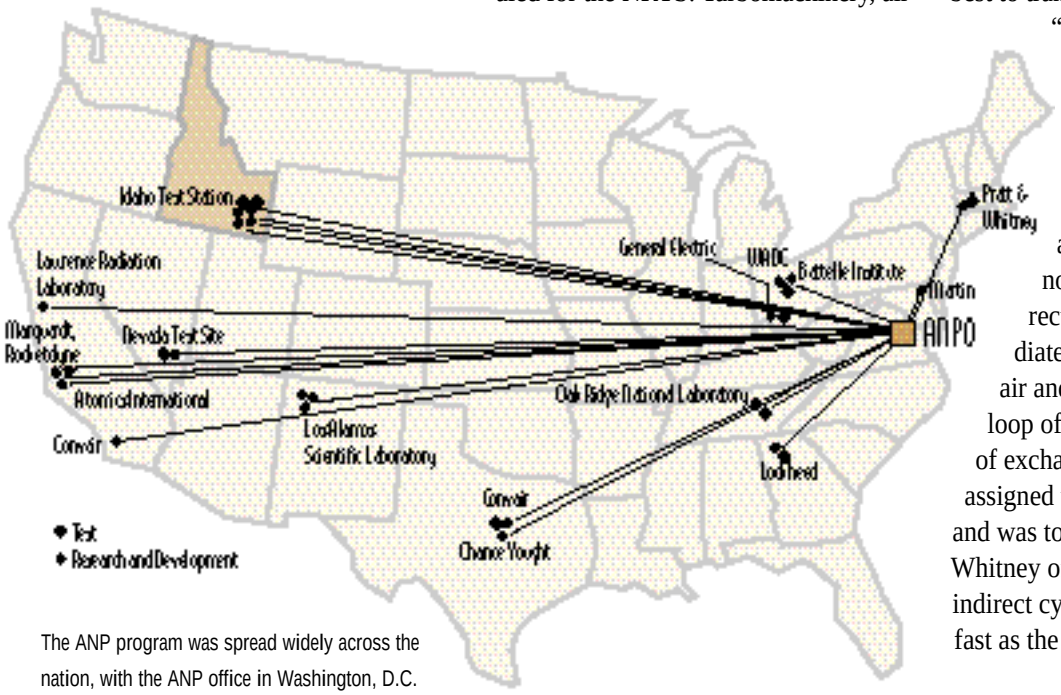
One of the policy shuffles occurred in 1953. Rumors reached Idaho Falls in May that the AEC was preparing to suspend the program and reduce its budget in Idaho. The AEC was now spending millions of dollars a year in Idaho and was fast becoming the largest employer in the state. Fat construction payrolls were extra fodder for the growth machine. Retrenchment was unthinkable.

The program survived, but in the face of the airplane's shiftable fortunes, the political and economic leaders in southeast Idaho now realized that the NRTS could shrink as well as grow. Old 1949 views that AEC decisions were based purely on technical grounds were thoroughly discredited. To defend and nurture its federal growth machine, the region needed an insider. Idaho needed representation on the JCAE itself. Idaho senator Henry Dworshak looked for his chance and wrote, with some understatement, to a senate colleague in 1956 that "there is sentiment in my state for me to sit on the Joint Committee on Atomic Energy." Upon his appointment, southeast Idaho was well pleased.[7]

Not all the Washington money for the ANP program was spent in Idaho. Pieces of the project were flung all over the nation. Engineers had conceived two approaches for the airplane's propulsion system, and only the ground tests for one approach were scheduled for the NRTS. Turbomachinery, airframe, shielding, and other studies took place in many other states.

In a conventional airplane, the combustion of chemical fuel produces heat. Hot compressed air passes through a turbine and is exhausted through an opening (nozzle) at the rear of the aircraft, providing thrust in the opposite direction. The function of a nuclear reactor was to produce heat, replacing the combustion chamber. It would have to fit within an airframe and generate extremely high temperatures. Shielding to protect the crew had to weigh as little as possible, or the plane couldn't get off the ground. The reactor and turbomachinery materials had to perform reliably amidst extreme heat, compression, and stress.

Akey engineering problem was how best to transfer the heat to the air. In the "direct cycle" approach, compressed air would flow through the reactor and absorb heat directly from the fuel elements. It would then pass through the turbine and be expelled through the nozzle. By contrast, the "indirect cycle" provided an intermediate heat exchanger between the air and the reactor, using a closed loop of liquid metal as the medium of exchange. The direct cycle was assigned to General Electric in 1951 and was to be tested in Idaho. (Pratt & Whitney of Massachusetts undertook the indirect cycle, which didn't progress as fast as the direct cycle testing.)[8]



The ANP program was spread widely across the nation, with the ANP office in Washington, D.C.

GE built a huge laboratory for the project in Evendale, Ohio, where it designed the reactor and the experiments that would run in the remoteness of Idaho. A new set of home-lab scientists began traveling to Idaho Falls, sometimes on a C-54 aircraft officially called "Site Flight" and unofficially, "Slite Fright."[9]

Courtesy of Wright-Patterson Air Force Base

Major General Donald Keirn

Donald Keirn, the earliest promoter of the project, was now a major general and the director of the program. He sent Air Force liaison officers to each field laboratory, including Idaho, to monitor progress. The Air Force desired to be as independent of its NRTS landlord as possible and declined to use most of the IDO's central services. Autonomy was important. Secrecy was important. Planners wanted plenty of room to expand. They would need to build a runway, for example. Although the purpose of the project was known to the public, the goal was to produce a weapons delivery system. Technical work was classified. GE wanted to be as distant from everyone else at the NRTS as possible. GE manned its own fire station, provided its own food service, supplied its own security force, and built its own fabrication shops and health physics labs.[10]

INEEL 57-1780

The IET in 1957. The reactor-jet engine assembly was sheltered in the mobile aluminum building. Exhaust went through the horizontal pipe to the stack. The control building is buried under earth shielding.

So the IDO opened up Test Area North (TAN), thirty miles northeast of Central. Lincoln Boulevard cut a new ribbon of asphalt across the desert, and State Highway 33 connecting Arco, TAN, Mud Lake, Terreton, and Rexburg took on new importance. The first phase of the project was called Initial Engine Test (IET), and the mission was simple: prove that nuclear heat could run a turbojet engine. The tests involved a modified J-47 engine, but no airplane and no flight.

The big difference between this reactor and all the other reactors then at the NRTS was that it was mobile. Contaminated air could not be allowed to blow out the nozzle indoors—or near work areas. Rather, the reactor-*cum*-engine traveled back and forth between an assembly area and the test pad, a distance of a mile and a half. A man driving a shielded locomotive hauled a dolly carrying the eighty-ton assembly on four-rail tracks. At the test pad, the engine connected to a "coupling station" where the exhaust was filtered, went up a 150-foot stack, and was released to the open air.

After the first test, the test engine assembly would become a mobile radioactive hazard. This situation called for a new safety philosophy: place the shielding around people rather than around the reactor. Thus, the IET control-room building and its entrance were well shielded. Near the test pad,

the control room was an elaborate bunker, its walls and ceilings made of thick reinforced concrete and covered with earth. Remote-control techniques connected dials and switches to leads for fuel, air, water, electricity, and monitoring devices.[11]

The first Heat Transfer Reactor Experiment (HTRE-1), "Heater One" in informal parlance, proved it could go critical on November 4, 1955, not yet attached to an engine. The enriched uranium fuel was clad with nickel-chromium. Water was the moderator and coolant. The engineers made no attempt to restrict the size or weight of the assembly or to approximate a flight version. The assembly was deliberately large so that crews could easily install monitoring devices and instrumentation.[12]

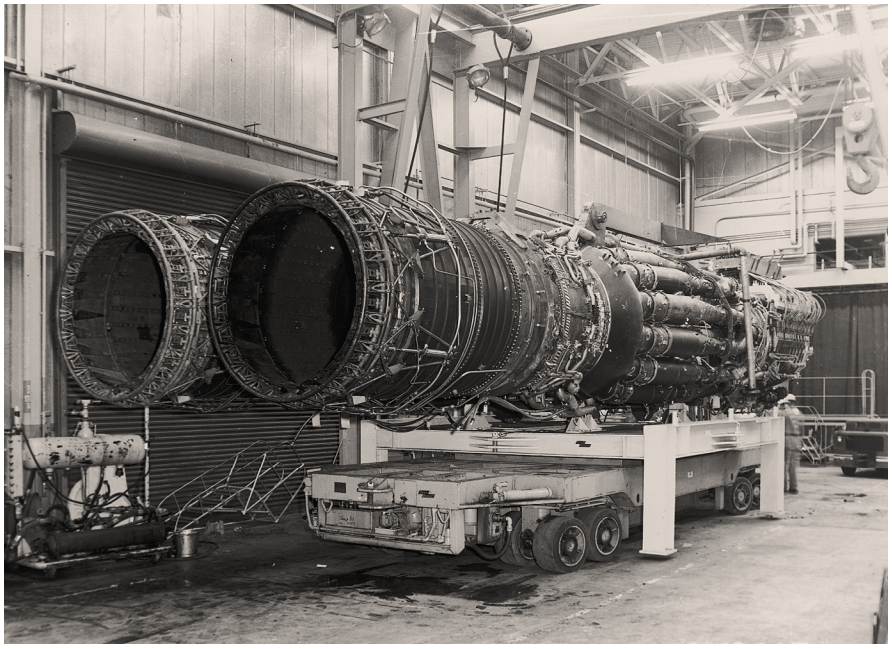
On December 30, 1955, HTRE-1 sat on its dolly at the test pad. The locomotive driver had taken cover. Inside the bunker, the scientists had checked and double-checked all systems. The engine began operating on chemical fuel. Operators gradually withdrew the control rods, taking the reactor critical. As the temperature rose, an automatic sensor closed the chemical fuel valve. The contraption worked. For the first time in the world, the heat of fissioning uranium alone powered an airplane engine. The GE test team had proven the principle. They cheered each other, buttoned up, and went off to celebrate at the nearest bar, which was ten miles away at Mud Lake.[13]

The test results went out to the rest of the ANP network. The reactor had produced more gamma radiation than expected. Oak Ridge, the scene of the major shielding research, considered the implications: additional shield weight would have to burden the aircraft unless ways could be found to reduce it. Experimentation with the HTRE-1 reactor, its fuel, and the engines continued. With this initial success, it was reasonable to plan the next phase of the Idaho program: an airplane hangar, a runway, and most obviously, an airplane.[14]

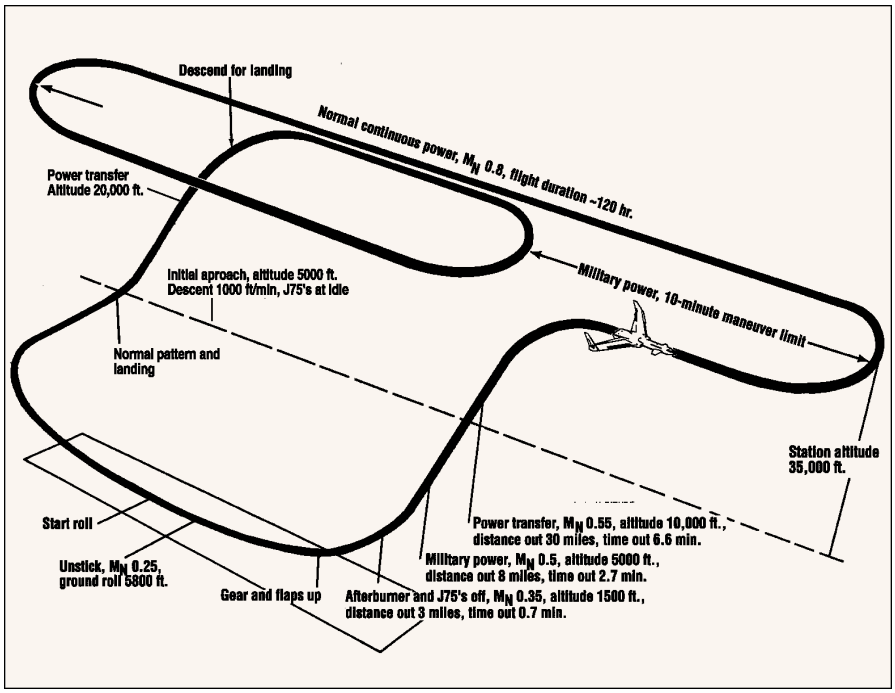
GE and the Air Force were imagining war-time scenarios: Suppose the bomber penetrates enemy territory and drops its payload of atomic bombs. Perhaps it takes a hit. Crippled, trailing contaminated exhaust, it nears the United States. What was the best route to Idaho? GE's chief HP, Carl Gamertsfelder, considered the implications.

INEEL 55-73

Right. TAN Hot Shop just after completion in 1955 and before operation began. Below. Jet engine before assembly with reactor.

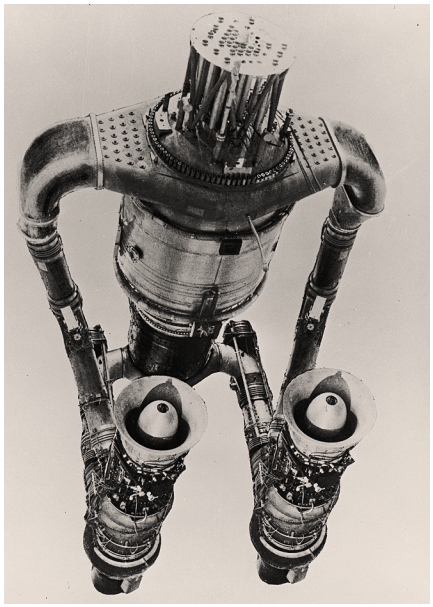


Courtesy of General Electric Aircraft Engines Division



APEX-901

Above. Typical mission profile envisaged by U.S. Air Force for a nuclear-powered aircraft flight. Below. HTRE-3 components: reactor shield, single chemical combustor mounted behind the reactor-shield assembly, two modified J-47 turbojet engines, and interconnecting ducting.



Courtesy of General Electric Aircraft Engines Division

The mission was...to fly [reconnais - sance] around Russia... If necessary, they would come in, dive down low, deliver a few bombs in strategic spots and leave. And then come back [to the American coast], turn off the reactors [to] let them cool off some, and fly through a corridor [on chemical fuel] back to our site.

We looked at population densities along the [possible corridor routes]. The air - plane would have been escorted in [and] escorted out. [If it crashed] we would have been able to dump tons and tons of foam, things of that kind... This was during the Cold War. People were serious.[15]

During 1955 and 1956, the Air Force was ascendant once more in Washington, so "Fly early" was the order of the day. If for no other reason than to invent and rehearse the procedures on the ground when an airplane returned from its mission, GE needed a special hangar—a Flight Engine Test (FET) facility. The power plant inside the airplane, crippled or not, would somehow have to be removed from the airframe and taken to GE's huge Hot Shop, disassembled and studied, repaired or replaced. Hangar crews would have to handle the ordinary maintenance of a hot airplane, not only its nuclear features. Such problems as extracting crew members from their shielded cockpit without exposing them to a gamma field had to be solved. Nothing about nuclear flight could be taken for granted. Money flowed, and NRTS construction payrolls bulged again.[16]

Meanwhile, HTRE experiments contin - ued, but reactor fuel and materials had a long way to go. GE wanted to irradi - ate fuel elements in the MTR, but they were too large to fit in the MTR's test holes and the ETR was not yet ready. So GE retooled the HTRE as a materi - als test reactor. Machinists drilled a hexagonal space in the center of the reactor. GE called it HTRE-2. The hole was a generous eleven inches wide across the sides of the hexagon. Physicists inserted various metals and fuel elements, subjecting them to neu - tron flux and temperatures up to 2,800 degrees F. for sustained periods of time. Their work moved high-heat reactor materials into the realm of ceramics.

Moving closer to its flight objective, GE built a completely new experiment. HTRE-3 operated between September 1959 and December 1960. The engines and the reactor were arranged horizontally, more typical of an aircraft, and had a flight-type shield. The reactor vessel was double-walled, with a gap of about seven inches between the two walls. When the reactor was running, operators filled the space between the two walls (the annulus) with water, which acted as a moderator and a shield. Richard Meservey, an instrumentation engineer, recalled how the operators managed to conduct numerous tests in fairly rapid order.

As soon as a test was finished, they drained the water from the annulus and pumped the space full of mercury. Mercury is a high-density material, and it made a great shield. It allowed the workers to climb back up on the assembly sooner to change out the instrumentation or make other adjustments. The mercury reduced their exposure. They didn't have to wait for the short-lived isotopes to decay away. As soon as they were finished changing the instruments, they would drain out the mercury and pump water back in. Then they'd haul the reactor back down the track to the coupling station and run another test. We had three-quarters of the free world's supply of mercury here at the Site at one time. We had so much, that when the program was over, we had to release it slowly back on the market so that it wouldn't cause an economic upheaval. It wasn't radioactive because the mercury wasn't in the annulus when the reactor was running, so it wasn't irradiated.[17]

The HTRE-3 experiments eventually ran two turbojet engines at a time at 2,000 degrees F. In December 1960, the experiments hit another milestone when the reactor started the engines without the help of any chemical fuel at all.[18]

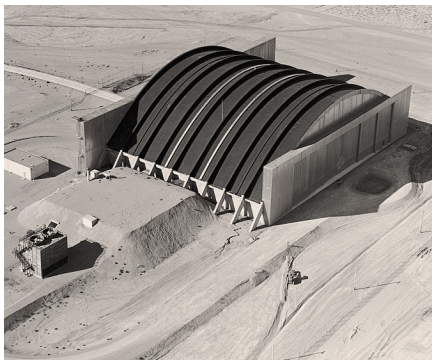
All GE tests involved IDO's Health and Safety personnel because the exhaust releases affected territory beyond the GE fence. Each time the jets operated, argon and other constituents of the air passing through the reactor became radioactive. Fuel elements occasionally ruptured or melted, discharging fission products. Some tests imitated accidents by deliberately blocking the flow of air to fuel elements, which also caused releases. The HPs collaborated with the U.S. Weather Bureau and defined the meteorological conditions under which each test could run. The Air Force chafed under this regimen and regarded John Horan, Dr. Beard's successor, as far too conservative. Horan recalled:

INEEL13245

INEEL 12139

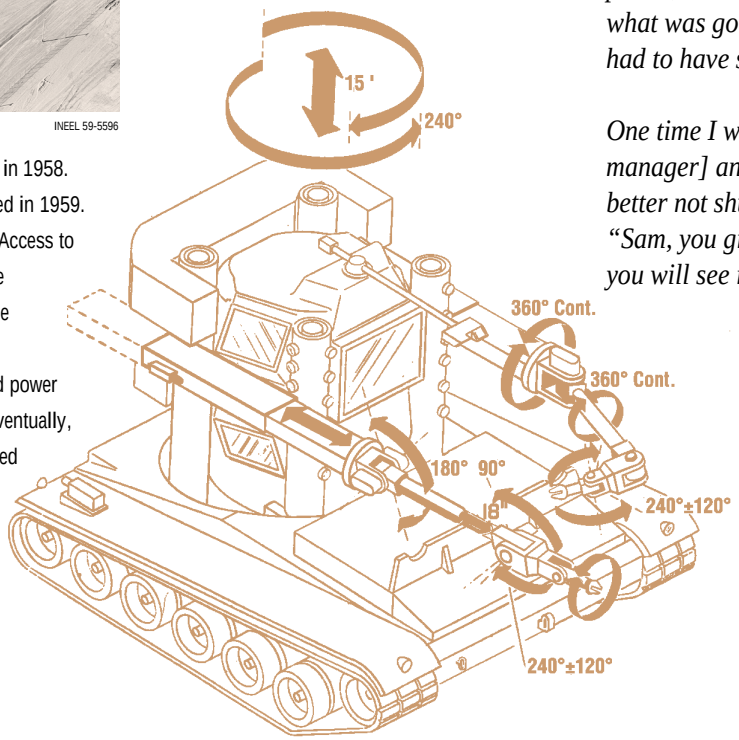
Above right. Shielded locomotive with turntable in background. Snow plow in front. Right. Looking east past the railroad turntable toward doors of ANP Assembly and Maintenance Building.

INEEL 59-5596



INEEL 59-5596

Above. The hangar under construction in 1958. Middle. The hangar as it was completed in 1959. Control building is shielded by earth. Access to it was via a shielded tunnel. Right. The "Beetle." This manned, shielded vehicle was designed for use in the hangar. Its purpose was to remove the reactor and power plants from the aircraft mockup, and eventually, from an actual aircraft. It was never used in Idaho, but moved to the nuclear rocket program.



We had a captain from the Air Force out there [at TAN] in charge, and peri - odically he would call me in town when we would not allow them to start up [because] the meteorology wasn't right for them to be running. He would...say, "I'm sitting here in my office looking out and the flag is in the right direction and it is standing straight out and exactly meeting your conditions."

I'd reply, "I'm sorry, but that is not the situation at 150 feet, where the effluent will be released."

The Air Force appealed unsuccessfully to the AEC operations office at Cincinnati for relief. Horan continued:

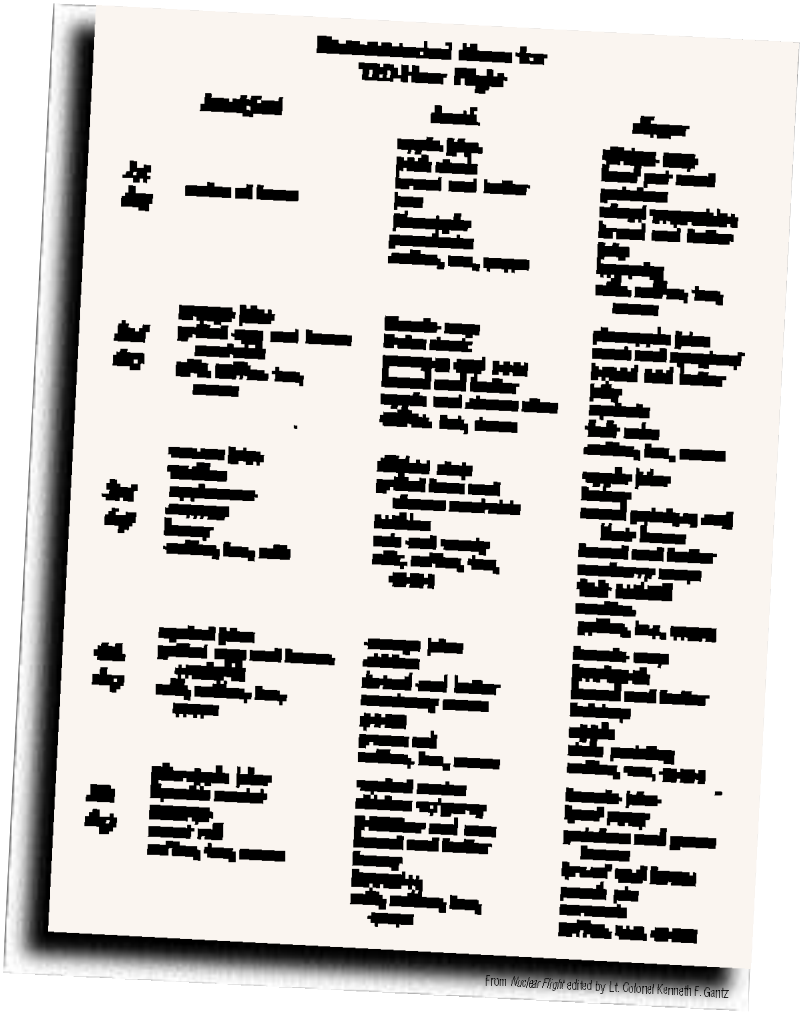
We told GE that they couldn't plan on using their full 500 mR exposure off-site. We said, "You're allowed ten per - cent [of that]." To the public, the NRTS was one site, and we interfaced with the public, not Cincinnati. We had to know what was going up the stacks, and we had to have shutdown authority.

One time I was in the office [of the GE manager] and he said, "By God, you better not shut us down." And I said, "Sam, you give us a reason to do it, and you will see it'll be done."[19]

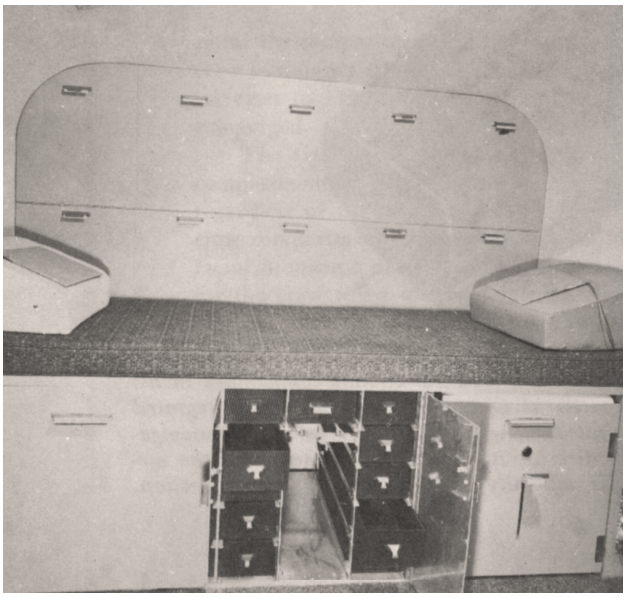
The $8 million hangar was finished in July 1959. The graceful barrel-vaulted building had a clear space of 320 feet by 234 feet. The designers figured the plane would weigh at least 600,000 pounds. It would reach 135 feet from wing tip to wing tip, be 205 feet long and 53 feet high or higher at the tail.[20]

Plans for the runway showed a strip 23,000-feet long—over four miles. Perhaps survey stakes went into the ground, but GE never built it. The AEC decided in December 1958 that neither the NRTS nor any other AEC installation would be used for an ANPflight test site. Despite the millions invested in the hangar building and its shielded control room, the wasted money was "more than outweighed by the potential risks involved." The AEC told the Air Force that nuclear test flights would have to originate from an island or coastal station and fly only over the ocean.[21]

Still, in 1960 the Air Force was confident that the hangar would be used for a prototype aircraft. It could be ground-tested in Idaho before it was hauled overland to a coastal base for flight tests. In Evendale, GE mocked up a compartment for a five-person bomber crew: commander, nuclear engineer, bombardier-navigator, defense director, and co-pilot. Located far forward in the airplane as distant as possible from the reactor, the shielded cabin contained a kitchen, work room, and sleeping quarters so detailed that they included a ventilated drawer for stuffing dirty underwear. Dietitians planned a nutritious five-day menu down to the peach pie for the fifth-day dessert.[22]



From *Nuclear Flight* edited by Lt. Colonel Kenneth F. Gantz



From Nuclear Flight edited by Lt. Colonel Kenneth F. Gantz

Above. Design of crew compartment for airplane took place in Evendale. Sleeping, storage, and relief facilities are integrated in a 36-sq.-ft. space. Two full-size beds permit simultaneous sleeping of two crewmen. Clothing and personal articles are stored in individual lockers above the bed. Right are containers for soiled clothing. The pull-out electric incinerator toilet is at the lower right and the second bed, a pull-out berth, is at the lower left.

The Idaho hangar reflected equal attention to detail. The shielded locomotive would tow the airplane inside on the four-rail track. Using remote controls from a bunker next door, operators would draw the plane abreast of a coupling station similar to the one at the test pad. The crew would slip from the cockpit through a hatch shielded with lead bricks and descend to the basement below. They would make their way through a maze of tunnels to a changing room, shed their contaminated clothing, shower, and submit to medical examinations and mission debriefings. Eventually, they would emerge in the control room. Back on the hangar floor, remote manipulations would lower the entire power plant to the floor of a platform elevator and it too would go below, its first stop before remote transport to the Hot Shop. A shielded window gave visual access into the hangar, and a side door leading to the control room was protected against accidental explosions or criticalities by a "shadow shield," a concrete barrier four feet thick intended to block gamma radiation from passing into the control room hallway.[23]

In January 1961 John F. Kennedy became president. Eisenhower already had suggested that either the direct or indirect approach to the airplane be canceled, greatly alarming the ANP corner of the "military-industrial complex." He never said which approach, and everyone expected Kennedy to make the choice.[24]

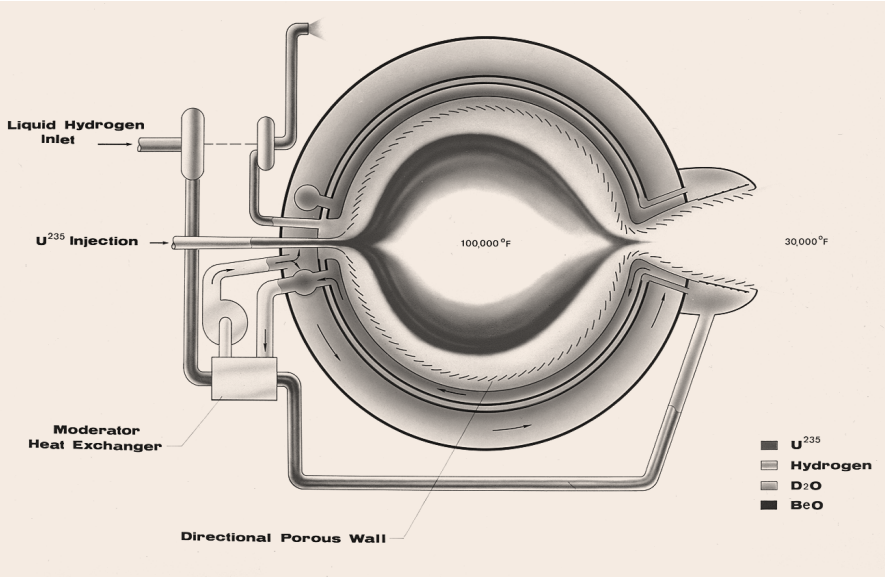
It had been fifteen years since the end of World War II, and as the Lexington Report had predicted, $1 billion had been spent on the project. But the airplane had not materialized. Supporters said reactor experiments were "on the threshold" of significant new progress; all the program needed was "less than one-fifth of one billion dollars" and a plane could fly in 1963. At the same time, the range and accuracy of guided missiles had greatly improved.[25]

The JCAE still felt the sting of Sputnik, the Soviet Union's successful September 1957 launch of the first satellite to circle the globe. Putting an atomic plane into the air before the Soviets could do so offered great psychological appeal. The JCAE was under no illusion that the promised 1963 airplane would be combat worthy. It would be a slow-flying subsonic showpiece with no function but to be the first.[26]

But the old coalition of doubters had heard such promises before, and they had the ear of the new president. Besides, Kennedy had ideas of his own. Eisenhower's years of budget cutting had eroded conventional defense capability to the point that the Army had only eleven combat-ready divisions, a shortage of ammunition, and low airlift capacity. In order to provide tactical air support for the Army, the Air Force admitted it would have to borrow ordnance from the Navy. Kennedy wanted more flexibility to take the initiative, realizing that a Third World existed, where the struggle against communism required political and economic initiatives. The nation needed a capacity to make limited responses—more missile-firing Polaris submarines, more Minuteman rockets, more guerrilla-warfare capability—not just a massive atomic arsenal.[27]

On March 28, 1961, Kennedy canceled the entire airplane project, saying, "the possibility of a militarily useful aircraft in the foreseeable future is still very remote..." He also canceled the Army's Nike-Zeus anti-missile missile and the Air Force's B-70 bomber, both unproven technologies.[28]

Kennedy made the cancellation effective instantly. Stunned, southeast Idaho flooded Senator Henry Dworshak with telegrams. Idaho Governor Robert Smylie wrote directly to President Kennedy, warning him that the loss of ANP's 500 jobs would be a blow to Idaho of "disastrous proportions" and



INEEL 71-3705

Above. Gas-core nuclear rocket concept. Uranium-235 gas is in the center like a bubble. Hydrogen flows around the uranium, heats up, and exits the core through a small opening, providing thrust.

asked for some replacement research that would keep the jobs in Idaho.[29]

At TAN, the Idaho Falls *Post-Register* reported, employees were "thunderstruck." One of them was Jay Kunze, an ANP physicist and engineer.[30]

There were employee meetings, and the word got out immediately. I was shocked. I had started with GE in 1959 and had a new baby and a new house. Now I was out of a job! I was scared stiff. But GE had a history of never laying off an engineer. The company kept about a hundred of us in Idaho...and sent others to San Jose or GE facilities elsewhere.

Eventually, we got into space electric power and worked on a thermionic reactor, in which the fuel elements were thermionic cells. The fuel gave off electrons to supply heat. Then Phillips experimented with the "710," a high-temperature reactor for rocket propulsion. The concept never went into operation.

Later, we investigated another concept for NASA rocket propulsion. This was for a manned mission to Mars. NASA hoped that a one-year mission to Mars using chemical fuel could be reduced to three months on nuclear fuel. It was a cavity reactor, a sphere about twelve inches in diameter. In the center was the fuel, uranium hexafluoride, which above room temperature, is a gas. Hydrogen would flow around the chain reaction in the fuel, heat up to temperatures up to 20,000 degrees F. and exit through a small nozzle, providing thrust.[31]

Thus, some replacement research came to Idaho. The new work made some use of TAN's empire of buildings. The hangar had never been used. The government had poured over $41 million into the Idaho ANP buildings and facilities through 1961. NASA put on hold its plans for a manned mission to Mars, so the Cavity Reactor and the other space-related reactors were shut down in the early 1970s. The vacant TAN facilities went up for rent, a testimonial that the NRTS, no matter how brilliant its scientists and engineers, could not control its destiny when the political winds of Washington blew across the desert.[32]

Chapter Fourteen

Imagining the Worst

The reactor must also function during startup and shutdown or load change and must be able to scram safely under a variety of postulated malfunctions.

–Nucleonics, 1960–

It isn't clear just when the word "excursion" migrated into the daily vocabulary of nuclear scientists. Among non-nuclear people, the word evokes picnics in the park and leisurely drives in the country. Reactor scientists appropriated the word to describe a potentially deadly hazard.

Among the early preoccupations of NRTS scientists was to imagine what kinds of accidents might endanger people—and then to minimize the chances of accidents. If power plants were to generate electricity, they would most likely be located near populated areas. For the sake of the population and the future of the nuclear power industry both, the plants had to operate safely.

An excursion is a sudden increase in the power level of a reactor. All of the reactor's accessories—the vessel that contains the fuel, the pumps that circulate the coolant, the control rods and the machines that move them in and out—are designed with an expectation that the reactor will not run hotter than a certain temperature. Removing heat is the single most important way to keep the reactor safe. It is possible for the accessories to be working well, but something within the core of the reactor—a badly-made fuel element, perhaps, or impurities in the coolant—can affect the rate at which the uranium atoms are fissioning. Instead of splitting at a certain rate per second, the atoms split at twice that rate, or four times. If unchecked, such an "excursion" could overwhelm the heat-removing apparatus, melt the fuel, inspire chemical explosions, and cause a release of fission products into the environment.

Argonne National Laboratory-West 201-709

BORAX-I, the "runaway" reactor.

In the 1950s, imagined accident scenarios opened up questions for which scientists had few answers. Does a rising temperature encourage or discourage the chain reaction? What happens while the fuel is heating up? Will the reaction continue? At what point will it stop? If the automatic controls or human operators fail to scram an excursioning reactor, what is the worst that can happen? Such questions pointed the way to formulating many parts of the overall safety research programs supported by the AEC.

The *Nautilus* prototype and the MTR used water for cooling. In both cases the water was pressurized to prevent the water from boiling in the core or turning to steam. The conventional wisdom was that steam bubbles would somehow affect the behavior of neutrons and cause the reactor to behave erratically, possibly overheating.

Samuel Untermyer, a scientist at Argonne National Laboratory, thought otherwise. Based on his observation of an accidental withdrawal of a control rod at a zero-power reactor in Chicago, he thought that if water bubbled or steamed in an overheating reactor core, the chain reaction would merely slow down until it died all by itself.

Argonne-West. EBR-II containment dome is to the right of the Fuel Cycle Facility.
Middle Butte is on horizon.

Argonne National Laboratory-West 103-Z5868

Automatic scrams or human judgment would not have to intervene. The more bubbles—or voids—the slower the reaction. The only way to prove it, however, was to try it. He set about designing a suitable test reactor.

Untermyer obtained the support of Walter Zinn and the AEC, and they set up an experiment in Idaho. The two of them didn't realize it at the time, but their innovative and unprecedented Boiling Water Reactor Experiment (BORAX) began an epoch spanning more than three decades in which the nuclear power industry all over the world—and later the space program—obtained many of its important safety answers from the NRTS. Only at the NRTS were scientists free to do experiments in which explosions or meltdowns might confirm or contradict their predictions.[1]

News reporters liked to call BORAX-I the "runaway reactor." Construction began with a simple hole in the ground about a half mile from the EBR. The reactor sat inside a shielding tank ten feet in diameter and open to the sky like a small swimming pool. The tank was partly above ground, so a hill of earth ten feet thick was mounded up against it for more shielding. Asmall platform over the earth gave access to the top of the tank. By May 1953 water and reactor were in the tank ready to go.[2]

Untermyer and his colleagues conducted over two hundred experiments in the next fourteen months. Positioned inside a control trailer a short distance from the reactor, he would pull the control rod out of the reactor core, for example, and the water would bubble and hiss, spit scalding water 150 feet above the tank. Then the reactor would shut itself down, the gush diminish, and the water grow calm. Tourists passing by on Highway 20/26 reported seeing a geyser like Old Faithful erupting on the Arco Desert. The team tried endless variations, different types of fuel elements and different types of "errors." With each series of experiments, they gradually increased the power level of the reactor.[3]

Argonne National Laboratory-West 103-42

BORAX-I "geyser" during another experiment.

The results proved Untermyer correct. In every case, the chain reaction stopped before the aluminum fuel plates became hot enough to melt. It appeared that boiling water reactors might therefore be "inherently" safe; that is, safe because of the way nature took its course, not because automatic controls, machinery, and human judgment operated perfectly one hundred percent of the time. Zinn thought the commercial possibility of boiling water reactors should be explored.[4]

It was wise, Untermyer thought, to make the point that a boiling water reactor could be pushed too far. He acquired the permissions needed to run a final test provoking the complete destruction of the reactor. He and Zinn calculated how much radioactivity might be released into the atmosphere and consulted with IDO health physicists and the meteorologists at the U.S. Weather Bureau's NRTS station. Zinn justified the experiment to AEC Headquarters: "The worst situation imaginable is one in which the immediate BORAX site would have to be inactivated for some weeks while decontamination is performed," he wrote. But unless scientists began to quantify the impacts of accidents, nuclear hazards would remain a topic for speculation, not knowledge.[5]

On the day scheduled, July 21, 1954, the wind was blowing in the wrong direction, so the meteorologist aborted the test. Official guests went away disappointed. The next day, amidst talk of using dynamite to simulate a visually satisfying event in case the reactor fizzled, the BORAX team welcomed the visitors again and positioned them at an observation post. Physicist Harold Lichtenberger was at

the controls. Highway patrol officers stood by to close Highway 20/26 if needed. As the test time drew near, drivers warmed up the emergency evacuation buses. By 7:50 a.m. the breeze was right, as all could see by looking at the smoke bombs ringing the area.

Worried that the excursion rod might stick and so ruin the show for the visitors, the crew decided to "give it everything" they had when ejecting the excursion rod by remote control from the control trailer.

Almost instantly, the reactor blew up with the force of three or four sticks of dynamite, tossing debris and an inky black column of smoke more than a hundred feet above the desert brush.

"Harold, you'd better stick the rods back in," Zinn shouted. "I don't think it will do any good," Lichtenberger replied, "There's one flying through the air!" Zinn was surprised. Previous excursion clouds had been silvery white, evidence of discharged steam and water. This dark cloud, with almost vertical sides, indicated a far different, more powerful reaction. "Within the column, and along its edges, and falling away from the edges" Zinn saw a "large quantity of debris," including a large sheet of plywood that sailed off across the desert like a giant playing card.

The reactor was totally destroyed. Within the control trailer Zinn detected a slight tremor, while most observers in the open felt a small shock wave.[6]

Geiger counters squawked and everyone took cover. The fallout cloud went south and then drifted back over the NRTS, diluted enough not to be dangerous, but concentrated enough to be measured. Zinn might have preferred that a steam explosion had not destroyed the reactor, but the explosion was deliberate, and it identified what later became known as the "threshold effect."

Argonne salvaged the BORAX-I control equipment and buried the rest where it lay. The team moved a short distance from the scene and built a new reactor called BORAX-II, twice the size of BORAX-I and dignified within a prefabricated metal building. They conducted hundreds more experiments, modifying the reactor core several times and renaming it upon each major change to BORAX-III, -IV, and -V. With each test, the experimenters understood more than before about the safety parameters for operating a boiling water reactor.

Argonne's ultimate goal was to evolve a reactor useful for electrical generation. Having proved that the reactor was stable during tests, the BORAX team looked around for a wet-steam turbine generator. For once, the pile of old Naval Proving Ground junk proved wanting, and they scrounged an abandoned plant from an old sawmill near Albuquerque, New Mexico. "Here we were," recalled Ray Haroldsen, Argonne electrical engineer, "[at] the forefront of knowledge, trying to get the old 1925 turbine going."[7]

But they managed. Soon they were ready for the next major proof of principle. After President Eisenhower's "Atoms for Peace" speech, the United Nations sponsored the first International Conference on Atomic Energy at Geneva, Switzerland, in 1955. It was an exciting moment for nuclear scientists because for the first time since the war, some of the secrecy surrounding nuclear knowledge was being lifted, and scientists, who before the war had recognized no national borders in scientific colloquy, could once more exchange information and showcase their achievements and ideas.[8]

Argonne scientists prepared fifty-one technical papers for presentation at the conference. They also decided that this was a suitable moment to demonstrate for the first time in the history of the world that nuclear power could provide real electricity to a real town. With the cooperation of Utah Power and Light (UP&L), they hauled a transformer on a flatbed truck to BORAX-III and patched the system into Arco. Ray Haroldsen said:

It was [trouble with] a transmission line that caused the lighting of Arco to be delayed about two days. We also lost about as much sleep. Engineers blew out several lines before successfully lighting the town. Those two sleepless days are something we will always remember.[9]

The little boiling water reactor made electrical contact with Arco (and the NRTS Central Facilities Area) on Sunday, July 17, 1955, running for something over an hour around midnight. Most citizens were tucked in for the night and none the wiser. Argonne had invited several international visitors to witness the entire procedure. Some watched as a switch broke UP&L's con-

nection to Arco while others had a bird's eye view from the butte overlooking the town. Film crews recorded everything.

Argonne kept the news from Arco for a week while Walter Zinn and the rest of Argonne's Geneva delegation prepared to make a splash in Geneva. On the morning of August 12, seventy-two delegates saw the fifteen-minute film while Argonne sent Arco a dispatch, hoping the citizens heard the news before the rest of the world. The same film played at 2 p.m. in Arco, the screening advertised by word of mouth and a car with a loudspeaker. Two hundred people showed up and promised to keep the secret until after the story was officially released a few hours later. Back in Geneva the international witnesses were on hand in the post-film buzz to affirm the credibility of the story. The Soviet Union, undoubtedly feeling upstaged, asserted that it hadn't happened. But Arco believed it, delighted.[10]

INEEL 55-2349

The BORAX tests continued through 1964. BORAX-V demonstrated the safety aspects of reheating steam generated by boiling water (superheated steam), potentially an improvement in the efficient generation of electricity. Argonne went on to design, build, and improve the country's first boiling water power plant, the Experimental Boiling Water Reactor (EBWR), at the Argonne Lab in Illinois. The plant ran from 1956 to 1967, gradually increasing its power level and reliability to the point where it supplied electricity for the entire Argonne Lab. By 1958, executives from General Electric were telling Senator Dworshak that boiling water reactors would be competitive with new fossil fuel plants by 1970.[11]

The BORAX series demonstrated to the AEC that the deliberate inducement of power excursions and the deliberate choking of coolant could be tested under controlled conditions without disaster and would provide useful safety information. Soon the AEC approved programs for pressurized water reactors and breeder reactors, and a parade of safety test reactors followed BORAX to the NRTS.[12]

By 1953, AEC Headquarters itself was preparing for the review and licensing activities that a commercial industry would eventually require. It created an Advisory Committee on Reactor Safeguards (ACRS). The AEC and industry both were represented on this body, which concerned itself with the location of reactors, their operational safety, radioactive fallout, and other safety issues. Dr. Doan became a member of this committee.[13]

INEEL 55-2351

Above. Clarence W. Byrne, local agent for Utah Power and Light Company at the Arco substation switch on July 17, 1955. Left. The view from the butte above Arco the same night.

In January 1955 the AEC began a Power Demonstration Reactor Program, inviting private utility companies to own, build, and operate prototype power reactors. The AEC would subsidize the costs in various ways and lend the necessary uranium fuel. The program accelerated the need for safety information because these reactors would be located near cities such as Chicago, Detroit, and Boston.[14]

The AEC also realized that the new industry would require an expansion in the ranks of nuclear physicists, engineers, and chemists. It desired to encourage students to undertake careers in nuclear specialties. Graduate students would need to acquire experience with nuclear reactors. That meant putting reactors on university campuses. The Aerojet-General Corporation already had designed a compact, university-affordable low-power reactor of a sort called a "swimming pool" reactor because it was moderated and shielded within a pool of water. But the AEC had a question: how could the placement of nuclear reactors in the heart of university campuses be made safe?

A group of people at the NRTS was ready to assist the AEC. One of its members was Warren Nyer, who later recalled:

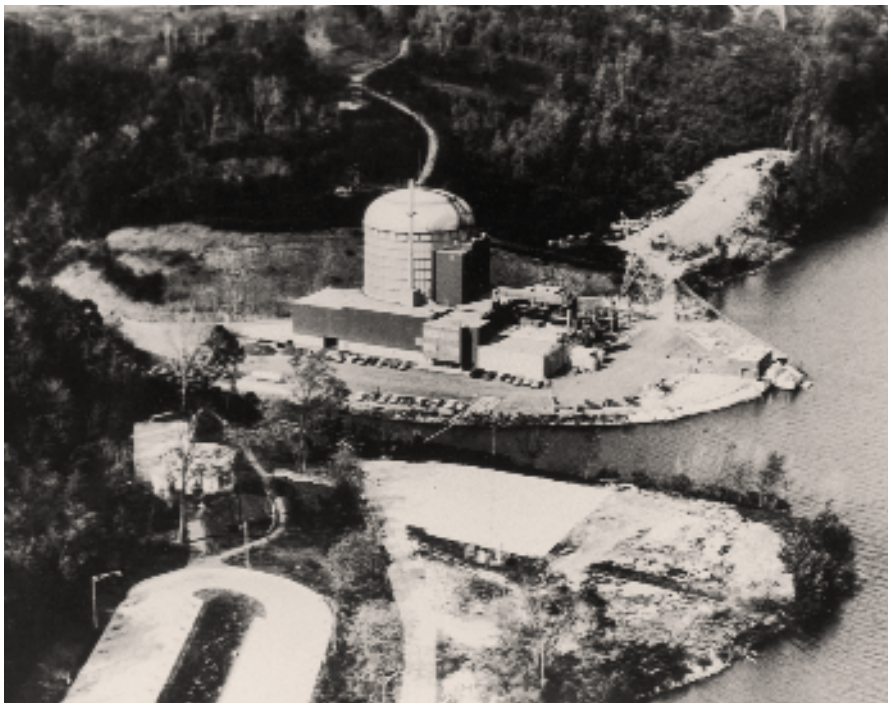
The AEC wanted to get the universities of the country involved. But all seasoned Ph.D.s were concerned with the conditions under which grad students could be safely permitted to use this new tool. Questions were being raised about supervision, inherent design, constraints, and the like. So the AEC said, "What will we do with all these graduate students mucking around the reactors that are going to be placed on the campuses?" We had to make sure they could handle these things safely.

Dr. Doan, Bion Philipson, Allan Johnson, and I went to Chicago to meet with Walter Zinn and a representative from AEC Headquarters to discuss the possibility of Phillips undertaking a project...[We discussed the BORAX experiments] and Argonne promised its support.

We got a letter shortly thereafter giving us the go-ahead and allocating the funds. The AEC was in effect asking, "What are the limits?...How much reactivity can we allow student reactors to have?...How safe can swimming pool reactors be made and still let many people have free access to it?" We were to explore the limits of the reactor's behavior, and it was expected that we would test the reactors to destruction.

Courtesy of University of Missouri

Above. Graduate student prepares experiment at University of Missouri Research Reactor. Below. The Peach Bottom power plant in Pennsylvania, part of the Power Demonstration Reactor Program. The reactor was housed in a containment building, and the plant was located distant from heavily populated areas.



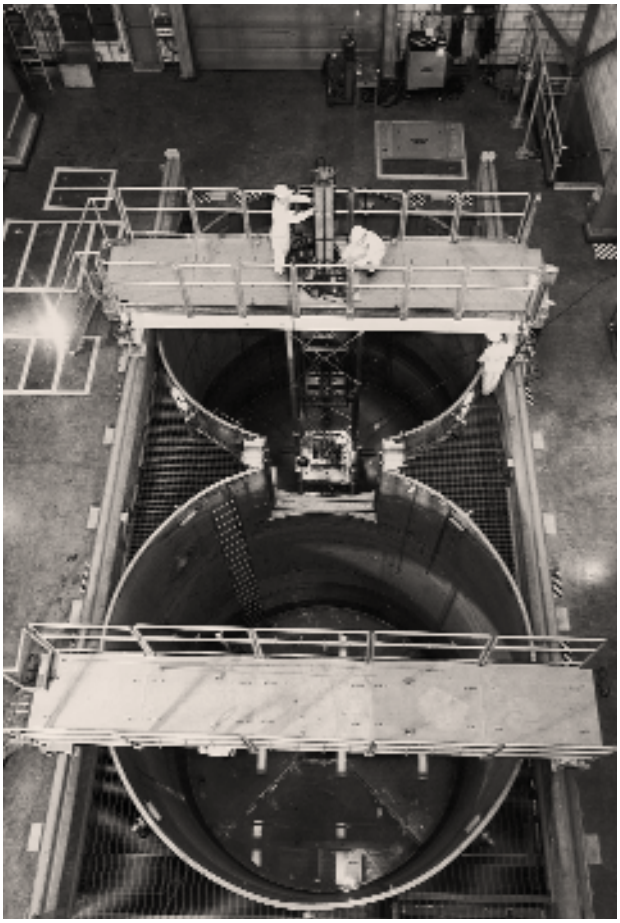
U.S. Department of Energy 68-8270

The following June [1955], eight or nine months later, we had our first reactor going critical. And that's how the SPERT program got started. Of course, it broadened to consider safety limits for other types of reactors, too. The SPERT program led to the LOFT (Loss of Fluid Test) program and the STEP (Safety Test Engineering Program).[15]

SPERT stood for Special Power Excursion Reactor Test. The IDO located the test complex about sixteen miles from the eastern NRTS boundary in a spot where dominant winds could help disperse fallout clouds during destructive tests. The SPERT complex embellished the architectural vocabulary of earthen shields, control bunkers, and buried reactor pits initiated by BORAX. The local newspapers cultivated a colorful vocabulary of their own as they reported on "blowup tests" and "mad reactors" that were "allowed to run wild."[16]

Phillips ran the SPERT program through 1970, developing reactors in a series that grew past SPERT-I to the more complex SPERT-II, -III, and -IV. Experiments regularly pushed reactors far beyond normal safety limits in order to discover what the normal safety limits were. The first SPERT-I (plate-type) core was sent deliberately to its destruction in November of 1962, followed by a new core and more tests.[17]

Instrumentation engineers, centered in the Instrumentation Lab at Central, found opportunities to be brilliant as they fashioned instruments and data recorders advancing the art of reporting the precise sequence of events and impact of a power excursion. Some of the first experiments in each of the SPERTs tested freshly invented resistance thermometers and techniques for calibrating them. Engineer Glen Bright, for example, invented a camera that could photograph events occurring inside an exceedingly hot fuel rod and see the actual onset of boiling between the fuel plates.[18]



INEEL 61-6873

Twin pools of the SPERT-IV reactor facility, under construction in 1961. The men on the bridge stand over the reactor pool. The other pool was used mainly to store fuel, but added to the general flexibility of operations.

Analysts pored over the images and the data, assessing their meaning and import, extracting information. When computers arrived, the analysts made the most of them. They sent their reports and recommendations to the ACRS and AEC, which were responsible for establishing licensing requirements not only for campus reactors, but all other commercial water-moderated reactors in the country. Physicists working for utility companies likewise examined the reports and considered whether their clients should choose boiling water, pressurized water, or some other reactor concept for power production. In fact, safety information was available world-wide, much of it presented at Atoms for Peace conferences in Geneva.[19]

The Detroit Edison Company, one of four utility companies to propose a project for the AEC's Power Demonstration Reactor Program, was the only one to select Zinn's breeder concept, cooled with liquid metal. Walker Cisler, the president of Detroit Edison, had embraced the elegant promise of the breeder to transform scarce uranium-235 into a non-issue. He prepared to build near Detroit a plant to be called the Enrico Fermi Atomic Power Plant. It took sev-

eral years to develop because the liquid-metal coolant and the fast-neutron habit of breeders were in scientific territory entirely different from water reactors, and they required safety-testing all their own.[20]

Cisler had followed the progress of the EBR-I. Early in 1953, technicians at the EBR-I removed samples of the U-238 blanket around the core and shipped them to Argonne's chemical engineering laboratory in Chicago. The chemists found what they were looking for: plutonium. The word went quickly to AEC Headquarters. Gordon Dean, one of the commissioners, recognized a momentous achievement in nuclear history and announced to the world, "The reactor is...burning up uranium and, in the process, it is changing non-fissionable uranium into fissionable plutonium at a rate that is at least equal to the rate at which U-235 is being consumed."[21]

Argonne had proved the principle. Zinn presented a long-range development plan to the AEC, convinced that in the long run, breeder reactors were the only type that would compete successfully against fossil fuel plants. He proposed that Argonne build a prototype breeder reactor in Idaho. Unlike EBR-I, this one would have a significant power production capacity and be built to safety-test full-size commercial hardware. Since plutonium was to become fuel, the accessories to the reactor would include a plant for recycling the spent fuel and recovering the plutonium economically. Experimental Breeder Reactor-II (EBR-II) would be a compact industrial plant: generating electricity and recycling its own fuel. The idea was still in the realm of experimentation. To consummate the vision, the project would have to solve one problem after another, safety and otherwise. Zinn and the AEC—and Detroit Edison—felt the problems were well worth solving.

Argonne National Laboratory-East 103-237

The core of EBR-I was about the size of a football. The 1955 incident melted about half of it.

To facilitate the design of EBR-II (and Fermi), Argonne turned EBR-I to the task of exploring excursions and the reactor's inherent shut-down potential. It appeared that under certain conditions, the reactivity in the core increased when temperatures went up. This was undesirable. Zinn wanted to push EBR-I fuel to a temperature of 500 degrees C. to see if it would lose reactivity. To get the fuel that hot, he had to take the drastic step of shutting off the flow of coolant. He also purposely disconnected the safety mechanisms that would automatically scram the reactor before it reached his test temperature. He knew that this could cause a meltdown if a scram wasn't timed perfectly and informed the AEC accordingly.[22]

On November 29, 1955, the EBR-I reactor was ready for the test. The plan was to scram the reactor when the power level reached 1,500 kilowatts or when the doubling of the fission rate occurred at a one-second interval. When this moment arrived, an assistant misunderstood the operator's instruction and scrammed the reactor with a slow-moving control rod, not the indicated faster one. The operator quickly reached over and pushed the proper button, but the lapse had cost two seconds. Fifteen minutes later, radioactivity within the control room set off the alarms and everyone evacuated the building. Half of the football-sized core had melted. Unlike BORAX,

the event produced no sound, no steam, no smoke, no explosion. Zinn reported the incident to the AEC the next day. Zinn the scientist absorbed what there was to learn and saw an opportunity—perhaps making lemonade out of a lemon—to learn how to handle a damaged core safely and efficiently.[23]

The episode, while being the first unintended meltdown in American nuclear history, possibly would have acquired the patina of "one of those things" that happens in the course of experimentation, except that AEC Headquarters decided not to inform the public. The news leaked out in April 1956, covered by the nuclear and national presses. The editor of *Nucleonics* warned the AEC that nuclear accidents were public business. In words that would later seem prophetic, he said, "Apart from the bad effect that secrecy would have on attitudes toward nuclear safety, such withholding of news is wrong in principle. It is beyond the authority of AEC to withhold information not affecting the national security. And because AEC operates in so much secrecy, public confidence in it will surely be undermined."[24]

Lost to public notice was the discovery of how the meltdown had occurred and why higher heat in the reactor had produced a positive temperature coefficient. Argonne's Idaho team extracted the core from the reactor, built a shielded coffin for it, and shipped it to Chicago. The analysts found that in the extraordinary heat, the fuel elements had bowed and expanded, bringing too many uranium atoms too close to one another. The heat had been greater on one side of the elements than the other, and since the fuel was clamped at both ends, it bent toward the higher heat, a simple mechanical event. In the future, this could be easily prevented.[25]

INEEL 69-4254

Operator demonstrates insertion of fuel element in ZPPR (Zero Power Physics Reactor), housed at Argonne-West. Physicists could mock up various arrangements of fuel and control elements and test them at low power. The reactor was made critical by moving one half of the reactor closer to the other.

EBR-I received a new core in 1957 employing zirconium spacers and other features to hold the fuel rigid. EBR-I continued to serve for experiments. In 1962 Argonne installed what would be EBR-I's last core, this one with plutonium fuel. Experiments continued until Argonne shut down the reactor in 1964, ready to move on with EBR-II, the next evolutionary step in the march toward commercial-sized fast breeders.[26]

To further understand the behavior of fast neutrons during an excursion—and while fuel was melting—Argonne built TREAT, the Transient Reactor Test Facility, "transient" being a term similar to "excursion," indicating very temporary bursts of power. The reactor would test candidate fuels for EBR-II as well. Because the transient temperatures would be extremely high, TREAT's special fuel was made by embedding and baking highly enriched uranium in graphite. When the temperature of fast-moving neutrons was made to spike, the graphite acted as a heat sink, protecting the fuel. Slots through the core provided an opening for a camera to record the events taking place in the test hole during the excursion.[27]

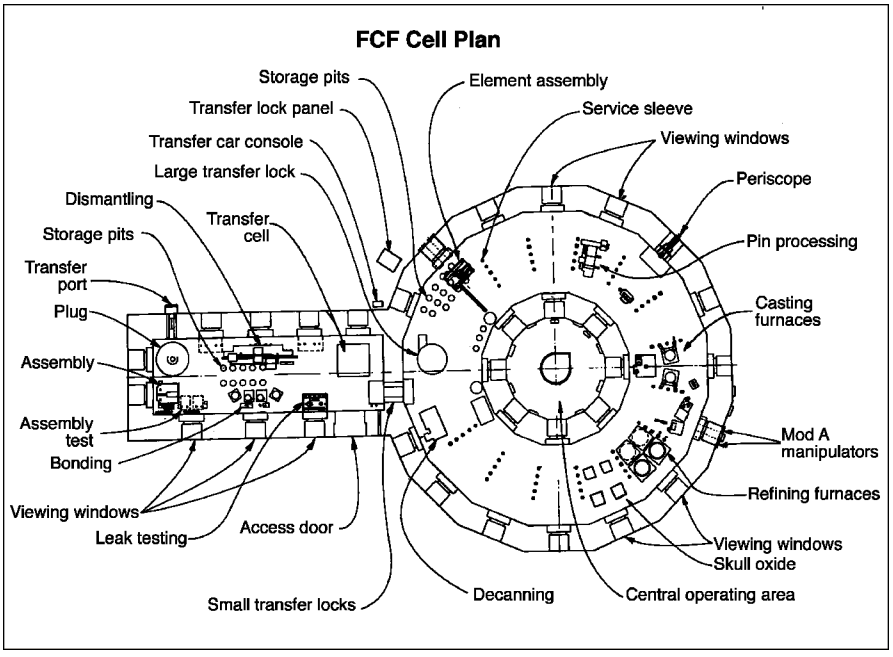
TREAT's early experiments deliberately melted fuel elements and assemblies to learn more about how fast-reactor cores would behave during a meltdown. As testing progressed, Argonne evolved

fuels and cladding materials that could survive higher and higher temperatures before they failed. For example, one early test series subjected EBR-II fuel to pulses of higher and higher temperatures. Thermocouples welded onto the cladding measured surface temperatures. At 970 degrees C., there was little damage. At 1,000 degrees, the cladding failed and molten uranium was ejected forcefully enough to damage nearby fuel elements. The tests showed that the cladding close to the base would fail first. The next test series did the meltdowns in a stagnant pool of sodium and then in an environment of flowing sodium. The design of fuel elements, then fuel assemblies, then entire reactor cores grew ever more sophisticated.[28]

The research going into the design of EBR-II required several support buildings. The IDO opened up a new area for Argonne at the NRTS. Still interested in reducing the travel time from the Idaho Falls airport, Argonne chose to build EBR-II and "Argonne-West" as close to the eastern boundary of the NRTS as possible. After 1955, new facilities went up regularly, including the Argonne Fast Source Reactor, a small low-power (one kilowatt) research reactor used for physics studies and to improve instrumentation and detection methods toward the design of EBR-II—and all fast-neutron reactors elsewhere.[29]

EBR-II went critical for the first time in November 1963. The reactor building included a feature new at the NRTS: a containment shell. The silver dome was made of inch-thick steel; inside, entry into the reactor room was *via* a set of airlock doors, a design borrowed from the Navy, to keep the room air-tight. The reactor, the coolant pumps, and the heat exchanger all operated inside a tank filled with 86,000 gallons of liquid sodium (not the alloy NaK). The secondary sodium loop transferred enough heat to a steam generator to produce the design level of 62.5 megawatts of electricity. To prevent accidents deriving from sodium/water contact, the building contained no circulating water.[30]

Next door to EBR-II, Argonne built the Fuel Cycle Facility (FCF), a special laboratory where scientists were imagining the best: a fully integrated power plant combining electrical generation with a small factory right on the premises to make new fuel elements out of the unfissioned uranium and the new plutonium from the reactor. The spent fuel would have to cool for only two weeks—not three or four months like MTR fuel. A pyrometallurgic process—melting and refining the fuel—would separate the good metal from the fission products. Instead of being shipped elsewhere to be fabricated into new fuel elements, fabrication too would be done on-site, eliminating transport costs. The radioactive waste would amount to tiny volumes compared to the liquid wastes being stored in the Chem Plant tanks. It would all be safe, reliable, clean, and in the end, cheaper than mining and hauling coal day after day and decade after decade.



Argonne National Laboratory-West

Floor plan for the Fuel Cycle Facility. Spent fuel came from EBR-II next door for on-site disassembly and recycling. The rectangular section was a hot cell with air atmosphere; the doughnut shaped section, argon gas. Workers could move around the work stations to complete the sequence of tasks required to disassemble fuel elements, heat the fuel in a refining furnace, separate uranium from waste products, and reassemble new fuel elements.

Chapter Fifteen

The SL-1 Reactor

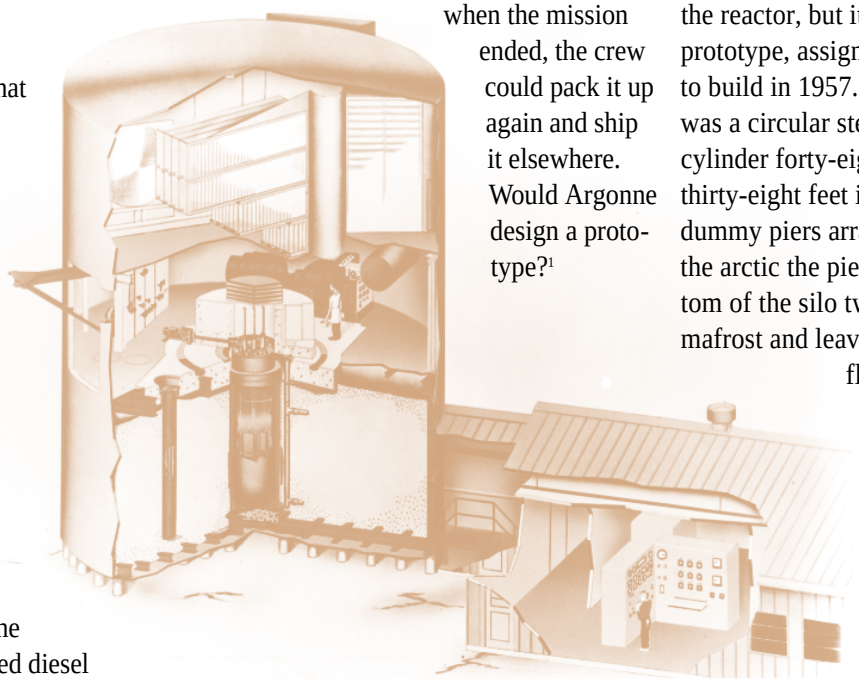
That experience eclipses all of the other experiences I had up there.

–Dr. George Voelz, NRTS Medical Director–

In the arctic tundra, a treeless plain north of the conifer forests of Canada and Alaska, plant life relies on shallow bogs and a few inches of top soil. Below, the soil is frozen all year long, permanently unresponsive to the spring thaw. Vast acreages of the tundra allow practically no life at all, the ground a dark and flinty mat of stones.

This was the setting that the U.S. Army described to the Argonne Lab as the destination for a small nuclear power plant. The Army had in mind the Distant Early Warning system, the DEW Line. Beginning in 1953, dozens of manned radar stations ringed the Arctic Circle, on constant watch for a Soviet air invasion. The Army regularly shipped diesel fuel to each station for heat and electricity. This was costly and sometimes hazardous in such remote areas, and the Army hoped to replace the diesel supply line with nuclear power.

The vision was to package a power plant in three or four pieces, fit them into cargo planes or trucks, and have soldiers assemble them in a few hours. Easy to operate, a plant would run at least three years on one fuel loading. The plant need generate only a thousand kilowatts, and when the mission ended, the crew could pack it up again and ship it elsewhere. Would Argonne design a prototype?[1]



INEEL 60-3227

Cutaway of SL-1 reactor and the control building. Reactor floor is above shielding gravel. Fan floor is above reactor floor.

Applying its BORAX experience, Argonne developed the project using a boiling water reactor concept. The virtue of the system was that steam from the boiling water powered the turbine directly, eliminating the weight and complexity of a secondary loop and heat exchanger equipment.[2]

With tundra permafrost conditions in mind, the Army wanted to test not only the reactor, but its building as well. The prototype, assigned to Idaho, was ready to build in 1957. The building shell was a circular steel tank, a silo-like cylinder forty-eight feet high and about thirty-eight feet in diameter. It sat on dummy piers arranged in a circle. In the arctic the piers would hold the bottom of the silo two feet above the permafrost and leave airspace between the floor and the ground. This would prevent transferring heat to the permafrost. Despite its armored appearance, the silo was not intended as a containment structure. Both the NRTS and potential arctic destinations were sufficiently remote, and the power level of the reactor

Pressure vessel for Stationary Low-Power Reactor has been placed during construction. Steel plate is going up around the reactor building. Circa 1958.

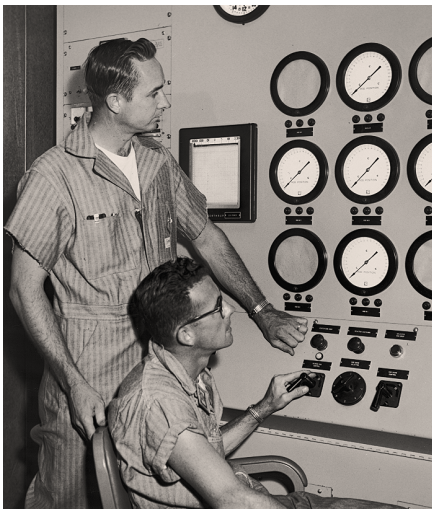
Argonne National Laboratory-West 103-4055

sufficiently low, that the AEC deemed such a feature unnecessary.[3]

Inside, the plant was arranged like a three-layer cake. In the bottom third, native stone and gravel shielded the pressure vessel containing the reactor. The middle third was the operating level, giving the crew access to the top of the reactor, the turbine generator, and control rod machinery. On top, a "fan floor" attic contained equipment to condense and cool the recirculating water. A weather-protected stairway snaked up the side of the cylinder to connect the adjacent control building to the operating floor level.[4]

After Argonne handed over the finished plant to the Army's operating contractor, Combustion Engineering (CE), the Army named the reactor Stationary Low-Power Reactor Number One, or SL-1. This name distinguished the reactor from a whole family of other small reactors that the Army already had built or was planning. Reactors were to be "stationary," "portable," or "mobile," depending on the intended field application, and rated for "low," "medium," or "high" power.[5]

The IDO opened up an Army Reactor Experimental Area (AREA) about a half mile north of State Highway 20 and ten miles east of Central Facilities.



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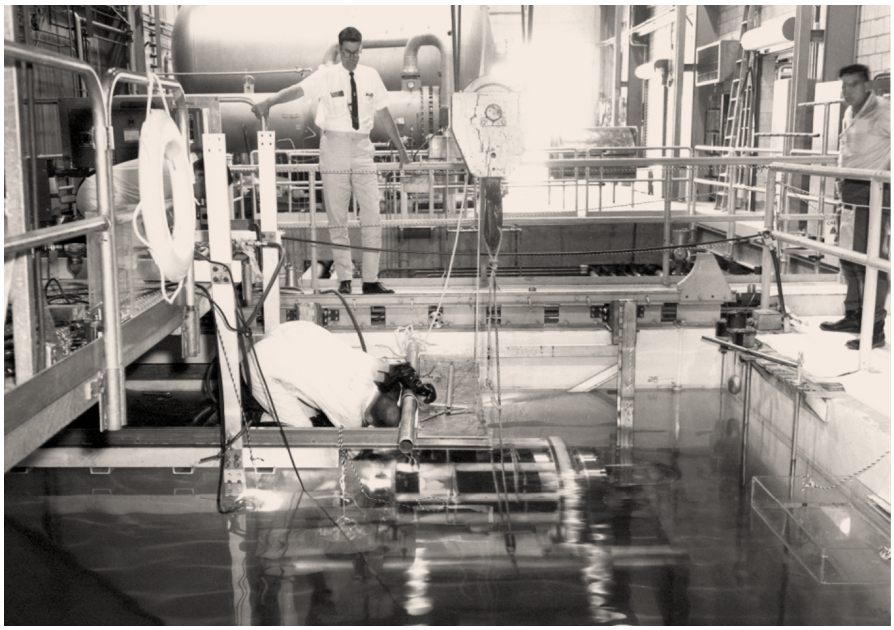


INEEL 63-4454

The SL-1 was the first of three anticipated Army experiments at the NRTS. The other two were intended to perfect a "mobile" reactor so miniaturized that it would fit on a truck and move whenever a field station moved. As of 1958 all the reactors built in the United States had been cooled with water or liquid metal. But gas was a coolant possibility and the Army chose to explore it for mobile reactors. Ultimately, the Army hoped ordinary air could be used, further simplifying the power plant and eliminating more weight. The Army contracted Aerojet General Corporation to design a Gas Cooled Reactor Experiment (GCRE) and do for the gas-cooled concept what BORAX, SPERT, and TREAT had done for the other concepts: determine its safe operating parameters and select the best fuel. That done, the Army would use the remoteness of the NRTS to field-test a prototype for the Mobile Low-Power Reactor, or ML-1.[6]

The IDO reserved sites for the three reactors at half mile intervals along an access road it named Fillmore Avenue. The GCRE, a water-moderated reactor situated in a "swimming pool" pit below the floor, went critical in 1959, and the ML-1 was expected to arrive sometime in 1961.[7]

Above. Cadremen at SL-1 control panel. Left. Operators make adjustments in GCRE reactor pit.

The Army planned to train its future DEW Line crews at the SL-1, so CE ran the reactor with a military crew. The Army and the Air Force sent trainees; the Navy, interested in the potential of the SL-1 for Navy missions, sent Seabees. The mixed "cadres" trained together and rotated to Idaho after several months of instruction at Fort Belvoir, Virginia, where the Army operated its prototype Stationary Medium-Power (SM-1) reactor eighteen miles from the White House.

The SL-1 went critical for the first time on August 11, 1958, and produced its first electricity two months later on October 24. Thereafter, the rhythm of work involved running the reactor for periods ranging between one and six weeks and then shutting down for training in maintenance and repair or to install improvements. The first cadre had been trained, tested, and certified by May 1959, and many others followed. CE's Christmas routine was to shut down the reactor, celebrate the holiday, and then do annual maintenance tasks before the next start-up.[8]

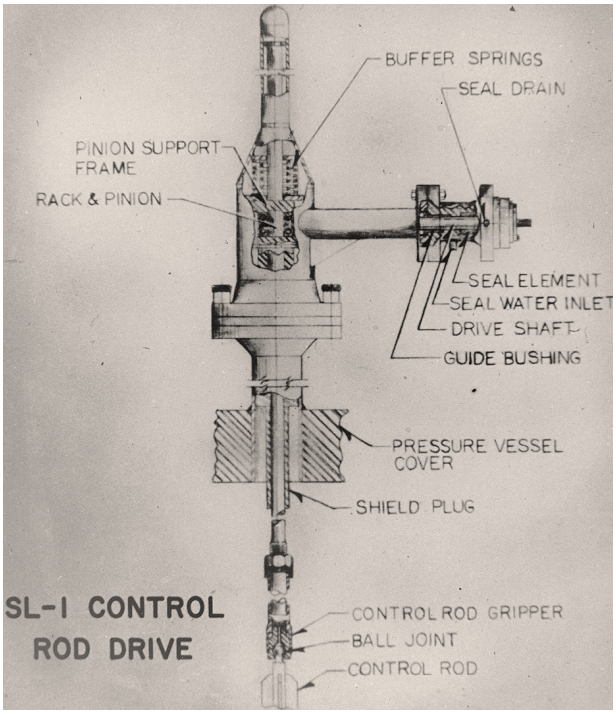
Accordingly, on December 23, 1960, CE shut down the reactor. Crews returned on December 27, reporting to work in three shifts around the clock. Start-up was scheduled for January 4, 1961. The men calibrated instruments and attended to the valves, pipes, and pump that circulated coolant water through the reactor. To do part of this work, they lowered the water level in the reactor about two feet.

The last task was to insert forty-four new cobalt flux wires into the core for later mapping of the reactor's neutron flux. The January 3 day shift inserted the flux wires. To gain access to the reactor core, they had moved out of the way several large concrete shielding blocks that ringed the top of the reactor. Then they disconnected the control rods from their drive mechanisms, these also being in the way. It would fall to the 4 p.m. shift to reconnect the control rods to the drive mechanism.[9]

In miserably cold weather—the temperature was headed for seventeen degrees below zero that night—the three-man crew arrived from Idaho Falls and set to work, the only workers at the SL-1 area. As usual for night shifts, no guards were posted at the entry gate, which the day-shift cadremen had locked behind them as they left.

Reconnecting the drive mechanisms involved several steps, one of which was to lift the control rod—manually—about three inches out of the reactor. At the top of the control rod was a small ball. A "gripper" from the drive mechanism latched onto this ball, completing the connection between the rod and the rest of the mechanism and its motor.

INEEL 58-2001



INEEL 61-203

Above. Enclosed stairway from SL-1 support building to operating floor of reactor silo. Left. The control rod drive mechanism. Note cruciform shape of control rod (bottom of drawing).

The control rods were not cylindrical in shape, as the name "rod" might imply. Rather they were cruciform, with four narrow fin-like projections that moved up and down the length of the core in narrow sheaths. The fuel zone was nearly twenty-eight inches long. Moving the rods three inches was safe and not enough to invite a chain reaction.[10]

In recent weeks, the control rods had seemed to stick slightly, perhaps because other items in the reactor core had bowed, invading clearance spaces and putting pressure on the sheath, crowding the slender fins of the control rods. The three men, wearing their gray coveralls, were in the silo at 9 p.m., two of them directly over or very close to the top of the reactor, working with the central control rod. At 9:01 something happened, the reactor went "prompt critical" and blew up.

When the reactor went critical, it released so much heat energy in four milliseconds that it flashed the water surrounding the fuel to steam. The steam, being of lower density than liquid water and thus a less effective moderator, quenched the nuclear reaction. The decay heat built up rapidly. With no system operating to remove the heat, twenty percent of the fuel melted. The steam forced upwards the seven-foot column of still-liquid water above it. The water rushed through the two feet of air space. It slammed against the lid of the pressure vessel at a velocity of 160 feet per second and 10,000 pounds per square inch exactly as if it were a piston—a water hammer. The entire vessel jumped nine feet into the air, hit the ceiling, and thumped back into place, shearing all of its connections to the piping and instrumentation systems. Iron pellets packed near the reactor as thermal insulation and radiation shielding scattered all over the floor. The water hammer expelled the control-rod shield plugs, water, fragments of fuel, fission products, and other metal from the top of the reactor, leaving open holes. The violence of the explosion killed all three of the men.[11]

INEEL 61-4

Scene at control station set up near junction of Highway 20 and Fillmore Avenue.

Two of them died instantly, one thrown sideways against a shielding block and the other straight upwards, where one of the shield plugs pinned his body to the ceiling. The head wounds of the third were fatal, but his pulse continued for another two hours. The blast blew shards of radioactive metal into their bodies, making them a danger to those who soon would try to rescue and recover them.[12]

It would take nearly two years of tenacious inquiry to make plain what had happened in two seconds, and the long process of discovery began immediately.

At 9:01 p.m., the heat-sensitive fire alarm above the SL-1 reactor radios one long and two shorts—the code for the SL-1 complex—at the security center and the three NRTS fire stations. Accident response procedures commence. A security force notifies the duty officer and sets off for SL-1. The firemen at Central, the closest to the Army complex, grab a card detailing the potential hazards at SL-1 and review it as the fire engine rolls. The duty officer tunes in to their conversation. Nine minutes later, they arrive at the locked gate. Equipped with keys, a detail covered by prior planning, the firemen unlock the gate. They observe no fires, no apparent disturbance, and

no one about in the freezing cold. They note a slight trail of steam coming from the reactor building, a typical sight in the cold.[13]

The firemen enter the control building carrying radiation detection instruments. They walk down the central corridor, calling, inspecting each room. In one, they see three lunch pails on a table. Finding nothing amiss, they move toward the door at the bottom of the covered stairway. The radiation indicator moves sharply. They withdraw.

By 9:17 p.m., an HP from the MTR arrives and, together with a fireman, approaches the stairs. Each wears a Scott Air-Pak, a 40-pound tank of air harnessed and buckled onto the back with a hose to a face mask. It pumps air to the face, so that if the mask leaks, air is expelled, protecting the wearer from dangerous gas or contaminated dust. As the rescuers start up the stairs, the detectors read 25 R/hr; they withdraw. By now, the security detail has determined that the men are nowhere else at the NRTS. Other searchers find no one in the SL-1 support buildings. The growing crowd of rescuers is forced to conclude that three cadremen are somewhere inside the very quiet reactor building.

In a few minutes, two more HPs arrive, dressed in fully protective clothing and equipped with Jordan Redectors, an instrument able to detect gamma radiation up to 500 R/hr. One of them ascends the stairs with two of the firemen, a constant eye on the Jordan. At the top of the stairs, they discern damage inside, no men. The indicator needle pegs. The HP orders all to withdraw.

Meanwhile, in accordance with the emergency plan, CE and IDO authorities had been notified. Around 9:20 p.m., John Horan, the IDO director of Health and Safety, answers the telephone at home and then tells his wife, "There's been an accident." He leaves for his Idaho Falls office where he has radio communication with the entire Site. As he passes the security desk, the guard tells him three people are missing, but there is no fire.

Horan declares a "Class 1" emergency, meaning the incident is restricted to one location. IDO personnel in Idaho Falls speed to the site—the IDO duty officer, environmental HPs, the medical director and his assistant, others. The news goes to AEC Headquarters. The weather station reports the direction of the wind. The Radiological Assistance Plan goes into effect, activating the HPs in other complexes for response. The fire department sets up an operations trailer at the intersection of Highway 20 and Fillmore Avenue. Security forces prepare to block Highway 20 traffic, if necessary.[14]

The environmental HPs take detectors into the desert beyond the SL-1, looking for radioactivity on the sagebrush that might have come from a cloud in the light breeze. Others head for Highway 20 and collect samples there. Horan orders an aircraft and asks the aerial-monitoring team to stand by. Then he thinks better of an idea to send them on a night monitoring expedition. Heretofore, they had not practiced low-level night flights. They will fly at 6:30 a.m. Meanwhile the ground surveyors conclude that the public—and they—can travel safely on Highway 20.[15]

HPs check Highway 20 for contamination on the morning after the accident.

INEEL 61-9

Around 10:30 p.m., the CE supervisor and HP arrive at SL-1, equip themselves, and enter the reactor building to look for the men. They find one badly mutilated and clearly dead, and they observe a small movement by another.

They withdraw, formulate a plan, and enter once more, this time with two other military men and an IDO HP. Radiation is estimated at up to 1,000 R/hr, lethal. The HPs will allow no one inside the building for longer than one minute, and they use stopwatches to time the rescuers and order them out when the minute is up. The five men rush up the stairway with a stretcher. They skid and slip on the water and the marble-like pellets littering the floor. Face masks fog up. Two men collect the man for whom they have some hope of survival while the others try, but fail, to locate the third man.

The rescuers place the man in a courier vehicle and drive toward the intersection with Highway 20. On the way, they meet an ambulance and transfer him. As they reach the intersection, the NRTS night nurse, Hazel Leisen, arrives in her car and enters the ambulance, hearing what proves to be the man's last breath. She applies an oxygen resuscitator to no avail. Around 11:00 p.m. the assistant medical director, Dr. John Spickard, pronounces the man dead.[16]

The accident was unprecedented. These were the first reactor casualties in the fourteen-year history of the AEC. Emergency planning had not accounted for an event quite like this one. All those involved in the recovery, therefore, now confronted situations and made decisions unlike any they had faced before.

One of the first was made by Dr. George Voelz, the medical director, who arrived a few minutes after his assistant and considered what should be done with the body. The dispensary at Central was completely unsuited for receiving a contaminated body. The small facility had been designed for the living; it consisted of one shower head installed under the dispensary's basement stairway. It was useless for this situation. Dr. Voelz recalled:

Because his level of radiation was so high, we had no place to put him. We left him in the ambulance until we could figure out what we were going to do next. The ambulance was sitting out in the desert, amongst the sagebrush. We decided the first thing we would do was see how much radioactive material we could remove by taking off the clothing. We wanted to get this done before the morning traffic came onto the Site. It was about four o'clock in the morning when we decided to try to take the clothing off under the lights of a couple of automobiles. Because the radiation levels were 500 rads per hour, we decided to work outside at 20 below zero in anti-C [anti-contamination] coveralls...

With the moisture [released in the explosion] and the cold temperatures, the [clothes] were just one solid chunk of ice, having sat out there most of the night. The health physicists had given us about a minute's working time [to remove his coveralls]. But we had anticipated this, and had some pretty heavy-duty tools that we could use on these coveralls... They had a stopwatch on us, and we got the job done. I remember we went a few seconds over. I think it was a minute and seventeen seconds.

That gives you an idea of how you have to improvise when you get into accident scenarios. We were able to get the clothing off, and we put him back in the ambulance...[17]

Removing the clothes didn't help. Radiation levels remained as before. They wrapped the body in blankets and draped lead aprons to protect the driver's seat in the ambulance. Around 6:30 a.m., the ambulance drove to the Chem Plant and into a large enclosed receiving bay. Near it a decontamination room lined with stainless steel served as a mortuary. Dr. Voelz had the body submerged in alcohol and ice to preserve it until he could develop a plan.

Because the reactor had not been operating, early speculation was that a chemical explosion had caused the accident. But of this no one could be certain. Radiation fields were extremely high within the silo. If the explosion hadn't killed the three men, the radiation would have.[18]

INEEL 61-1221

A crew prepares to collect a water sample from within the SL-1 reactor building.

In the daylight of January 4, Horan deliberately slowed the pace of recovery operations. The victims were beyond saving, and it was now imperative to prevent further injuries. Allan Johnson told Horan, "John, I'm setting up a special account for the SL-1. Don't hold back on anything you need...it will be covered." They decided to document pictorially everything they could about the accident and the subsequent proceedings.[19]

We wanted the nation and the world to learn what our experience was. It was unique, and we wanted to make sure that people knew our successes and our failures. That is why three movies were produced. For the first one of the basic accident, we took all the people that were involved in the initial response, and they played in the movie the role that they actually did that night. That was part of our effort to be as factual as we could and not have some actor do it.[20]

AEC Headquarters appointed an investigating committee and a technical advisory committee. Most of them arrived on January 4, ready to begin. The JCAE sent one of its staff to provide it with independent information as soon as possible. The national press sent reporters. AEC Headquarters staff arrived, and other AEC labs sent specialists as well. Later, the investigating committee complimented the IDO on its management of the crisis, but said also that the rapid arrival of so many outsiders, including themselves, had been a disservice to the IDO and the contractors as they undertook the recovery.[21]

IDO's immediate priorities were to determine what threat the accident posed to public health, retrieve the other two men, and discover if the reactor was stable or not. The airplane pilots reported that the roof of the reactor was intact, undamaged. A cloud of radioactive iodine-131 had drifted south toward Atomic City, but its dispersion and mixing with air had reduced its concentation well below any health concerns. Ground surveys found that the only place needing to be quarantined was the immediate SL-1 yard, where the rescue attempt had tracked some contamination. Beyond that, amounts above background levels were negligible.[22]

A squad of six volunteers, all cadremen, spent January 4 rehearsing a plan to retrieve the body of the second man in two-man relays. Someone else ran into the silo to grab the logbook and a neutron detector. Crews decontaminated the ambulance. The medical staff set up a temporary decontamination center at the GCRE building just up the road from SL-1. The men who had retrieved the first body had not waited for special gloves; they—and in particular their hands—had to be washed clean of contamination, a process involving water, potassium permanganate, and plenty of scrubbing. All who had been involved received medical check-ups. The medical staff found no radiation injuries and hospitalized no one.[23]

That night, the cadremen retrieved their second comrade. The film and radiation foils in his dosimeter badge had been blown away by the explosion. In lieu of those items, radiochemists examined the gold buckle of one victim's watch-

band and a tiny screw in a pocket cigarette lighter. They found radioactive gold-198 and copper-64. Only neutron capture could have created such isotopes. Then they identified other fission products and several isotopes of uranium in the debris that had come out of the reactor building with the men. All of this evidence proved that the reactor had gone critical.[24]

INEEL61-685

The third man finally was found. His position directly above the reactor presented a new hazard. Aside from the obvious difficulty of working in a high radiation field at an awkward location, physicists feared that if pieces of debris near him fell onto or into the reactor through the open shield-plug holes, the disturbance might start a chain reaction. A photographer suited up and entered the room for one minute, taking as many photographs as possible. With the help of the photos, a plan took shape for the retrieval. Army volunteers from a special Chemical Radiological Unit at Dugway Proving Ground wanted the practical experience offered by the challenge of removing the body. The twenty-four enlisted men and five officers perfected a plan and rehearsed their moves on a full-scale mock-up of the SL-1 erected at Central. They rigged a special net on the boom of a crane and positioned it to prevent the body or anything else falling onto the reactor. Metal workers shielded the crane operator's cab. On January 9, eight men, paired in two-man relays limited to sixty-five seconds inside the building, recovered the body and lowered it to the ground.[25]

The body joined the other two at the Chem Plant. A team of health physics specialists and a forensic pathologist from Los Alamos conducted autopsies, improvising with long-handled instruments and other procedures to keep themselves safe. They hoped that the men's injuries might contribute some insight into where they had been at the moment of the accident and what might have caused it. Most urgently, they managed to reduce the radiation fields emanating from each body to between one and ten percent of the original levels.[26]

The subject of burial already had been quietly controversial within the top ranks of IDO and AEC management. A.R. Luedecke, AEC general manager, had proposed that the men be buried together somewhere on the NRTS site and a monument erected in their memory. Johnson and other IDO officials objected strenuously, feeling that the men's families deserved the right to conduct funeral rites of their own choosing and as naturally as possible. Their view prevailed. The IDO ordered

INEEL 61-674

Above. Recovery crews practiced at a mock-up, seen here under construction, at Central Facilities Area. Left. Crew from Dugway Proving Ground.

three standard metal caskets from Idaho Falls and had them delivered to one of the NRTS shops. Craftsmen lined them with lead. Extra lead wrap shielded body parts still heavily contaminated. Aside from protecting people who would handle the caskets, the caskets had to meet radiological shipping standards set by the Interstate Commerce Commission. Preparations complete, the respective military services took possession of the bodies and flew them to the destinations requested by the families. A health physicist accompanied each to provide any necessary advice and consultation.[27]

The retrieval of the third body ended what came to be known as Phase One of the SL-1 recovery. Phase Two lasted from January 10 through late April, the time it took for CE to be certain that the reactor was stable. No one entered the silo during those months. Operators dangled remotely controlled closed-circuit television and other equipment inside the reactor from the boom of a crane. CE finally concluded that the core no longer contained any moderating water and that the reactor could not go critical again.

That done, it was time to clean up the site and see if the reactor core could reveal the cause of the accident. After President Kennedy canceled the nuclear airplane project in March, GE had people available and offered to clean up the building, decontaminate the site, and investigate. GE physicist Jay Kunze said later that the GE scientists considered the SL-1 job to be a choice assignment. BORAX and SPERT had failed to blow up. SL-1 should have been inherently safe. What had gone wrong? They welcomed a chance to solve the puzzle. But the cleanup had to come first. Kunze continued:

INEEL 61-667

The stretcher rig. Crews practiced before the rig was inserted into the reactor building to collect the body of the third man.

When IDO first asked GE if it could use the Hot Shop to analyze the reactor, GE said, "It's not available." But after the cancellation, the word was, "The Hot Shop is available!" GE had about five hundred people at the Site, eighty percent of whom were due to be terminated, most of those to be transferred to other GE sites as a result of the cancellation of the Aircraft Nuclear Propulsion Project. All of the professionals managed to find jobs with this project.

The SL-1 was a mess. It hadn't been cleaned up at all. To clean it up, people had to make short trips inside and do limited tasks within a couple of minutes and then get out. Even though you suited up, those couple of minutes would expose you to your quarterly dose of radiation, and you couldn't go back in for three months or do any other work that could potentially expose you. Hundreds of people at GE, including those about to be transferred and many workers from other locations at the Site [and from Dugway], volunteered to take their quarterly radiation dose doing clean-up at the reactor. For many clean-up tasks, that was the only way of handling it. I don't remember anyone being particularly fearful of the risk.[28]

The time keepers were the HPs, who stood half-way down the stairway and banged on metal when someone's vacuum-cleaning stint was over. By November, the passage of time and removal of debris had reduced radiation levels. It was time to remove the reactor. Anticipating that the forty-mile truck ride to the TAN Hot Shop might disturb some of the evidence, the GE team went underneath the reactor and drilled several holes in the bottom of the pressure vessel. Through a special

tube, they inserted a camera and took pictures inside the core.

The GE team had for months been examining debris fragments and other recovered reactor parts in an attempt to acquire as much information as possible before having to take the drastic action of cutting the pipes connecting the vessel to the rest of the plant's equipment. Kunze recalled:

Our main concern was how to cut those large pipes so that a crane could lift the vessel up thirteen feet and then out and onto a truck. At first we envisioned no method except to use manpower in the form of many welders with their pipe-cutting torches, taking turns cutting as much pipe as possible before receiving their allowable maximum radiation dose.

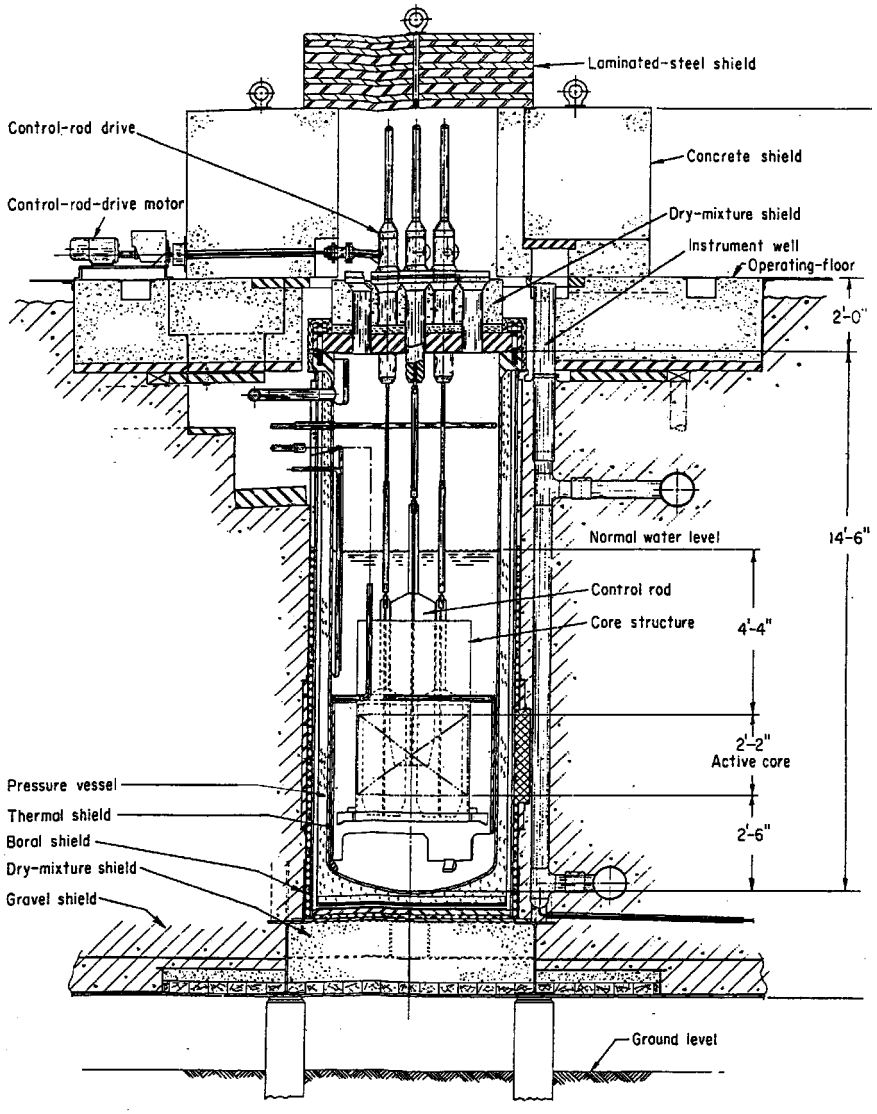
But we continued to play around with basic physics ideas—and came across the idea that the water, ejected upward by the nuclear steam explosion, had transferred its momentum to the vessel, perhaps sufficiently to cause the vessel to break the pipes and be lifted. Our calculations indicated that the vessel may have risen enough to hit the ceiling immediately following the brief nuclear excursion. So we took a close look at the fan floor, that is, the ceiling of the reactor room, and saw that certain small dents matched up with the head of the vessel. Now we saw that there was no need to worry about how to cut the pipes. Much personnel risk and engineering frustration had been eliminated, all the result of the nature of this still somewhat mysterious accident.

We examined the recovered central control rod, plug, and housing mechanism carefully in the Hot Shop. The assembly had been recovered essentially with the rod in the "down" position. However, upon disassembly, scratch marks on the rod extension and the inside of the guide tube clearly showed that the guide tube had collapsed, the result of the 10,000-pound water hammer pressure, and had seized the rod extension at the 26 1/4 inch withdrawn position.

Subsequently, as the unit hit the ceiling, the extension rod was forced back down to nearly the zero withdrawn position.[29]

Scratch marks had been made on the way back down, confirming that the rod originally had been withdrawn 26 1/4 inches. That the rod had been withdrawn and then jammed back down into the reactor to its "safe" position after hitting the ceiling was a bizarre coincidence. One finding had led to

Schematic of SL-1 reactor.



another, and the team gradually recreated the mysterious two seconds. The mechanical and material evidence, combined with the nuclear and chemical evidence, forced them to believe that the central control rod had been withdrawn very rapidly. They built a mock-up of the reactor vessel with identically sheathed and weighted control rods. In King Arthur fashion, men of lesser, similar, and greater strength as the crew tried to lift the rod. Most managed with little difficulty. The scientists questioned the cadremen: "Did you know that the reactor would go critical if the central control rod were removed?" Answer: "Of course! We often talked about what we would do if we were at a radar station and the Russians came. We'd yank it out."[30]

On November 29, a large crane lifted the reactor vessel out of the silo and onto a truck for the trip to the Hot Shop the next day. Once it was inside the huge remotely-operated laboratory, the scientists re-photographed the core and plugged the holes. They filled the vessel with water and confirmed that the reactor was quite subcritical; it had given its one burst in the accident and that was all. Then they examined every inch of the vessel. They were particularly grateful that the flux wires had been freshly installed, for they portrayed the neutron flux uncompromised by previous history.[31]

Thus the core and the mangled pieces of metal surrendered their story. In July 1962, the GE investigators published their final report, observing that manual withdrawal of the central control rod could explain the accident: "No other means of withdrawing the rod has been found to be in accordance with the evidence."[32]

CHAPTER SIXTEEN

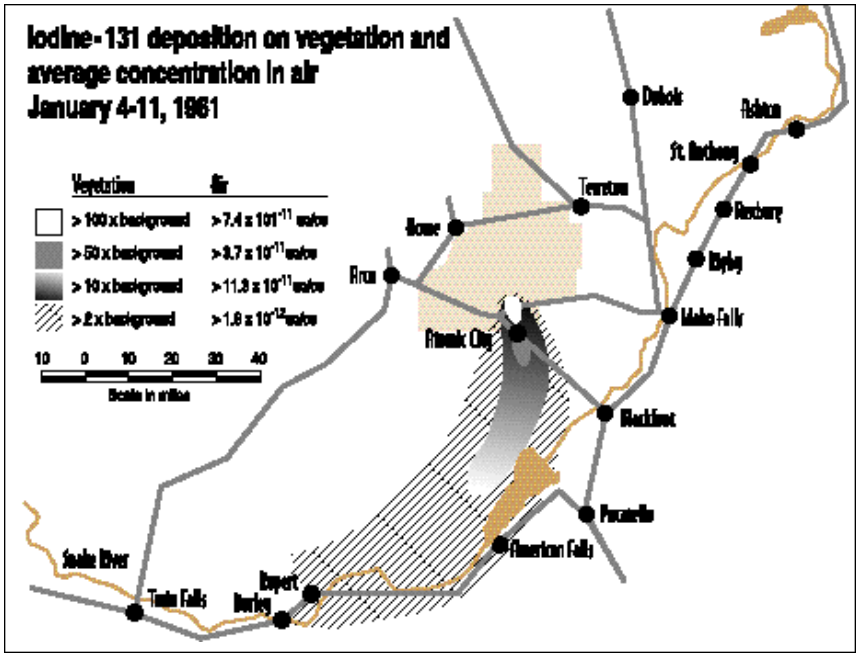
THE AFTERMATH

The development of atomic energy will of a certainty continue to achieve for mankind's benefit new goals that now challenge the imagination... Distressing as this tragic occurrence surely must be, it is to be observed that it came under such circumstances of time and place as to make certain the prevention of a disaster that could be much worse... It [is] progress that should be generally recognized and accepted with fortitude...

–Editor, Idaho Daily Statesman, January 6, 1961–

Editorial comment in Idaho and other newspapers categorized the SL-1 accident as a regrettable mishap, an inevitable occurrence if society were to accrue the benefits of a new technology. A few by-lined reporters tended toward emotional metaphors, one characterizing the reactor as a "monster" that had "broken loose for only a moment and destroyed three of its keepers." But such excess was the exception. Some editors followed the emotional lead of southeast Idaho citizens. Wrote one, "The fact that citizens of Arco and other communities in that area of Idaho are sleeping undisturbed by worry over such accidents is a comfort to the rest of us."[1]

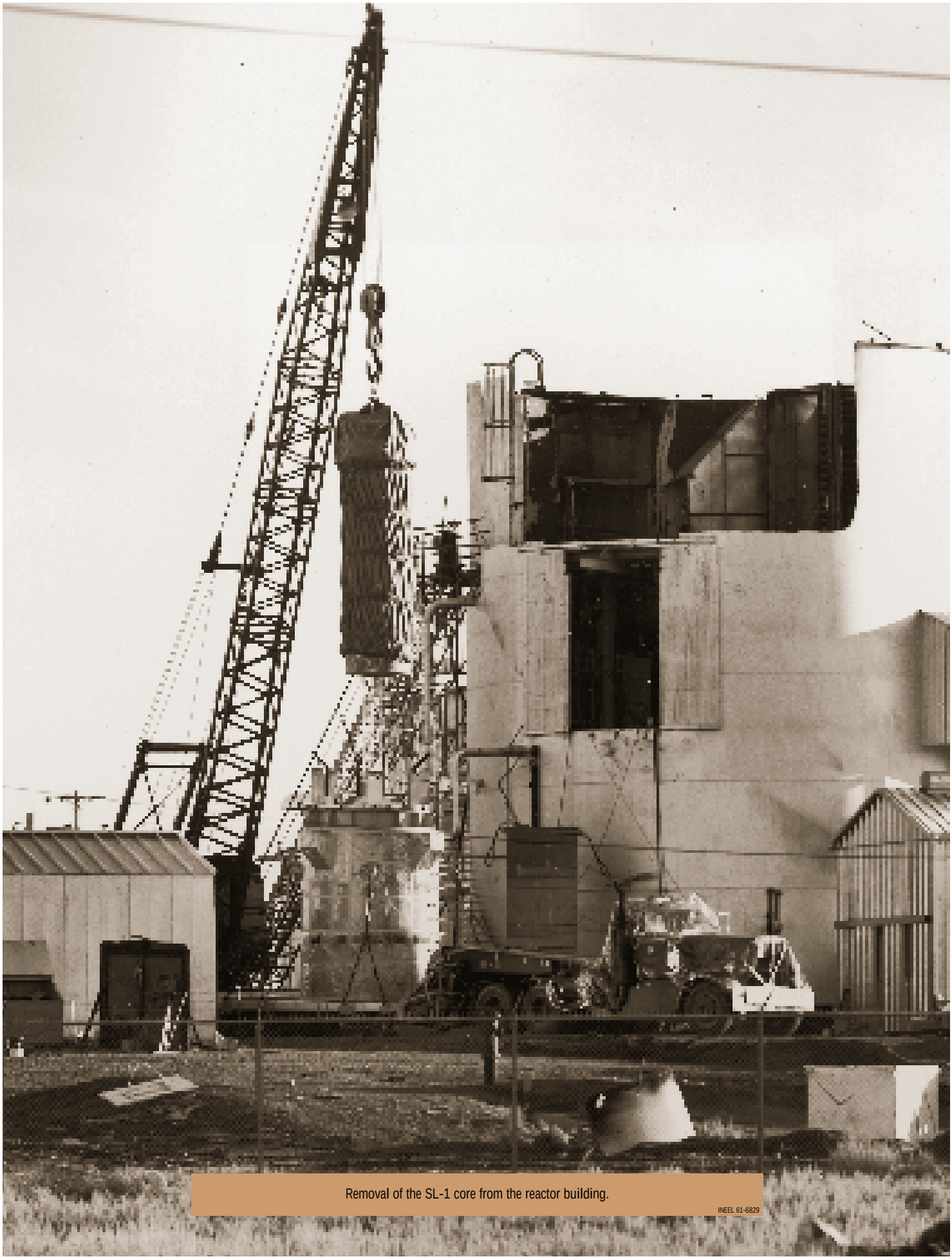
Boise's *Idaho Daily Statesman* mentioned other "atomic mishaps" at the NRTS—the EBR-I meltdown, an unplanned 1958 excursion in the HTRE-1, and a criticality at the Chem Plant in October 1959—and marked this as the first to cause loss of life. Later the *Statesman* instructed the reader on the distinction between nuclear and chemical blasts and described the mechanism of an excursion, or "runaway," and the role of control rods in controlling a chain reaction.[2]



DOE/ID 12119 Vol. 1

Dose reconstruction project in 1991 identified probable path of I-131 plume released by SL-1 accident.

Newspapers followed the story for about two weeks and then the articles trailed off. Reporters described the Army mission for the "new style" reactor, the location and extent of the radiation hazard, public safety, and the unfolding understanding that the accident was a nuclear excursion. As the bodies were identified and recovered, the reporters described the unique interment plans for the victims.[3]



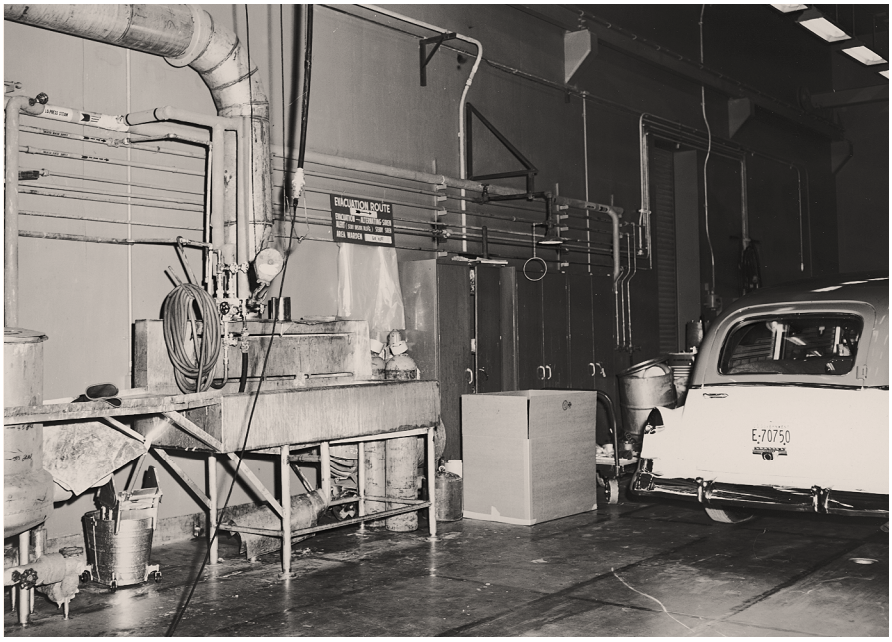
Removal of the SL-1 core from the reactor building.

INEEL 61-6829

In Washington, D.C., commentators wondered about long-term repercussions on the AEC's atomic power program. The AEC and the JCAE were in the midst of deciding how close to metropolitan areas nuclear reactors could be situated. GE and Westinghouse spokesmen worried that the accident might set back public acceptance of nuclear reactors for years.[4]

In this connection, Walter Reuther, president of the United Auto Workers (UAW) and the Industrial Union Department of the AFL-CIO, was quick to exploit the accident. The UAW was in court—by now the case had gone to the U.S. Supreme Court—challenging the AEC's recent decision permitting the Fermi fast-breeder reactor to locate near Detroit. It was not safe, the union claimed. The union had a list of forty purported reactor accidents that demonstrated why the Fermi reactor was a mistake. Reuther said the SL-1 accident confirmed the validity of the union's position, pointing out that Fermi was three hundred times larger than the SL–1. "It is clear from Tuesday night's accident that thousands of people would have been overexposed to radiation if the SL-1 reactor had been built near populated areas." Ultimately, the union failed to stop the Fermi plant. Some answered Reuther by noting that the SL-1 evidence refuted his argument because even without an engineered containment structure, radioactivity had remained mostly within the building.[5]

In Idaho Falls, the Oil, Chemical, and Atomic Workers International Union Local 2-652, expressed more credible complaints in a letter to Senator Henry Dworshak. To the concern that the reactor had been permitted to operate despite sticking control rods, the union added a list of items that patently had not been considered in emergency plans—the inadequate dispensary, the lack of proper lead caskets, the nonexistent shift disaster teams, and instruments unable to read high radiation fields. Further, health physicists had been called from all over the Site, leaving their own areas vulnerable. The autopsy physicians, said the unions, received enough exposure to make them less available for future emergencies. People who had responded early and received heavy radiation exposures were, in general, less available or more vulnerable in the event of any future emergency. The union asked for a Congressional investigation, that workers be compensated for over-exposures resulting in loss of pay, and for a public airing of all the facts.[6]



INEEL 61-1699

Ambulance used at SL-1 was decontaminated at the Chem Plant and returned to service.

The AEC defended itself, telling Dworshak that the public had received all available information, excepting medical, about the event. It agreed that the accident had exposed weaknesses in its emergency plans, but that the IDO had executed the plans that were in place.[7]

The JCAE scheduled hearings for June 12-15 on the broader subject of Radiation Safety and Regulation and invited AEC testimony on the accident. AEC commissioner Robert Wilson said that reactor design would henceforth not allow a reactor to go critical upon the motion of only one control rod. He blamed the contractor for allowing operating decisions by unqualified personnel. The AEC, he said, should assign independent groups to do periodic appraisals of every AEC or licensed reactor. The discussion averted a Congressional investigation specifically on the SL-1. The JCAE apparently was satisfied with the reports of the SL-1 Investigating Board, which by June was wrapping up its work.[8]

The board had listened to scores of witnesses. With no evidence that the cadre's actions had caused the accident, the board absolved it of responsibility. The board said that an "unusual movement of the central control rod" was more plausible as the cause of the accident than other hypotheses. Then the board pried open the layers of administration surrounding the reactor, and here it spoke assertively, sparing no one a share of blame.

Combustion Engineering had permitted substandard conditions to develop in the reactor, the board said, yet continued to operate. The responsibility for safety appraisals belonged to the IDO and AEC Headquarters, but the criticism was broad:

There appears to have been some lack of clear definition of assignments, within the AEC, of responsibility for insuring continuing reactor safety appraisals and inspections... It is conceivable that clearer definition of these aspects of AEC staff responsibilities might also have prevented the SL-1 accident.[9]

INEEL 61-947

A mockup of the SL-1 reactor top. Analysts tried to determine where the three cadremen were standing at the moment of the accident.

Early in December 1961, Allan Johnson ended his nearly eight-year career as IDO manager. He said it was for personal reasons, a desire to return to private life. Around the Site, however, people wondered if the AEC had forced the resignation as a way to signify that blame had settled somewhere and a price paid.[10]

The AEC called for change elsewhere as well. Immediately after the accident, it surveyed all the nation's licensed reactors, then numbering forty-seven. Licensees were asked for information on shut-down procedures and control components. The AEC modified some of the licenses, limiting certain operating parameters. The AEC ordered its own reactor managers to review shut-down margins and to assure that control systems operated fully within design specifications. Maintenance and operation were to take place only under fully qualified supervisors.

For low-power critical facilities, including the ones at the NRTS, the AEC ordered that all operating and shutdown procedures be written in detail. Joe Hensheid, supervisor of the ETR Critical Facility, recalled:[11]

The SL-1 accident was a big watershed point. Up until then, our detailed procedures weren't much, but we were able to get a lot done in a short amount of time. After SL-1, the reactor [I worked with] was shut down, and we had many, many reviews of procedures. Some reactors at the Site went two years before starting up again. There were committees, and everyone was reviewing procedures and developing formalized sign-offs. It turned into a totally new way of doing business with reactors. Procedural documents that originally had been two pages long were expanded into thick books, and all activity became rigidly prescribed...those years of committee meetings with no experiments were hard on everyone.[12]

INEEL 62-6216

INEEL 63-1666

Left. ML-1 Test Building at Army Reactor Area-IV. Power conversion component faces the door. Top of circular reactor component is behind it. Below. Aerial view of ML-1 test area. Control trailer is in lower center behind shielding berm. Reactor was in Test Building in upper center of view.

The accident inspired the AEC's Advisory Committee on Reactor Safeguards (ACRS) to continue its strong interest in learning more about the type of destructive accident represented by the SL-1. The SPERT program particularly received strong support. The ACRS was looking toward the future when power reactors would contain far more fuel and a bigger inventory of fission products than the SL-1. It requested that safety researchers look for a way to build large reactors so that a neutron disturbance or excursion in one region of fuel could not propagate to the rest of it. In such an event, the ACRS hoped that "destruction of more than a small part of the reactor is demonstrably impossible."[13]

The SL-1 disaster had no apparent impact on the Army's plans for small nuclear power plants. In the immediate aftermath of the accident, it ordered its Portable Medium-Power reactor, operating on the Greenland ice cap, to shut down pending a review of its control rods and operating procedures. The Army continued its experiments in Idaho. Work at the GCRE had produced the data for a pin-type fuel design for the Army's "mobile" prototype. A month after the accident, Aerojet-General in Downey, California, loaded the prototype ML-1 onto an Army semi-trailer and hauled it to Idaho for field testing.[14]

The little reactor went critical for the first time later in 1961 and ran as a power plant for the first time on September 21, 1962, making history as the smallest nuclear power plant on record to produce electricity. It reached full-power operation on February 28,

1963, and this first run continued until March 4, 1963. Despite these benchmarks, the ML-1 proved disappointing, typically operating only a few days or hours before shutting down because of leaks, failed welds, and other problems. After its four-day March 1963 run, for instance, the crew found that the coolant, nitrogen gas, had been leaking into the moderator water. By the time of its final shut-down on May 29, 1964, the ML-1 had accumulated only 664 hours of operation.[15]

At the end, Aerojet disassembled the ML-1 reactor at the TAN Hot Shop to discover the reason for its last failure. Temperatures over 1,200°F had corroded the steel pipes containing the gas. The ML-1 concept was too advanced for the materials available.

That finding came in 1965. The escalating war in Vietnam forced the Army to evaluate its spending and research priorities. The Army's prototype reactors in Greenland and elsewhere had acquitted themselves well, and it appeared that the life-time cost of a nuclear power plant was lower than that of a conventional plant. But the initial cost was far higher. As it set war-time budgets, the Army opted for low first-cost alternatives. Economists suggested that this was false economy, but the Army canceled its program in 1965 and never restored it. The reactor skid, control rod shields, and other ML-1 parts ended up in the NRTS Burial Ground.[16]

The remains of the SL-1 building did not go to the Burial Ground. After abandoning early thoughts of restoring the building, GE concluded that hauling the contaminated debris to the Burial Ground, a distance of sixteen miles and partly on Highway 20/26 would subject laborers to too much avoidable risk. Instead, it built two large pits and a trench about 1,600 feet away from the SL-1 compound. The walls of the silo, the power conversion and fan-floor equipment, the shielding gravel, and the contaminated soil that had been gathered during the clean-up all went into the pits. Three feet of clean earth shielded the material. An exclusion fence with hazard warnings went up around the area, the only monument to the reactor.[17]

The IDO completed its film, which included the reenacted crisis response, an animated segment explaining the water hammer, and lessons learned about emergency planning. Planners and operators at other AEC labs and commercial nuclear power plants used it as a training device for years after the accident. Manufacturers of detection instruments increased the upper limit to 1,000 R/hr. Makers of respirators

INEEL 62-1710

Right. Foundation piers and gravel were all that remained by 1962. Debris went to a special SL-1 burial ground. Below. Dismantling the SL-1 foundation piers required the use of shaped charges. Here crew wires caps to charges.

INEEL67-2587

learned that their equipment had to work in sub-zero temperatures. The IDO continued to concern itself with emergency planning, developing techniques and equipment to reduce personnel exposures and save equipment losses in accident responses.[18]

In connection with its continued work on emergency planning, the NRTS became identified as the major source—only source, in fact—of experience with the execution of emergency plans. C. Wayne Bills, one of the IDO managers of the recovery, said later:

I averaged a call a month on SL-1 for over twenty years. Nuclear accidents are rare! Years later, after the accident at Three Mile Island, they quickly looked for decontamination, photography, dosimetry, environmental monitoring, and other techniques from the SL-1 accident and reactor safety program to apply to their recovery.[19]

Twenty-two of the people who had responded to the SL-1 alarm received radiation exposures in the range of three to 27 Roentgens total body exposure. Three of them received more than 25 R. The exposure guide that had been set up by IDO's prior emergency plan allowed rescue personnel a 100 R dose to save a life and 25 R to save valuable property.[20]

In March 1962 the AEC awarded Certificates for Heroism and other recognitions to thirty-two SL-1 participants at a ceremony at the Idaho Falls High School Little Theater. Among them were the military men, the nurse Hazel Leisen, doctors Voelz and Spickard, and the many others from IDO, Phillips, and other contractors who had performed "special acts of service" or attempted a rescue at great risk to themselves.[21]

INEEL 62-3983

The SL-1 complex in 1962. The dirt road leads to the SL-1 burial ground.

To the surprise of GE and Westinghouse, the accident failed to have an immediate impact on the public's acceptance of nuclear power. However, the accident's long-term impact on the progress of the industry might be measured by the frequency with which it appeared in nuclear-protest literature, a genre that flourished in the 1970s and 1980s. Several books listed nuclear accidents, near-accidents, and mishaps, describing them in language aimed to outrage or frighten the reader. The accounts of SL-1 were often inaccurate, and authors sometimes gave more-trivial events equal weight. The accident became part of a litany of events employed in these attempts to erode pubic confidence in the safety of nuclear power.[22]

For the NRTS people involved, the experiences of the crisis and the recovery were the kind that permanently etched themselves in the memory. Nearly a thousand people were involved in the crisis and clean-up. People at the periphery of events heard stories and retold them. Over the years, the stories gave the SL-1 accident a quality of legend, and these co-exist with thousands of facts describing the event, the results of the investigation, and the scientific analysis.

Much of the legend grew up around the question of cause that the investigation could not answer: did one of the cadremen deliberately withdraw the control rod, and if so, why? Or did the control rod stick, causing over-exertion and a sudden release? All of the science at the NRTS was unequal to this most perplexing question.

INEEL 81-3966

A 1961 photograph of the damaged top of the SL-1 reactor vessel was reused in 1981 to convey a safety message.

CHAPTER SEVENTEEN

SCIENCE IN THE DESERT

The promise and prospects of nuclear energy were high and the problems were few. We were the good guys.

–William Ginkel–

Hugo N. Eskildson replaced Allan Johnson as the IDO manager, but after a troubled term lasting only two years, he left the NRTS. The interlude had been uncomfortable for other IDO administrators and the business leaders of the town, who realized how important their mutual regard had become. The IDO wanted to preserve the support it enjoyed from the community, and the business leaders wanted to preserve an environment in which that support would continue. As Allan Johnson pointed out when he resigned, the NRTS had grown on his watch from 1,400 to 4,000 employees. The number of reactors had risen from seven to thirty. The NRTS was fulfilling its promise as a propellant for regional economic growth.[1]

The AEC elevated Eskildson's deputy, William Ginkel, as acting manager in September 1963, making it permanent in April 1964. Ginkel was the first of the managers not to share the military background of his predecessors. He had worked as a civilian at Oak Ridge from 1944 through 1950, first for contractor Tennessee Eastman and then for the AEC, involved with the chemical aspects of keeping track of uranium. His degrees at the University of Rochester included chemical engineering and business administration. With the opening of the NRTS, he saw an opportunity for promotion and a chance to join an emerging engineering outfit. After a successful IDO interview, he wondered how he might persuade his southern-born wife to love the West. Used to lush vegetation,

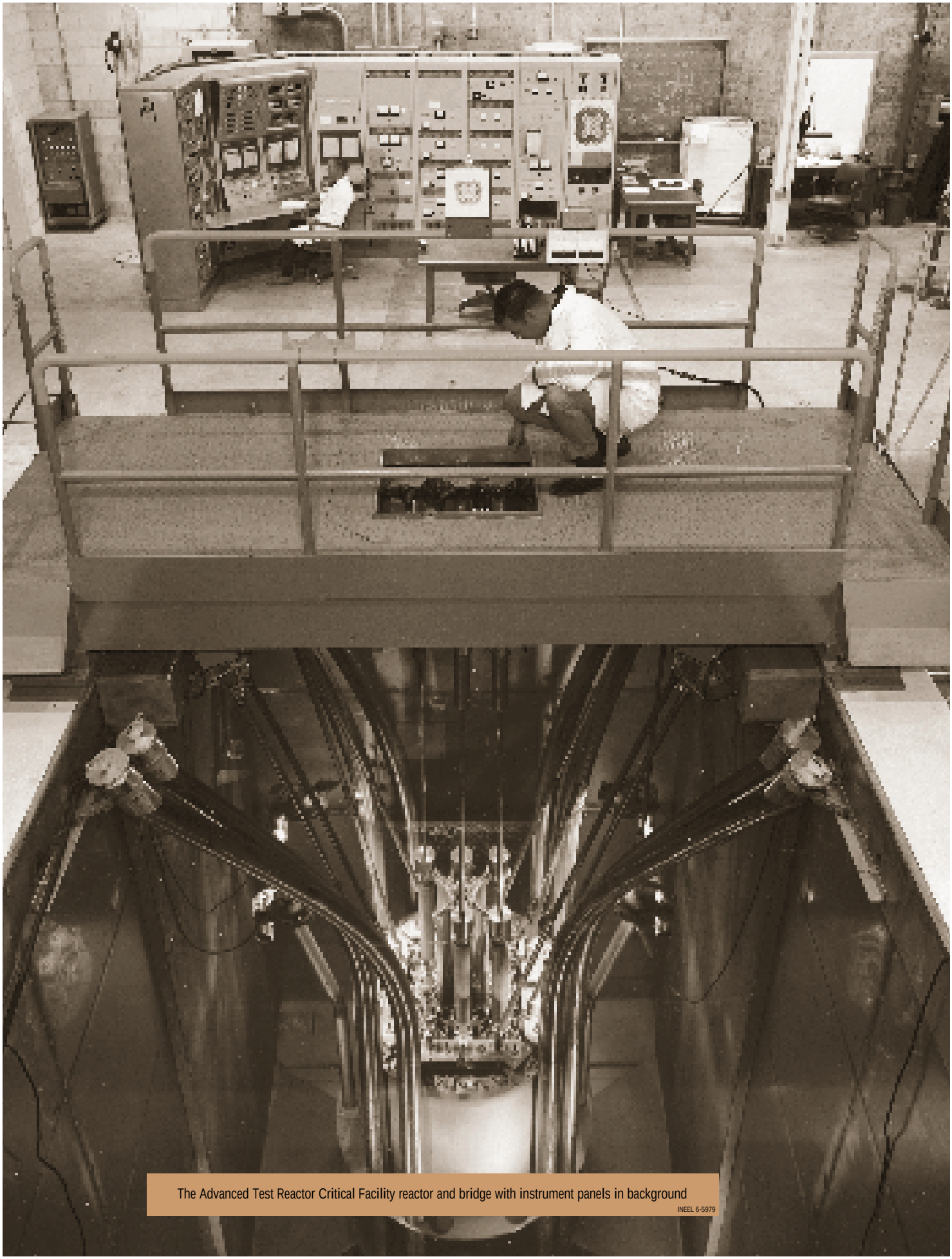
INEEL Cultural Resources

William Ginkel

she had her doubts about the desert. He sent her photographs of the lovely gardens around Idaho Falls'Tautphaus Park and the Latter Day Saints temple. Desert or no, Idaho offered them both—and others who had lived behind the security gates of a government town—the welcome prospect of living a more civilian life in a traditional American neighborhood. After a series of promotions, at first in work related to the Chem Plant, and a short hiatus at Knolls Atomic Power Laboratory in Schenectady, Ginkel reached the upper tier of IDO management.[2]

Just as Ginkel moved into the manager's office, Dr. Richard Doan, aged sixty-five, retired from Phillips and the NRTS. Doan's unembroidered approach to work lasted through his final day on the job. "He spent his last day as if it were any other day—no round of goodbyes, he just worked until five o'clock and walked out," wrote one of his colleagues. Doan's retirement proved not to be very thorough. He had been a member of the AEC's Advisory Committee on Reactor Safeguards since its inception, and he continued to serve on this committee and as an advisor to the licensing staff for the AEC.[3]

Ginkel took office as reactor research was in full flourish everywhere at the Site. The success of the original four projects had led to second and third



The Advanced Test Reactor Critical Facility reactor and bridge with instrument panels in background

INEEL 6-5979

INEEL Cultural Resources

Deslonde deBoisblanc

generations of the concepts they represented. In late 1963, construction crews were back in force, the annual payroll was high and growing, and new initiatives were evident everywhere. Even space-age projects had arrived at the NRTS. Nationally, nuclear power plants were about to move into the commercial market, and the demand for safety testing, NRTS-style, was growing. No matter where he looked around the desert, Ginkel could observe an impressive array of activity.

At the Test Reactor Area, the Navy was emerging as Phillips' major customer, and a third big testing reactor was on the way. The Navy's nuclear fuels were getting more complex, and the Navy wanted a test reactor with more precision than the ETR. It wanted to test full-scale fuel elements, which were getting larger and thicker, not just samples. Also, it wanted faster results, which meant having space in the reactor to run several tests at the same time and expose them to a very high flux of neutrons. ETR flux was too low and its test loops were too small.[4]

Besides that, the normal way of operating the MTR and ETR created problems. Typically, control rods moved up or down during operation to regulate the power level of the reactor. But if a test sample several inches long was in the reactor parallel to a control rod, the neutron exposure to the top and bottom halves of the sample would not be the same for the duration of the test. In the MTR the variation could amount to thirty percent; in the ETR, ten percent. The Navy wanted to reduce the percentage even more. Its planned experiments required perfect symmetry—or as close to perfect as possible—along the entire length of a test sample.

In the late 1950s, the AEC and the Navy invited a number of companies to make proposals for an advanced test reactor that would serve not only the Navy but the AEC's other test needs for many years to come. Despite study periods of up to three years, none of several responses met the Navy's demanding requirements within a reasonable cost or time. It appeared that the aluminum-clad/enriched-uranium reactor concept might have reached its limit of performance.[5]

The Navy asked Phillips to take two months to review previous proposals and come up, if possible, with a conceptual design. This challenge handed NRTS people a chance to prove they could still produce brilliant ideas. One of them, Deslonde deBoisblanc, a scientist with no doctorate in physics but who nonetheless had a feel for the way neutrons behave, created an elegant design for the reactor core in 1959. The design, named Advanced Test Reactor (ATR), first of all solved the symmetry problem. DeBoisblanc described the ATR's new way of controlling the power level.

I tried to avoid a common problem encountered in most other test reactors, where the control elements move up or down. In the ATR, the larger range of control is accomplished by rotating six - teen beryllium cylinders with hafnium shells that cover 120° of the outer sur - face. (Hafnium is a strong neutron absorber.) The cylinders are situated around the core. When rotated singly or in groups, the hafnium moves closer or farther from the core, thereby control - ling reactivity without disturbing the vertical power profile.

The design also included small neutron-absorbing control rods. Unlike control rods in earlier reactors, these were not moved slowly up or down during reactor operations to effect their control, but either fully inserted or fully removed.

Another ground-breaking—and aesthetically satisfying—innovation in the ATR was how it wrapped the reactor's fuel around the samples in serpentine fashion, more than doubling the neutron flux (available in the ETR) to the sample. As deBoisblanc relates, it was during the long drive home from the Site that the "Aha!" moment occurred.

As was the custom, I was driving Byron Leonard, our consultant from Internuclear Company, to his hotel in

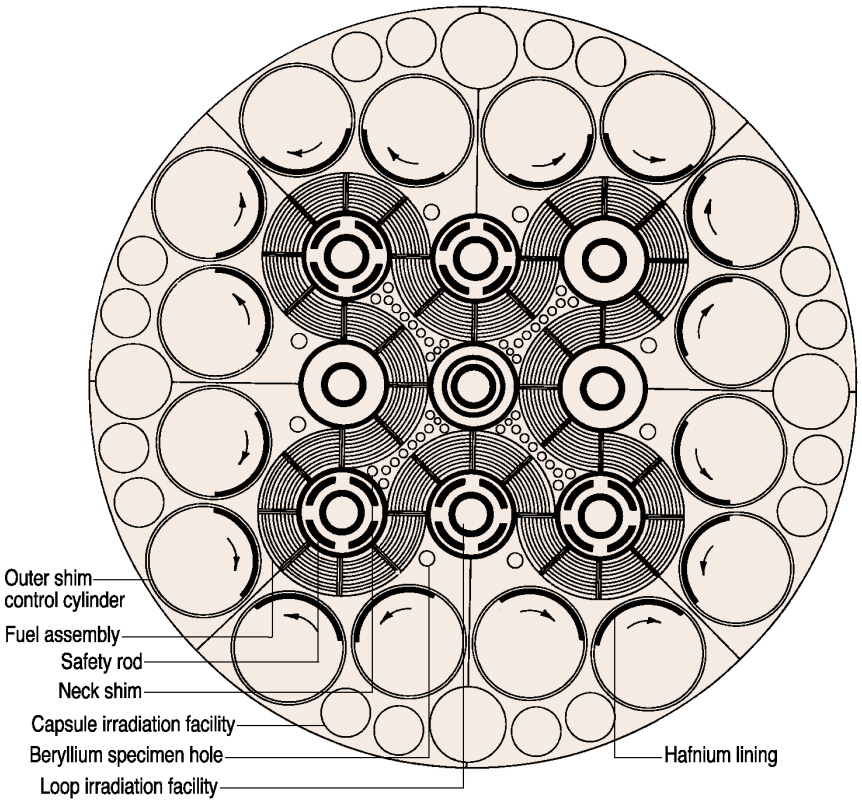
Idaho Falls. It was one of those lingering twilight evenings, still quite light. On that straight stretch of Highway 20 across the desert, with its sage brush and the frequent lava flow patches, there wasn't much to distract us.

I started to describe a novel way to look at the problem before us. I thought of breeder reactors, where the effort is to minimize the leakage of neutrons. I tried to think how we might make the neutrons leak in the direction of the sample, where we wanted to maximize the number of neutrons absorbed into the Navy's samples.

If we placed water between the ATR fuel and the sample, the fast neutrons would "leak" into the water and collide with hydrogen. This would slow them down and they would pile up to create a high slow-neutron flux. This is the so-called "flux trap," which I didn't invent.

I reached over across the front seat of the car and with my finger drew four circles for test loops, and then a snake-like fuel line partially around each loop. Immediately, I saw that we could place another loop at the very center because the four arcs that surrounded the center loop were almost as effective as a circle. It soon became obvious that by placing a beryllium reflector properly we could gain four more attractive loop locations.

The more we looked at that strange arrangement, the better it looked. Possible new locations for control elements became apparent. Byron was so excited he volunteered to lay out the configuration. He didn't get much sleep that night, but what he produced was remarkable. His plan view showed that the entire serpentine fuel arrangement could be produced with only one type of fuel element. The number of test loops grew from the original four to nine.[6]



This schematic drawing of the ATR core in cross section shows the arrangement of the nine test holes, the serpentine arrangement of the fuel assemblies, and the sixteen control cylinders. Note the hafnium lining on the cylinders. The hafnium-lined portion of the cylinder could be turned toward or away from the test hole, depending on the desired neutron flux.

The next several days brought the usual questions from devil's advocates. As always with a "rich" design, each negative, when resolved, revealed new capability. They sensed they had a winner. "We quickly loaded the ETR Critical Facility," said deBoisblanc, "to model the serpentine geometry. The stunning success of that program is another story in itself. The mockup was really the clincher."[7]

Arranging the core into multiple different flux-trap regions—in which the power level could be different in each simultaneously—was something that deBoisblanc did invent. Satisfied, the AEC and the Navy selected the ATR cloverleaf design. Native ingenuity at the NRTS had influenced the destiny of the lab one more time.[8]

Now the ATR was under construction just two hundred yards away from the MTR. At the groundbreaking in 1961, Governor Smylie had said that the $40

million project was the largest construction project in the history of Idaho, eclipsing the Mountain Home Air Base, which had cost over $30 million. With a capability of operating at 250 megawatts, the ATR would be the largest test reactor in the world. If projections held, it would begin operating in 1965.[9]

The MTR was still working, having surpassed 11,500 experiments. At the Second Geneva Conference on the Peaceful Uses of Atomic Energy in 1958, Phillips announced that the MTR had run on plutonium-239 fuel at a power level of thirty megawatts for several months, adding more luster to its reputation. As the first water-moderated reactor to do this, the reactor confirmed that plutonium could be a reliable and controllable fuel for power reactors. It was another first-in-the-world for the MTR.[10]

The ETR had been in service since 1957. The ETR's on-stream time was lower than the MTR's, mainly because the elaborate experiments took more time to set up. Competition for its service was heavy, especially with the space program considering nuclear applications.[11]

Other TRA facilities were equally busy. The early zero-power reactors had given way to more advanced models. The Gamma Facility had irradiated its first 100,000 samples and was approaching 200,000. The neutron physics program continued its exploration of neutron interactions with matter. The work most immediately served reactor designers, but also moved 20th century physics along in its progress toward understanding the atomic nucleus and ever smaller particles of matter.[12]

The NRTS had long ago burst the seams of its Naval Proving Ground inheritance at Central Facilities. The growing safety and materials testing programs needed support labs and office space. About $1 million worth of new space had been built in 1962, and more was on the way. The sponsors of MTR and ETR reactor experiments had to design the experiments, but they needed NRTS welders, pipe fitters, carpenters, mechanics, heavy equipment operators, and other specialists to build them. New and larger craft shops were popping up. Whenever a project or program vacated a building, someone else usually was waiting in the wings, seeking relief from crowded conditions elsewhere.[13]

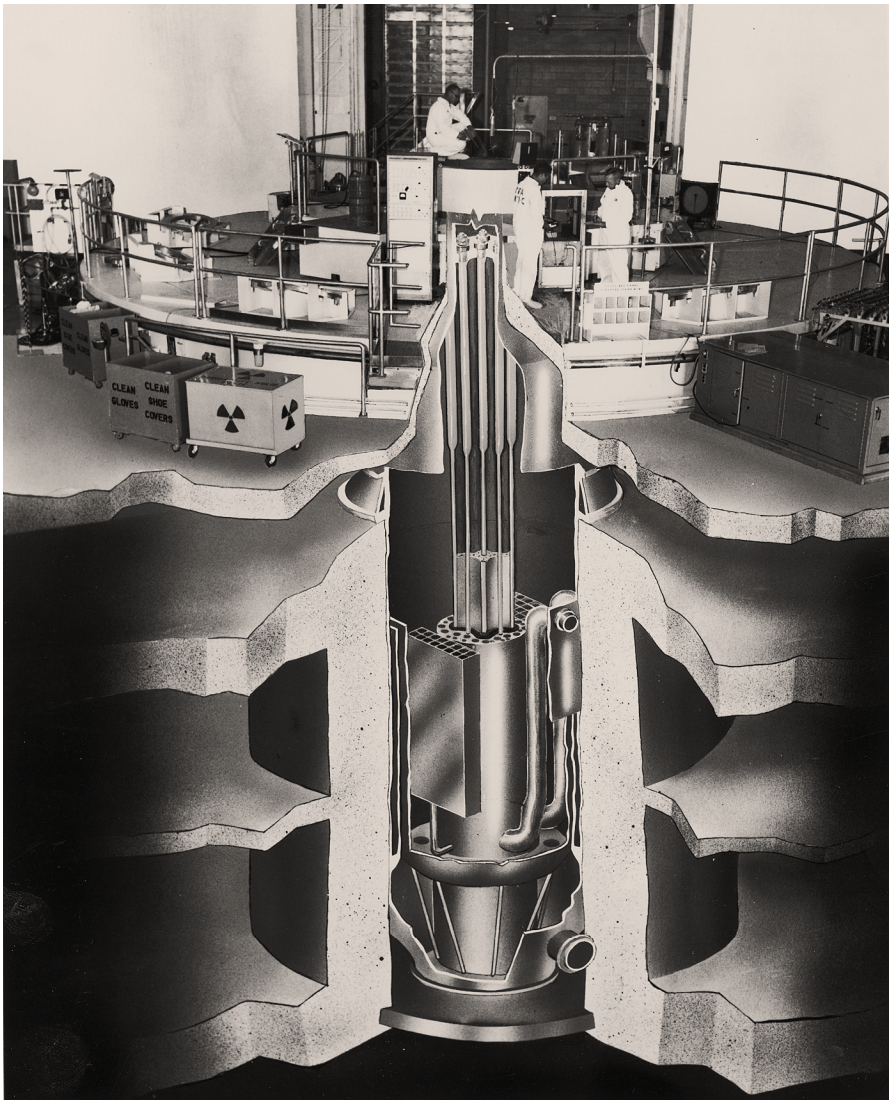


Photo and schematic of ATR showing basements below operating floor.

INEEL 68-4967

One project that shut down in 1963 was the Organic Moderated Reactor Experiment (OMRE). The art of diphenyl isomers had advanced since Argonne's tar-making days, and this low-cost experiment ($1.8 million) had used something called Santowax-R as the coolant. The reactor operated for six years, proved itself with a succession of different cores, and served its purpose. The advantage of the waxy substance was that it liquefied at high temperatures but didn't corrode metal as water did. It could operate at low pressures, significantly reducing the risk of leaking.[14]

A California company, Atomics International (AI), had proposed and co-financed OMRE, the first such partnership between the AEC and the private sector at the NRTS. The HPs often recalled the California roots of the reactor because some of the process gauges were located outside the building. To examine them on a typical Idaho winter day required bundling up for the cold.[15]

The AEC decided to refine the OMRE concept and scale it up. The Experimental Organic Cooled Reactor (EOCR) went up next door, equipped with special testing loops and other advanced features. By December 1962, the facility was nearly complete. Then the AEC canceled the program, deciding the concept could not improve on the performance of breeder or water-cooled reactors. The EOCR was never loaded with fuel and never went critical. The building was recycled for storage and office space until the 1980s brought another recycle as a training center for the Site's security forces.[16]

Nevertheless, the concept had one chance elsewhere in the United States. The town of Piqua, Ohio, had responded to AEC's Power Demonstration Reactor Program and applied for a project. Its 11.4-megawatt reactor had been modeled after the OMRE and went critical in 1963. The town had to shut it down three years later when wax built up in the reactor core, making it hard to maintain and operate. Irradiation had changed some of the wax, which melted at higher temperatures.[17]

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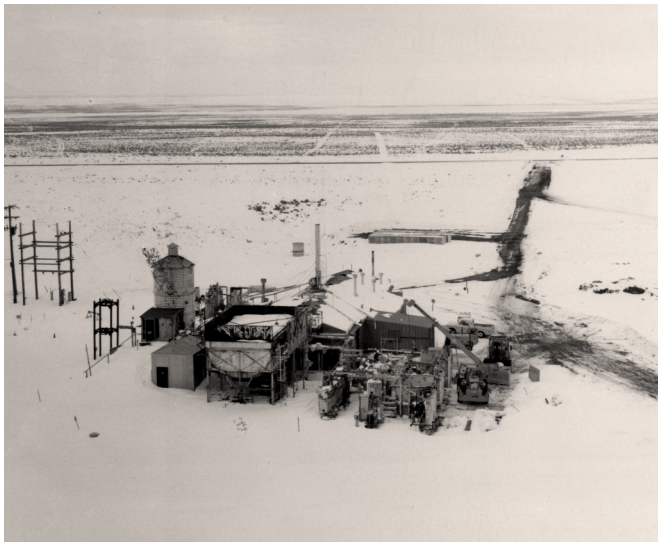

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Left. EOCR reactor facility in 1978. Below left. OMRE as it looked in 1978 prior to demolition. This was the first demolition as part of the official decontamination and decommissioning (D&D) program initiated by EG&G Idaho. Scientists researched D&D methods, tools, and procedures. Below right. OMRE area in 1980 after D&D.

At Test Area North, things were happening at the old ANP facilities. A new series of reactors was going critical—and destructive tests taking place as scheduled. The National Aeronautics and Space Administration (NASA) was sending satellites into orbit and imagining future space exploration. It wanted to know if nuclear reactors might produce electricity for heat and experiments on space missions. Solar cells and chemical batteries were useful for short missions, but for longer ventures, these methods were either too low-power or too heavy. Reactors might optimize long life and light weight. Its development program was called Systems for Nuclear Auxiliary Power, SNAP.[18]

NASAplanned to launch its first reactor into space in 1965 with an Atlas-Agena rocket. But first, it had to consider the consequences of potential accidents. A rocket might fail, for example, and the payload—reactor included—plunge into the ocean. NASAasked Phillips, which was conducting a safety program called Safety Test Engineering Program (STEP), to test a mock-up of the reactor, named SNAP-10A, and determine the radiation levels that might be released in such an accident. The NRTS had simulated submarines in the ocean, so it was no problem simulating a rocket crash in the ocean. The action on April 1, 1964, was at TAN. Richard Meservey, in charge of instrumentation, recalled:[19]

They took an old ANP double-wide rail car, put a huge tank on it and filled it with water. The tank had a plexiglass sleeve in the center to exclude water. The reactor was placed in the center of that plexiglass sleeve. When they were ready to run the test, they used explosives to drive the plexiglass sleeve away so water could rush in on the reactor. That simulated crashing into the ocean.

My job was to measure the temperature of the fireball if one should occur. I had a little hoghouse, a triangular structure set up at the ANP coupling station near the test. We had to worry about neutrons coming out and destroying the instruments, so we set up paraffin and cadmium shielding to thermalize the neutrons, and lead to stop the gamma radiation.

A fireball did develop and blew the reactor all over the area. We used a front surface mirror so that the direct radiation would not destroy the infrared temperature detectors. The detectors "looked" at the fireball via the mirror from behind the shielding. We knew we'd lose all the thermocouples in the fireball, so we used an optical pyrometer to measure the heat. It worked well.[20]

The program tested three SNAP reactors to destruction. HPs went on the road once more, tracing small puffs of radioactive iodine. Photographers captured the most informative views of the

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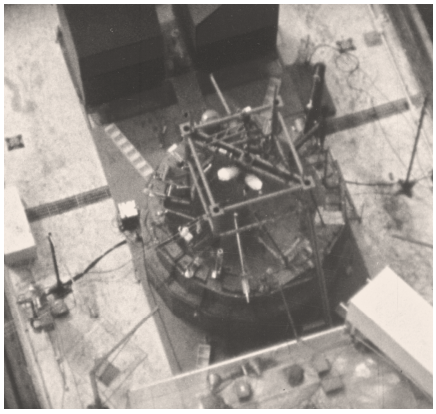
Left. The ANP's shielded locomotive was recycled for use with SNAP transient experiments at TAN. Below. SNAPTRAN-3 destructive experiment, April 1, 1964.



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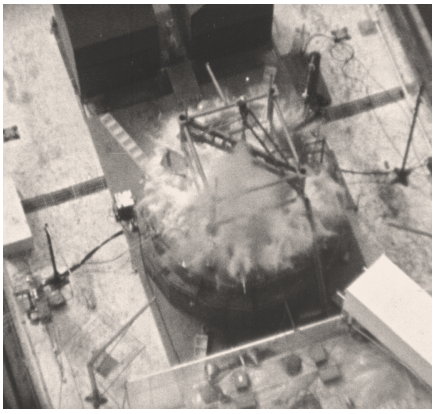

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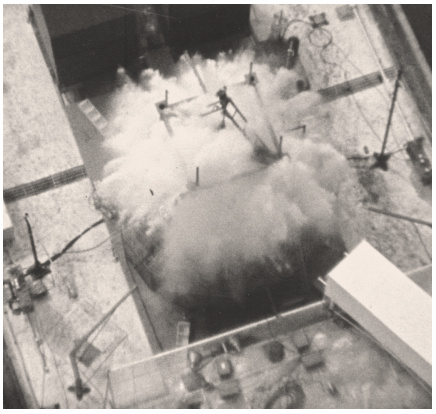

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explosions. Safety engineers imagined what else could go wrong—an accidental criticality on the way to the launch pad, for example. Then they engineered ways to prevent such an occurrence, such as shipping the fuel in small separate packages. The tests proved that the reactor would destroy itself, not continue to operate and build up a high inventory of radioactive fission products if it fell into the water.[21]

Reactor work, perhaps less photogenic than the destructive tests at TAN, was underway at every other corner of the Site. The Army was trying to perfect its small mobile reactor, the ML-1, hoping to conduct a continuous 500-hour run in the spring of 1964. At the NRF, the Navy was building the S5G natural circulation reactor prototype and enlarging the Expended Core Facility. The SPERT and TREAT investigations continued to unravel the mysteries of fuel behavior under abnormal conditions.

At Argonne-West, the first-generation breeder reactor was giving way to the second, the EBR-II. The venerable EBR-I ended its useful life in December 1963. It had run on four different fuel loadings since 1951. The first had bred new fuel at a scant ratio of 1.01, just barely replacing the fissioned fuel. The crew had mastered the handling of NaK coolant, learned from the 1955 meltdown what had caused instability in the fuel, and finally proved that plutonium fuel, although it had a low melting point and deformed under stress, could be managed in a breeder reactor as well as uranium. In fact, the breeding ratio improved to 1.27. And the locally made electromagnetic pump worked through all four core loadings, trouble-free.[22]

Now EBR-II was moving the breeder concept forward, scaling up twenty times larger than EBR-I. After its first criticality in November 1963, it advanced to the next milestones.

Argonne National Laboratory-West 5814

EBR-II turbine generator.

August 1964 saw the turbo-generating equipment produce electricity, at first in small amounts, then up to 62.5 megawatts. The reactor supplied all the power needs of Argonne-West with enough to spare for part of the demand elsewhere on the NRTS electrical grid.[23]

Argonne scientists were attempting a far more daring goal with EBR-II than merely producing electricity. The idea was to produce it efficiently. In addition to recycling its own fuel on the premises, Argonne also envisioned fuel that would "burn up," i.e., fission, a high percentage of its uranium fuel before it got so clogged up with fission products that it could no longer sustain a chain reaction. Unlike most other reactor fuels, EBR-II fuel was made of pure metal, not oxides. The fuel elements were pin-shaped, thirteen and a half inches long and of a smaller diameter than an ordinary pencil. The standard fuel was mostly uranium, enriched to 67 percent U-235, but alloyed with a few other metals. A standard fuel subassembly took 91 pins, which were arranged in a hexagonal pattern in the reactor. Aside from its excellent heat-transfer properties and superior breeding qualities, the metal fuel made it feasible to melt, refine, and fabricate new fuel elements just down the hall—literally.[24]

In September 1964, the EBR-II reactor operators removed spent fuel pins from the reactor—now containing fission products and uranium. About one percent of the fuel had burned up. After letting it cool for two weeks, they sent it through the FCF, the special argon-atmosphere recycling facility attached to the reactor building. (Argon gas was used to prevent sodium fires that were possible in ordinary air.) At a series of work stations arranged around the large circular cell, technicians removed spacer wires and chopped the pins into convenient sizes. Safe behind shielding windows, they manipulated their tools and ran the small furnace, heating the metal to 1,400°C and refining it. Finally, they vacuum-cast new pins in Vycor glass molds. The fission product waste ended up in a crucible as a blob vaguely resembling a skull, which is what they were called. New fuel pins, however, were ready for a trial run in the reactor.[25]

The pins performed well, as expected. EBR-II proved the principle. It continued running with recycled fuel from 1964 to 1969. By 1969, Argonne would raise the burn-up rate to 1.8 percent. During those years, there had been no shipping costs. No transit risks. No wasting of good enriched uranium. No storing of spent fuel under water for months and months. No liquid wastes that might leak. Just blobs of hazardous waste to manage. For those who worried about terrorists stealing plutonium, the set-up offered little opportunity.[26]

Of all of the reactor research done thus far by the AEC, EBR-II and its fuel recycling operation was the closest thing to a perpetual energy machine that had been invented. The political outlook for Argonne's breeder research looked as promising as the scientific. When the AEC abandoned the organic-cooled concept in 1962, it elevated the breeder concept at the same time. The Federal Power Commission (FPC) estimated that American energy consumption would double by 1990. It figured that the nation's fossil fuel supplies would be depleted within two hundred years. The FPC believed nuclear energy could—and should—displace fossil fuels and supply as much as two-thirds of the country's electricity by the year 2000. Under this scenario, the AEC accelerated its work on breeder reactors. The success of EBR-II was only a beginning. The concept still had a long way to go before it could safely scale up to a size competitive with fossil fuel power plants.[27]

Thus, the AEC had authorized Argonne to design a third-generation testing breeder reactor in Idaho. The Fast-Reactor Test Facility (FARET) would

Right. Inside the FCF's argon atmosphere hot cell. Note manipulators at right. Below. The view in the working corridor outside the hot cell windows.

Argonne National Laboratory-West H5673

Argonne National Laboratory-West G5264

take the concept well beyond EBR-II and the only other operating breeder reactor in the country, the Fermi plant in Detroit. It appeared, although it was not yet certain, that funding would be approved and that Argonne-West might see FARET under construction in 1965.[28]

Not all nuclear research at the NRTS was conducted at reactors. Environmental and health studies continued, and in 1963 the IDO went into the dairy farm business. Partly because of the growing frequency of destructive tests at the NRTS, each of which released small amounts of radioiodine-131, the IDO Health and Safety Division wanted to get a firm handle on the impact of these releases. If a large accidental release occurred—and one had occurred in England in 1957 because of a fire at Windscale's reprocessing plant—the IDO wanted to be ready with better emergency plans, not only for Site employees but also for downwind residents beyond the NRTS. To do that required a method of predicting how the iodine would behave. In addition, the information might improve the reactor siting criteria used at the NRTS.[29]

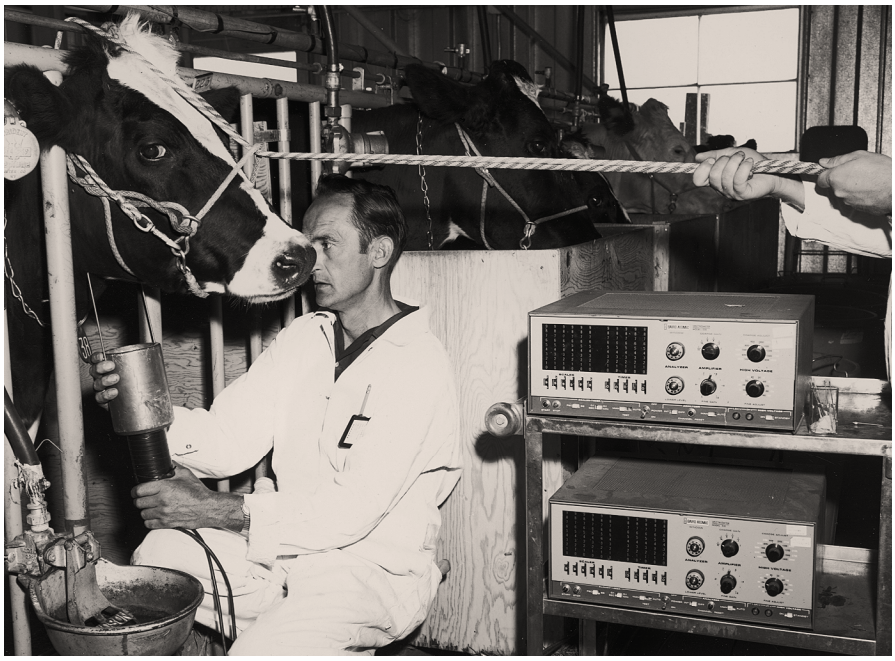
The pathway of I-131 from the air to grass to cows to milk and to humans had been generally understood since the 1950s. But local doses could be calculated only if local transfer patterns were known. Previous studies elsewhere had taken place mostly in laboratories. No one had tested how iodine actually behaved in a natural environment.[30]

The IDO knew there was nothing like a field study to answer questions and create predictive models. What amount of an I-131 release would deposit on the grass? After a cow ate the grass, how much radioiodine would go to its thyroid, through its body, or to its milk? After conducting a feasibility experiment on a field of crested wheatgrass near the southern edge of the Site, the IDO requested funds for a multi-year program.

In setting up the Experimental Dairy Farm, the scientists called upon local county agents and others to help them decide how much acreage would support how many cows, what kind of vegetation was typical on nearby ranches, and the details of cow management. Montana State University lent Hereford cows for the testing season. Because of this, John Horan observed later, "We had some of the best pedigreed animals in the world."[31]

The dairy farm project, managed by Clyde Hawley, used twenty-seven acres of flat ground about seven miles northeast of the Chem Plant—easy to get to and easy to cultivate. He set up a grid of detection instruments, dotting the pasture in regular lines and rows. Press releases went out, describing the purpose of the project and seeking bids from local farmers to care for the farm and six cows, irrigate the pasture, and keep milking records.[32]

The program was called CERT (Controlled Environmental Radioiodine Tests) and would involve many experiments over several years. Typically the manager ran tests at different times of the year. When ready for a given test, he would order iodine-131 generators from Oak Ridge and set them up at the upwind edge of the pasture and trigger



INEEL 69-5648

Inside the barn at the Experimental Dairy Farm.

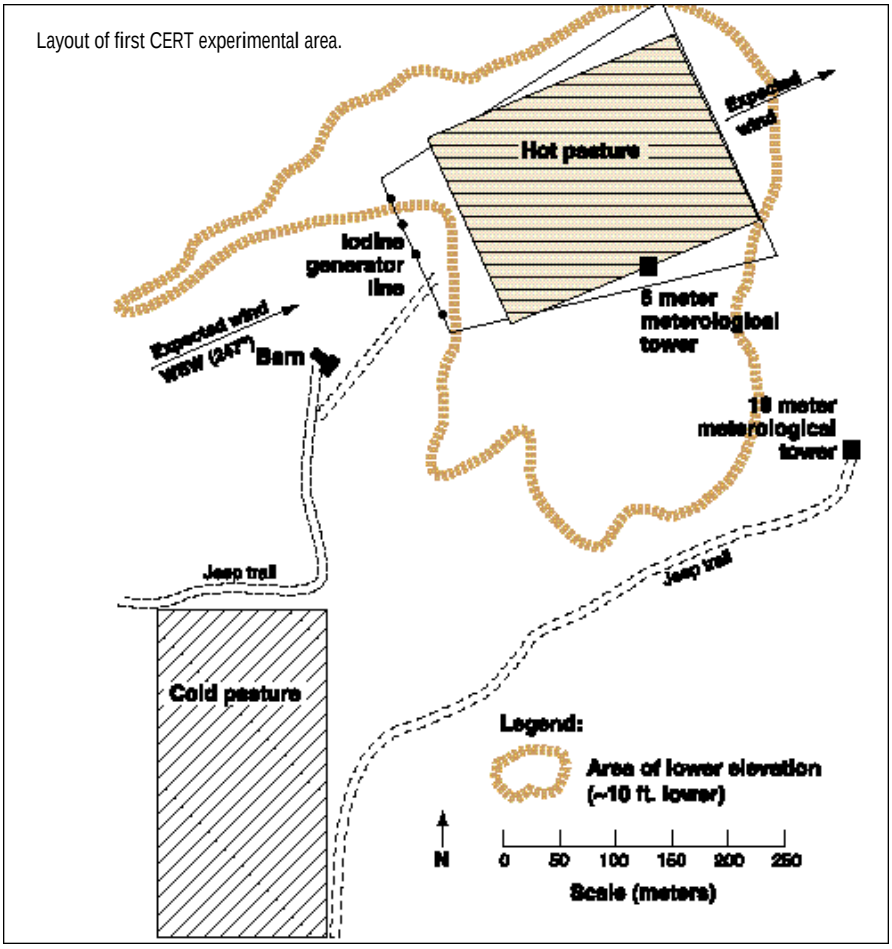
the release. Some iodine accumulated on the pasture grass. Cows ate the grass. Someone milked the cows. Technicians took samples of air, grass, and milk at suitably timed intervals, taking into account the eight-day half-life of the iodine. The IDO medical director, Dr. George Voelz, was a project advisor and recalled some of the early discussions.

We got to thinking about it. "Why don't we take it one step further? We'll get a few of us to volunteer to drink the milk, and we'll take the final step into the human." Clyde came to me to discuss it. The amounts were quite small, and I didn't see any problem. Ultimately he got six people to volunteer, all people working with him.

My concern was with the handling of the milk—bacteriological contamination. [The fact was,] we weren't set up as a milk supplier. He arranged to get a little home pasteurizer. In reality, we probably spent more time, at least as much time, talking about the bacteriology as we did the radiation.[33]

The proposal went to the IDO counsel. John Horan recalled discussing the implications of the Nuremberg Code. Nazi doctors had been convicted for crimes against humanity for human experimentation. In 1946 a code of conduct had been developed to guide human medical studies involving an element of risk. The key tenet was that "voluntary consent is essential." An approval and a sample consent form came from AEC Headquarters. It excluded Phillips or other contractor employees from participating because the AEC felt that the contracts provided insufficient liability protection to the government in case of a future claim.[34]

Layout of first CERT experimental area.



IDO-12035

The experiments completed the last link in the iodine chain, imitating an accidental release. At first, the IDO volunteers simply sat in the field during the release and breathed. In later tests, after the cows had eaten contaminated grass, the people drank small quantities of milk. Subsequent counts, made possible because highly sensitive equipment was available to detect the small traces, identified how much iodine went to the thyroid and how much was excreted.[35]

The CERT program continued until 1977 in a series of twenty-nine experiments, although only a few early ones involved the human consumption of milk. Most of the tests aimed to discover how seasonal conditions or different grasses affected the behavior of the iodine. Taken as a whole, they demonstrated that iodine uptake was a function of vegetation type, climate, and the time of year. The measurements made it possible to predict from known releases how much iodine would make it through the consumption chain to human bodies.

The project expanded to include a laboratory in which to isolate variables that couldn't be controlled in the field and to help refine predictive models. The findings brought practical realism to emergency planning and reactor siting at the NRTS. But the impact of the work went much farther. CERT findings helped persuade the AEC to reduce the amount of radioiodine that a commercial light-water reactor would be allowed to discharge. The new standard—a maximum of five millirem annual total body exposure—was one thousandth of the standard in effect before the CERT experiments.[36]

INEEL 60-2485

Over at the Chem Plant, the demand for recovered enriched U-235 had been slow for the last few years. After 1959, Hanford no longer sent highly enriched slugs to Idaho. From January 1960 through December 1963, the plant was on-line for a total of only twelve months. Runs were a month here, two months there. Likewise, the amounts of uranium were small, coming mostly from the MTR and ETR. The SL-1 fuel passed through the plant in 1962. After each run, the liquid waste went, as usual, to the big storage tanks.[37]

Then in 1963 things changed dramatically. The Waste Calcining Facility (WCF) went on line and revolutionized the management of radioactive liquid waste. Ever since the late 1940s, AEC chemists had been discussing what to do with the useless acidic by-products of uranium recovery. Pouring it in endless rows of tanks was obviously not a good idea. Acid corroded tanks—most likely within fifty years—and the long half-lives that made the waste such a hazard needed to be isolated from the environment for centuries, perhaps millennia. Chemists therefore talked of "ultimate" disposal and regarded tank storage as an "interim" step along the way.[38]

Chemists at various AEC labs came up with ideas on how to remove water from the waste and reduce it to a solid. The AEC decided to try only one of the ideas, a fluidized-bed calcination process, and build it at the Chem Plant. The development program began in 1955, as scientists at Argonne National Laboratory tested the method in small-scale models. The process not only solidified the waste, but the product was granular, free-flowing, and easily handled by pneumatic transport techniques. Phillips engineers started designing the plant in 1956.[39]

To design the plant, the engineers had to know which radioactive elements volatilized and which remained solid. Argonne identified what became of the different chemicals in the waste when heated to various temperatures. By 1957 Phillips had enough data to design a demonstration plant. The next year the Fluor Corporation started building

INEEL 59-925

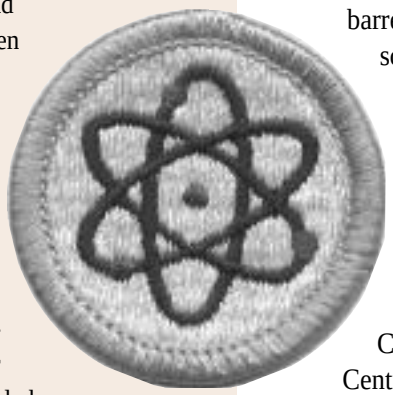
Above. Construction workers lower the calciner vessel into the calciner cell through a hatch. Left. Two of three surplus Navy gun barrels are shown in place during construction of the Waste Calcining Facility.

Atomic Energy Merit Badge

The 1960s expansion of nuclear power led the Boy Scouts of America to introduce the "Atomic Energy Merit Badge" to acquaint scouts with a nuclear energy career. This was the 104th merit badge in the series of Boy Scout badges, approved in 1963. Members of the American Nuclear Society expected to assist when scout troops asked for help.

The badge was a symbol of the lithium atom on a yellow background enclosed in a green circle.

To earn the badge, the scout had to discuss the meaning of terms such as alpha particle, curie, fallout, dosimeter, neutron activation, and Roentgen. He also had to select five scientists from a list of ten and explain their discoveries.



Required projects included making three-dimensional models of isotopes, explaining the difference between atomic weight and atomic number, and drawing the standard radiation hazard symbol.

A choice of optional projects might involve the scout in making and using a Geiger counter, building a model of a nuclear reactor, visiting a medical office using X-rays, making a cloud chamber, visiting an industrial plant where radioisotopes were being used, or comparing the progress of irradiated seeds next to non-irradiated seeds by growing both to maturity and noting any differences.

The AEC sent Idaho Senator Len Jordan two hundred booklets about the badge to distribute to his Boy Scout and Explorer Scout constituents.[43]

the facility just east of the Chem Plant's main process building and south of the storage tanks.[40]

The most common construction scene was the placing of concrete for thick shielding walls around the process cells—all of which were below grade. The engineers could not avoid locating three "hot" pipes directly beneath an access corridor where people would be working. At least one pipe would contain calcine—highly radioactive—on its way to a storage bin. So they made shielding tunnels out of Navy gun barrels, another successful scrounge courtesy of the old Proving Ground.[41]

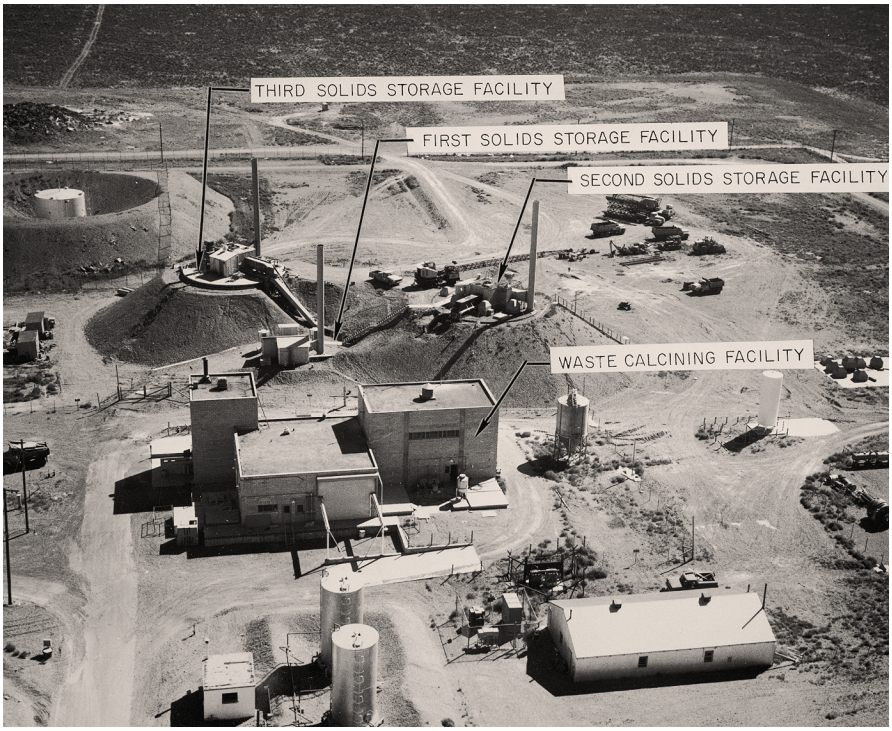
Learning to operate the fluidized bed required considerable experimentation, much of which was conducted at the Chemical Engineering Lab at Central Facilities. In 1961 Phillips began two years of "cold" operations, running simulated waste through the plant. The trials illuminated deficiencies in the equipment or the process, all of which the engineers had to adjust. At the same time, the safety teams imagined how malfunctions or human failures might put people in jeopardy. For example, what would happen if the plant had to shut down with calcine still sitting in the calciner vessel? Would decay heat cause the vessel to overheat? Answers to questions like this produced more engineered adjustments, more instrumentation, redundant equipment, and refinement of operating procedures.[42]

Now it was two days before Christmas in 1963. The years of preliminaries finally were coming to an end. Someone turned certain valves, and the hot waste from one of the Chem Plant tanks flowed into the building as a liquid and left as a solid. The magic was in the calciner—a cylindrical vessel four feet in diameter. It began by placing a bed of grainy material resembling sand (dolomite) at the bottom of the vessel. A NaK heat source placed within the bed of sand heated it to 400°C Then hot air flowed into the bed through fourteen holes at the bottom of the vessel, placing the grains in motion, or "fluidizing" them, like popcorn being air-popped in a theater lobby. Liquid waste, containing mostly aluminum nitrate, entered the vessel as a fine mist. In the hot environment, nature took its course. The water vaporized. Nitrate salts decomposed to nitrogen oxides and metal oxides. The solids adhered to the starter grains tumbling around in the vessel. As the process continued, the solids knocked against each other, causing small particles to flake off and form new starter grains for the liquid feed, which kept on coming.

As the solid—called alumina—accumulated, it left the calciner vessel through an overflow pipe. Pneumatic processes took over and moved it through a pipe (the Navy gun barrel) and on to storage bins east of the building. The water vapor and other off-gases left the vessel by another route, were treated, washed, and filtered and then exited the stack. One of the fission products in the waste, ruthenium-106, formed a volatile oxide that could not be allowed to go up the stack. The off-gas was routed into vessels containing silica gel, which absorbed the ruthenium-106.[44]

The calcine went to one of the bins in a "bin set," a group of four to seven tall, vertical steel bins nested together inside a thick reinforced concrete vault, in turn surrounded by earth and gravel shielding. The bins stood mostly above grade level, so the whole affair resembled a barren hill. Cooling air circulated past the bins, carrying off the heat of radioactive decay. Atop each hill were small shelters, called doghouses, for filters and the fans used to pull the air from within the bin set and send it up a small stack.[45]

INEEL 71-0848



INEEL 72-4571

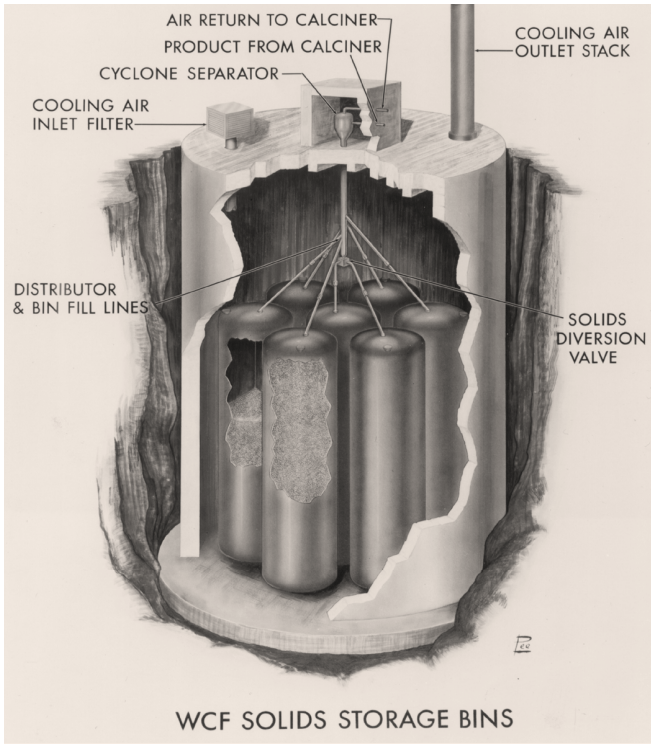
Above. One of seven "bins" is lowered into a bin set under construction. Bins will receive calcine and were built to last 500 years. Below. Waste Calcining Facility in 1972 showing location of the first three bin sets.

Operators referred to each run as a "campaign." The first one lasted until October 1964. Two 300,000-gallon tanks and part of a third were emptied before the campaign was forced to stop. In an excess of success, the campaign had filled up all the available calcine bins. Half a million gallons of liquid had been transformed into 7,500 bulk cubic feet of solid—a reduction in volume better than 9 to 1. The WCF had exceeded its design rate of 60 gallons an hour. None of the feed lines plugged up. Remote lubricating systems worked so well that no spares had to be put into service. The alumina traveled without incident from the calciner to the storage bins, despite several bends in the pipe. The gases leaving the stack included some strontium-90 and ruthenium-106, but the levels were below guideline limits. New bin sets went under construction, designed to last at least five hundred years and made so the calcine could be retrieved at any time in the future.[46]

Analysts who had predicted such matters as particle size and other properties of the alumina were gratified to find that performance matched prediction. The author of one report on the campaign credited these excellent results to the ten cold runs of the previous two years. All the rehearsing had made for a skillful and resourceful crew.[47]

Of all the innovations that streamed out of the NRTS, waste calcining turned out to be one of the most under-exploited outside of Idaho and the most profoundly valuable within Idaho. Neither Bill Ginkel nor anyone else could know it at the time, but the dry calcine tucked away in the bins would prove to be the safest, most environmentally reliable of all the methods then in use at any AEC facility for holding highly radioactive waste. The calcine could be retrieved from the bins if its constituents were ever desired for re-use. Or it could be transformed to a more inert ceramic or glass form for its "ultimate" disposal. At Hanford and Savannah River, where much larger volumes of waste accumulated, the practice was to put the waste, neutralized with sodium hydroxide in carbon steel tanks. This caused solids to settle into a radioactive sludge in the bottom of the tank—a sticky goo. It could not be re-dissolved in nitric acid without destroying the carbon-steel container as well. Nor could it be calcined. Several of the tanks leaked. Many Chem Plant scientists thought they had demonstrated a better mousetrap—a way to store very hazardous radioactive waste for centuries without threatening the environment—but the technology didn't transfer to other AEC facilities.[48]

The calciner, the breeder/fuel recycle experiments, the artful ATR, the reactor safety studies—all of the NRTS programs were at the leading edge of a hopeful new age of security and energy abundance. The NRTS was a unique place where opportunity was granted equally to all of the workers—meteorologists, health physicists, welders, chemists, electricians, instrument-makers, mechanics, laborers, physicists, engineers, managers, carpenters—to exercise daily their gifts of curiosity, imagination, and ingenuity. The founders had created in the desert a safe environment in which to experiment, to "prove the principle" and then to move engineering progress even farther. The laboratory was sanctioned by the nation and treasured by its neighbors. But the character of the national nuclear enterprise—and the Idaho neighborhood—was about to change. So would the NRTS.



INEEL 66-6863

Graphic representation of underground facility for storage of calcined wastes in granular form.

The Bus Ride

Hundreds of Site buses have traveled the roads of southeast Idaho carrying thousands of employees safely to and from work. Accidents were rare, but memories are abundant.

For 22 of the 34 years that I worked at the Site, I commuted a hundred miles a day to and from the Site on government buses, a total of over a half million miles. In the early days, the old Brill buses were rough riding, had straight-back seats, no air conditioning, and poor heaters. Their gasoline engines were very prone to breakdowns, especially in the middle of the desert on a hot summer afternoon or during an icy blizzard.

Joe W. Henscheid

I was one of those who played bridge in the back of the buses. We called it "bus bridge," because the rules were a little different. The bus ride only lasted an hour, so you had to bid to the ultimate.

In those days, around 1961, women couldn't wear slacks to work. We had to wear dresses and heels, no matter what the weather. During a terrible blizzard, an accident ahead stranded the bus caravan about halfway between Central and Idaho Falls. The bus driver kept the engine running to keep the bus warm, but it was a long time before another bus came along, and finally it ran out of gas. As the bus got colder, they put the women in the aisle seats, which were warmer than the ones by the window.

The men could get off the bus, turn their backs, and relieve themselves, but the women were handicapped by high heels and bare legs in trying to get out into the wind and the snow. Mostly, we never did, so there was a lot of discomfort. I think we finally got home around 2 a.m.

Above (top to bottom) White Bus, Brill Bus, Carpenter Bus, Gillig Bus, Crown Bus, Current Bus - MCI

After this episode, Phillips relented some on the dress code. Whenever the temperature got below zero, we could wear slacks.

Myrna Perry

We had a blizzard warning and the weather was getting worse and worse. At the time, I was at the Site. [The roads to Idaho Falls and Blackfoot closed.] Now the only way to go was to head for Mud Lake and the Interstate. So we convoyed and headed to town.

But a truck got stalled on the on-ramp to the Interstate, so the convoy had to head back to Central. On the way, the convoy picked up cars of people that had been coming from Salmon. They crawled into the line-up of buses and went back with us, feeling safer with a lot of company.

One bus stopped in Mud Lake and filled up with beer (although management didn't know this until weeks later). Gradually we made it to Central where Riley Foote, the manager of the cafeteria, caught up with us. I asked Riley to get out the steaks. He did, and we fed everyone who was there, even people who didn't belong to the Site. I washed dishes. People slept all over the place or played cards all night long.

For days after this, I got calls from people who normally worked at the Site and who hadn't got caught in the storm. They said how sorry they were that they missed the party.

Chuck Rice

CHAPTER EIGHTEEN

THE SHAW EFFECT...

It appears also that [long-term changes at the NRTS] will be influenced by technology trends, national policy, and other factors largely outside the control or option of the immediate community or the State itself.

–William Ginkel, 1967–

The ATR start-up group was having a bad day, and it wasn't the first one. It was preparing to bring the reactor critical for the first time. As the operators rotated the control cylinders, they saw that the count-rate recorders were not behaving according to prediction. It could mean a delay like an earlier one when the stainless-steel coolant pipe had been accidentally over-pressurized. Some of the pipe, thirty-six inches in diameter, had bulged and deformed. The pipe was ruined. Replacing it had cost millions of dollars and a year of time.[1]

In the face of this new trouble, the team shut down the reactor, opened the pressure vessel, removed the fuel, and inspected. They soon discovered that the drive mechanisms for the sixteen control cylinders would not rotate on command. Each of the drive units had been installed backwards. The problem took less time and money to fix than the earlier problem, and in an earlier day, might have been considered just one of the routine bugs that accompany any complex new project.

This time, the ATR start-up problems and parts failures came under the close scrutiny of Milton Shaw, since late 1964 the director of AEC-Headquarters' Division of Reactor Development and Technology. He sent investigators to discover the management failures that must have caused the mishap, an intense process that further postponed the start-up.[2]

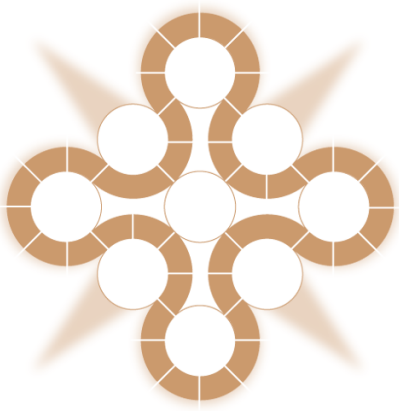
As a former aide to Admiral Rickover, Shaw had been exposed to the safety philosophy of the Nuclear Navy. As wholeheartedly as Rickover, he believed in accident prevention *via* excellence, quality control, and redundancy. He once said of himself, "My wife jokes that when I build a dog house, it'll withstand a seismic event." Although such features had not been absent from NRTS safety philosophy, the principles of Site remoteness and geographical separation of reactors had been major guarantors of public safety. It was likely that if Shaw chose to assert his convictions, the shift in emphasis would change the comfortable old way of doing things at the NRTS.[3]

INEEL 68-3496

Aerial view of TRA looking south. The large ATR building is at right of photo. Its associated cooling towers are below it and farther to the right.

Loss of Fluid Test Facility tunnel entrance

INEEL 79-5542



Above. Logo for Aerojet Nuclear Corporation. Middle. Logo for Idaho Nuclear Corporation. Below. Logo for Allied Chemical.

A forceful and skillful manager, Shaw also practiced his mentor's "abrasive interface" style of dealing with people, making no virtue of tact even on ceremonial occasions. The president of an IDO contractor, Chuck Rice, recalled one such occasion:

After I had been elected president of Nuclear [Aerojet Nuclear], we had a big dinner for key managers in the company at the Stardust Motel. Milton Shaw was there, Bill Ginkel, many from Aerojet, all the way down to branch managers. Shaw got up and did his Rickover-type tirade on all that these people in the room had done wrong. They were lousy managers, had poor control, and so on.

When it was my turn to speak, I got up and listed the outstanding accomplishments of the group and complimented them on the work they had done so well.

As I walked out after dinner, deBoisblanc came up and said, "I really appreciated the comments. You'll be fired, but it was nice to hear it."

The next day there was a meeting on whether to fire Rice or not. Shaw said, "Find out the reason for his speech. Then we'll decide." Someone called me and I said, "Shaw works at Headquarters, I work here. If we are to do well, I've got to invite the people who work here to join my party." I kept my job.[4]

Later, Rice and Shaw developed a warmer relationship. But Shaw's observation of the ATR troubles reinforced his view that a quality assurance approach to reactor operations—even test reactors like the ATR—was the only correct approach. Parts and systems must meet standards, and management must assure the standards be observed. The ATR problems had made a strong impression on him. Years later, he still referred to them when discussing the quality issue with the JCAE.[5]

As Shaw considered the state of the AEC's national reactor program, he felt there was duplication of effort and poor coordination among the labs. Key members of the AEC commission and the JCAE supported him in this view. Shaw felt that the situation justified reform, redirection, and tight control. His introduction to the ATR gave him no reason to exempt the NRTS or its contractors from this overall appraisal. Shaw's new broom began the sweep, and the dust-up generated discord and anxiety, program changes, and personnel dislocations. Some misunderstandings lasted for years.[6]

Phillips' five-year operating contract, which the AEC had renewed regularly since Phillips began at the Site in 1951, was scheduled to conclude in 1966. In March of 1965 the AEC announced a new approach to selecting the next contractor. The AEC wanted contractors that intended to invest in the nuclear industry. While Phillips had a laudable record—and in fact would continue to manage reactor safety research—Phillips' only involvement in the industry, aside from uranium mining, had been at the NRTS. The company was inclined more to research, not engineering. It had no other nuclear involvement.[7]

By June 1965, thirty companies said they were interested in the $29 million contract. The Idaho Falls newspaper kept track of the "titan firms" visiting the Site. Ginkel and his staff rented the Elks Club for briefings and conducted Site tours for the visitors. Up for new management were all three materials testing reactors (MTR, ETR, ATR), their supporting engineering groups and zero-power reactors, the Chem Plant, the Hot Shop and other TAN facilities, most of the site-wide craft and other services—and 1,800 people ranging from bus drivers to scientists. The deal, as usual, would be cost plus fixed fee.[8]

The AEC liked the Aerojet General Corporation. The company, which had been founded in 1942 to design and build rocket engines, had managed a project for the AEC and NASA in Nevada called NERVA, a joint effort to develop a nuclear-powered rocket. The AEC liked Aerojet's "disciplined approach to engineering and quality, which Aerojet...had developed in its Space Program operations." Aerojet also had the right kind of ambitions. It wanted to become a major nuclear player and had entered the field of commercial gas-cooled reactors. Managing the NRTS would give its people the experience and competencies necessary to make the grade. Aerojet's proposal was managed by Allan C. Johnson, who, after his post-SL-1 departure from the NRTS, had landed on his feet at Aerojet. As assistant to Aerojet's chairman, he and J. Bion Philipson, an NRTS pioneer then also with Aerojet, led the company to the winner's box.[9]

There was a catch. Aerojet had little experience in chemistry, an unacceptable weakness considering the importance of the Chem Plant. The AEC suggested a shot-gun marriage between Aerojet and one of the other bidders, Allied Chemical. The two companies adjusted their bids and created Idaho Nuclear Corporation (INC), with an understanding that Allied expertise would manage the Chem Plant. Allied held a minority interest in the company (Phillips continued to manage the STEP program as an independent contractor). Dr. Charles H. Trent from Aerojet became president and Bion Philipson his deputy. The new regime began on July 1, 1966.[10]

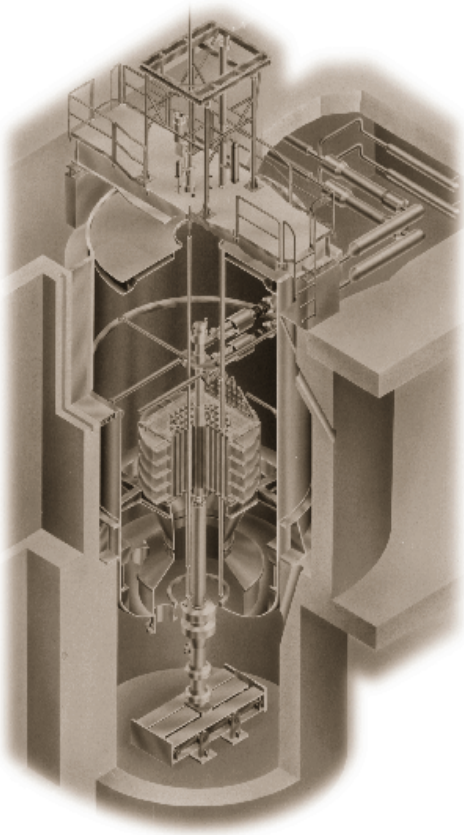
The change jolted Phillips employees, some of whom had been part of the Phillips family for most of their careers. "Suddenly, we were like an arm grafted onto a new body," observed one of them. Gradually, they adapted, although Aerojet never re-created the Phillips' style of benign paternalism. The Frank Phillips Men's Club and the Jane Phillips Sorority disappeared.[11]

Shaw soon felt compelled by the rapid onset of the commercial power industry to reorganize the safety test program (STEP) for water-moderated reactors. The STEP program had progressed far beyond the NASAtests studying the impact of ocean crashes on reactors launched into space. The program now involved two main branches. One was to continue exploring reactor excursions. The SPERT IV facility would be supplanted by a much larger and more sophisticated reactor called the Power Burst Facility (PBF). It would subject test fuel to transient bursts of energy far surpassing the capability of any previous reactors.

The second branch opened up research on an altogether new realm of possible accidents. In 1963 the New Jersey Central Power and Light Company said it would build a 515-megawatt nuclear power plant because this was cheaper than all the other options, including coal. General Electric would build the plant for a fixed price and hand it over to the utility to operate. This "turnkey" contract—and others that followed—signaled that GE and its chief competitor, Westinghouse, were ready to go commercial. The two companies scaled up the power plants to higher and higher power levels, each aiming to become market leader. Within another two years, they were designing

INEEL 72-2662

Loading fuel into PBF reactor, 1972.



Cutaway illustration of the PBF reactor.

1,000-megawatt reactors, far exceeding any previous AEC demonstration projects. The fierce competitive struggle led the two companies to sell reactors as loss-leader products. The true profitability or economic superiority of nuclear over fossil fuel plants was—at least at that time—debatable.[12]

The huge plants presented new safety problems. The AEC's Division of Nuclear Safety, which performed licensing and safety reviews of proposed plants, had thus far dealt with plants of much lower power. Even so, the AEC had not permitted them to locate near highly populated areas. Additionally, the reactor buildings had to be built so that if an accident occurred, the fission products—should they escape the cladding and the reactor pressure vessel—would not pass beyond a third barrier called a containment vessel. Typically, containment vessels were dome-shaped and constructed to withstand the pressures that might result from a steam explosion.

In the new plants, the reactor core contained tons of fuel. Analysts imagined the consequences if the coolant somehow failed to carry away the heat of fissioning. Suppose a pipe leaked or broke? The SPERT tests had proven that such a situation would easily put a stop to the chain reaction: the loss of pressure would allow the water to turn to steam; the lower density of steam would fail to moderate the neutrons; and the nuclear reaction would stop. But the radioactive decay of the fission products inside the fuel elements would continue to produce heat and continue to need cooling. Even though the decay heat was a small percent of the heat of a fissioning reactor, it was enough to melt the fuel and clad metal, leading to potentially violent interactions with water or air.

Clearly, more was at stake in a large commercial reactor. If something happened to the coolant flow, an emergency back-up system had to send water to the core and carry heat away. It was chiefly a matter of engineering, not physics.

Scientists at Brookhaven National Laboratory attempted to define what might be at stake. They imagined the worst case loss-of-coolant accident (LOCA) in a reactor located very near a large city. They elaborated it with the worst possible weather conditions. Then they calculated the consequences if the fuel melted. They speculated that it would drop to the bottom of the pressure vessel, melt through it, fall to the concrete floor and basements beneath the power plant, burn through the concrete, and proceed through the earth "to China," or at least in the direction of China, until the fuel cooled naturally. Worse, steam pressure might rupture the containment vessel and send fission products into the atmosphere whichever way the wind was blowing. Having breached their triple containment, the fission products would be an immediate hazard in the air and could eventually contaminate soil and water supplies.[13]

New Jersey Central and other license applicants were proposing a variety of back-up cooling systems that would prevent fuel from ever getting hot enough to head for China. The trouble was that these had not been proven to work. None of the safety testing at the NRTS—or anywhere else—had tested a large-reactor LOCA, the China Syndrome, or how the many variables in large-scale reactor systems would interact. Consequently, AEC regulators had a host of new technical questions. The Phillips engineers had anticipated many of the questions and were ready with a plan. In 1963 Phillips began a $19.4 million program to build a special reactor to explore LOCAs. The main idea was to load up the reactor and the containment building with instrumentation, operate the reactor, and then withhold the coolant to "see what happens."[14]

The Loss-of-Fluid Test (LOFT) reactor was to be a 50-megawatt reactor with fuel elements clad in stainless steel and

surrounded by a containment vessel. Phillips placed the domed structure next to the old hangar building at TAN, finding the old four-track railroad and other ANP facilities very adaptable to a new mission. The shielded control building next to the hangar became the LOFT control room. Phillips hauled out the old shielded locomotive, intending to move the reactor from the containment building to the Hot Shop for detailed examination after the experiment. Kaiser Engineers broke ground for the project on October 14, 1964, a happy ceremony that brought the vice-chairman of the JCAE, Chet Holifield, to Idaho to make the featured speech.[15]

The LOFT experiment was fairly simple. It would be a small version of a large reactor, the containment vessel an integral part of the test. The cooling-system components would come "off the shelf" from the commercial vendors who sold to General Electric and Westinghouse, not from the fabrication shops at the NRTS where parts were so often given individual attention, not mass produced. In a series of non-nuclear experiments, the operators would first test the performance of the components—the emergency sprays, pressure suppression devices, and other emergency equipment that would supposedly come into play if the regular coolant pipe broke. They would also find out how much pressure the containment vessel could endure.[16]

After those tests, the grand finale would be the NRTS specialty—a test to destruction. Operators would "break" an 18-inch coolant pipe, delay the insertion of the control rods, cut off the cooling water, and decline to spray water onto the core. They could study the melting fuel, perhaps learn something useful about the dynamics of the process. The instrumentation would keep track of the fission products, measuring what fraction of the total might reach the atmosphere. They expected to learn enough about LOCAs to define more precisely the sequence of events and the exact nature of the hazards. The data would be extrapolated to larger-scale reactors. The test was expected to take place in the winter of 1968.[17]

The LOFT project hit a snag immediately. The new commercial reactors proposed to use zircaloy cladding instead of stainless steel. In 1965, therefore, Phillips changed the LOFT reactor design for zircaloy-clad fuel. This affected the parameters for the safe operation of the LOFT reactor, so the safety studies had to be redone. These changes delayed the project. Back in Washington, the regulators were trying to cope with license applications. They wondered whether the proposed tests, being performed on a small reactor, would actually tell them anything relevant about large reactors. Some of the AEC staff doubted that the methods for analyzing the core melt or the water interaction with melting zircaloy were sophisticated enough to produce meaningful data. Nor were they sure that the containment vessel would withstand the gas pressures generated during the meltdown.[18]

Milton Shaw wondered if the LOFT project would fall prey to the same kinds of problems as the ATR. He saw the possibility that unreliable parts or equipment might interfere with good

INEEL 67-2104

Governor Don Samuelson (center) visits LOFT site in 1967. Bill Ginkel on left, Joe P. Lyon of INC on right.

test results. What was the point of an experiment if it used the wrong parts, the wrong materials, and met the wrong specifications? Results could never be duplicated. The project was about ten percent complete, and the reactor's eighty-ton pressure vessel had been fabricated. Nevertheless, Shaw stopped the work to "regroup and do the job right." Quality assurance hit the LOFT project. The experiment was going to become much more complex.[19]

But not immediately. Forward motion on LOFT stalled while contending forces within AEC Headquarters settled their differences—sometimes at a leisurely pace. The issue of power plant siting had divided the regulatory and development arms of the AEC. With their low confidence in the utilities' proposals for untested backup safety systems, the regulators were reluctant to allow power plants close to cities, the load centers. On the development side, Shaw, the commissioners, and the JCAE resisted imposing excessive or unnecessary costs on utility companies. The grip of nuclear power on economic viability was too tenuous, and they didn't want the fledgling industry to falter because of unnecessary costs.

Related to the siting issue, a difference of opinion emerged on how to—or whether to—research the China Syndrome. One view was that the AEC should confront it directly: test it, understand it, characterize it, and learn how to make it inherently impossible. This had been one purpose of the original test plan for the LOFT experiment. The other view was that this was costly and unnecessary. The China Syndrome should simply be prevented. Emergency core cooling system (ECCS) engineering should be so foolproof that nuclear fuel would never have a chance to melt. If anything was to be researched, it should be these engineering preventatives.[20]

Shaw felt that standards and criteria, combined with experience and good engineering judgment would protect public safety. He sided with those who felt it was possible to prevent accidents by building reliable back-up systems—defense-in-depth. Understanding the moment-by-moment progress of an accident that would never happen was a waste of money.

As the 1960s wore on, the debate continued. The regulatory staff had no independent control of a research budget, so their needs for research results on LOCAs went unmet. Staff committees formed, talked, and dissolved. At the same time, applications kept coming in for review; the regulators needed the results of LOFT-type experiments and they didn't have them.

For LOFT the upshot of all the talk was a loss of support for the original experiments. Those advocating research on the mechanism of the China Syndrome ultimately were disappointed. Aside from Shaw's determination to make LOFT a showcase for new quality assurance procedures, the project drifted. People were laid off. Work stopped, started, stopped. Funds were held back or stinted, even though they had been appropriated.

The AEC desired to see improved accountability in management, so in 1969 Phillips joined Aerojet and Allied as a minority partner in the operating contract. As Bill Ginkel said at the time, the AEC was looking for "upgraded engineering, standards, codes and guides, documentation, plant reliability, and quality level of performance." Absorbing Phillips into the corporation was intended to strengthen overall management of NRTS programs. Aerojet continued as the majority partner.[21]

Personnel layoffs soon followed and continued into 1971. Idaho scientists wrote angry letters to the Idaho congressional delegation, blaming LOFT problems on poor policy direction and bungled management from Washington. Some people thought Shaw was robbing LOFT funds to support his greater interest in breeder reactor development. Aerojet hired new people for the LOFT project at the same time it was letting go of Idaho people. "The deteriorating situation at the NRTS...continues to worsen," wrote one employee to Senator Len Jordan. In a departure from previous custom, the new LOFT work center—174 employees—was moved from the Site to the Rogers Hotel in Idaho Falls, which contributed further to resentment and misunderstanding.[22]

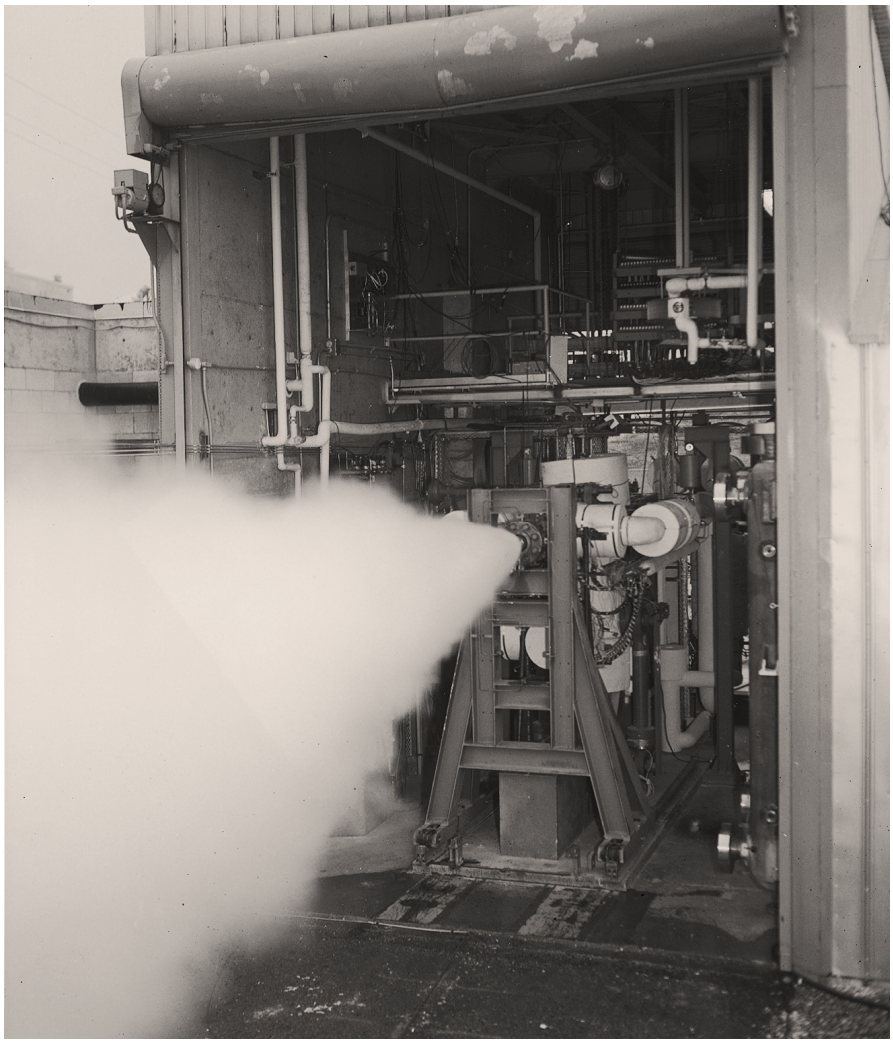
A belief arose that the Shaw/Aerojet managers were autocratic and vindictive, eliminating people who dissented from the official point of view. The *Post-Register* called for the congressional delegation to rescue the NRTS from the poor AEC management that was causing both the layoffs and "scientific disillusionment" at the Site. Governor Cecil Andrus made a similar appeal. "We can ill afford the loss," he wrote of the layoffs.[23]

INEEL 69-6280

Aerojet president Chuck Rice tried to explain the general upheaval in morale and the impact of Shaw's new procedures to Idaho congressman Orval Hansen:

In the past, reactor and environmental safety was derived from experienced experts working together as a loosely knit team, each member of which expected the remaining members to perform the appropriate functions at the appropriate time without clear cut lines of responsibility and delegated authorities. In response to AEC desires and directives, this informal system has, in a period of less than one year, been replaced by a highly formalized system that places primary reliance on unswerving adherence to a set of interlocking procedures and responsibilities that have been subjected to multiple reviews by boards of specialists. The writing of procurement specifications has become a job for the skilled engineer rather than the purchasing agent. Carefully documented engineering studies have replaced the quick fix by the maintenance man.[24]

Meanwhile, the STEP program operators had managed to carry out useful work in spite of difficulties. They developed computer models predicting the behavior of coolant in a LOCA. Among other experimental devices, they built a simulated reactor called Semiscale to help understand how coolant water would behave as it depressurized after a pipe broke. This process was called a "blowdown." Blowdown tests and computer analysis of the simulated accidents led to computer programs, called codes, capable of predicting the performance of backup cooling systems during a blowdown. The codes originated at the NRTS with the help of the INEL Supercomputing Center (ISC), which was built in 1968.[25]



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Above. Semiscale was a simulated reactor. Instrumentation leads leave head of the core. Left. Semiscale blowdown test, 1968, simulated a break in a coolant pipe.

The Semiscale heat source was electrical but created the same high temperatures as a reactor. Between November 1970 and March 1971, a series of tests demonstrated—unexpectedly—that after certain accidents, steam pressure in the coolant pipes prevented any emergency water at all from gaining access to the core. If this was a picture of what might happen in a large reactor, the problem was serious indeed. The margins of safety that had previously been assumed for commercial emergency core cooling systems would have to be revised downward.[26]

The findings provoked the AEC to hold hearings on the matter. Semiscale scientists from Idaho traveled to Washington to explain their findings before people who were reluctant to believe that the Semiscale results could be extrapolated to large reactors. Nevertheless, Idaho research was solid and persuasive. The AEC adopted a set of requirements more conservative than had been the case before. They were "Interim" Acceptance Criteria, a set of safety requirements that a utility company had to meet in order to obtain a license from the AEC. The Criteria went into effect immediately, without the customary time elapsing for further comment. NRTS work thus had an impact on safety requirements for commercial reactors.[27]

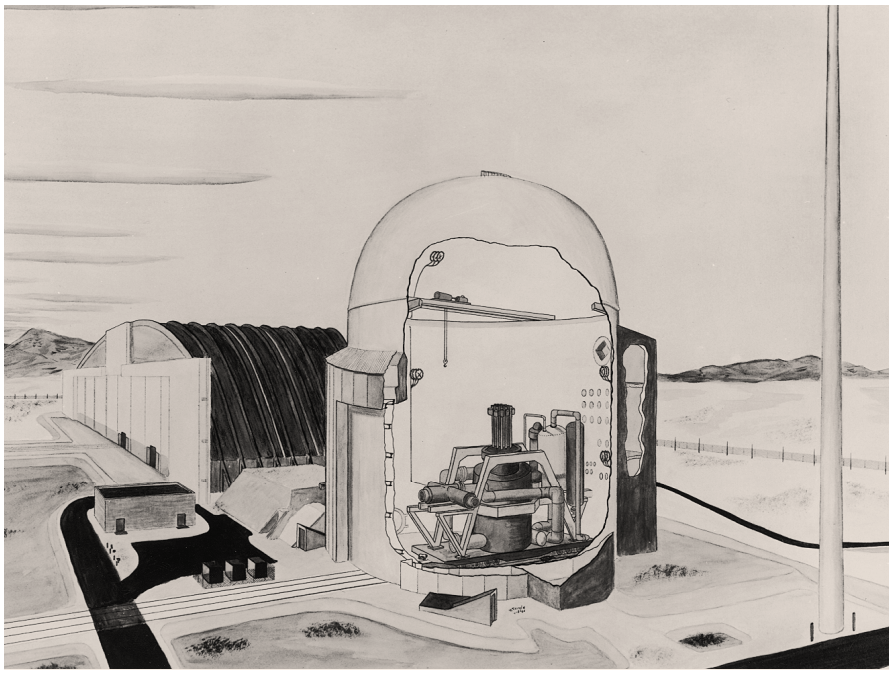
Milton Shaw finally decided how he wanted to redirect the LOFT program. The AEC regulators needed to examine plans for emergency cooling systems, predict their performance in an accident, and then decide whether or not to approve the plans. With such complex systems as a nuclear reactor, they were using computer models. Therefore, the testing program at the LOFT reactor in Idaho should verify the accuracy of the codes. With reliable codes, the regulators could confidently evaluate proposed power plant design proposals.[28]

For the LOFT team, it was like starting over. Reorienting the project took time and required more money. The reactor needed more elaborate piping and instrumentation—all quality assured. The project slipped its schedule repeatedly. The completion date moved out to 1971, then 1972, 1973, and beyond. Phillips, and then Aerojet, could not get fabricators to supply the major primary pump and heat exchangers on schedule. The standards were set so high that vendors refused to bid on the secondary coolant pump. Code specifications for piping and steam generators changed, and this caused more delays. Construction halted completely from May 1968 to October 1970.[29]

For all of the delays, Shaw had blamed Phillips. Idaho scientists resented this unfairness. Shaw himself had authored the delay. The quality-oriented delays were particularly irritating. Why should standards that would protect the crew of a submarine apply to short-term experiments in a remote, isolated desert? But the conditions of work at the NRTS had changed. Scientists began to realize that the early traditions were giving way. The outcome of the LOFT struggles showed that they were losing their early freedom to define their own research problems.[30]

In 1971 when it was time for the IDO to negotiate a new operating contract, Aerojet took over completely, subcontracting with Allied to run the Chem Plant and assuming the STEP program from Phillips. The name changed from

An artist's view of LOFT circa 1964 shows reactor inside domed containment building.



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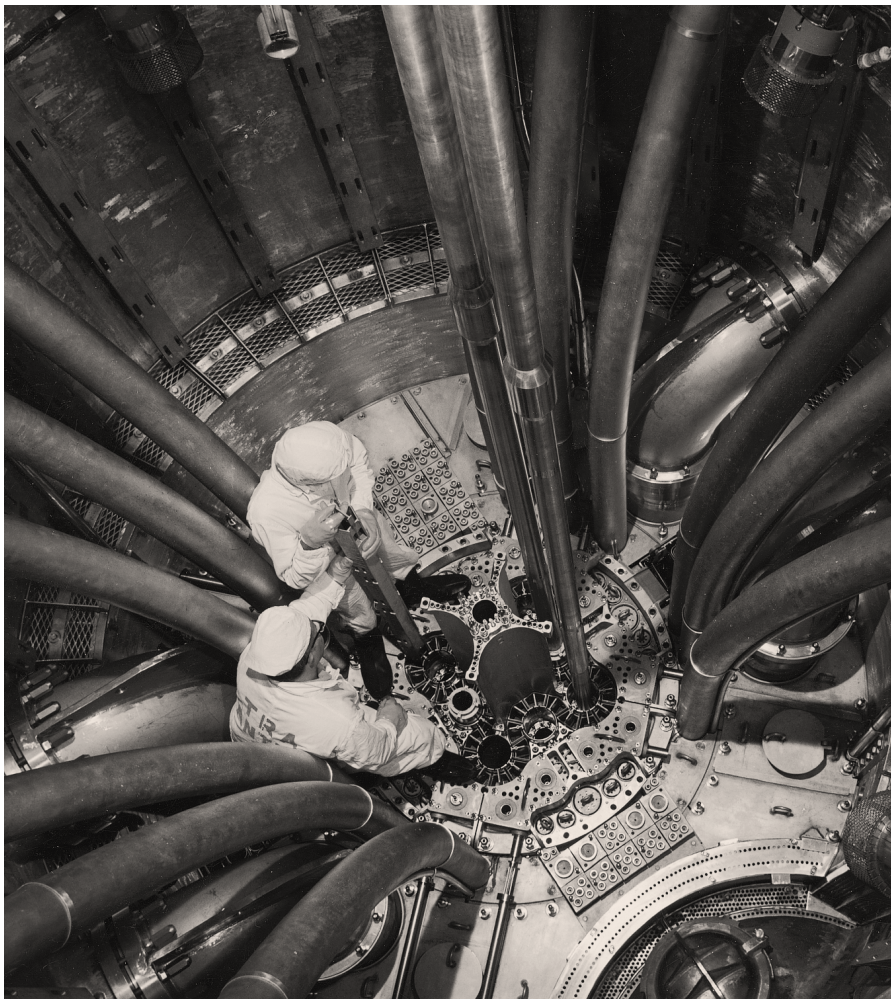
INC to ANC—Aerojet Nuclear Corporation. Phillips, co-inventor of the world's only reactor testing station, was, with little ceremony, gone for good. Its earlier ambitions regarding nuclear energy had abated; changes in the NRTS programs and the environment in which it now operated gave it little further stake in testing nuclear reactors.[31]

In 1972, *Science* magazine charted the LOFT-centered erosion of affection between the NRTS and AEC Headquarters. The author, Robert Gillette, described with dismay how NRTS scientists met him secretly one night on a back street in Idaho Falls and then drove to one of their homes. "That men nationally recognized in their profession felt they had to do this shows how far relations between the AEC and Idaho have deteriorated," he wrote. But the new Aerojet manager, Charles Leeper, supported Shaw. "The highly creative days and the permissive times are behind us," he said, "and the demands now are for a hard bitten reduction to economical practices."[32]

Although work protocols, management philosophy, and the burden of paperwork had changed, it was still possible to do good work at the NRTS. Better days were ahead for LOFT.

After the troubled start-up of the ATR, the reactor went on to perform superbly, like a theatrical play after a poor dress rehearsal. In August 1969, the operators ran it for the first time at its full power level of 250 megawatts. The designers originally expected to run the ATR twenty-one days before having to shut down and reload new fuel. In practice, they ran in thirty-four day cycles and longer. In the next ten years, the ATR regularly set new performance records, running at 98.2 percent operating efficiency and on-line eighty percent of the year. This was a superior accomplishment because the ATR was so complex a machine that any of four hundred different reactor and experimental systems could fail and shut down the reactor. Breaking performance records meant that a team was sharp, diligent, and skillful.[33]

The Shaw effect was not limited to the total reorientation of the LOFT program and the imposition of a new style of management and procurement. It also played out in the theater of operations at Argonne-West. Shaw had a strong commitment to the future of the breeder reactor. But it turned out that he did not have a strong commitment to Argonne-West. When this became apparent to the eastern Idaho supporters of the NRTS, a boost machine went into high gear.



INEEL 67-5184

ATR technicians check the fit of a dummy fuel element in the reactor core (before ATR became operational). The curved pipes are for instrument leads and reactor coolant. The vertical pipes provide paths for experiments into the core area.

Chapter Nineteen

...and the Idaho Boost

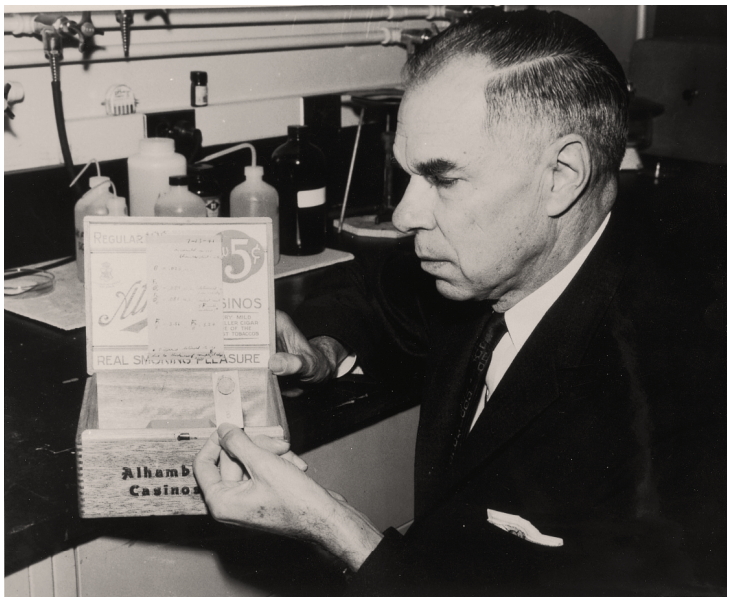
There can be a great future for the state in atomic energy development.

–Idaho Governor Don Samuelson, 1967–

Milton Shaw and the AEC canceled Argonne's FARET reactor. Never mind that Congress had authorized the funds. Times had changed. Old breeder plans were not the right breeder plans. Atoms for peace had become a fact. Between 1965 and 1970, utility companies in the United States ordered a hundred nuclear power plants—all of them moderated and cooled by water. Shaw and the others felt that the torch had passed to industry, and water-moderated reactors should no longer require federally subsidized research.[1]

The national coal lobby had objected for years that Congress subsidized nuclear power. Congress was unfair, it said, to displace coal plants by financing the research that would make commercial nuclear power possible. The lobby had protested the AEC's reactor demonstration program. It objected to federal insurance subsidies for utility companies in the event of a nuclear accident.[2]

The AEC and the JCAE were in a position, therefore, in 1964 to make a concession to the coal industry while at the same time advancing to the next level of the nuclear future, which was to bring liquid-metal-cooled fast-breeder reactors to the commercial market. It could conclude research on water-cooled concepts.



U.S. Department of Energy 66-7696

Glenn Seaborg holding the first tiny sample of the fissionable form of the nuclear fuel plutonium-239. This sample is now at the Smithsonian Institution in Washington, D.C.

Ideas about the world's reserves of uranium were still driving reactor development ideas. The global wave of new nuclear power plants would consume more and more uranium, probably depleting it if the demand for energy continued to grow. Water-moderated reactors used uranium extremely inefficiently. Of the uranium in a reactor core, a typical commercial reactor burned about one percent, perhaps a little more. The rest of the uranium—the unfissioned U-235 and the U-238—could be recycled at great expense or discarded as a contaminated waste. A breeder, on the other hand, could produce something valuable—plutonium fuel—out of U-238 and thus convert it into an energy source. The breeder could use nearly *all* of the uranium. Besides, breeders had the potential of burning up a higher percentage of the fuel to begin with.[3]

Therefore, Shaw and the AEC shifted their resources to the breeder. Glenn Seaborg, a Nobel laureate chemist who

Nuclear energy exhibit attracts Idaho Falls visitors in 1969.

Idaho State Historical Society MS326

as part of the Manhattan Project had made the world's first plutonium, became chairman of the AEC in 1961. Seaborg was completely committed to the "plutonium economy" of the breeder reactor. He told President Kennedy in 1962 that the way for the United States to maintain nuclear reactor technological preeminence in the world was to perfect the breeder reactor as a safe and commercially viable source of energy. He even suggested that plutonium would eventually replace gold as the standard of the monetary system.[4]

Washington politics favored the AEC's new focus on the breeder. But many safety and engineering questions still remained to be solved if breeder reactors were to scale-up to commercial proportions. Physics and chemistry questions remained. As a more distant achievement, therefore, the breeder represented less of a threat to the coal industry and their opposition evaporated. The breeder research program would take many more years.[5]

Shaw spent 1965 considering how best to redirect the AEC's breeder program and then decided, with AEC approval, to manage it directly from his own office. This arrangement was a departure from the AEC's more typical assignment of contractor management to its field offices. Shaw's critics, among them Albert Crewe, the director of Argonne National Laboratory, publicly challenged Shaw's "cult of perfection" in experimental work. If research methods lived with the safety requirements for nuclear submarines, he said, so little would be accomplished that Europe would take the lead in breeder technology.[6]

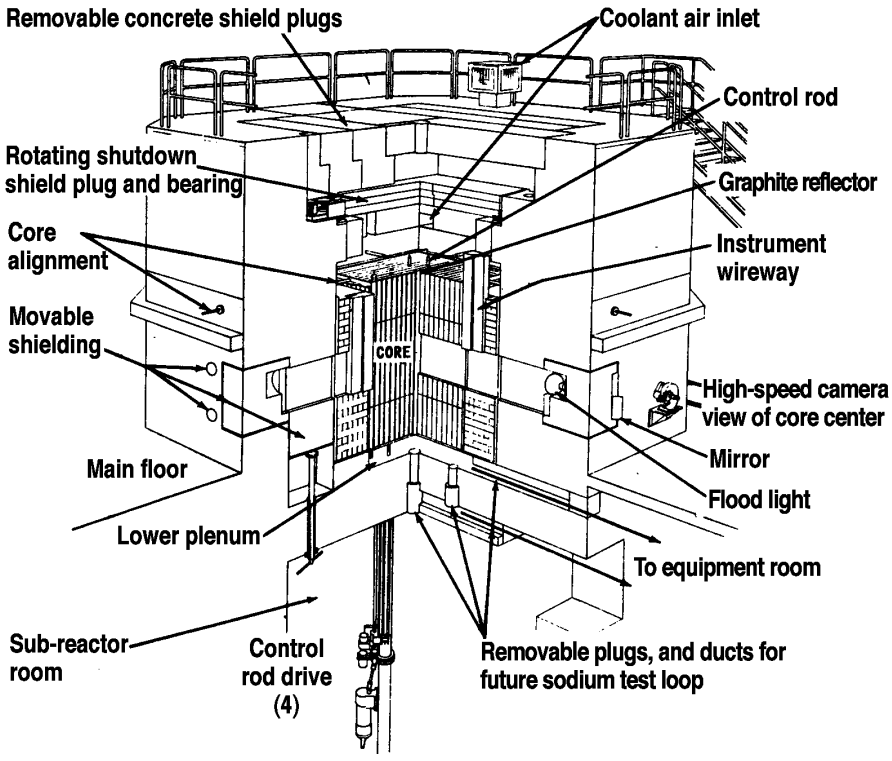
Shaw felt that the breeder program needed a large test reactor. Goals for testing fuel and components had to be aggressive if the breeder was to make it to the commercial market. The FARET reactor was too small, the Argonne program too unambitious. Instead, he chose Hanford to design a new reactor, named the Fast-Flux Test Facility (FFTF). The open conflict between Shaw and Crewe didn't help Argonne. In view of Crewe's public antipathy for Shaw, the new reactor wasn't going to Argonne. Still, even if Hanford designed it, Argonne assumed the FFTF could still be built in Idaho.[7]

The technical issue appeared to be the type of fuel planned for each reactor. Argonne's efforts with EBR-II fuel to date had been to improve uranium-

Argonne National Laboratory-West 7330

Above. Original exterior of TREAT reactor building.

Below. Perspective drawing of the TREAT reactor.



Argonne National Laboratory-West Report ANL-6034

plutonium fuel so that it could operate in a reactor at higher and higher temperatures without melting the fuel or cladding. The economics of a commercial reactor would require an operating temperature of about 1,200°F, a target that Argonne had not yet reached. Shaw and others felt that fuel made of oxides or carbides of uranium and plutonium and cladding of zirconium and titanium alloys held more promise for higher operating temperatures. In this larger scheme of research, Shaw wanted the EBR-II to shift its program emphasis and become a materials testing reactor for these new fuel concepts. The new FFTF would have test loops in which fuel elements six inches in diameter and three to four feet long could be irradiated in an environment producing more neutron flux than even the ATR was capable.[8]

Shaw opened a Liquid Metal Fast Breeder Reactor (LMFBR) office at Argonne's Chicago and Idaho locations and staffed them with people who reported directly to him. The atmosphere was not cordial. Shaw's people demanded copies of all trip reports, conference reports, and program documents containing conclusions and recommendations. He laid his quality template on all planning documents: objectives, criteria, standards, alternatives, priorities, rationale, and more. He told Crewe that he expected Argonne to "serve as an extension" of the LMFBR office. He rejected initiatives from the field. A historian of the Argonne lab described Argonne's new role as "captive handmaiden" of Shaw's office, its autonomy gone.[9]

In Idaho Falls, business leaders responded swiftly to Idaho's loss of the FARET

Idaho State Historical Society 103-C5413

Governor Robert Smylie

reactor. By this time, they were well-practiced observers and promoters of the NRTS. The spirit of the "party plan" was still intact. The team now included the Idaho governor's office and the Idaho congressional delegation. The new editor of the Idaho Falls *Post-Register*, Robb Brady, forged an important link between the NRTS and the public. These groups eyed the flow of money and ideas in Washington, D.C. They kept a tally of projects gained and lost, proposed and canceled. They watched the NRTS employment and budget statistics like hawks. All understood that competition for federal research funds was a growing fact of life.

Information flowed freely among the players, and they followed up in carefully orchestrated moves. The newspaper kept readers informed, and Brady's thoughtful editorials were so well considered that they circulated in Washington, D.C. Political party affiliation made no apparent difference in who spoke with whom. In April 1964, for example, Republican Governor Robert Smylie sent a telegram to each member of the delegation, at the time consisting of two Democrats and two Republicans:[10]

Urge you support AEC project 630-A for Arco, Idaho AEC installation. Now before JCAE. Efforts currently exerted to assign same to Hanford. If shifted, will have detrimental effect in eastern Idaho.[11]

The effort succeeded, and the 630-A reactor experiment went to TAN. The project, intended to advance a nuclear-powered civilian maritime fleet, was of modest budgetary impact, but it helped preserve the NRTS as an important AEC facility. Better that Idaho get the work than Hanford.

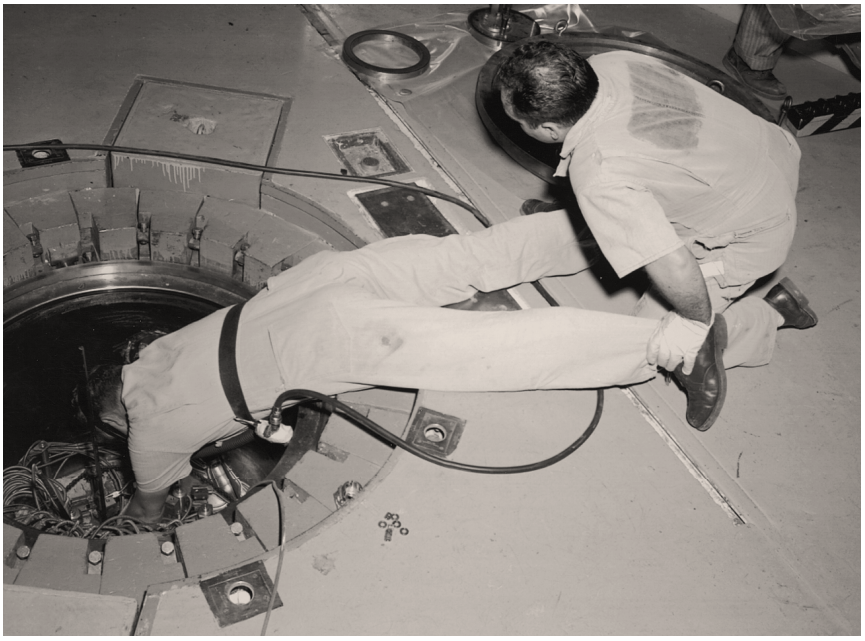
While Hanford designed the FFTF, the Idaho boost machine worked on another project. In 1965, the AEC asked the National Academy of Sciences (NAS) to select a location for a proposed National Accelerator Laboratory, a $348 million particle accelerator known as the "Bevatron." Editor Brady thought it was a long shot for Idaho, given the absence of a nuclear physics program at Idaho State University (ISU) in Pocatello.[12]

Nevertheless, Governor Smylie was game. He established a special Idaho Accelerator Committee, on which men from the business community and from Ginkel's office all helped to coordinate the promotion. Headed by Fred Rooney, an executive with the FMC Corporation in east Idaho, the committee included Brady and a professional publicist named Don Watson. The com-

mittee decided early that if Idaho didn't make it through the "first turnstyle"—over a hundred applicants from forty-three states were competing—Idaho could fall back to a regional deal involving Utah, Montana, Nevada, and Oregon. Political trading would be possible, Rooney told Smylie. In the meantime, Brady would make a discreet contact with AEC commissioner James Ramey, and another committee member would contact Glenn Seaborg.[13]

Watson developed the "livability" sections of the proposal and orchestrated the reception of the NAS fact-finding team when it visited the Site. "Voluntary turnover of scientific personnel at the NRTS is low almost to the point of being non-existent," said the proposal. Along with the technical data on the cost of electrical power at the NRTS went statistics on the below-national-average high school drop-out rate in Idaho Falls. Idaho slipped through the first turnstyle, but it was crowded: eighty-four other proposals also made the cut.[14]

The NAS committee did not favor Idaho. The NRTS was not near the right kind of university. Although ISU was geographically near, the Idaho legislature had done little to support the AEC through higher education. Only in 1965 had it made its first significant gesture by authorizing a training program at ISU for health physicists. This situation in no way lent Idaho any status in academic circles concerned with high-energy physics. Smylie regretted Idaho's neglect.[15]



Argonne National Laboratory-West 1173

Teamwork inside the NRTS duplicated the outside teamwork among NRTS supporters. Here, technicians work over the core of EBR-I.

Amonth after that disappointment, Smylie dissolved his old Nuclear Radiation Hazards Safety Committee and created a Committee on Nuclear Science and Industry to take its place. The state's interest in the NRTS shifted firmly from the Health Department to the Department of Commerce and Development. The eleven volunteer members were to advise him, Commerce and Development personnel, and the legislature on all matters "pertaining to nuclear energy and the utilization of same in the State of Idaho." Among other forces, Idaho was competing with Hanford's home state of Washington, which called itself "the Nuclear Progress State," had funded a promotional office, and was distributing full-color brochures touting Washington's "Total Nuclear Environment."[16]

Smylie appointed business promoters and members of Bill Ginkel's staff to the committee. Evidence of the state's new enthusiasm for nuclear industry appeared immediately. A 1966 analysis of the state's industrial opportunities identified atomic energy as one of the state's promising growth industries, NTRS's "600 engineers" a valuable asset. The committee recommended that the Idaho legislature create an office similar to Washington State's, run by a state commission. The cause would be helped, too, if Idaho could express its positive interest in atomic energy by regulating radioactive materials in the state, an activity then managed by the AEC.[17]

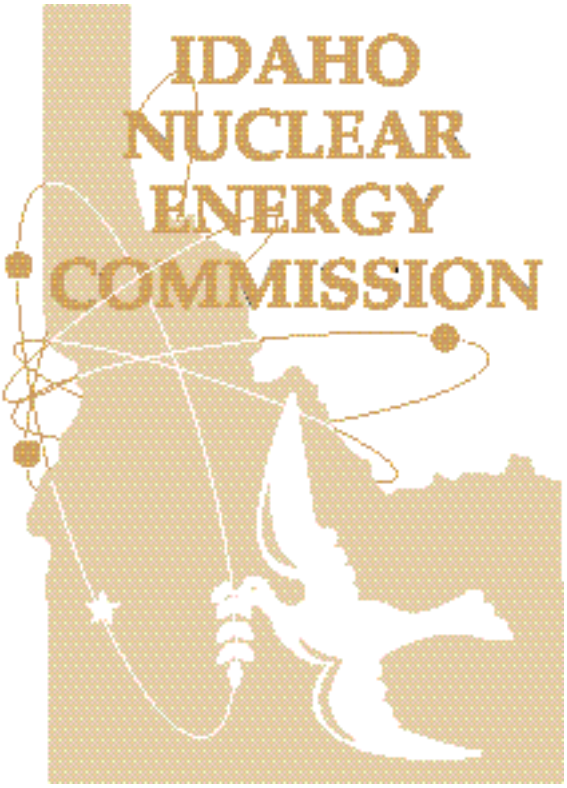
Among its first acts, the Governor's committee decided that Idaho should fight to have the FFTF built in Idaho. Feelings ran high because many viewed the cancellation of FARET as a political act, not solely a technical one. The NRTS was the obvious place to build it. Breeder technology had been born, proven, matured, and safety-tested at the NRTS. Where else was there a bet-

ter team or better facilities? To duplicate these elsewhere would waste the AEC's investment at Idaho.[18]

The strategy was to combat "Washington State/AEC power with Idaho/Illinois power." Robb Brady, the chairman, reviewed with the congressional delegation the poor state of the current NRTS win/loss record. As of 1966, cancellations had included the army program, the merchant ship project, a lithium-cooled reactor, the organic-cooled program, and FARET. It was time for a win. As for the rules of the campaign, partisan politics were out. The gist of Brady's analysis, paralleled by Ginkel's, was that the NRTS needed a "new platform" if the NRTS was to enjoy long-term stability free of wide swings in employment levels. It seemed that the most promising new missions were the FFTF and nuclear applications for the space program.[19]

In January 1967, the AEC, following Shaw's recommendation, sited the FFTF at Hanford. The justification—that there was a strong overlap from design to construction—rang hollow in Idaho. Reactor designs from all over the country had been built successfully in Idaho for years. Idaho's new governor, Don Samuelson, sent a "strenuous protest" to Seaborg. Editorial opinion in Idaho Falls was harsh. Congressman James McClure demanded explanations. But the Idaho/Illinois axis could not undo the decision.[20]

The Idaho Legislature, then in session, took the loss into account as it considered the idea of a state promotional office. Samuelson threw his wholehearted support behind the idea. The legislature created the Idaho Nuclear Energy Commission (INEC) and funded a director and small office for it. Idaho had in the past created commissions to promote potatoes, beans, wheat, and peas. The hallowed tradition now embraced nuclear energy.

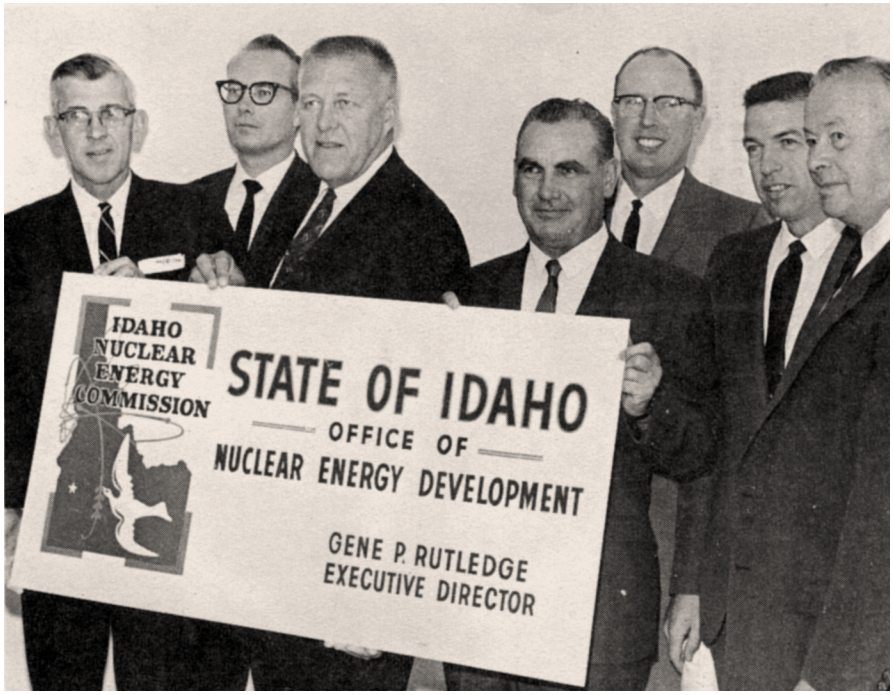


INEC was to advance the nuclear possibilities in the state by stimulating the interest of industry, agriculture, and education. Commercial developments, aside from diversifying Idaho's economy, would augment and support the NRTS base. INEC would advise the governor, report progress, and administer grants.[22]

Ginkel welcomed the INEC and encouraged the board to direct their energies "*around* and *beyond* the NRTS," not solely at the NRTS itself. He had observed traditional Idaho industries fail to exploit good nuclear opportunities. No one in the Idaho timber industry, for example, had answered an AEC invitation to develop an irradiated, plastic-impregnated wood product. Idaho also had not bid on a chance to test whether irradiating meat could preserve it without refrigeration. After all, Ginkel said, the Army had first irradiated beef in the MTR canals.[23]

Samuelson appointed the five commissioners, two from Idaho Falls, two from Pocatello, one from Boise. The chairman, Steele Barnett, was an executive with the Boise Cascade Corporation, headquartered in Boise. The legislation dictated that INEC be bi-partisan, with no more than three members from one party. The administrator of the state's radiation control office was an *ex officio* member, preserving a connection to the regulatory and health interests of the state.[24]

The enabling legislation gave INEC an official start date of July 1, 1967, but the commissioners met early and laid plans. They felt that hiring a "top-notch" executive secretary was crucial, and they found him at the Naval Reactors Facility. Gene Rutledge, a Westinghouse chemist then working at a non-chemist post, took the job. He had come years earlier from South Carolina to work on the *Nautilus* prototype. "I'd just like to



1967 INEC Annual Report

Gene Rutledge, second from left, poses with Governor Don Samuelson, third from left, and the members of the INEC Commission

be a salesman," he said as he began with INEC. He had his chance and he grabbed it with both hands.[25]

Hired on August 1, he was ready with a 21-point program six days later. The first thing was to survey Idaho and identify the ways that atomic energy and radiation could enhance existing industries: agriculture, timber and forestry, mining. Idaho should ally with other western states in promoting nuclear industries in the Pacific Northwest. Beyond that there was a whole frontier of industrial possibility: irradiation might give cotton fabric qualities of permanent press, irradiation could improve vulcanized rubber. Public education was important. Above all, the NRTS must be preserved and given new missions. Idaho must never allow the AEC to abandon it.[26]

Rutledge hit the deck running and never stopped. He had the governor proclaim the 25th anniversary of the first Chicago pile. Exhibits entitled "This Atomic World" began appearing at state fairs across the state, often promoted by the current Miss Idaho. A sophisticated exhibit called the Nuclear Energy Museum appeared for a week at the Idaho Falls High School in August 1969. Rutledge arranged a symposium in the town of Salmon, Idaho, to discuss the future of the thorium market, thorium being a potential breeder-related fuel found in Idaho. Anuclear exhibit appeared in the Idaho Statehouse, taking its place next to the familiar exhibits celebrating Idaho mining and farming. Boise Cascade conducted seminars on the potential of irradiation in the timber industry. INEC sponsored a television show each week entitled "Idaho and the Atom" to showcase ideas and guest speakers. Rutledge even arranged for eminent scientist Dr. Willard F. Libby to accept a title as "science advisor" to Governor Samuelson, further embroidering Idaho's image as a science-friendly state.[27]

Rutledge specialized in the sponsorship of multiple high-profile activities. He discovered that the AEC had a portable cesium food irradiator on tour in the Pacific Northwest. Soon, news releases poured out of the Governor's office, the Twin Falls County Republican Central Committee, and INEC. Robert Erkins, the owner and manager of the Snake River Trout Farm near Buhl, Idaho, was persuaded to host the irradiator at his trout farm for one week in April 1968. The public was warmly invited. The Twin Falls newspaper, the *Times-News*, gave front page coverage to the story for two days and also published photos. Governor Samuelson, Lt. Gov. Jack Murphy, and Secretary of State Pete Cenarussa all left Boise to have a look at the irradiator—and be photographed while doing so.[28]

The legislature continued to support INEC's recommendations. Idaho became an "agreement state," taking over from the AEC the task of issuing licenses for the use of medical and industrial radioactive materials. The work cost the state money and gave it no advantage other than giving the rest of the world the impression that Idaho welcomed nuclear industry. The day of the signing ceremony, August 14, 1968, was well publicized, and two AEC commissioners flew in for the event.[29]

Rutledge, INEC, and its allies quickly forged an elaborate network of institutional connections. The legislature was helpful by appropriating funds to the Board of Education so INEC could make nuclear research grants. It entered into a Western Interstate Nuclear Compact. The Compact was a regional version of INEC, promoting nuclear technology in the West and facilitating mutual interests in power plant siting, mutual aid in case of a nuclear transport accident, and waste disposal. Rutledge was Idaho's representative. Several western universities formed an association to encourage the assignment of their students and faculty to the AEC's western labs. The Western Governors Association created nuclear issue committees, and Samuelson joined them. In Idaho Falls, the Chamber of Commerce maintained an active atomic energy committee and kept in touch with the Eastern Idaho Nuclear Industrial Council (EINIC), a group that formed in 1969 to foster nuclear spin-off industries. NRTS scientists had formed a chapter of the American Nuclear Society, and their expertise was always available.[30]

The nuclear boost machine was fully charged. It had a proactive governor, a supportive congressional delegation, a friendly legislature, a state commission, energetic staff, regional ties within the state and in the West, educational resources, and a nuclear-friendly populace. One of the most important goals of the entire apparatus was to support and protect the interests of the NRTS.

Idaho State Historical Society MS 326

Nuclear energy exhibit at Idaho Falls High School in 1969.

In 1968 the AEC announced that it would decommission the MTR in early 1970. By that time, the ATR would be fully functioning, and between the ATR and the ETR, the MTR would have no further mission. All of the MTR's neutron beam research would end. Alarmed, INEC formed a study committee to consider this and advise Samuelson. The problem was serious, but it handed INEC a tremendous opportunity. All of INEC's promotions paled in comparison to what soon became its single biggest goal: to save the MTR.[31]

Chapter Twenty

A Question of Mission

Idaho has established beyond question its attitude and posture toward the atomic energy industry.

–Idaho Department of Commerce–

The White House staff had wired up the sound system. A technician from one of the national radio stations tampered with it and accidentally cut the signal from the microphone to the loudspeakers. The President of the United States, Lyndon B. Johnson, had just begun to address a huge audience, and no one could hear him. Bill Ginkel, sitting on the platform with other dignitaries and acting as the master of ceremonies, saw the stricken faces of his staff as they looked to him to do something. He fervently wished he could, as the president's displeasure was quite apparent.[1]

The platform was adjacent to the Technical Services Building at Central, facing Lincoln Boulevard and a crowd of more than 12,000 people. It was August 26, 1966. Less than twenty years after the invention of the NRTS, one of its giant achievements was on this day being designated as a Registered National Historic Landmark. EBR-I had been decommissioned only two years previously, and now it was in the national pantheon along with Valley Forge, Hoover Dam, and the site in Chicago where the world's first self-sustained nuclear reaction had taken place. The matter of the speaker wire, the only flaw in the highly orchestrated event, was soon corrected.[2]

NRTS supporters had grasped the visit as a superior opportunity to show off the NRTS. The arrangements committee extended well beyond the IDO. The Eastern Idaho Chamber of Commerce and the bank presidents from the surrounding towns lent their resources to the elaborate occasion. Volunteers of the Eastern Idaho Labor and Trades Council built the speaker's stand. The members of the American Nuclear Society and the top administrative tier of the IDO had discreetly suggested that the president use the occasion to make a major policy address on nuclear energy. To their disappointment, Johnson was not inclined. He did, however, affirm his faith in the potential of nuclear energy for the future: "What happened here merely raised the curtain on a promising drama in our long journey to a better life."[3]

Argonne National Laboratory-East 1534

President Lyndon Johnson and Dr. Glenn Seaborg attend the designation of EBR-I as a National Historic Landmark.

Still, he was the first president to visit the NRTS, and honoring the EBR-I was a worthy reason. AEC Chairman Glenn Seaborg dedicated the plaque at EBR-I, and on dignitary platform were Lady Bird Johnson, four AEC commissioners, Admiral Rickover, Governor Smylie, and congressional representatives as well.[4]

Behind the public facade, other agendas were at work. Ginkel had a chance to discuss the AEC budget with the president, and the IDO had a chance to give the AEC commissioners a very good impression of the NRTS. Milton Shaw's staff held a round of business meetings and could see how far the NRTS had pro-

President Johnson affixes landmark plaque inside EBR-I.

Argonne National Laboratory-West 1519

gressed on Shaw's quality initiative—perhaps more than other AEC labs. Later, the AEC awarded Ginkel a Distinguished Service Award, and Ginkel credited the recognition partly to the exposure brought by the president's visit. In the circle of towns surrounding the NRTS, the event affirmed the value of the NRTS mission to the nation and placed it under a warm and welcome spotlight.[5]

The potential demise of the MTR was an entirely different proposition than the end of EBR-I. All agreed that the EBR-I had fulfilled its useful life, but there was no such consensus regarding the MTR. Some of the HPs thought the machine was "decrepit," too aged and battered to protect its operators from radiation hazards. Certainly, the large test loops of the ETR and ATR attested to its obsolescence in the Nuclear Navy program. But the MTR had beam holes. The ETR and ATR did not. No other reactor west of the Mississippi River had this feature, and if the MTR shut down, it would foreclose a whole class of research potential in Idaho, and indeed anywhere else in the western United States. At least, that was how NRTS supporters saw it.

So the MTR had to be saved. INEC's first salvo was a round of appeals to the AEC to change its mind. Samuelson, ten other western governors, the congressional delegation, and INEC all failed to get the AEC to reconsider. Samuelson offered state funds to help retain the MTR.[6]

Wilfrid E. Johnson, one of the AEC commissioners, came to Idaho Falls and explained the AEC position to the Rotary Club:

We are having extreme difficulty these days in obtaining funding for many of our programs and I can give no assurance or even encouragement at this point in time that we will be able to keep the MTR operating.[7]

INEEL 4383

The view toward the core of the MTR through a beam hole.

The next phase of the campaign saw Rutledge collecting testimonials and ideas from MTR scientists and the region's universities about how the MTR might be reborn. A vision took shape, and in no time, INEC encapsulated it in a brochure: "MTR, Today an Irradiation Facility, Tomorrow...Western Beam Research Reactor, The Hub for Neutron Research in the Western United States." The beam hole feature of the MTR had been underexploited, said the brochure, compared to the in-pile materials testing function of the reactor. Universities and industries of the West might now use the reactor for basic, applied, and developmental research. The tradition of the MTR at the frontier of knowledge could continue to benefit western states.[8]

The entire Idaho nuclear network embraced the Western Beam Research Reactor (WBRR). The governor went on television expressing the state's support. Editorials and news articles explained the idea to the public. NRTS scientists warned that without the MTR, its team of fifty skilled scientists would break up and perhaps be lost to Idaho. INEC saturated the service club circuit with the MTR message. More letters went from the congressional delegation to the AEC administrator, the commissioners, and the White House. In its 1969 session, the Idaho legislature raised its level of appropriations for nuclear-oriented research to $200,000, hoping it would help retain the MTR. The lieutenant governor led a delegation to Washington, D.C., for an audience with the JCAE. Remarks celebrating the MTR and its potential as the WBRR went into the *Congressional Record*.[9]

Behind the scenes, Governor Samuelson asked Bill Ginkel to lay on the mantle, as it were, of the MTR's proposed new *persona*. Change its name from MTR to WBRR, he urged. Make it more open to university users and eliminate security clearances. Establish a users group to evaluate research proposals. Create an office to help coordinate university activities. Provide temporary housing for researchers at the NRTS.[10]

If Ginkel was inclined to follow Samuelson's recommendations, he found no soft spot at AEC Headquarters, which mustered not the slightest enthusiasm. The highly secretive business of the Nuclear Navy occupied the ETR and the ATR, and the MTR could not easily be isolated from the rest of the complex. The no-nonsense, PERT-charting engineers in Washington were trying to streamline, redirect all available resources to the breeder program, and compete for funds. INEC was asking the AEC to subsidize the MTR for a very unrelated mission at a cost approaching $5 million a year.

Obviously, INEC needed big money but couldn't seem to raise it. The Commission succeeded in persuading the AEC to postpone the MTR decommission date to June 1970. But the campaign wore on through 1970 and into 1971, with more of the same results. Rutledge kept the issue at the highest possible profile with an endless stream of letters and appeals. He looked everywhere for investors, nurtured leads, and came up empty every time. Representatives of GE inspected the MTR, but later concluded that the combined capacity of other reactors, public and private, could meet market demand for irradiation. Glenn Seaborg told Utah Senator Wallace Bennett that education was the only justification for preserving the MTR, and other education priorities existed elsewhere.[11]

Idaho State Historical Society 66-132.1

Governor Don Samuelson

The AEC, therefore, turned down a proposal from twenty-five western universities asking the AEC to operate the reactor. The universities offered no funds, although private industries pledged over $400,000 in business to make industrial isotopes. The AEC rejected commercial involvement without the concurrent sponsorship of a public agency such as the National Science Foundation (NSF). So Rutledge followed that path, and the NSF promised to look into it.[12]

Before the NSF made its report, the MTR ran its last experiment. After months of preparation, the team loaded the reactor with plutonium fuel. They named the core "Phoenix" after the legendary bird that had lived five hundred years, burned itself to ashes, and then rose to live again. The reactor demonstrated that plutonium fuel could be controlled safely in a water-moderated reactor. The long-envisioned nuclear fuel cycle, beginning with the creation of fissile material in a breeder reactor, could be closed. Mission accomplished, the AEC shut down the reactor on April 23, 1970.[13]

INEC doggedly trudged on. A few days after the shut-down, Idaho newspapers happened to carry a story from the Idaho Fish and Game Department. Among the 250,000 pheasants shot during the 1969 hunting season, a few had more mercury in their blood than was safe for human consumption. State biologists suspected that the birds had eaten grain contaminated with a fungicide containing mercury. How widespread was the problem? Would the Department have to cancel the pheasant hunt for 1970?

Rutledge saw a perfect chance to demonstrate why the MTR could not be allowed to fade away. The MTR could irradiate pheasant samples. If mercury was present, neutrons would transform it to a radioactive isotope, which could quickly be identified and measured. Once more, he tripped all the wires in INEC's network. A flurry of calls, letters, proposals, and conferences ensued. Dr. Libby got involved. The State Board of Education came up with funds

"to the absolute limit of our fiscal capabilities."[14]

The IDO cooperated. Aerojet, the MTR contractor, brought the reactor critical one more time for forty-eight hours in August 1970. Governor Samuelson went to observe. The scientists loaded the old machine with a thousand samples of pheasant, fish, grasses, mutton, beef, and pork from all around the state. The publicity was good. The results were good. The Fish and Game Department decided the mercury problem had been localized and temporary. The pheasant season opened on schedule that fall.[15]

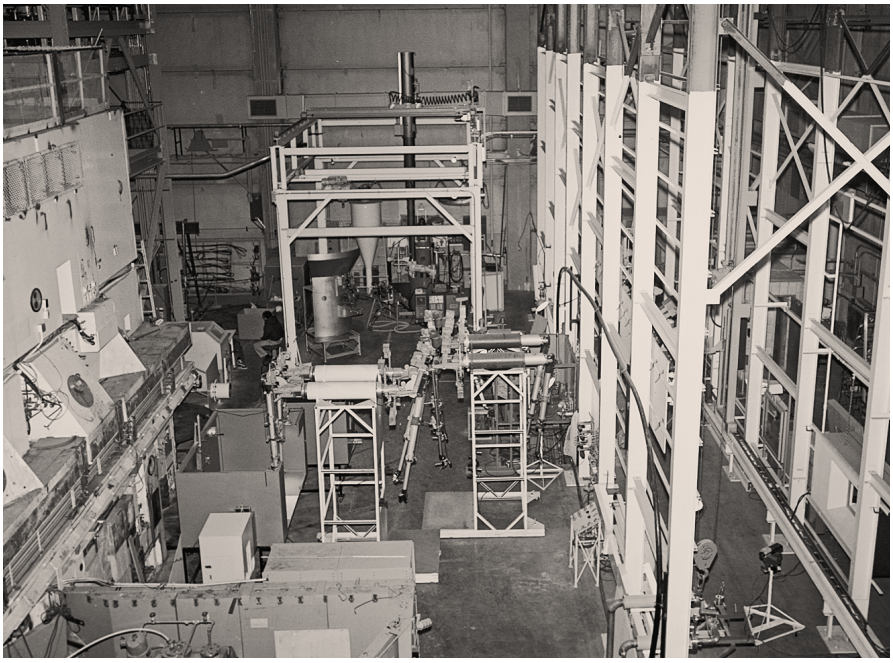
At last, the AEC offered Governor Samuelson a chance to rent the MTR for $1 a year. If Idaho didn't want it, the AEC would establish a minimum acceptable bid and sell the MTR to the highest commercial bidder. The terms were difficult. MTR use had to be restricted to educational, research, and government functions. Idaho had to pay the MTR contractor full costs (which ranged in the multi-millions) and the AEC would contribute nothing.[16]

Dr. Libby urged the governor to take the deal, but Rutledge and the INEC board knew that without commercial business, the state and the universities could not develop an income stream fast enough to make the MTR a going concern. Even maintaining it in a standby condition would quickly drain Idaho resources. The state was hardly wealthy; in 1970, its population base was only about 713,000 people.[17]

The last, faint hope for the MTR dissolved when the NSF said that reactors at "eastern facilities" were sufficient for any likely demand. Nuclear research in environmental matters, crime abatement, cancer, and biology was not expected to exceed their capabilities, so the MTR was surplus even for non-government research.[18]

The fight was over. The MTR team broke up. Dr. Robert Brugger eventually left Idaho to run the nuclear physics program at the University of Missouri, which possessed one of the swimming pool reactors that had inspired the SPERT program. Others remained at the NRTS, but they had to "redirect" themselves to other work.

The failure to keep the MTR alive was not a failure of heart or drive. The effort to save it was a creative foray to retain a research mission that had made the NRTS worthy of the name "national laboratory," even if the Site did not possess the name. Money didn't materialize, partly because demand was no longer growing as it had earlier; existing capacity elsewhere was sufficient. The message from GE had made this clear. National nuclear reactor research was beginning to decline, and the loss of the MTR was an early sign of it. Possibly, there was the political reality that the national power base for basic research was vested at the universities of Chicago, California, Princeton, and others. Funds for a new western university research center would have reduced these universities' slices of the budgetary pie. The NRTS, lacking a strong champion within the AEC, was poorly equipped to compete with the political delegations of Illinois and



INEEL 82-1776

After the MTR was decommissioned, its floor space was available for other uses. This 1982 view shows a mockup of the CPP New Waste Calcining Facility.

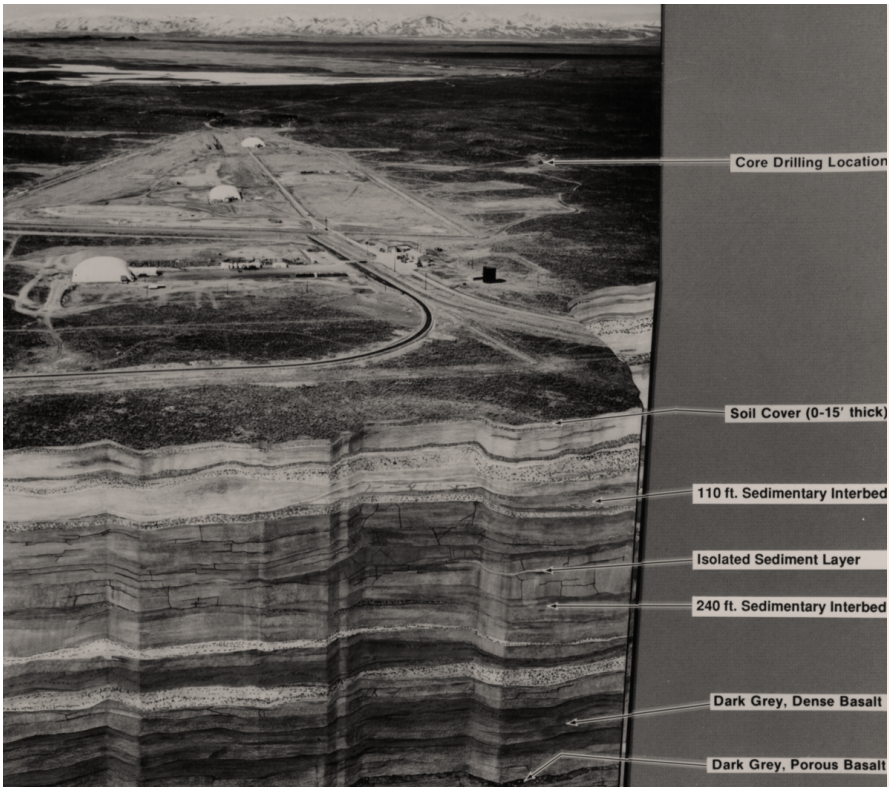
California. The NRTS was not a weapons production center, nor was it associated with a major science university. One participant at the time, C. Wayne Bills, reflected later that the NRTS had an image as merely a service outfit for the Navy or Argonne. Its unique pool of brilliant scientists and engineers was easily fended off. "I learned how much energy could be wasted by not knowing the problem," he said of the great "charge" to save the MTR.[19]

New reactor projects had become very scarce at the NRTS. By 1972, most of the reactors that were going to be built at the NRTS had been built or were under construction (a reactor called NRAD went critical at Argonne-West in October 1977, but it was a commercial Triga reactor, not a new reactor type). After PBF and LOFT (and the Triga), the only reactors that would attain first criticality after 1970, there were no more. The NRTS mission to test reactors had been accomplished. In all, the NRTS had been home to fifty two reactors. All but two of them went critical. (See Appendix B.) The NRTS fledglings—the Nuclear Navy and the nuclear power industry—had become giants making their own way in the world. Both of the major commercial reactor concepts, pressurized water and boiling water, had been proven in Idaho. After 1970, the thrust of NRTS nuclear research increasingly was conservative: to enhance proven concepts. The ETR and the ATR were at the service of the Navy; and the safety testing program at LOFT and PBF supported the Nuclear Regulatory Commission and the nuclear power industry.[20]

During the height of the MTR campaign, another plutonium fire ripped through Rocky Flats. The fire occurred on May 11, 1969, and resulted in more damage than from any previous Rocky Flats fire. In June, the *New York Times* ran a story on the fire and mentioned that the debris—ton after ton of concrete blocks, metal shielding material, rubber, piping, coveralls—would go to the NRTS to be buried. A customer of Robert Erkins'trout farm clipped the story and sent it to Erkins, wondering if the plutonium might somehow contaminate the fish. Erkins was alarmed. The pure spring water supplying his business came from the aquifer system underlying the NRTS. He visualized plutonium seeping from the burial trenches into the soil, finding a path through six hundred feet of the fissured rock below, and leaching into the flow-

INEEL2522

Above. Part of the sea of barrels from Rocky Flats.
Below. An illustration depicts the subsurface beneath the NTRS Burial Ground.



National Oceanic and Atmospheric Administration

ing waters of the aquifer. If plutonium contaminated the aquifer, or if the rest of the world thought that it had, his business could be finished.[21]

He sent off a letter to Governor Samuelson. He questioned Bill Ginkel, who wrote a response intended to reassure:

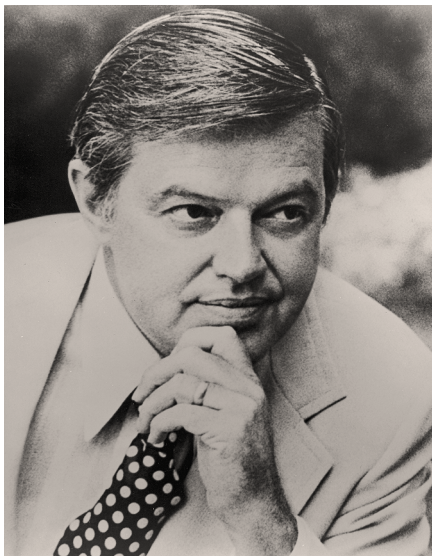
We have zealously guarded the water resources at the NRTS by an extensive environmental research and monitoring program which has extended over two decades. We have never found any evi - dence of movement of the plutonium or other wastes through the soil at any location in the burial ground. Because of the desert conditions, the soil does not contain sufficient moisture to pro - vide transport for this material. Moreover, the plutonium is in an essen - tially insoluble form... Tracer studies have demonstrated that the water under the south-central part of the Site is moving at the rate of 10 to 20 feet per day. At this rate, the water currently under the southern boundary of the Site can be expected to reach the Thousand Springs area on the Snake River after the year 2070.[22]

Ginkel also said that if signs of migration ever were found, the waste was not beyond recovery or countermeasures. He reminded Erkins that plutonium was about thirty times more valuable than gold, and that all reasonable efforts were made to recover it before the waste went to Idaho. In newspapers, Ginkel was quoted as saying, "We have substantial technical experience. There's no real or potential basis for alarm—ever." Erkins was not reassured. He sent letters to newspaper editors all over the state, who obligingly published or quoted from them. The *South Idaho Press* said Idahoans "should be alarmed generally," and quoted Robert Lee, the director of the Idaho Water Resources Board, who said, "If the aquifer became radioactive, we would be wiped out." The editor called for the creation of a "national dump" at some barren place where the waste could never cause harm to anyone and quoted Erkins:

Basic common sense would tell anyone that you do not store your garbage over your water supply regardless of the type of garbage. How then can we con - tinue to permit disposal of radioactive material over the source of one of the world's great spring water systems?[23]

Erkins kindled doubts elsewhere in the agricultural community of south Idaho, most of which relied on the aquifer or the Snake River into which it flowed. Samuelson attempted to get the facts, but found that federal agencies seemed to have differing assessments of NRTS waste burial practices. In addition, his own state employees were issuing contradictory statements, fueling more press coverage.[24]

"This confusion is not leading us anywhere," decided Samuelson. He put a stop to *ad hoc* staff comments to the press and created a State Task Force to "thoroughly examine, through a coordinated approach, any possible atomic pollution to the aquifer and then recommend a course of action." The committee consisted of the director of the health department, the state reclamation engineer, the director of the Water Resources Board, Gene Rutledge, and a representative from the Idaho Reclamation Association. Bill Ginkel and John Horan immediately invited the task force to have a look around.[25]



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Senator Frank Church

The public outcry reached Idaho senator Frank Church. He decided to coordinate resources on a federal level. He asked the USGS, the U.S. Public Health Service, the Federal Water Pollution Control Administration (FWPCA), and the Bureau of Sport Fisheries and Wildlife to conduct a joint study independently of the AEC to assess the long-term implications of NRTS burial practices. His news release said that Church had acted after NRTS officials had "acknowledged publicly" that radioactive wastes from both the NRTS and Rocky Flats were being buried above the aquifer. The practice had been known to the state for years, but this fact did not become part of the public discussion on the issue.[26]

Church discovered that the AEC had in 1966 requested a National Academy of Sciences (NAS) committee to survey radioactive waste research and development at the AEC's four major plants storing such waste. The resulting report pointed out that each facility had different standards and used different definitions for low-, intermediate-, and high-level wastes. The AEC's 1948 decision to let each lab handle waste its own way had become a chicken come home to roost. The NAS authors felt that each site was in a poor geological location. They suggested that the AEC start over and put its waste-generating plants in areas selected for geological suitability. Although the NAS committee had visited neither Hanford nor NRTS before making its report, it challenged the NRTS judgment that hazardous amounts of radioactivity would not reach the aquifer. Later, the committee examined both sites and informed the AEC that neither was creating a hazard. The AEC had not published the report.[27]

INEEL 75-3513

Damaged waste barrels retrieved in the 1970s were sometimes placed in "overpack" barrels.

Senator Church demanded that the AEC release what he called the "suppressed" report. When he obtained a copy, he published it in the *Congressional Record*. Glenn Seaborg, AEC chairman, said the report had gone "beyond its purpose" and delved unbidden into operational issues. This explanation, which could have been interpreted as a polite way of saying its authors were ill-informed, seemed suspect to the public. After all, it appeared to them that the NRTS had "secretly" been burying plutonium-laced waste. Part of the Idaho public began to think that the AEC and the IDO were not to be trusted. These doubts planted the seeds of a new citizen coalition, and it would evolve as a protest network, not a support group.[28]

At their October meeting, Governor Samuelson's task force staff faced a predicament. The staff had no means—no funds or qualified analysts—to make an independent assessment of NRTS waste management practices. The only available information was in the hands of the people who said there was no problem—the AEC and the USGS. If there were a hazard, the staff presumed the AEC would not release any information to substantiate it. Nevertheless, they accepted Ginkel's invitation to visit the Site. They would collect what information they could and let Samuelson know if the problem was serious or not. Gene Rutledge requested that the IDO articulate and make public long-term plans for waste management.[29]

The issue continued to bubble. The State Board of Health, whose members went on the NRTS tour with the Task Force as they looked over the Burial Ground, the SL-1 burial plot, and the injection wells, decided they saw no current dangers, but asked the AEC to stop burying waste in the desert. Dr. Theos J. Thompson, an AEC commissioner visiting Idaho in November to dedicate Argonne's new Zero Power Physics Reactor, asserted that contamination from buried solid wastes would never reach the aquifer. To questions about the practice of injecting low-level radioactive liquids into the aquifer, he said "regardless of how it sounds," these planned releases would not endanger people. He described the tiny amount of radioactivity in the releases in relation to the tremendous diluting power of the aquifer. He had no objection to Idaho monitoring the NRTS, but observed that it would duplicate personnel and equipment already on the job.[30]

On the first day of 1970, President Richard Nixon signed the National Environmental Policy Act (NEPA). NEPA was a triumph of the growing environmental movement. It had been inspired partly by frightening examples of air and water pollution so serious that they threatened public health. Therefore, the national press was interested in discovering further examples. Later in January, *ABC Network News* sent a reporter to Idaho Falls to prepare a story on the aquifer for a weekly program called "First Tuesday."[31]

INEEL 77-2632

Environmental monitoring technician collects soil samples from beneath a storage trench. He holds radiation detector in his right hand.

Radioactivity was in other news. An AEC scientist named Arthur Tamplin from the Lawrence Radiation Laboratory in California went public with his view that the AEC's radiation exposure standards should be tightened by a factor of ten. He represented one of two general views about the hazard of radiation. One opinion was that exposure to radiation was a natural phenomenon, and that a very low annual dose was a normal risk of living. Tamplin held the opposing view, that any amount of radiation, no matter how small, is deleterious to human life.[32]

These concerns about the hazards of radioactivity helped focus a lively public interest on the NRTS. Senator Church's four federal agencies weighed in with their combined report. "We find no problems that have occurred and that none are likely," they said.

Nevertheless, they recommended ways to improve NRTS practices, such as increasing the soil barrier above and below the pits and trenches in the Burial Ground, better control of snow melt, and more study of the basalt and alluvial layers beneath the Burial Ground. In addition to monitoring soil and water to confirm the absence of contamination, monitoring also should positively affirm that radioactivity had not migrated beyond the burial area. It suggested that waste with plutonium and americium (long-lived transuranic elements) should be stored so that it could be removed if necessary.[33]

Governor Samuelson's Task Force wrapped up its own work a few months later. It, too, found "no evidence of any present hazard." Nor was any hazard likely in the future. The AEC had written the Task Force to say that the AEC would start removing the TRU waste in the Burial Ground before the end of the decade, reiterating a statement that Glenn Seaborg had made earlier to Senator Frank Church. With that kind of schedule, the problem obviously would disappear. The Task Force also thought it was time the Idaho governor's office establish a formal liaison with the NRTS and hire qualified experts to maintain a continuing check on NRTS waste management.[34]

AEC Headquarters also had been receiving public complaints from several other parts of the country regarding the waste management practices at some of its other facilities. It created a new division called the Office of Waste Management and Transportation and announced that it had chosen a salt mine in Lyons, Kansas, for an evaluation as an underground repository for Rocky Flats and other radioactive waste. The AEC expected to start shipping wastes to Kansas around 1975. Undoubtedly, this expectation underlay AEC intentions to begin removing buried waste from Idaho. Further, AEC Headquarters began the long-deferred task of developing a set of policies, standards, and criteria that would apply uniformly to waste management practices at all of its laboratories.[35]

In response to the new attention being focused on waste, Ginkel's staff began considering the implications for its own waste management practices. "We want some new thinking on the Burial Ground," was the message to George Wehmann, director of IDO'S Office of Waste Management. Furthermore, the AEC in March of 1970 directed that TRU waste be segregated from other kinds of nuclear waste and also be stored so that it could be retrieved at a later date.[36]

Wehmann looked at various problems. Part of the Burial Ground area had lava rock fairly close to the surface, making it unsuitable for pit and trench burial. He concluded that if this area were covered with asphalt paving, it could be used for above-ground storage, and this plan eventually went into effect as a way of making economical use of Burial Ground space.[37]

On the recommendation of John Horan, the IDO had told Rocky Flats in the fall of 1969 that it could no longer expect to deliver waste for burial during the winter and spring months (due to flood hazards and the reassessment of practices then underway). After the AEC's March 1970 directive, there would be no more subsurface Rocky Flats burials at all. The Rocky Flats barrels and boxes went to asphalt pads built adjacent to the old Burial Ground, where the barrels were stacked on their sides to prevent water from pooling on the tops.[38]

One day, someone noticed water leaking from a few of the barrels. Wehmann recalled:

This was happening despite the assertions of Rocky Flats that they were sending only solids in these barrels. I went to Rocky Flats and we had a don-

INEEL 70-5212

A 1970 view of the Burial Ground shows the Transuranic Storage Area in the foreground, a new destination for Rocky Flats transuranic waste.

nybrook. They said there couldn't be water in the barrels. I watched them fill the barrels with waste encased and sealed in plastic bags and then seal the barrels. Then we looked at the drums [barrels] in the storage yard. We found clear liquid on top of the drums. Well, they weren't tending to details. The barrels were standing up in the rain. They were using sponge gaskets to seal the barrel lids, and these weren't always sealed perfectly. In those cases, the seals acted like a syphon, sucking water into the barrel.[39]

INEEL74-2808

So Rocky Flats changed its ways, discontinued outdoor storage, and repackaged nearly 2,000 barrels. It soon improved the plastic liner inside the barrel, improved the sealant, and substituted a better seal on the barrel itself.

The IDO also had to consider the AEC's decision to retrieve Rocky Flats waste barrels that had been buried between 1954 and 1970. Exhuming what had not been intended for retrieval presented a number of questions. Retrieving stacked-up barrels probably would be easy. But the practice of dumping Rocky Flats barrels from truck beds into the pits, while it had kept costs down and reduced radiation exposure to workers, also dented and damaged the barrels. The soil most intimate with these barrels may have adsorbed flecks of radioactivity. Exposing soil to the drying winds of the desert could produce dust. If it contained plutonium, the dust was a potential health hazard. Then there was the old problem of not being sure what Rocky Flats had actually sent to the Burial Ground. Its industrial garbage and fire debris may have included laboratory solvents like carbon tetrachloride and trichloroethylene or other low-level radioactive items. These needed due respect if they were to be disturbed. Mixed wastes were a complication; workers had to be defended from two kinds of hazards: radioactive materials and hazardous chemicals. Techniques for handling one might be unsuited to handling the other.

Retrieval thus required practical research. Could older barrels be safely retrieved and, if so, at what cost? As usual, the only way to find out was to begin the job, first by removing and examining a few barrels of several different vintages, and then by proceeding with a practical plan. By 1978, over 20,000 barrels had been removed from below the ground and stacked on asphalt pads. Not unexpectedly, the barrels that had been damaged during the days of random dumping were not as easily dealt with as the others. To protect workers from wind and weather during retrieval operations, the work area was sheltered within a temporary air-supported "building" that looked from the outside like a very large pillow. Made of fabric, it was anchored to the ground and kept inflated by a constant flow of air pumped into the build-

INEEL77-1262

Above. Air-supported building inflates after being moved to new work location. Left. Barrel retrieval takes place in pits 11 and 12 inside air-supported building in 1977.

INEEL 76-1380

INEEL 76-2954

Above. An aerial view of the RWMC in 1976, facing west. Three air support buildings indicate locations of work areas. Below. The "Three Cell Personnel Entry" was used to control contamination levels on workers' clothing as they exited work areas during the Early Waste Retrieval Project of 1976.

ing. When a new work area opened, the building was moved to the new spot. Most of the 20,000 barrels had been buried relatively recently or in the very early days of by-hand stacking.[40]

The IDO prepared itself for the day when the AEC designated some other location outside of Idaho as the final resting place for the Rocky Flats barrels and crates. New standards for the barrels indicated they should have a life of twenty years. Monitoring of the environment increased around the area; enhanced soil compaction methods went into use; and new techniques made more efficient use of limited space.[40]

Obviously, the name Burial Ground no longer was appropriate, even though the low-level radioactive waste (non-transuranic) from the NRTS would continue to be buried there. Wehmann had it changed in 1970 to Radioactive Waste Management Complex. The NRTS had a new mission: waste retrieval.

Chapter Twenty-One

By The End of this Decade

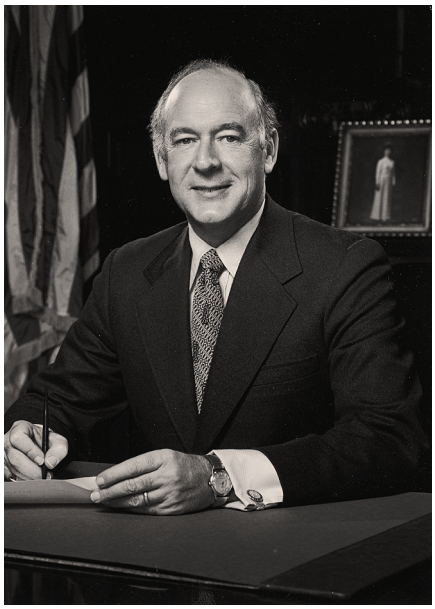
[There is] the likelihood of the AEC almost surreptitiously permitting Idaho's NRTS burial ground to evolve into one of the nation's large de facto burial grounds...

–Cecil Andrus–

Cecil D. Andrus, elected governor of Idaho in 1970, had a nuclear vision for the development of southeast Idaho. The growing season of this high-elevation part of the state might be extended by irradiating seeds to cause their early germination. Then a nuclear reactor somewhere in the region could lend its heat to irrigation water for the seeds, further extending the growing season. The agricultural base of the region could diversify, no longer limited to potatoes and a short list of other crops. The reactor's abundant electricity would short-circuit any further debate about damming Idaho rivers for more hydroelectric power, an issue growing ever more controversial. The reactor also would complement the research and development activity at the NRTS, further diversifying the economy.[1]

There was more. Nuclear reactors might power an electrolytic process making hydrogen fuel from water. Hydrogen was non-toxic and upon combustion produced only water as waste. Hydrogen-powered aircraft could carry Idaho agricultural abundance to Asia. The whole scheme invited new industries, expanded the economic base, and resolved potential energy shortages.[2]

The vision required research. Did irradiation really cause seeds to germinate early? Would there be any undesirable side effects to using reactor cooling water for irrigation? Where might nuclear power plants best be located?



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Governor Cecil D. Andrus

How long would it take to develop economic hydrogen fuel? Andrus posed these questions to professors at the University of Idaho (U of I). Soon study proposals were under way, with titles such as "A Conceptual Study of a Nuclear Energy Park for the State of Idaho," and "Agrocargo Hydrogen Study." Perhaps the NRTS could become the center for research applying atomic age energy to agriculture not only in the United States but the rest of the world as well.[3]

The governor's enthusiasm for a nuclear-based future in southeast Idaho encouraged the INEC board and helped it focus its research grants. Andrus's staff researched additional questions, such as whether the Environmental Protection Agency (EPA) had established minimum standards on plutonium in the soil.[4]

Bill Ginkel cooperated. By July 1, 1973, U of I professors were ready to start an experiment just outside the perimeter fence of the Chem Plant. They would use thermally warm water from the plant's operations to irrigate certain forest trees and ornamental plants to test how far the growing season could be extended.[5]

Researchers from University of Idaho examine young trees grown using thermally warm Chem Plant water.

INEEL 74-3023

He and Andrus also arranged the closer relationship that Samuelson's Task Force had recommended between their two offices. From then on, the two offices defended each other from surprises, sent advance copies of press releases, and cultivated mutual understanding. The agenda of Idaho Falls business leaders to preserve the public image of the NRTS was now also the governor's agenda.

Andrus had a plan to bulwark shaky public confidence in the NRTS. He asked Dixy Lee Ray, the Chair of the AEC after September 1972, to finance an independent surveillance system so that the State of Idaho could monitor the NRTS for any radioactive contamination emanating from the Site. The State could cross-match its data with the AEC's regular environmental monitoring reports. She thought it was a good idea, but felt that Congress was unlikely to appropriate the funds.[6]

Then Andrus's early nuclear vision began to fade. Events in 1973 and 1974 beyond Idaho helped deflect his energy from nuclear economics to nuclear politics. First, Andrus—and the rest of the world—learned that a Hanford waste storage tank containing highly radioactive waste was leaking. This wasn't the first tank to leak—Hanford tanks had been leaking since 1958—but this leak had gone unnoticed for several weeks. What kind of stewardship was that? Could it happen at the NRTS? The Idaho public wasn't sure.

Next, Idaho's radiation control officer, Michael Christie, found an article in the *Washington Post* reporting that the AEC was considering the NRTS, along with Hanford and Nevada, as a "dump for A-wastes." He had sat on Samuelson's Task Force, and this news hinted that the AEC might reverse previous assurances that, because of its location over the Snake River Plain Aquifer, Idaho would not become a waste repository. Christie told Andrus, "It is imperative that this type of consideration by the AEC be stopped." It was news that Andrus felt should have come from Ginkel but hadn't.[7]

Andrus, together with Senator Frank Church, wrote Commissioner Dixy Lee Ray that they had understood that Idaho was not to be used as a repository for wastes. They wanted her assurance "in writing" that except for fuels to be reprocessed and calcined, the NRTS would not receive wastes from any place that hadn't previously sent wastes. She must state, they said, that the NRTS was not being considered as an interim or permanent storage site for long-lived wastes in any form. Finally, she must tell them that the AEC was using "all efforts" to develop a national waste repository so that long-lived radioactive wastes currently in Idaho could begin to leave the NRTS by "the end of this decade."[8]

Her reply was disappointing. She gave no satisfaction on the first point. The AEC had to make the best use of all its facilities. Any waste going to Idaho would be handled safely. Previous AEC orders that the NRTS exhume and repackage plutonium-contaminated wastes would continue. Nor did she make any promise on the second point. She left it open that Idaho might be considered for interim—but not long-term—storage of long-lived nuclear

INEEL Cultural Resources

R. Glenn Bradley

waste. On the last item, however, she was definite. The schedule for Idaho's plutonium-contaminated waste "recognizes our commitment to be ready to start moving this waste from that site by the end of this decade."[9]

Bill Ginkel retired as manager of the NRTS in September 1973. R. Glenn Bradley took his place. Andrus's first official encounter with him was far different than his first with Ginkel. Ginkel had made the first move, facilitating the clearance needed for Andrus to access all NRTS facilities. Now Andrus put Bradley on notice that his office was to stay in "direct contact with my staff" concerning any unusual increases in the waste entering Idaho for interim storage. He told Bradley that many Idahoans feared the AEC would "make Idaho the nation's *de facto* repository for atomic wastes of all varieties." The

two grew to understand each other's political constituencies—Andrus had the Idaho electorate and Bradley had AEC Headquarters—and worked out amiable protocols.[10]

Meanwhile, publications with a national readership—*Smithsonian, Readers Digest,* and *US News and World Report*—were publishing articles with titles such as "Rising Dangers of Atomic Wastes" and "Nuclear Terrorism: A Threat to the Future?" Some scientists imagined disaster scenarios involving terrorists, the theft of plutonium, and the making of bombs. Many journalists no longer differentiated between waste and spent fuel. It was all waste, and wherever it went was a "dump."[11]

Andrus fought hard to distance the NRTS from this kind of background noise. He started by trying to distance the NRTS from Hanford's problems, which Dixy Lee Ray had characterized as "not only regrettable, but disgraceful." Andrus decided to lead a press tour of the RWMC, the Chem Plant, and their associated laboratories in December 1973. Bradley collaborated. Both hoped the tour would "ameliorate suspicion within the ranks of the uninformed media concerning the treatment of wastes at the NRTS." They promised reporters that the trip would not be an IDO "sales job." All questions would be answered. Andrus readied himself to identify the Chem Plant's calcining program as a key point of difference between Hanford and the NRTS. Here was commendable evidence that the NRTS employed "better techniques than Hanford." Reporters would also see the areas where boxes and barrels had been buried and lost their integrity, and where "at the most, plutonium has migrated only 6" into the ground underneath."[12]

The press tour went well, and the major Idaho papers featured the story within the next few days. With the press informed and the AEC promising that the NRTS would not evolve into a permanent waste depository, Andrus hoped the issue had been settled.

Boise State University Library ISS-100

Governor Andrus at RWMC.

Boise State University Library

The December 1973 press tour took the governor (foreground) and reporters to the Chem Plant.

Then Bradley told him that TRU waste from the Argonne Laboratory in Illinois was headed for Idaho. Andrus told Bradley he suspected the AEC capable of letting the NRTS gradually evolve into a large burial ground by sending one small shipment of waste after another and calling it "interim." In the eyes of the press particularly, this shipment was going to look like another step in the wrong direction.[13]

Bradley reminded him that the shipment was consistent with Dixy Lee Ray's earlier letter and did not contradict any of the assurances she had made. It was, on the other hand, quite possible that the NRTS might qualify as the best site for an interim storage facility that would reprocess and repackage not only the TRU waste already at the NRTS, but also from other sources. After all, in dealing with the waste already present, the NRTS was acquiring a unique expertise in that field. He expected research and development funding towards that end to bring $1.1 million into Idaho in FY 1975.[14]

But an "interim" storage plan that might last thirty to fifty years looked too much like "*de facto* permanent" to Andrus. Despite the view held by Andrus's office, in southeast Idaho, and among others that the NRTS was practicing the best safety methods in handling all of its waste, and that neither public health nor the Snake River Plain Aquifer was in jeopardy, the State of Idaho embarked on a mission that would dominate its relationship with the NRTS for the rest of the century: to make the AEC remove buried Rocky Flats waste from Idaho.[15]

The mission effectively dissolved Andrus's thoughts of a nuclear-based economic renaissance in southeast Idaho, although he continued to support new initiatives for the NRTS. It interfered with the boost machine campaigns for expansion of the NRTS and lent an "us against the world" patina to the feelings of east Idaho residents. The high public profile of the issue eventually gave the NRTS an image, at least in more distant parts of the state, as a place of great danger and risk. Grass-roots political movements found a target for environmental and anti-proliferation protests.

The first skirmish in the campaign to remove waste began with an AEC proposal to build an above-ground vault for the storage of spent fuel from commercial power plants. The candidate sites were Hanford, Nevada, and Idaho. The AEC released a draft EIS (environmental impact statement), numbered WASH-1539 for its origin at AEC Headquarters, in September 1974 and solicited comments for a hearing in November.

Andrus swiftly named a Blue Ribbon Study Commission, raising an awareness of the issue all over Idaho, and charged it with reviewing the draft and making recommendations. The Commission absorbed public attention instead of Andrus, who was running for re-election as governor. The president of Idaho State University, William E. Davis, was the chairman. Other members included Cyril Slansky from the Site's Chem Plant, Al Wilson of INEC, Kent Just of the Idaho Falls Chamber of Commerce, and representatives of orga-

nized labor, the East Idaho Nuclear Industry Council (EINIC), the Idaho Farm Bureau, a newspaper editor from Burley, executives from Idaho Power Company and Boise Cascade, and others. Mike Christie, the state's radiation expert, was an *ad hoc* member.[16]

Frank K. Pittman, head of AEC Headquarters' Division of Waste Management and Transportation, met with the Commission during its October meeting to discuss the proposal. But it was the removal of existing waste that was on the minds of the Commission, and Pittman discussed it freely:

Pittman: ...it is logical to store transuranic waste here because of the technical know-how.

Wilson: As far as Idaho, we have been given the feeling that the Governor and Senator Church feel that transuranic waste presently stored in Idaho will start to be moved by the end of the decade.

Pittman: [An AEC] letter to Senator Church indicated that material buried in Idaho would start to be moved out—but it is not feasible. Is your worry about material buried prior to the present material? If we dig up old material, an environmental impact study will have to be made to see if it could be taken out safely.

Wilson: The Governor's and Senator Church's concern is based on the location of our aquifer. The concern certainly includes people other than Idaho Falls and Arco.[17]

The Commission drafted and adopted an interim report and decided to put it before the public in a series of six public hearings around the state. Various interest groups began to take positions on both sides regarding the storage vault proposal. The unions were for it, environmentalists were not, potato growers and water users opposed it, the Idaho Falls City Council favored it.[18]

In its final report, the Commission's first comment was to affirm its belief that present waste management practices at the Site were ostensibly safe and responsible; they posed no threat to the environment. After that, the recommendations were of a sufficiently innocuous nature that a majority could agree. The Commission declined to endorse the expansion of the NRTS for storing commercial spent fuel because the draft EIS was "inadequate." It suggested that commercial spent fuel

In 1975, the Site was designated as a National Environmental Research Park (NERP). All lands within the Site boundaries are a protected outdoor laboratory where scientists from the Department of Energy, other federal and state agencies, universities and private research foundations conduct ecological studies. The Idaho NERP, covering some 570,000 acres, is the largest undisturbed area of sagebrush vegetation in the Intermountain West. The NERP has a large number of paleontological, historic, and prehistoric archaeological sites. It also has over 400 species of plants and a wide variety of animal life. Common reptiles, fish, raptors, and over 40 mammal species, including elk, deer, moose and, most noticeably, pronghorn antelope, can be found here.

INEEL 91-35-8-1

should remain where it was until it could go directly to a permanent repository or to an interim site closer to a final repository. The Commission then embraced Governor Andrus's mission and asked the AEC to give its "firm commitment" and a schedule for removing buried TRU waste from the NRTS. It requested that the AEC finance an independent environmental monitoring capability for Idaho. Finally, almost as an afterthought, the Commission said it favored "a strong nuclear program" in Idaho as a matter of policy, provided it maintained a high level of environmental quality.[19]

At the hearing on November 12, 1974, the constituent member organizations of the Blue Ribbon Commission came out squarely for or against the proposal. Andrus himself endorsed the findings of the Blue Ribbon Commission. He restated the AEC end-of-decade commitment and demanded the AEC set a schedule. Kent Just, speaking for the Idaho Falls Chamber of Commerce, said he did not fully understand why waste management practices had changed from burial to above-ground storage. "I am not certain if it was solely through public pressure or in conjunction with new techniques," said Just. "We are not absolutely sure the burial was a mistake..." If Just expected to receive clarification on this point from either the IDO or the AEC, he apparently didn't receive any.[20]

After the hearing, Andrus conferred with Glenn Bradley. He assured Bradley that his testimony had not precluded receipt of Rocky Flats waste for interim storage. His position was still consistent with the view that the NRTS not receive TRU waste from new sources. Nor was he critical of current waste practices. But, "you and AEC-DC should recognize the wisdom of removing TRU waste at the end of this decade." And if you don't intend to, he wrote, "notify me in writing as soon as possible."[21]

The rising tide of public doubt compromised the whole-hearted support of Senator James McClure for the WASH-1539 proposal, eroding his power to boost the project. Then serving his second term, he demanded publicly that the AEC investigate reports that "huge quantities" of highly radioactive wastes had been buried in cardboard cartons. "If there is even a 'minimal danger' of contamination of the Snake River Aquifer," he said, "then that is more than the people of Idaho should be expected to live with." A subsequent *Post-Register* editorial accused him of taking "potshots" threatening Idaho's chances of bringing in a project worth $3 billion in the next twenty-five years. Later, McClure mended his own bridge to Idaho Falls and endorsed the WASH-1539 proposal—but only if all the waste was above ground, constantly monitored, dry, and interim. And, he added, the material buried in the early years should be removed.[22]

INEEL 97-620-1-9

RWMC activities in 1997 included waste storage, waste evaluation, environmental monitoring, waste repackaging, and waste management research and development.

Kent Just thought that Andrus perhaps had used the Blue Ribbon Commission to deflect pressure from himself during the election campaign. He deeply regretted that Andrus's position had no technical basis. Equally, he was dismayed that the IDO had chosen to emphasize the dollar value of the project in Idaho instead of its technical or scientific merits.[23]

In the next few years, Andrus overlooked no opportunity to remind the IDO and its Washington counterparts that they had committed to start removing radioactive wastes from Idaho by the end of the 1970s. His staff scrutinized every AEC and IDO message, press release, and report for evidence of an agency careless of its commitments.[24]

In the end, the AEC did not go forward with the WASH-1539 proposal, for reasons other than the events in Idaho. Still, the IDO took several steps to redeem itself in the eyes of a doubting Idaho public. It held an open house and invited visitors to examine the waste retrieval facility. Among its usual annual output of public relations pamphlets and brochures, the IDO produced one specifically about the RWMC for the first time. It reached out to groups such as the League of Women Voters, which had opposed any expansion of waste management facilities. Andrus hinted to Bradley that he should venture onto the turf of the potato growers and other NRTS opponents. It was the same sort of work that IDO managers had done ever since 1949 when Bill Johnston began with the Kiwanis and Rotary club circuit, but Andrus thought the relevant circuit had grown far larger; he worried that Bradley didn't venture far enough.[25]

The RWMC pamphlet told the public that "a number of years will be necessary to retrieve, treat, and repackage these wastes." The idea of digging up the old Burial Ground had become a well-articulated IDO practice and policy.

The evolution of this policy seemed laced with irony. No investigations had said that NRTS waste practices had posed any risk to the Snake River Plain Aquifer. The IDO had not acknowledged the old practices as a miscalculation of risks, nor had it qualified or quantified the nature of future risks. Governors' committees and IDO citizen advisory committees since the early 1950s had not raised doubts about the safety of Site practices. Kent Just had hinted that the new AEC/IDO policy was a capitulation to public sentiment. If so, it was a tribute to Andrus's effectiveness. The tasks of retrieving, processing, and moving TRU waste continued to be goals of the AEC, the IDO, and the State of Idaho for the rest of the century—and beyond.[26]

Chapter Twenty-Two

Jumping the Fence

It was an opportunity to step outside the Site boundaries...

–Jay Kunze–

With the MTR out of business after 1970, the physicists who hadn't left Idaho were available for other work. Fortunately, this surplus of NRTS talent dovetailed with national events that offered new opportunities. In 1971 not long after an electrical "brownout" in the eastern states, President Richard Nixon warned Congress that the country should not take its energy supply for granted. He suggested that a new government department unify the country's energy development programs. But the price of energy was sufficiently low that Congress did little at the time.[1]

However, the NRTS and the AEC's other national laboratory facilities began to expand their research to non-nuclear energy sources. East Idaho business leaders were exploring every avenue they could to diversify and build new programs at the NRTS, so this was a welcome development. The employment numbers at the Site were about 5,600, having fallen from a peak employment of 6,145 in mid-1965. The Eastern Idaho Nuclear Industrial Council published a brochure entitled *Potentially Available Facilities*, which identified 223,000 square feet of space available in twenty vacant NRTS buildings. Diversification was highly desirable.[2]

INEEL 77-9183

Well drilling at Raft River.

The IDO contractor, Aerojet Nuclear, was wide open to new possibilities. It created an office to pursue research work in alternative energy sources such as solar, geothermal, wind, and tidal energy. Physicist Jay Kunze headed the office and began looking around.[3]

Kunze learned of the geothermal waters that flowed from artesian wells in the Raft River Valley in Idaho, about 150 miles southwest of Idaho Falls and near the Utah border. A number of years previously, some farmers had drilled irrigation wells and to their surprise brought up boiling water. The remote valley had a population of a few hundred souls and received its electricity from the Bonneville Power Administration (BPA) through the Raft River Rural Electrical Cooperative. The co-op manager, Edwin Schlender, inspired by the national discussion about potential energy shortages, wondered if the hot water below the valley might produce electricity at a price competitive with that of the BPA. He hired a geologist to investigate the resource and applied for a water right from the Idaho Department of Water Resources (IDWR). Several neighboring landowners prepared to protest the application because the water table in the valley had been declining over the years and they feared new wells would worsen the situation.[4]

Kunze and his boss, Dr. Robert Brugger, drove down the highway one day in 1972 toward Malta, Idaho, to visit the cooperative. The Raft River is a north-flowing tributary to the Snake

The Raft River Pilot Plant at night.

INEEL 74-3023

River, rising in the Raft River Mountains that stride the Idaho/Utah border. Beneath the valley surface, geological features such as faults intersecting each other at depths of several thousand feet provide heat and pathways to subterranean water reservoirs. Conditions such as these are common elsewhere in Idaho and other western states. Kunze recalled the trip.

Bob and I went to visit Ed Schlender. I felt a little uneasy going down there with the message, "Hello, we're from the government; we're here to help you." But the manager took to us, and we took to him. We developed a friendly relationship and started to put together a project. We worked with the Idaho Department of Water Resources, the public power agencies, and the BPA. The Raft River people gave us a lot of support, moral and otherwise. It was an opportunity to step outside the Site boundaries and attempt to develop a resource that would benefit Idaho.[5]

A research proposal took shape. Kunze worked with the Raft River neighbors and collaborated with the IDWR. He hired Clay Nichols, a geologic engineer with a specialty in geothermal geology, who had done his doctoral dissertation at the University of Oklahoma on geothermal systems and was then teaching at Boise State University. They went to Washington, D.C., in August 1973, seeking federal grant support. The objective was to drill wells deep into the fractured rock, bring up water at a temperature of 300°F, install turbine/generator equipment using a working fluid other than water, and generate electricity. The engineering challenge was to make the system work economically. The water was 50°F cooler than what then was understood to be economic. As a nonnuclear project and one that would take place off-Site, the project was a significant departure from the NRTS tradition.[6]

Support rolled in from the usual network, aided by an apparent energy crisis. In the fall of 1973, the petroleum exporting countries of the Middle East embargoed the shipment of crude oil to the United States. The energy shortages that followed were the worst the country had experienced since World War II and lent an air of urgency to the quest for alternative energy supplies. Congress was quite willing to finance research that might produce greater national energy independence. Governor Cecil Andrus eagerly promoted the project. Idaho senator Frank Church was at the peak of his political power. He was chair of the Interior Committee's Subcommittee on Water and Power and, along with Idaho Senator James McClure, in a good position to help the project.[7]

Church, whose mother lived in a Boise neighborhood heated by geothermal water, had said, "Oh, we can't let this money go to Los Alamos!" Idaho muscled out other contenders, including other national AEC facilities, for some of the millions available for geothermal funding. The project began in 1974 with a plan to build, operate, and test a five-megawatt pilot plant. The geothermal water would exchange its heat to isobutane, which would drive the turbine. If successful, the project might have broader application elsewhere in the West.[8]

The program quickly attracted workers from various disciplines. Scientists converged in the Raft River Valley like a surgical team over a critical patient. Chemists analyzed the water. Radiologists determined its radioactive qualities. Geophysicists tried to understand the fractured rock below the surface. Seismic experts set up earthquake recorders. Hydrologists monitored the effect of hot water withdrawals on the cool groundwater system. Biologists identified the plant and animal species in the area, making a baseline for future comparisons. The old, old question of the right valve for a new job required engineers to invent a method to shut off the flow of boiling water originating at a thousand feet below the earth's surface. Metallurgists put samples of carbon steel and other metals into a loop of hot water to figure out corrosion rates. Computer programmers simulated the entire pilot plant system to aid with predictions. Even the technology of the fluidized bed moved to Raft River, as chemical engineers tried to keep the hot water from depositing chemical crud in heat exchanger tubes.[9]

The team set up side experiments. Could better drill bits do the job? They tried new ideas. What kind of pipe insulation would best prevent heat loss? They buried some pipe and compared the results with spray-on insulation. If geothermal water were used for irrigation, would salts build up in the soil over time? Someone staked out plots for trees, wheat, oats, potatoes, and beets. How about warm water being used for fish culture? Up went raceways and a fish pond for shrimp, perch, catfish, and tilapia. What went on inside a geothermal well? Special elec-

tronic instruments were snaked down the wells on cables. In short, the standard NRTS multi-disciplinary attack on a problem had a thorough workout.

The environmental monitoring studies at Raft River called for scientists and engineers in new specialties. Much of the talent was youthful, and several of the geothermal recruits were young women who were riding the crest of enthusiasm brought about by the environmental movement—and the crest of confidence brought about by the women's movement. Kunze hired Susan Stiger, a civil engineer with an academic focus on the environment and hydrogeology, to create the environmental program at Raft River. At the time, no models existed for comprehensive characterization of environmental features and their interactions. Once more, NRTS energy research was "all new" for a new generation.[10]

INEEL 79-10129

Old trailers served as field offices and crew quarters at Raft River. Monitoring the performance of wells and fluids sometimes required 24-hour-a-day operation. No one seemed to mind. Kunze recalled another woman he hired:

We needed a geologist to examine cuttings while the well was being drilled. Someone referred me to a lady geologist named Susan Prestwich who lived in Idaho Falls. She had "sat wells" for her family business in Utah. I thought, "Drilling crews are known to be roughnecks. I can't send a woman out there all night to work that well!" But I talked to her, and she said, "Don't worry, I can handle those guys."[11]

And she did. Prestwich was the first female drilling engineer (and geologist) ever hired at the Site. As it had been for hundreds of NRTS male scientists and engineers before her, the chance of discovering something new was motive enough to endure an all-nighter. She continued with Aerojet and EG&G, the new Site contractor in 1976. Her career eventually took her to the Department of Energy in Washington. Stiger continued her career with Bechtel Corporation, returning to the Site in 1999 to manage the entire environmental management program when Bechtel became the contractor.

Kunze and Roger Stoker, the chief geologist for the geothermal project, extended the reach of the project to Boise. Geothermal wells drilled in the 1890s had heated homes in the city's Warm Springs neighborhood for decades, but the question was whether geothermal water might be found elsewhere on the Boise Front faultline. A team including Clay Nichols and Roy Mink from Boise State University selected a site for a test well on Boise

INEEL 81-4752

Above. Inside a geothermally heated greenhouse near Raft River test facility. Left. Raft River Pilot Plant.

City-owned land. The well produced 165°F water at a depth of about a thousand feet. A second well on Bureau of Land Management property nearby likewise found hot water, although slightly deeper. The wells were turned over to the city and the state, which developed systems to heat commercial and state office buildings in and near downtown Boise.[12]

The Raft River Pilot Plant started up in October 1981 and then ran briefly in 1982. Power from the plant went out on the regional electrical grid. It proved that the binary cycle using isobutane could work. For a number of reasons, including the depth of the wells, the system could not compete with the economics of hydropower production in the Pacific Northwest (where the costs of building public power dams are not charged to customers), but in some parts of the world, the system could compete with coal-burning plants that required special pollution controls.[13]

The project ended abruptly in the first half of 1982. After the election of Republican Ronald Reagan in 1980, the project (among many others) became a symbol of the Democratic party's supposed inclination to finance programs more properly in the domain of private enterprise. In addition, the energy supply crisis clearly had ended. Funding for geothermal research was drastically reduced. Frank Church was defeated in the 1980 election, and Raft River lost its most influential supporter.[14]

The IDO informed IDWR that no further funding was available for the project. Neither it nor Raft River Rural Electric pursued a water right, and the informal agreement between IDO and IDWR ended. The Pacific Northwest had entered a period of energy surplus, and neither Idaho Power Company nor BPA desired to buy power from Raft River. The IDO eventually asked the General Services Administration to sell the project, which was done officially on February 8, 1984. Hydra-Co Enterprises acquired the Raft River property and moved the pilot plant to Nevada.[15]

Other alternative energy programs sprouted at the NRTS in the 1970s. Site scientists found themselves involved in industrial energy conservation, the production of alcohol fuel, and solar energy research. They tested batteries for electric vehicles, developed glass and aluminum recovery systems for solid waste programs, and examined the energy potential in biomass production. The Site became the nation's lead laboratory for a hydropower program in which the government loaned funds to utilities and municipalities for small innovative hydropower systems. As a result of this program, Idaho Falls installed a low-head bulb-turbine system in the Snake River to increase its municipal electrical supply. Many of these programs involved commercial clients other than the federal government.[16]

The impact of the new programs helped increase employment levels at the Site, although the major nuclear activities at Argonne, the Naval Reactors Facility, the Test Reactor Area, the Chem Plant, and the LOFT facilities continued as the major NRTS missions. Maintaining a stable but growing employment base at the NRTS was important to the economic vitality of southeast Idaho. All of the national laboratories were diversifying

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Non-nuclear research at the NRTS included vortex studies. Large commercial airlines flew through plumes of smoke while cameras recorded the disturbance.

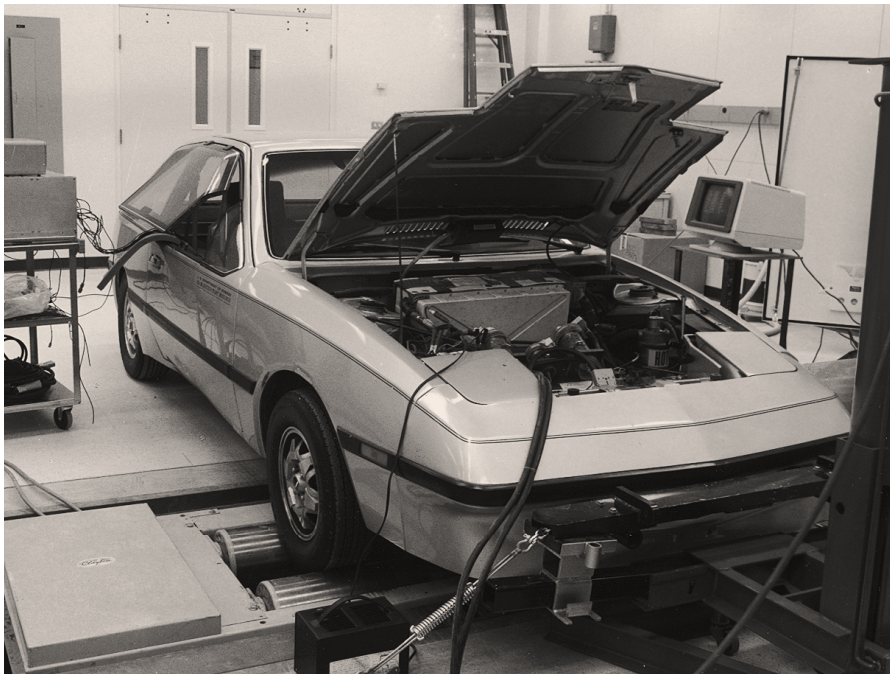
Courtesy of Orval Hansen

Orval Hansen

their missions, so an entrepreneurial approach to competition had to be added to traditional political approaches.

In this connection, a feeling had arisen over the years amongst Site scientists and administrators, members of EINIC, and others that the NRTS had gone far beyond the proof-testing of nuclear reactor concepts. Its nuclear safety engineering research had become a national force; its research in neutron physics, of global importance. The NRTS was a leader in radiation and environmental protection and advanced computer modeling. It was a world-class innovator in instrumentation and, despite Milton Shaw's shift of breeder work to Hanford, in the field of breeder reactors. Now, because of the environmental monitoring and waste management research at the old Burial Ground, the Site was becoming a leader in the technologies of waste management and retrieval.

Below. Advanced battery technology developed at INEL was used in a cooperative research project with the United States Advanced Battery Consortium.



INEEL 84-464-2-8

In short, by the early 1970s the Site had grown out of its role as a "testing station." It was truly a "laboratory." Furthermore, it was long past due for NRTS scientists to push back when people from Headquarters or other AEC "laboratories" slighted their importance from time to time. For example, in annual reports, the AEC didn't identify the NRTS as a laboratory and had no particular category to define the "thing" that was the NRTS. Obviously the NRTS needed a new name. The internal organization of the AEC had always made it hard to compete for funds and attention during a Cold War when military research and weapons production—and the labs that served those needs directly—had such strong champions.[17]

Around 1974, NRTS supporters asked Idaho congressman Orval Hansen to take the lead in getting the AEC commissioners to designate the NRTS as a "national laboratory," a mission he undertook enthusiastically. Elected in 1968, Hansen had gained a seat on the JCAE in 1971. Dixy Lee Ray became the chair of the AEC in 1972, appointed by President Nixon. She made internal reforms of the AEC that made her unpopular with senior members of the JCAE, entrenched interests at the AEC, and the commercial nuclear industry—a trio whose close relationship had sometimes had been referred to as an "iron triangle." Hansen described the name-change mission.

I went directly to Dixy Lee Ray, chairman of the AEC. I proposed that in addition to being designated as a laboratory that the new name include "Idaho" and that it should be known as a "national" laboratory to give it sta-

tus similar to other national laboratories. I firmly believe that Dixy's positive response was due, in large part, to her desire to do a personal favor to me. I had given her total support on the JCAE at a time when some other members of the committee resisted changes she was making in the AEC including those affecting Milt Shaw. She was grateful for my support and we developed a warm and close relationship. She knew that the requested name change would help me politically.

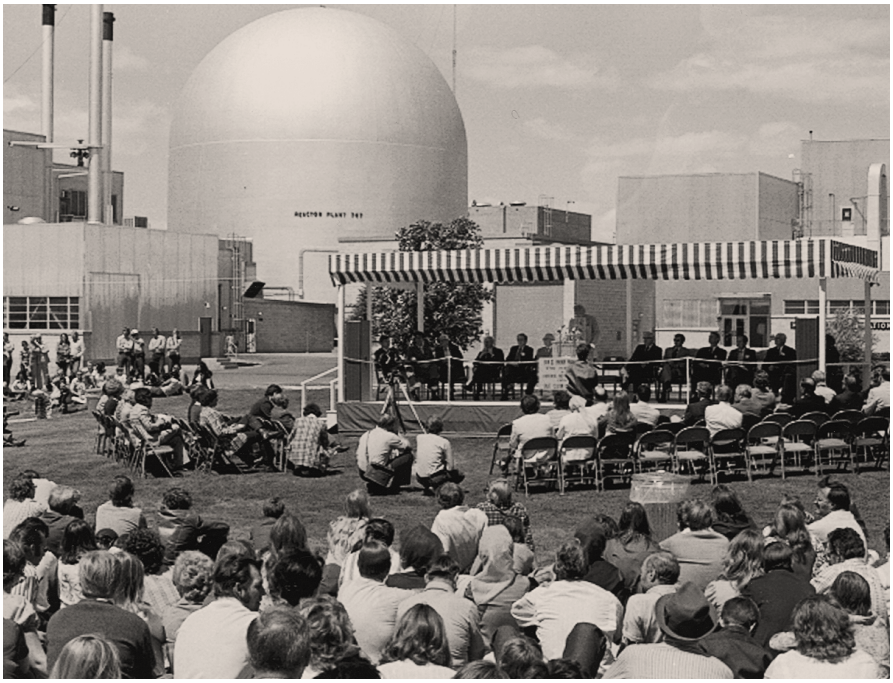
There was resistance to the requested name change. The national laboratories were a kind of club. There was little enthusiasm for the apparent elevation of a more narrowly specialized installation to national laboratory status. I believe that the resistance influenced the name finally selected. I suggested that it be the Idaho National Energy Laboratory which would be more descriptive of its mission. I don't want to leave the impression that politics played the dominant role in the name change. I believe that we had a strong case to make.[18]

Although Hansen didn't feel that "engineering," the adjective finally selected to describe the laboratory, adequately reflected the kind of research, testing, and development of advanced technologies being done in Idaho, he had achieved his main goal: status for the Site as a national laboratory and a name that identified it with its state.

In August 1974, preparations were underway in Idaho to celebrate the tenth anniversary of EBR-II. The plan was to use this occasion, to take place at Argonne West, to announce the new name. Hansen invited Vice President Gerald Ford to do the honor. Ford agreed to come to Idaho, but in early August it became clear that President Nixon had been involved in a criminal cover-up and that his resignation was imminent. Ford canceled his trip to Idaho, but AEC Commissioner William Anders, a former Apollo astronaut, dignified the speakers'dais and pronounced that the NRTS would be known thereafter as the Idaho National Engineering Laboratory (INEL).[19]

Later in the year other name changes occurred in Washington, D.C. By October 1974 the Arab oil embargo had lifted, the crisis in the presidency had passed, and Congress was ready to reform the AEC, separating its developmental and regulatory functions into two agencies. The Energy Reorganization Act of 1974 abolished the AEC and distributed its developmental functions to the Energy Research and Development Administration (ERDA). The bill transferred to ERDAseveral energy programs formerly in the Department of Interior (coal, mining) and the Environmental Protection Agency (automotive systems). The regulatory and licensing function went to a new agency called the Nuclear Regulatory Commission (NRC).

The new agencies went into effect in January 1975. Jimmy Carter became president in 1976. That winter, a shortage of natural gas in the New England states helped shape Carter's view that conservation must become a major element in a national energy plan. Carter promoted further reorganization aiming for a more comprehensive planning approach. Congress created the Department of Energy (DOE) in 1977. James Schlesinger, who earlier had



Argonne National Laboratory-West S5843

AEC Commissioner William Anders announces that the NRTS will be renamed the Idaho National Engineering Laboratory. EBR-II is in the background.

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Charles E. Williams

been an AEC commissioner, became the first Secretary of Energy and a member of the president's cabinet.[20]

With these changes, the nation's nuclear enterprise had effectively been shifted from the custody of a powerful congressional committee to the executive branch. The route to political influence became far more diffuse than it had been. Presidential politics became at least as important as congressional politics, and this contributed further to the decline in nuclear research already underway. For example, one of Carter's goals was to eliminate the country's dependence on nuclear energy by the year 2000. Schlesinger organized DOE not by types of fuel (nuclear, fossil, geothermal), but by different processes along a continuum from research through development to commercialization. The organizational chart changed frequently during the 1980s, but the old sheltered autonomy, such as it was, of the AEC/JCAE system was gone for good.[21]

The forces that had changed the nuclear outlook at the national level had gathered their strength from the local political dynamics of the nation's fifty states. Idaho citizens had no commercial power plant upon which to focus their concern about environmental degradation, their fear of nuclear accidents, or their protests to the Cold War arms race. But they did have the INEL.

Leadership at the Idaho governor's office, the IDO, and IDO's prime contractor all changed about the same time. Carter drafted Cecil Andrus, who had won his second term as governor in 1974, as Secretary of the Interior. Lt. Governor John Evans moved into the governor's chair in 1977 and then won his own election as governor in 1978. Charles E. Williams, previously the deputy manager at the Nevada Test Site, succeeded Glenn Bradley as IDO manager in 1976. Aerojet lost its bid to extend its operating contract in 1976, and the new prime contractor was EG&G Idaho.

Evans continued the Andrus campaign to remove nuclear waste from Idaho. At his first opportunity, a public hearing on waste management, he reminded ERDA of its obligations to Idaho. Evans wanted an action schedule and "I respectfully request that this commitment be put in writing." The Idaho Potato Growers and Shippers and many others commended Evans for his stand. The general sentiment was that the sooner the waste was removed from above the aquifer, the better.[22]

DOE canceled its plans to develop a repository in Kansas, setting back any plans it may have had to remove waste from Idaho during the 1970s. Evans responded by turning to the national waste management picture, investing considerable energy in the Nuclear Power Subcommittee of the National Governors Association. The best hope for Idaho to see the last of the waste was to assure that national policy created a better place for it. He felt that Idaho had little legal means of preventing DOE from sending new wastes to Idaho in the interim. But, he said, "I would use the powers of this office to protest in the strongest possible manner. I think that kind of public pressure would stop it."[23]

In November 1979 the INEL monitoring program found a trace of tritium in a water sample taken from the aquifer near the southern INEL boundary. The press covered this news, and explained that it had come from the Chem Plant injection well. The news provoked a public reaction similar to the earlier one about the TRU buried at the Site, and again Senator Frank Church called for an investigation.[24]

By this time, grass roots environmental and peace movements in Idaho had gathered momentum and were strong enough to help build the "public pressure" Evans had invited. The Idaho Conservation League had organized in 1973 and its membership grew quickly throughout the 1970s. Its agenda was broadly aimed at several issues, including wilderness preservation and energy conservation. In response to the news about the injection well, a group of environmentalists and pacifists in Boise organized the Snake River Alliance to work for the closure of the well and an end to the practice of waste injection. The group quickly recruited members, particularly in the Twin Falls area where citizens felt themselves potentially in the direct path of the hazard. Aside from its objection to the well, the Snake River Alliance evinced a mistrust of the DOE and a concern that nuclear fuels could be directed toward weapons production. Other groups such as the Groundwater Alliance based in Ketchum, Idaho, also organized and found common cause with the Snake River Alliance.

These groups held meetings, published newsletters, appeared at hearings, scraped together funds, and learned to make the most of NEPA-mandated public hearings and other opportunities to get their messages to the press, the public, and the politicians.

For the first time since 1949, the finely meshed network of interests protecting and nurturing the INEL was forced to contend with an antagonistic network fighting for different goals. The governor's office, while not a complete dropout from the old network, had to acknowledge the new network and the electorate it represented.

The public was alarmed at INEL's overt and deliberate introduction of a radioactive substance directly into the aquifer. How could this be safe? Evans read their letters and realized that the State had to provide a counterweight to the public's faltering confidence in the INEL. Once more, a governor of Idaho created a special task force of distinguished authorities to investigate the situation at INEL and make recommendations. Once more the IDO conducted tours and answered questions. The IDO reminded the group that it had been sending quarterly and annual monitoring reports to the governor and Idaho's health officers for years. The practice was no secret. Monitoring would continue. Site drinking water was safe. Chem Plant improvements already had reduced the amount of tritium entering the waste stream. The State was welcome to take its own samples.[25]

The task force traveled around the state and heard public comments. In the end, it concluded that "no immediate health hazard exists, and it seems unlikely that a long-term hazard is posed by current disposal practices." It complimented the INEL for its "forthright and helpful" assistance and noted no evidence of a cover-up. The INEL had been cleared once more of taking undue risks with public safety. Nevertheless, the committee recommended that the practice of discharging radioactive liquid wastes through the injection well to the aquifer be discontinued in favor of some other alternative that would somehow prove to be "more acceptable." Public perceptions were important, it said.[26]

The task force advised the governor to do everything possible to prevent this low-level waste from entering the aquifer. Idaho should improve its independent monitoring capability, it said, repeating a suggestion made to Andrus by a previous committee.[27]

The next three years saw the campaign to plug the injection well unfold at several venues. The IDO hired the Fluor Corporation to analyze how the Chem Plant operations might be engineered to end the injection of tritium-contaminated water. The governor gave the Fluor study time to mature and in the meantime protested DOE waste shipments into Idaho. He redoubled his efforts to accelerate the moment when a national storage facility would relieve the state. By this time, DOE had settled on a location in New Mexico for a Waste Isolation Pilot Plant (WIPP), a project replacing the salt mine in Kansas as a potential repository for TRU waste. A date for moving any waste from Idaho had moved into the mid-1980s.

The Snake River Alliance and its associates kept the waste issue alive in their newsletters and meetings. In September 1980 they held a protest rally near EBR-I, calling for an end to the injec-

tion well, an end to shipments from Rocky Flats, and an end to breeder reactors in general. Environmental degradation and the production of weapons were two faces of the same issue. Sam Day, the editor of the *Progressive* and the featured speaker, observed that the breeder reactor, because of its ability to make plutonium, "probably represents the greatest danger beyond nuclear war itself to the future and welfare of humankind." Another speaker asserted that the INEL was "the home and playground" for the U.S. breeder reactor program. The business community in Idaho Falls felt that such comments were "absurd."[28]

As the governor's office waited for the IDO to act on an alternative to the injection well, the relationship between the two offices deteriorated. Idaho wanted more than just to look over an INEL lab technician's shoulder while collecting a water sample. It wanted to examine engineering drawings and specifications, to be notified prior to certain construction projects, to be sent an inventory of every air pollution emission source at the Site, and more. But the IDO manager had conveyed to Evans his view that activity within the boundaries of the Site was "none of the state's business." The editor of the *Post-Register* called for an end to the "spitting match" between the two offices so they could solve the problem together.[29]

Although the Fluor Report had been completed in 1980, the IDO managed to delay for nearly three years a decision on the injection well. The governor's staff characterized the IDO as "stubborn." In May 1983 Charles Williams left the IDO, and DOE appointed Troy Wade to take his place. At last, things began to move faster and with more amity.[30]

On February 9, 1984, Governor John Evans stood near the Chem Plant in his overcoat against the chill weather and diverted a stream of waste water into an evaporation pond. The four-acre pond was sixteen feet deep, its bottom allowing the percolation of water into the soil. Radionuclides would interact with the soil and become trapped just below the pond. The tritium would evaporate into the air with the water. IDO said the project had cost $800,000.[31]

Possibly for the first time, an Idaho governor had been the ceremonial figurehead to dedicate a new project at the Site. The environmental network regarded the closing of the well as a victory for the citizens of Idaho, apparently not concerned with the fact that the tritium would henceforth dilute and undergo radioactive decay in the air instead of underground.

Behind the scenes, the governor had also won another kind of victory. He had signed a Working Agreement with the IDO. It allowed the governor's employees to accompany INEL monitoring technicians on the job. Idaho could split water samples with IDO and perform its own independent analysis. The IDO and the governor reaffirmed their promises not to surprise each other in public. Any press releases about environmental releases or problems would come after both parties had reviewed and signed off on them. The governor's office was now in a position to monitor the Site. The State of Idaho finally had arrived inside the INEL fence.[32]

INEEL 84-0091-3-9

DOE-IDOmanager Troy Wade (left) and Governor John Evans open the new evaporation pond at the Chem Plant on February 9, 1984.

Chapter Twenty-Three

The Endowment of Uranium

The growth in the world's inventory of plutonium can be brought to a halt and then reversed.

–Till, Chang, and Hannum, 1997–

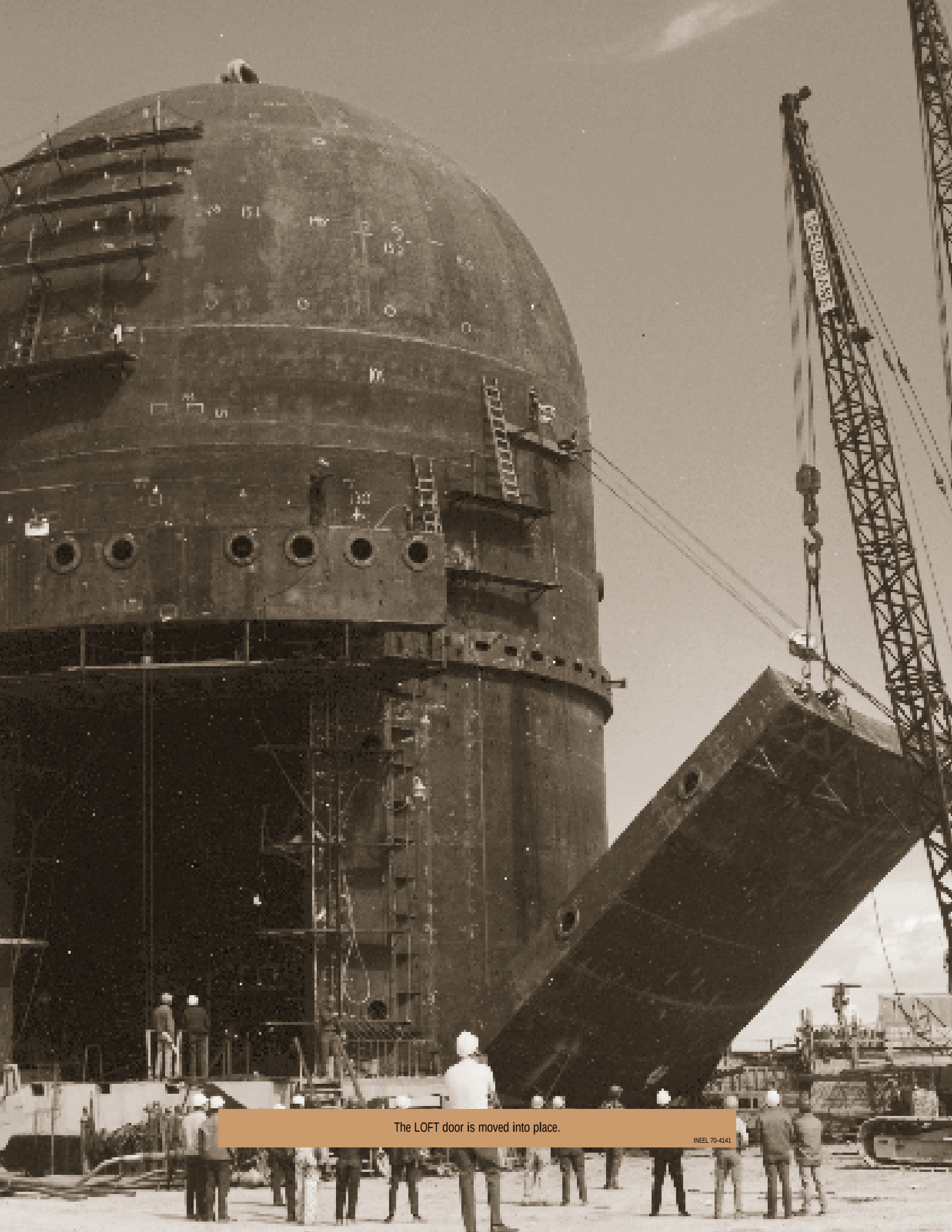
As Site employees began to get used to their new name in 1974, the national reactor safety testing program, which included LOFT, PBF, Semiscale, and other INEL projects, finally emerged from the policy chaos of the previous ten years. Early in her term as AEC chair, Dixy Lee Ray had created a new Division of Reactor Safety Research in the AEC. She removed safety research from the control of Milton Shaw. Shaw then left the AEC. Around the Site (and at other AEC facilities), this development produced either general rejoicing or, among those who had admired his tenacity and hard-nosed management approach, a sense of regret.[1]

INEEL 73-3710

LOFT reactor being moved into containment vessel.

Allocations for safety research improved immediately, and the LOFT program picked up steam. During the lean years, the Phillips and Aerojet teams had barely kept the project grinding forward. Once it became clear that the mission of the reactor would include repeated LOCA experiments, the designers had to re-engineer a complex water-management system and a special holding tank (the blowdown vessel) so that the reactor could "lose" its cooling water without flooding the reactor chamber or causing other damage to the test facility. Solving this problem had created extra costs. When rigorous specifications resulted in no bids from vendors for main coolant pumps and valves, LOFT project engineers scrounged these items from *NS Savannah*, the nation's first and only nuclear-powered merchant ship. Launched in 1961, it had been decommissioned and was about to be scrapped. Other LOFT parts came from as far away as a United States Air Force base in Vietnam. Site craft shops proceeded to modify and polish the hand-me-downs for the LOFT plant.[2]

Another implication of repeated experiments was that the reactor might require detailed examination after each test. This could be done in the TAN Hot Shop. The engineers decided to recycle the same equipment and use the same method that the ANP had used to move its reactor experiments back and forth. The four-rail track and the shielded locomotive were pressed once more into service. If the reactor was to leave the containment building, the building would need a very large, very heavy door. Before each test the door would have to be well-sealed to retain potential contamination inside the building. The 200-ton door had been installed in November



The LOFT door is moved into place.

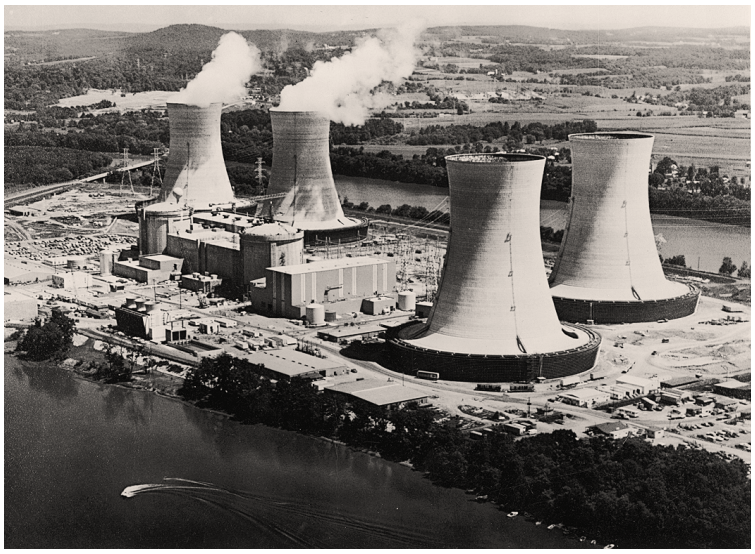
INEEL 70-4141

1970. As it turned out, operators did not remove the reactor after the tests because of the complexity of auxiliary piping and other systems around the reactor. But they did open the door between tests to facilitate preparations for the next test.[3]

LOFT engineers—the ones at the Rogers Hotel—had created computer models predicting how different types of emergency core cooling systems would supposedly perform if a reactor lost its coolant. Some systems pumped new cooling water into the core; others injected cooling water from pressurized tanks. The purpose of the LOFT experiments was to provide empirical validation—or not—for the theory behind the computer models.[4]

The first nuclear test on December 10, 1978, imitated a "double-ended guillotine break," where the coolant flooded from both ends of a broken pipe. This was presumed to be among the worst kinds of accidents. The computer model had predicted that the fuel temperature could rise to 1,350°F and that the emergency system would restore cooling water within 90 seconds. The computer proved to be conservative. The coolant was restored within 44 seconds, and the maximum temperature of the fuel rose to about 1,000°F. More tests were planned to imitate other accidents, but the assessment of what kinds of breaks to test was about to change.[5]

On March 28, 1979, at the Three Mile Island 2 (TMI) nuclear power plant near Harrisburg, Pennsylvania, the main pumps circulating the secondary coolant stopped running. This prevented heat removal from the primary cooling system. The turbine shut down, and the reactor likewise. Decay heat continued to heat the water near the core. This caused a pressure surge and forced open a pressure relief valve. Emergency pumps began to restore circulation. As pressure subsided, the pressure relief valve should have closed, but it stayed open.



INEEL 79-9362

Three Mile Island Nuclear Station in 1979.

The operators didn't know, couldn't see, and hadn't been trained to imagine that the valve was open. Because of other events and faulty indicators, they believed too much water was entering the vessel and shut down the emergency pumps. They started, then stopped the primary coolant circulating pumps. Water pressure fell, and some of the water in the pressure vessel flashed to steam. One thing after another went wrong with instruments, equipment, computers, and human judgment. During the next sixteen hours, a third of the core melted, although no one knew what this fraction was until much later. The hot core material did not melt through the reactor vessel, let alone down to China. About twenty curies of radioiodine were released to the environment.[6]

In the immediate effort to understand the condition of the reactor, inspectors from the NRC arrived from Washington, D.C., and concluded that the zirconium-clad metal was interacting chemically with the hot steam to create hydrogen gas. They feared that a bubble of the gas could interfere with the flow of cooling water through the core. Analysts speculated that a large gas bubble could explode and blow open the containment shell.[7]

Urgent questions about the hydrogen came to INEL scientists. Within twenty-four hours, they had modified the piping at the Semiscale facility to represent the situation at TMI and delivered reassuring information about the hydrogen bubble. Fear of an explosion lifted. President Carter visited the TMI plant for a briefing on the condition of the facility, a gesture that soothed the country and calmed Harrisburg citizens. A support team flew from INEL to

Pennsylvania and became part of the effort to secure the plant in a cold shutdown position.[8]

But the hard-slogging work of investigation was just beginning. How could the place be cleaned up enough to start analyzing what had taken place inside the reactor? What exactly had happened to the fuel elements inside the reactor vessel? Where had all the fission products gone after the fuel-rod cladding had burst or melted?

The PBF reactor at INEL had been designed to continue the tradition of SPERT in testing the performance of fuel elements during transients, or sudden bursts of power and heat. But it could handle a far larger repertoire of simulated accident scenarios than could SPERT. By this time, the many varieties of imagined accidents had acquired highly specific names and acronyms: reactivity-initiated accidents (RIA), power-cooling-mismatch (PCM) accidents, anticipated transients without scram (ATWS), loss-of-coolant accidents (LOCA), and severe fuel damage (SFD) accidents. During each accident simulation, sophisticated instruments recorded temperatures of fuel, of cladding, of coolant; the building pressure inside the fuel rods; the change in shape of fuel rods during the event. Monitors detected and timed the precise movement of fission products as they escaped from a fuel rod whose cladding had failed. As usual, PBF tests took place only after a computer program had predicted the results of the test. Constant refinement—and post-test examination of melted and mangled fuel rods in a hot cell—brought predictions and actual results into closer and closer agreement.[9]

Now the TMI operators wanted to know the shape and condition of the fuel inside their damaged pressure vessel. After the PBF had run simulations of the TMI accident, INEL scientists took the test bundle, still in its container vessel, to Argonne-West's Neutron Radiography (NRAD) reactor and made neutron radiographs of the core. The images showed a combination of melted fuel and a mass of rubble collapsed at the bottom. Beverly Cook was one of the INEL engineers to take the news to TMI.

We made slides of the images for a presentation to the people in Pennsylvania and flew out there. They still had not seen the inside of the TMI vessel. Using the PBF simulation, we told them what their core would look like. We showed them zones of melted fuel and how they would lay over rubble at the bottom. They didn't believe it. They couldn't believe that so much of their core had melted. But we knew that the uranium oxide in the fuel had interacted with other metals and caused more melting than they thought.

Later, when the TMI core was opened up for the remote insertion of cameras, we watched the procedure as it unfolded on a videotape. The camera went in from the top and was gradually sent further and further into the vessel. No one had edited the remarks of the camera operators as they were doing this, and we heard them say in amazement, "Where's the core?" and other deletable expletives. They weren't finding anything at all at the top of the vessel, just foot after foot of empty space. When they finally got a look at it, the core lay pretty much exactly as we had predicted.[10]

The connection between INEL and TMI continued in many forms. INEL teams developed training and emergency response techniques for TMI accident scenarios, many of which had been learned because of the post-TMI investigation and the Semiscale tests. Later, INEL scientists helped evaluate the condition of the TMI fuel. INEL transportation managers arranged the highly complicated task of packaging the fuel and other core debris for a trip to Idaho for further examination and temporary storage.[11]

The purpose in bringing the fuel to the INEL was to determine what had taken place in the core during the accident. What was below the rubble bed and its solidified sublayer? INEL specialists designed and built a 20,000-pound "core bore" machine in the thirty months after the accident and took it to TMI. Adapted from a commercial drilling machine, it had to fit through an air lock and operate remotely. The drill bits bit through ceramic and metal to reach the interior of the reactor vessel. After a hole was drilled, a remotely operated television camera inspected the interior of the core. With these techniques the scientists mapped the core, learned where the fission products were located, and developed a plan to ship the materials safely to Idaho for further examination and temporary storage. The last shipment of TMI debris arrived in Idaho in 1990 and the fuel examination program continued for several years.[12]

After this real accident, which had involved a "small" leak caused by the stuck pressure-relief valve, the focus of LOFT and Semiscale experiments shifted to investigating small leaks and a

variety of operational transients and accident scenarios associated with them. Whereas PBF had focused on fuel behavior during the accident, LOFT tests focused on the cooling water. By December 1980, LOFT managers had designed a series of tests to simulate the TMI accident and verify predictive computer codes. Taken as a whole, these tests persuaded former doubters that INEL safety test results could be scaled to commercial-sized power plants. One of the tests successfully duplicated an incident that had occurred at an Arkansas power plant.[13]

The INELtest programs attracted worldwide interest. At first financed by the NRC, sponsorship shifted to the international Organization of Economic Cooperation and Development in January 1983, which contributed to a $93 million test program that continued from 1983 to 1986. The nuclear tests concluded in July 1985 with a deliberate melting of the LOFT reactor's test-fuel bundle, somewhat fulfilling LOFT's original destiny as a "meltdown" reactor. One purpose of the test, aside from comparing actual results with the predicted results, was to trace the path of fission products released in the melt. The results suggested that a failure of the containment vessel was not likely to create nearly the radioactive exposures to the public as the most extreme, but theoretical, scenarios had imagined.[14]

Because of the PBF, LOFT, Semiscale, and other safety testing facilities—a Two-Phase Flow Loop, for example, which examined in minute detail the relationships between steam and water during an accident—the INEL had acquired a global reputation as the best technical source of data about the behavior of pressurized-water nuclear power plants during an accident. The INEL found that its advanced computer codes, simulators, instrumentation labs, damage analysis capabilities, risk evaluation techniques, and training methods continued to be in demand.[15]

Since the very beginning of the commercial nuclear power industry, the engineers and scientists at the INEL had been among the strong proponents of the idea that the nation's nuclear power plants must operate with an impeccable safety record. They had felt that their work could make important contributions to the safe design and operation of these plants. At times, they had met with resistance in Washington along the way by those who felt that commercial plants already had adequate safety designs. In the end, the nuclear reactor safety codes designed and proved at INEL, known by such names as RELAP5, TRAC-BD1, and FRAP-CON, were in widespread use by the nuclear industry that initially had been so skeptical.[16]

By the time LOFT ran its simulation of the TMI accident in 1985, the course of nuclear research at the Site was rapidly diminishing. The SPERT series of experiments had ended in 1970, and PBF went on standby status in 1985. At the Test Reactor Area, the ETR joined the MTR in retirement in 1981, leaving only the ATR to serve the Navy fuel examination and materials testing programs. Computer power had displaced many types of experiments formerly accomplished with the help of low-power and test reactors.[17]

The only corner at INEL engaged in the development of new reactor concepts was Argonne-West. Ronald Reagan's election in 1980 brought fresh political support for the nation's nuclear enterprise, despite a wave of doubt arising from many citizens after the TMI accident. Reagan supported the continued commercial development of nuclear power. He wanted the breeder reactor to move toward its destiny as a safe, economically viable solution to energy shortages. At Hanford, the FFTF went critical for the first time in 1980 and reached full power in 1982. Supporting it, EBR-II had earlier been transformed into a materials testing reactor, irradiating candidate fuels and doing related safety testing.

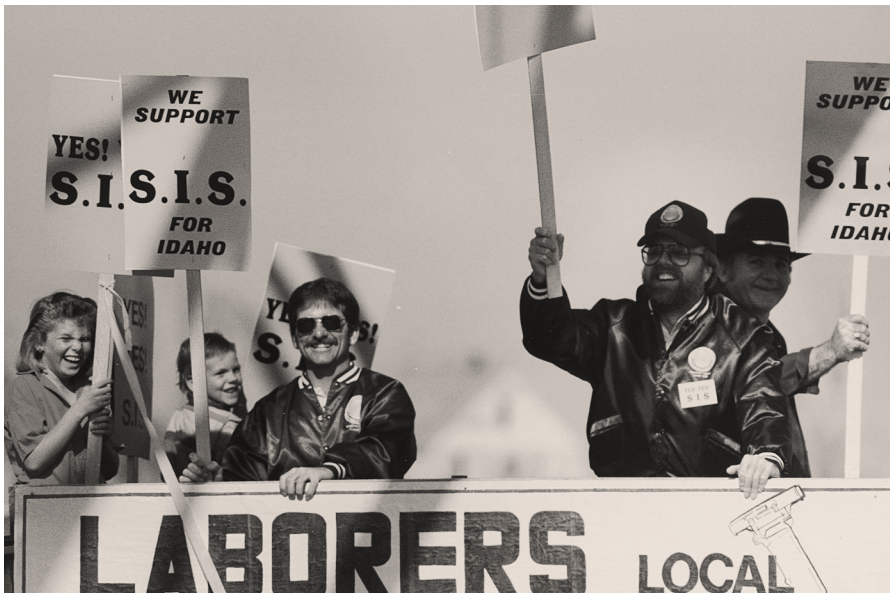
Reagan urged Congress to continue to support the construction of a large demonstration plant at Clinch River, Tennessee. This project was to be financed by the joint effort of DOE and contributions from more than seven hundred utility companies. The project would finally, it was hoped, demonstrate the commercial feasibility and safety of the Liquid Metal Fast Breeder Reactor (LMFBR). In its beginning, the concept promised to breed plutonium fuel at a rate to double the initial fuel loading in eight to ten years of operation.[18]

The impact of Ronald Reagan's presidency was felt in a number of other ways at the Site. In 1983 Reagan undertook the Strategic Defense Initiative (SDI), a research and development program to devise a defense against intercontinental ballistic missiles. More than the breeder program, the SDI offered opportunities to expand the INEL. The

Idaho nuclear boosters went to work, crippled as they were by a governor distracted by an injection well and the "green" protest network. Now that funds were flowing for defense projects, supporters hoped that INEL expertise could attract some of it. Although they had tried and failed some years earlier to land the (Clinch River) breeder in Idaho, this time they had some success.[19]

Idaho's major asset in Washington was now Senator James McClure. With the help of his advocacy, DOE selected the INEL as the site of a New Production Reactor (NPR) to manufacture tritium replenishment for the warheads on Pershing II, Trident, and Cruise missiles. A spokesperson for the Snake River Alliance asserted that "the people can stop it" and promised to be vocal about the difference between past INEL activities and this kind of weapons work. The Idaho Conservation League position was, "We are, in general, opposed to expansion of all nuclear-related activity at the INEL Site..." Site personnel, on the other hand, began preparing for the new reactor.[20]

INEEL 88-121-1-30



INEEL 88-121-1-18

DOE next selected INEL as the site for a Special Isotope Separations (SIS) plant to make plutonium for weapons. Not a reactor, the $500 million project would import plutonium from Hanford, use lasers to vaporize it and remove impurities, and then send it to Rocky Flats for fabrication. By-products would remain in Idaho. The project was to be located at the Chem Plant, and soon employees began the complex work of developing this project.[21]

In October 1983, 240 United States Marines had been killed in Lebanon by a terrorist car-bomb. Shocked by the vulnerability of the troops, Congress insisted on a general upgrade in readiness and security against anti-terrorist activity both inside and outside the nation. At INEL, the security force doubled in 1984 and the IDO took delivery of two helicopters by December 1984. Four new guard posts went up around the Site, and DOE attempted to restrict commercial air traffic from flying over the Site. Helicopter surveillance patrols began in 1985.[22]

Eventually, the major nuclear defense activities planned for the INEL, the New Production Reactor and the

Not everyone agreed that the Special Isotope Separation project was right for the INEL.

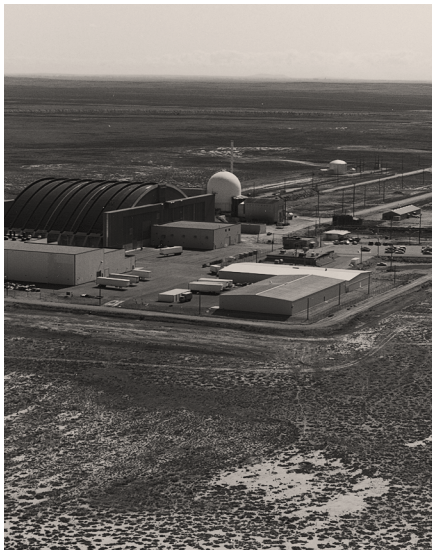
Special Isotope Separations facility, were canceled by DOE, but not because of Idaho protests. Secretary of Energy James Watkins asked Congress in 1990 to cancel the SIS plant because weapons needs could be met with existing plutonium resources. In fact his predecessor, John S. Herrington, had once declared that the nation was "awash in plutonium." The Soviet Union was coming apart, future weapons needs were revised, and a general downsizing of the weapons complex began. The New Production Reactor faded, as Watkins looked into the possibility that a linear accelerator could produce tritium.[23]

Only one major defense project materialized in Idaho, and it had more to do with conventional than nuclear defense. Still, it was as secret as any traditional nuclear weapon. When IDO manager Troy Wade announced it in 1983, he could only describe what it was not: not a reactor, not related to nuclear fusion, and not a space-related project. He said it didn't involve weapons or radioactive hazards.[24]

But the project did involve uranium. And it was intended for non-peaceful purposes, if not directly as a weapon. The project went under construction in the fall of 1983. The United States Army had secretly developed an armor package using depleted uranium for its M1-A1 Abrams Main Battle Tank. The East Idaho Nuclear Industrial Council had been trying to market the empty hangar building at TAN for years, and the building at last found a customer. Its expansive clear space was roomy enough to hide an 82,000-square-foot building three stories high from the eyes of satellites passing overhead. The building—and the remoteness of Idaho—were ideal for the secret manufacturing project.[25]

The junk that had accumulated in the hangar-as-storage-closet over the years was moved out of the way, and the IDO hired Exxon Nuclear Idaho Company to set up shop. Fresh barbed wire went up around the area, and signs went up in the cafeteria warning workers not to discuss classified information. The hangar doors were welded shut. The ANP's never-used coupling station and hatch access to the basement remained in its original place, encompassed as part of a stairway landing and part of a few offices. Because its purpose was secret, Site workers and the press called it Project X. Its official name—Specific Manufacturing Capability (SMC)—gave little away. In 1985 Exxon produced the first production prototype and by 1988 regular shipments headed for Lima, Ohio, where the material was fitted onto the tanks. The project employed five hundred people, most of whom managed to do their jobs without knowing how their product was to be used.[26]

In 1990 the Army announced to the public and to its employees what was



INEEL 93-293-17-3

Above. Support buildings for Project X went up around the TAN Hangar. Below. An employee appreciation day held in 1991 at SMC gave employees an opportunity to see the M1-A1 Abrams tank in action.

INEEL 91-0116-2-28

being made. Soon after, the tanks received their first combat experience in the 1991 Persian Gulf War, where they withstood direct hits from enemy fire. The Army decided to produce 1,150 M1-A2 tanks by retrofitting older M1 tanks. The armor production work, with a reduced work force, was expected to keep the hangar occupied until at least the year 2003. The formulas and production processes remained secret, and the Army merely conceded that the armor was denser than lead.[27]

INEL's move to defense programs proved to be a mixed blessing for relations between INEL and the State of Idaho. On the one hand, the new projects boosted employment and budgets at the INEL and, by extension of the economic multiplier, the entire economy of southeast Idaho. On the other hand, the defense build-up aroused the greater energies of pacifists and environmentalists, who mounted vigorous protests across the state. These placed the governor's office in a predicament. John Evans' staff, for example, debated the political hazards involved should he consummate a deal with the IDO: You shut down the Chem Plant injection well, and the governor will support the new defense projects.[28]

More was new at the Chem Plant in the early 1980s than Governor Evans's evaporation pond. A second generation of process facilities was replacing the well-used originals. Beginning in the mid-1970s, new construction had been a constant activity at the Chem Plant. Construction trailers, warehouses, temporary contractor office buildings, and laydown yards cluttered up the complex.

The old Waste Calcining Facility had worn out. Small scratches and pits on the metal surfaces of vessels and pipes attracted deposits of radionuclides that were hard, if not impossible, to remove. Hazards to the maintenance and repair crews were increasing at the same time that exposure standards were becoming more stringent. The designers had not anticipated that waste feed containing fluorides would pass through the pipes and vessels in the plant, but these and other exotic chemicals had helped to age it.[29]

DOE selected the Ralph M. Parsons Company as concept designer of a new calcining facility. It was to meet four main goals: be safer for workers, raise the process capacity from 1,800 gallons to 3,000 gallons a day, handle the chemistry of future wastes, and discharge even less radioactivity into the atmosphere. Every feature of the plant was up for improvement—the heating system, the handling of ruthenium, even the shape of the calciner vessel. Federal rules that had followed from environmental protection laws now required that future decontamination and final decommissioning be considered in the design.[30]

The new calciner started hot operations in 1982. In some ways, its design was a tribute to the original plant. It was in a single building with the process cells below grade. Shielded equipment cubicles next to the cells housed high-maintenance items—although this time they had air locks. Back-up equipment was installed from the start so that a failure would not have to shut down a campaign. More chores could be done remotely, so there were more shielded glass viewing windows and manipulators. Old annoyances such as awkward lifting lugs on heavy objects were eliminated.[31]

The makeover of the Chem Plant included a better air filtration system, a new Remote Analytical Laboratory, and other upgrades. New locker rooms and a cafeteria replaced their worn-out originals. The uranium reprocessing plant itself was rebuilt in stages beginning in 1979. This time, new fuel storage basins were located adjacent to the process building so fuel could move underwater directly to the dissolvers. The arrangement eliminated the tedious loading and unloading of casks for an overland journey of one-third of a mile. The huge pools had 2,600 fuel storage positions. The process cells could dissolve modern fuel elements using hydrofluoric acid. The method had been invented at INEL, so the process was named "Fluorinel." The $200 million plant featured remote- and computer-controlled management of the process. Despite its great cost, the plant was expected to recover enough uranium and other commercial by-products in five years to pay back the cost—and continue efficiently for decades to come.[32]

Beyond the INEL, most of the AEC's old demonstration power plants had long since come to the end of their operational life. Their nuclear fuel, some of which had been exotic or unusual, needed to be removed. If the unfissioned U-235 could not be recovered, it needed secure storage somewhere. The AEC assigned some of it to Idaho, handing the Chem Plant a new mission: storing the fuel. Some of it,

Reactor Safety Testing

The INEL work in reactor safety was a complex and detailed interaction between the familiar procedures of scientific inquiry: making predictions and then verifying them with empirical tests. Each test confirmed the prediction or helped to refine the next iteration. Computers made it possible to model systems with huge numbers of variables. The safety tests at the INEL involved several interrelated programs, among which were:

Advanced Code Development

Predicted the thermal hydraulic behavior of coolant in the primary coolant system based on new models. The models resulted from small-scale experiments, carefully instrumented to obtain accurate data. The models were incorporated in an overall code called RELAP.

Fuel Behavior Program

Tested the performance of fuel pins in conditions of normal and transient conditions. Tests were done in the MTR, ETR, and ATR. The work included the creation and experimental confirmation of a Fuel Rod Analysis Program (FRAP) using the Power Burst Facility.

Full-Length Emergency Core Heating Tests (FLECHT)

Using twelve-foot non-nuclear bundles of fuel rods, tests determined the effectiveness of emergency core cooling systems in pressurized-water reactors.

INEEL 82-4005

Developed at INEL, RELAP5 is a program that gives over 50,000 computational instructions to a large computer. It calculates overall nuclear power plant system responses to accident situations such as the one at Three Mile Island.

Fission Product Behavior Experiments

Small-scale tests helped assess the accuracy of computer models describing the release of fission products and where they went after a loss-of-coolant accident (LOCA).

Containment Analysis Program

Experiments were performed at Sandia National Laboratory and in Idaho; additional analytical work was done at the INEL.

Emergency Core Cooling Systems Analysis

Combination of experimental and analytical work that evaluated and predicted how products made by various manufacturers would actually perform. Results of Semiscale and LOFT experiments were part of this program.

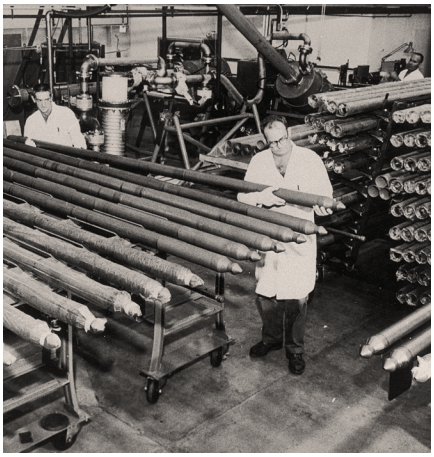
Semiscale

Experiments tested and verified computer models of LOCAs. In the event of a leak in a primary coolant system, water pressure would fall, a process called “blowdown.” Semiscale studied this thermal-hydraulic phenomenon in detail.

LOFT Integral Test Program

An experimental reactor provided empirical data supporting behavior predictions for pressurized-water reactors under LOCAconditions. The program evaluated engineered safety features and assessed the margins of safety in their performance.

like the special graphite fuel used in rocket propulsion experiments in Nevada, could not be stored in water due to undesirable chemical reactions.

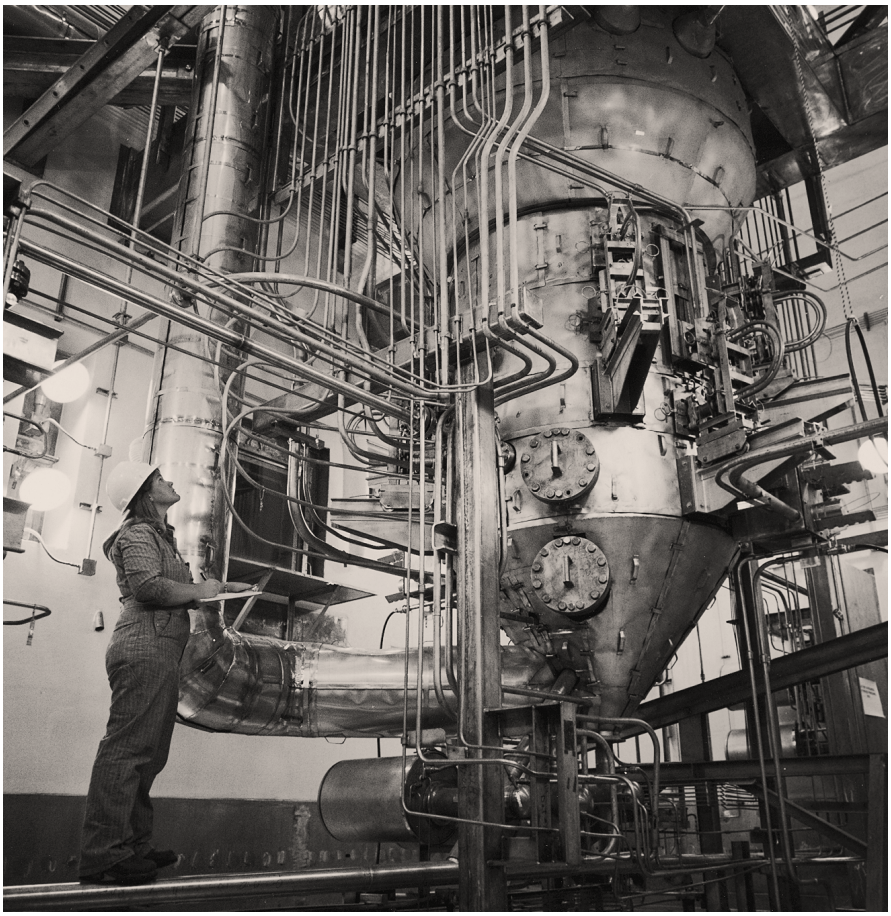


AEC-67-7886

So dry storage cells were added to the Chem Plant landscape. Fuel from Peach Bottom Atomic Power Station, Pennsylvania, and Ft. St. Vrain Nuclear Generating Station, Colorado, eventually arrived in Idaho for safekeeping.

Meanwhile, the power of anti-nuclear protests (overshadowed, some historians think, by the management mistakes of the electric utility industry) was derailing the progress for uranium that scientists and policy-makers had taken for granted since the 1950s. Scientists had expected, first, that breeders would eventually replace water-moderated reactors because only breeders fulfilled the endowment of all uranium, not just the tiny percent of U-235 in the natural metal, as a benefit to human society. Water-moderated reactors had been easier to develop, but they wasted uranium. Second, the nuclear industry would reprocess spent fuel in commercial plants similar to the Chem Plant. Spent fuel would not be stored indefinitely as a waste, but recycled to conserve the resource. Third, the disposition of radioactive waste would in due course yield to both scientific and political solutions.[33]

President Carter and many of his staff believed that civilian nuclear energy offered opportunities for the illicit assembly of nuclear weapons. A Los Alamos physicist named Theodore Taylor contended that it would be easy to divert nuclear materials from commercial operations and make bombs. As a nuclear weapons insider since the Manhattan Project, Taylor's credibility was regarded as excellent by many, and he described his fears in forums such as the *New Yorker* magazine. At the same time, the number of nations in the world which had developed sufficient expertise to conduct nuclear weapons tests grew to include India, which detonated a nuclear device in May 1974. Brazil and Pakistan seemed to be next in line; West Germany was about to send Brazil both a fuel enrichment plant and a fuel reprocessing plant.[34]



INEEL 81-3072

Above. Peach Bottom fuel elements, consisting of uranium and thorium carbides clad in graphite, before they were loaded into the reactor. The reactor went critical on March 3, 1966, with 682 elements loaded in the core. Left. The New Waste Calcining Facility calciner vessel.

Carter decided to eliminate as many opportunities for the "proliferation" of nuclear weapons as possible. He permanently canceled construction of a commercial fuel reprocessing plant at Barnwell, South Carolina. Henceforth, spent fuel had to be stored in heavily shielded facilities at power plants or elsewhere. Hoping to enlist the rest of the international nuclear community in the cause, Carter then supported an International Nuclear Fuel Cycle Evaluation (INFCE), a technical study of the characteristics—including their potential attraction for illicit diversion—of reactor fuels in use around the world. Carter opposed the Clinch River breeder demonstration, although Congress continued to fund it. Ronald Reagan defeated Carter and threw his support behind Clinch River, but the government's investment in the project was rising at an unacceptable rate. Congress ended the project in 1983.[35]

With reprocessing activities canceled due to fears of proliferation, Clinch River canceled because of spiraling costs, and anxiety about radioactive waste generating political protests all over the country, the old template for the progress of uranium was rendered completely obsolete.

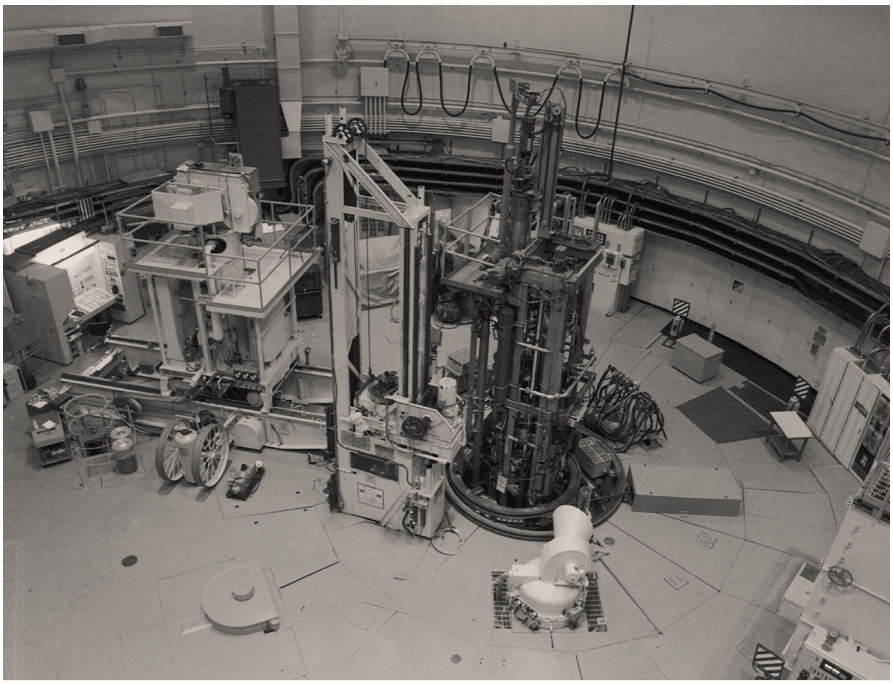
Still, the situation offered someone an opportunity to be brilliant. The death of Clinch River, the fuel for which was to be a uranium oxide, opened the door to a new way of thinking about breeders. At Argonne, physicist Charles Till took charge of Argonne's nuclear reactor program in 1980. Earlier, he had directed the technical work of one of INFCE's working groups. Up until now, the evolution of reactors had flowed more or less from the revelations of science. Society and the environment had been forced to adapt accordingly. Perhaps it was time that a reactor design meet the specifications of society.[36]

That was Till's insight. As he compared Clinch River's oxide fuel to other types, its many disadvantages became startlingly clear. For one thing, the fuel would have to be reprocessed using technology that would purify the plutonium, an imagined opportunity for diversion. Till returned to the idea of a metal fuel along the lines that the EBR-II team had been developing—and recycling on-site—before Milton Shaw had truncated its progress. The old EBR-II fuel was uranium, substantially enriched, but uranium only. A new fuel should contain a mix of uranium and plutonium because the fissile material created in the reactor would include plutonium, and the plutonium—in metal form—should be part of the recycling process. Till said later,

Metal fuel had a number of advantages. It was cheap, easy to make. The LMFBR fuel was expensive and it needed a huge expensive facility for reprocessing that might be economic if it could serve fifty big reactors, but the problem was get - ting from the first to the fiftieth.

INEEL 98-0537

Above. Well-guarded bunker at the Chem Plant (CPP-651) stores uranium. Below. Operating floor of EBR-II reactor (inside the dome).



Argonne National Laboratory-West CC5262

We needed a different kind of reprocessing. It should be cheap, be part of the reactor plant and be as easy to deal with as routine maintenance. Just turn the fuel around. A couple of the old pyroprocessing people at Argonne East said, "We think we can make electrorefining work." They were the best chemists in the world in that field, for they had worked with it before. They had the expertise to recognize that this might be possible.[37]

So Till and his colleagues developed a new reactor concept. At the time, the Argonne Lab was, like the INEL and other national labs, considering what new initiatives were available in the world of the mid-1980s. Argonne's Board of Governors was asking for proposals. Till prepared one. But first, he made a pilgrimage to visit Hans Bethe. Bethe had been the head of theoretical physics at Los Alamos during the Manhattan Project and was revered as one of the giants of 20th-century physics. Till called on him at Cornell University and described the physics of the new reactor concept.

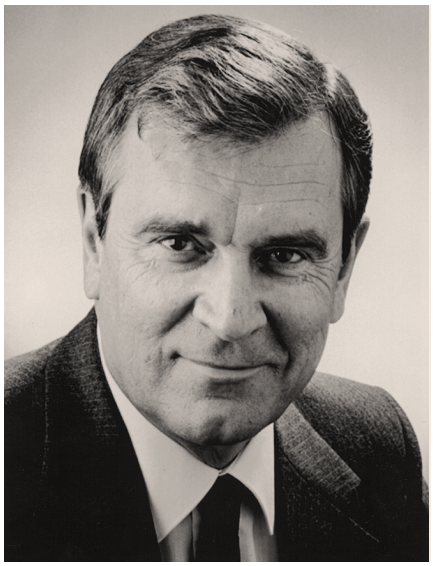
We packed up and I took the leading person in each technical field with me. We crowded into his small office, and each man gave him a one-hour briefing. As he understood a point, he would say, "Yes, yes, yes," indicating that you should move along.

At the end he said, "All the pieces fit. What do you want me to do?"

Bethe's affirmation that the reactor was sensible, simple, and likely to work was all that Till wanted. Bethe had a reputation as someone who never sugar-coated his opinions, and he stated his opinion of Till's reactor in letters to the President's science advisor, the chairman of the Senate Energy Committee, and Idaho's Senator James McClure. The support of each of these individuals was necessary to start the project. McClure needed assurance that in supporting a project of obvious benefit to his home state, he would be on solid technical ground. Support for the project followed soon after the letters.[38]

Till drove to the Board of Governor's meeting to make his proposal. On the way, he realized that he had not given the reactor a name. He decided on Integral Fast Reactor (IFR). It was a somewhat opaque name that declined to use the baggage-laden word "breeder" but highlighted the integration of the reactor with on-site fuel recycling. Thus prepared, Till began by listing the specifications that the world of the 1980s seemed to be asking of a nuclear reactor.

World population was growing, he said. Demand for electricity would continue to grow. It was important to conserve all energy resources. It was important to limit greenhouse gases and prevent rapid global climate change. Asian and other economies desired a growing share of the world's energy resources if they were to meet rising expectations for a better material life. At the same time, fear of plutonium diversion was curbing nuclear development. Water-moderated reactors were producing plutonium as a waste in their spent fuel, and this material was piling up. Isolating it for centuries was a tremendous expense, and in the United States, at least, the political system had thus far failed to decide where to store it.



Argonne National Laboratory-West

Dr. Charles Till

And finally, after the TMI accident, the public was losing its faith in the safety of nuclear energy.[39]

Taking all that into account, a new reactor should be inherently safe, burn up plutonium in a manner discouraging diversion, and not generate large volumes of long-lasting waste. The IFR met these conditions, and EBR-II in Idaho could prove it.

Argonne committed to the project, DOE agreed to fund it, and Till had his charter. Engineers began to modify EBR-II, the fuel recycling facility, and TREAT for their new mission. No one had made even small experimental quantities of metal fuels for at least fifteen years, but Leon Walters, the head of EBR-II metallurgy, knew how it was done. Within a few months, he had fabricated the fuel elements, and the old routine of carrying out nuclear experiments to prove a principle began once more at the INEL.[40]

Chapter Twenty-Four

The Uranium Trail Fades

We are eliminating programs that are no longer needed, such as nuclear power research and development. (Applause.)

–President Bill Clinton, State of the Union Address, 1993–

The technicians loaded EBR-II with the new IFR fuel pins. Made of plutonium, uranium, and zirconium, the fuel pins conducted heat well, a virtue that helped to keep the temperature of the fuel low. Furthermore, the first test assemblies had achieved a nineteen to twenty percent burnup rate, which was far better than what Charles Till considered necessary for commercial feasibility. Commercial water-moderated reactors were still averaging only three to four percent burnup. If the rest of the IFR tests went as well as the fuel burnup demonstration, the IFR might change the world of nuclear energy rather dramatically. [1]

This April day in 1986 was the moment to prove that a nuclear reactor could be safe because of the natural laws of physics, not because of complex, highly engineered emergency systems and consistent human performance. The reactor sat in EBR-II's tank of liquid sodium coolant, ready for the test. For over twenty years, this solid little sodium-cooled reactor had run safely and reliably, contributing electricity steadily to the Site. The coolant, which had a poor reputation among some engineers because it reacts with water and air, in fact conducted heat (very well) and operated at atmospheric pressure. The piping was never subjected to the stresses introduced to a system when water circulated under high pressure. In practical experience, the sodium coolant had proved to be a non-problem. Sodium had the additional benefit of not causing corrosion or the crud that went with it.[2]

Argonne National Laboratory-West 13277-29

Visitors at EBR-II during the first test on April 3, 1986, watch gauges that show the coolant temperature rise—and fall—after the coolant pump "failed."

The designers of the IFR fuel felt that its safety reliability rested on the fact that hot metal expands. If the pencil-thin fuel pins overheated, the metal would swell and the plutonium and uranium atoms would move farther apart from one another and lose reactivity. If the coolant failed to circulate for some reason, the chain reaction should shut down before the fuel could melt, all without any help from scram buttons or control rods.

At least, that was the principle to be proved. As in the exciting days of the 1950s, Argonne invited distinguished visitors from all over the world—utility executives, scientists, and representatives of governments—to witness what they hoped would be a historic day. The plan was to simulate a complete electrical blackout occurring while the reactor operated at full power. They would initiate two types of accidents that day. In the first, the pumps would "fail" to move the coolant, pre-

Space was available at the Irradiated Fuel Storage Facility for additional fuel from Ft. St. Vrain reactor. Distances and dividers were arranged to prevent accidental criticalities.

INEEL 74-110

saging the accident at Chernobyl later that month; and in the second, the heat exchange between the reactor core and the electrical generator would cease, as had happened at TMI.

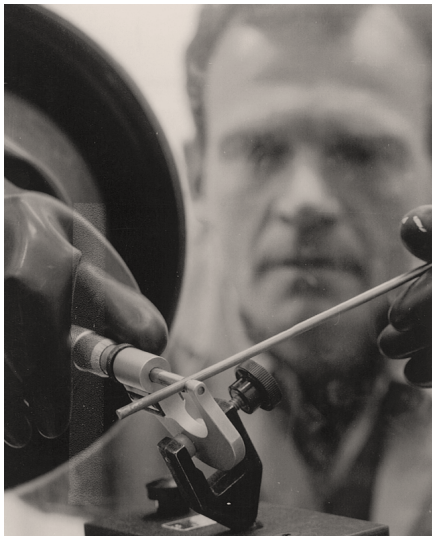
As the experiment began the reactor was at full power. The pumps then shut down. Till and the others eyed the gauges. The temperature in the reactor shot straight up, "not a pretty sight to anyone who's had anything to do with a reactor," observed Till later. But the temperature spiked quickly, and within a few minutes the reactor's power dropped to zero. The temperature returned to normal. The IFR operators, meanwhile, stood back, their hands in the air, so to speak, disengaged from the controls. Neither they nor an emergency core cooling system had been necessary for the reactor to recover safely all by itself.[3]

"It worked on the blackboard, it worked in computer simulations, and the engineers were willing to bet their lives that it would work in practice," wrote an admiring reporter of the demonstration. The implications for a commercial reactor were good: an IFR would need less reliance on emergency power and core cooling accessories, reducing the capital cost of the plant. Afew environmental organizations took notice of the IFR. A spokeswoman for the Audubon Society said that she supported the development of solar energy as the best way to save the planet from fossil fuel heat contamination, but she also favored testing "these so-called idiot-proof reactors."[4]

The Argonne team now could move on to prove the next principle: that the IFR could solve the nuclear waste problem.

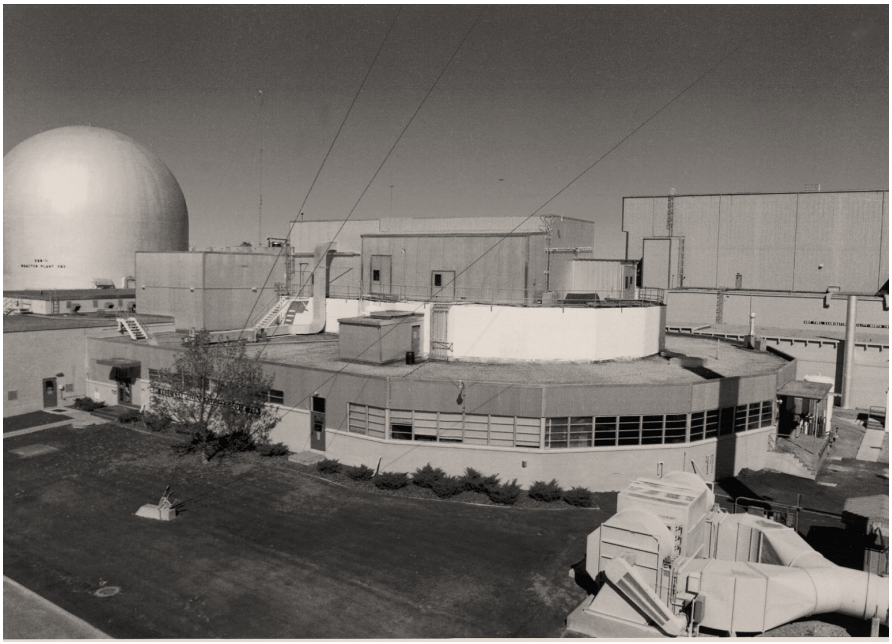
Like all other reactor fuels, the IFR fuel generated fission and activation products, the latter of which included plutonium, americium, and the other long-lived TRU elements. These elements required isolation from the environment for centuries, and these were the ones to be recycled as IFR fuel. By contrast, the most dangerously energetic fission products would decay to harmless levels within a few hundred years.

Recycling was to be done within the same doughnut-shaped argon-atmosphere cell next door to EBR-II where Argonne had re-cast uranium metal fuel in the 1960s. The recipe began with chopping up the fuel and dissolving it in a solution of cadmium and molten salt. Upon applying an electric current through the material, the plutonium and uranium (and other TRU elements and some fission products) accumulated on collector electrodes. The rest of the fission products remained in the cadmium and salt. Thus separated, the uranium and plutonium could be recast into new fuel pins and sent back to the reactor to generate more electricity. The rest was waste,



Argonne National Laboratory-West 15455

Above. Using a glovebox, a technician performs a quality assurance check on a new IFR fuel pin. Below. The exterior shape of the Fuel Cycle Facility reflects the circular architecture of the argon-atmosphere laboratory.



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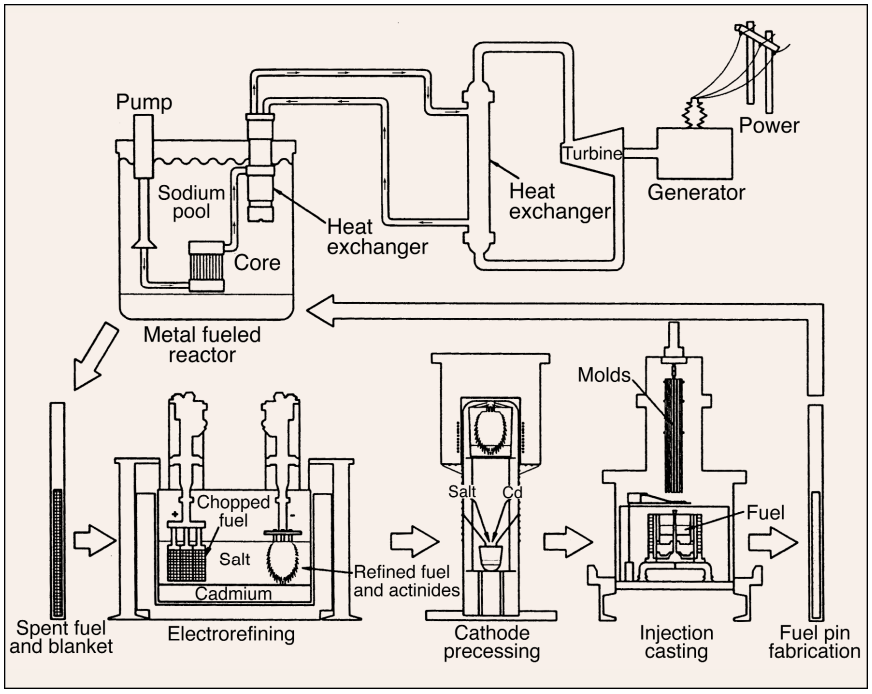
but it lacked the great volumes of contaminated water and long-half-life chemicals typical of Chem Plant recovery processes.

The recycling of plutonium promised to assuage fears about terrorist diversion. Because the plutonium was mixed up with other TRU elements and fission products, it was dirty, impure, and highly radioactive, not the kind of "weapons grade" material required for making bombs. If someone managed to steal it, the would-be bomb-maker would have to refine it in a facility similar to the Chem Plant. Terrorists or rogue states would have a hard time hiding one of those.

Argonne proceeded. Additional preparations and safety studies were required before launching the final experiments. When all was ready, EBR-II would need to burn IFR fuel in the reactor for two years or so, recycle the spent fuel into new fuel pins, and then burn the new fuel for another two years. This would "close the loop" and demonstrate the continued reliability of the reactor operating on its new recycled fuel while producing electricity at the same time.

Three weeks after the IFR fuel had passed its test so well, an accident occurred at the Chernobyl reactor in the USSR, overshadowing the good news. Far worse than the TMI accident, steam and fuel vapor explosions blew the top off the reactor and released into the atmosphere great quantities of radioactivity, more than that released in the bombing of Hiroshima. Opponents of nuclear power felt confirmed in their objections to any and all nuclear reactors, even the IFR. To the shelves of nuclear literature were added books with titles such as as *Final Warning: The Legacy of Chernobyl*.[5]



Argonne National Laboratory-West 15242

The Integral Fast Reactor concept. Fuel makes electricity and when spent, goes next door to be recycled as new fuel pins.

Initially, the stark contrast between the safe and harmless shutdown of EBR-II and the dramatic events at Chernobyl—each initiated by the same turning off of the coolant pumps—worked to the advantage of the IFR, but as the decade ended, the political environment in Washington, D.C., became more hostile to the IFR. Many of the nuclear opponents from the Carter years still wielded influence at policy-making levels. Consumer advocates like Ralph Nader called for the government to give up nuclear research altogether and concentrate on renewable energy alternatives. By the time Bill Clinton won election as president in 1992, the weight of political sentiment continued to be unfavorable for nuclear power. In fact, in his first State of the Union address, he told Congress that he felt nuclear power research was no longer needed.[6]

To nuclear opponents, the IFR looked like any other dangerous plutonium-breeding reactor. The program was canceled in 1994, despite the best efforts of the Idaho congressional delegation to keep the project funded. Argonne shut down EBR-II for the last time on September 30, 1994. It had not had its chance to demonstrate the full fuel cycle. After a technically sensational thirty-year run, the reactor was grounded

for political reasons before it could prove its most important principle.[7]

Like a spool that had tumbled to the ground and unwound its thread, INEL research on new reactor concepts rolled to a stop. Many INEL scientists had invested their careers and their patriotism on the proposition that the United States should become and remain the world leader in nuclear technology. It appeared to them that such leadership was now likely to pass to Japan or some other nation. It was a moment of profound and, for some, bitter regret.

The Cold War, one of the igniters of patriotism, was a spool that had come to the end of its thread as well. Perestroika and Glasnost changed the USSR. Lithuania declared itself independent of the Soviet "union." The USSR collapsed. The Berlin Wall came down. In November 1990 President George Bush said the Cold War was over. American defense spending declined, and the U.S. Navy scaled back its nuclear fleet. With this, the Navy's training needs diminished and the Navy started to close some of its training facilities.[8]

At the INEL, the Navy shut down its reactors and the research and training programs associated with them. It had shut down the S1W prototype on October 17, 1989, before the Cold War had ended, citing the prototype's age and the high cost of its continued operation. Its last core had operated for twenty-two years, the longest of any nuclear reactor core in the world at that time. The A1W prototype ran until January 1994, and S5G until May 1995. The regular arrival and departure of trainees ended. Only the Expended Core Facility remained. Despite a diminished fleet complement, the Navy planned to continue shipping reactor cores to Idaho.[9]

Thus the number of reactors actually operating at the INEL went down to three. The ATR and the ATRC (its low-power auxiliary) remained operating as an essential part of the Navy's fuel examination and materials testing program. Indeed, the Navy was the ATR's biggest customer, although the reactor continued to manufacture isotopes of interest to medical and industrial markets. At Argonne-West, the low-power NRAD reactor operated from time to time as a tool for neutron radiography, a method of taking pictures of radioactive materials by directing a stream of neutrons at the subject. NRAD had taken the pictures of the TMI fuel-failure simulations. The TREAT reactor was in standby at Argonne, but without an assignment. The uranium trail was carrying the merest trickle of fresh reactor fuel into Idaho.[10]

However, DOE still needed to ship Rocky Flats TRU waste and spent reactor fuel to INEL for storage. The Idaho governor, on the other hand, did not support these missions. In stark contrast to its tolerance of INEL's earlier nuclear missions, the governor's office now wrestled with DOE to keep these forms of uranium and plutonium from entering the state. Although the IDO played a role in the struggles, the decisions about INEL missions in the scheme of things came primarily from DOE in Washington, D.C.

The wrestling match had begun not long after Cecil D. Andrus became Idaho governor for his third term in

Admiral Bruce DeMars (left) and Governor Cecil Andrus discuss naval nuclear propulsion in the S5G prototype.

Boise State University Library ISS 102

1986. He had returned to the state after serving the Carter administration and took office after John Evans completed his second term. Andrus knew that the decade of the 1970s had passed without DOE removing any buried waste from the INEL. But he could also see that during the 1980s, DOE had prepared a deep underground salt cavern near Carlsbad, New Mexico, to isolate and store the waste. In 1988 the Waste Isolation Pilot Plant (WIPP) seemed nearly ready to open.[11]

In September 1988 Andrus and Don Ofte, who had followed Troy Wade as IDO manager in 1987, went to New Mexico for a first-hand look at the WIPP. While there, Andrus was unable to extract from DOE officials an opening date for the plant. New Mexico opponents were promoting delay, and Andrus feared that the decade of the 1980s also would pass without any waste leaving Idaho. Meanwhile, Rocky Flats continued sending waste to the INEL. For Andrus, the predicament with the INEL had not changed. As he had observed more than once, the INEL was of enormous importance to the Idaho economy. It seemed that the only way to ensure public confidence in the INEL was to protect its environmental integrity and restore the Site's credibility with the public. That meant removing any reasonable possibility that the aquifer could become contaminated because of buried radioactive waste.[12]

Andrus contemplated what strategies a small state like Idaho might use to muscle the federal government into opening WIPP and proceeding with the removal of waste from Idaho. One idea was to shine a very bright light on the problem and make it pertinent to the national government and other states as well. As he wrote later, he had learned from his experience as a cabinet secretary that "the government in our nation's capitol reacts only to crises." He set out to create one.[13]

Idaho State Journal

Shoshone-Bannock tribal police block train shipment of Naval spent fuel.

On October 20, 1988, after DOE officially postponed the opening of WIPP, Andrus ordered the Idaho State Police to stop at the border any railcars bringing shipments from Rocky Flats to INEL. The order stranded a boxcar that had come as far as Blackfoot but had not completed its journey to the INEL. DOE honored the closure and turned away a shipment from Illinois before it had a chance to reach a roadblock at the Idaho border. CBS television invited the governor to appear on its morning news program. On October 23, a Sunday, the *New York Times* published a photograph of an Idaho state trooper, his arms folded across his chest and eyes shaded by the visor of his hat, standing in front of his patrol car guarding the boxcar. Andrus had his bright light. "They have broken their word too many times," Andrus said of DOE's failure to open WIPP. "They cannot give us a date." DOE turned the Blackfoot car around and sent it back to Rocky Flats.[14]

The governor's actions did not open WIPP, but it shut off the flow of Rocky Flats waste to the INEL. It might also have shut off shipments of TMI fuel to Idaho, but Ofte persuaded Andrus not to:

Not long after Rocky Flats shut down, I discussed with [Andrus] and his staff all of the materials coming to the INEL. The TMI fuel was controversial, and Andrus wanted to stop that, too. I explained how we had been tasked to analyze the TMI accident because we were the uniquely qualified facility in the country with the capability to do it. We had cooperative agreements with the Germans and the Japanese, and this was

a nationally and internationally important project. He agreed to let it enter the state, and we shook hands. He told me later, he regretted it, but he said he wouldn't go back on his word.[15]

As it happened, DOE shut down production at Rocky Flats temporarily in December 1989 to deal with safety and management problems at the site, interrupting the production of waste that otherwise would have gone to Idaho. In 1991, after reassessing military requirements in the post-Cold War world, DOE decided that its arsenals no longer needed fresh nuclear warheads, and DOE stopped making plutonium weapons parts at the plant.[16]

INEEL89-631-1-8

Barrels of Rocky Flats waste stand in a certification staging area ready to go to the Waste Isolation Pilot Plant in 1989.

The concept of "waste dump" took on a new meaning when Andrus learned in 1990 that INEL planned to accept for storage at the Chem Plant spent graphite fuel from the Public Service Company of Colorado, which was decommissioning its Fort St. Vrain reactor in Platteville. The fuel belonged to DOE, which had a contract with the utility company to store the fuel after it had been used up. DOE had built the Irradiated Fuel Storage Facility at the Chem Plant in 1975. It already stored fuel from Fort St. Vrain that had been shipped many years previously. These next shipments would send the balance of the fuel and fill hundreds of remaining vacant storage cells.

Andrus saw this move as new evidence of DOE's intention to convert INEL's "superb laboratory" into a "de facto waste dump." He once again threatened to mobilize the state police to stop shipments at the Idaho border. The Shoshone-Bannock Tribe supported him, attempting to forbid shipments on the stretch of interstate highway crossing its reservation on the way to INEL.[17]

Much of the subsequent struggle took place in the courts. A long series of legal filings ensued and kept the IDO legal staff and the governor's attorneys busy for the next several years. With the help of temporary injunctions, Idaho managed to prevent the fuel from entering the state until September of 1991, when the 9th Circuit Court of Appeals in San Francisco sided with Colorado and DOE. Andrus's roadblock was ruled unconstitutional.

Idaho responded with another wave of litigation. During a short interlude in the fall of 1991 in which no judicial injunction prohibited fuel shipments, at least two Colorado shipments made it into the Chem Plant. Another injunction soon followed, and those shipments proved to be the last. The Colorado utility decided not to await the final outcome of the legal battles, which it feared could take years. It wanted to remodel Fort St. Vrain as a gas-fired power plant and proceeded to erect a spent-fuel storage building next door to the reactor.[18]

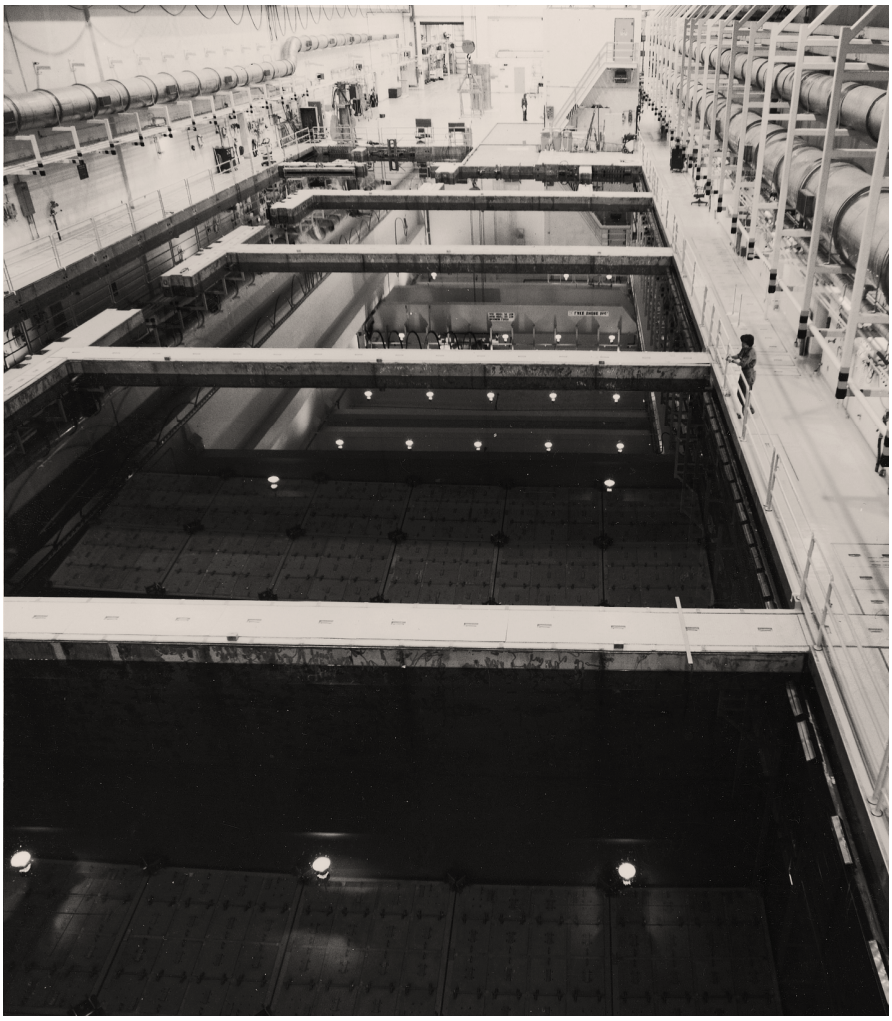
In April 1992 DOE announced that it would no longer reprocess any spent nuclear fuel at the Chem Plant. The country's need for enriched uranium was much reduced, it said. Since July 1988 the Chem Plant had processed no fuel while its underground pipes had been upgraded (placed in double conduit as extra protection against leaks), and now the shutdown was to be permanent. The Chem Plant would store spent Navy fuel instead of reprocessing it. The question of how long the fuel would be stored was unclear. At the direction of Congress, DOE was con-

sidering a site at Yucca Mountain, Nevada, as a potential place to store spent reactor fuel. But the technical and ultimate political viability of this idea was far from certain.[19]

This turn of events brought Navy fuel into the continuing swarm of litigation, court orders, and political spotlights. Previously, Andrus had not sought to interfere with Navy fuel shipments into Idaho, partly because he considered the Navy's business a matter of national security and partly because the fuel had traditionally been reprocessed at the Chem Plant. However, he saw storage without reprocessing as an entirely new kind of mission. He soon concluded that the Navy saw Idaho as a weak state, a remote place where it could "dump" its spent nuclear fuel. He wanted such activity placed under the scrutiny of the nation's environmental laws.[20]

Meanwhile, the IDO had embarked on the preparation of an Environmental Impact Statement (EIS) on waste management at the INEL, a study that would include waste burial practices and environmental restoration at the Site. (DOE Headquarters was to do a parallel study on its national waste management program.) Upon a finding by the U.S. District judge that DOE'S national program for the disposition of its spent fuel also should be subject to an EIS, DOE decided to add this item, national in scope, to the EIS already underway. Later, the study also embraced the Navy's spent fuel.[21]

The expensive project placed the burden of effort on the IDO staff in Idaho Falls to prepare and coordinate a document affecting Navy and DOE spent nuclear fuel operations across the entire national DOE complex—as well as a very large percentage of the work done at the INEL. It was a huge undertaking. The forces in conflict—the state of Idaho, the U.S. Navy, and DOE—now relied on an EIS to fulfill their conflicting hopes. The Navy wanted to send its fuel to Idaho. Idaho wanted a scientific document to demonstrate that storing TRU waste and spent fuel above the aquifer was environmentally unacceptable. DOE wanted to manage its national responsibilities and use its resources at the INEL in the most optimal way, hopefully welcomed by its host state.



INEEL 85-267-1-8

The Fluorinel and Storage Facility at the Chem Plant in 1985. Fuel stored at the Chem Plant's 1950s-built storage basin was to move into this new facility.

The nation's environmental laws, which had been conferring on the states new powers of participation, intervention, and comment on federal activities ever since the beginning of the environmental movement, had given Idaho standing to discuss and influence the Site's internal affairs. In the old debate between the Site and Idaho about states'rights, the environmental movement had swung the pendulum decidedly in favor of Idaho.[22]

The court had told the Navy that while the EIS was being prepared, it could not ship its fuel into the Site. The Navy needed to defuel its ships, wished to send the fuel to Idaho, and didn't want to wait for the years it might take before a final EIS was published. The Navy decided to negotiate with Governor Andrus, hoping to ease the court's injunction before the EIS was completed. Soon the Secretary of the Navy himself, John H. Dalton, was trading letters with Andrus about what they might agree upon.

Andrus had a list of items to place on the negotiation table. The Snake River Alliance had recently brought to Andrus's attention a technical study that had questioned the reliability of the Chem Plant's 1950s-built storage basin (Building CPP-603) in an earthquake. Therefore, Andrus insisted that spent fuel being stored in this building be moved to safer quarters. In general, spent fuel should be stored above-ground and dry, not below ground in pools of water. Also, DOE should speed up the calcining of sodium-bearing liquid waste sitting in the aging storage tanks at the Chem Plant. Aside from the freedom to ship reactor cores to Idaho, the Navy wanted Andrus to help persuade the environmental community to accept whatever agreement they made. "Let's all be heroes," wrote Dalton.[23]

When the discussions were over, the Navy was allowed to ship nineteen (of sixty-four) containers of fuel to Idaho, plus any others certified to be needed for national security. DOE agreed to accelerate the items on Idaho's work list and to make grants supporting the diversification of the economy in eastern Idaho. The IDO staff, already embarked on its massive EIS, was given milestone dates and had to complete the study on an aggressively accelerated schedule. The Navy and DOE agreed not to appeal the judge's injunction on further shipments or his decision requiring DOE to examine the agency's spent nuclear fuel program in an EIS. With Idaho's assent, the judge amended the order and allowed the nineteen shipments.[24]

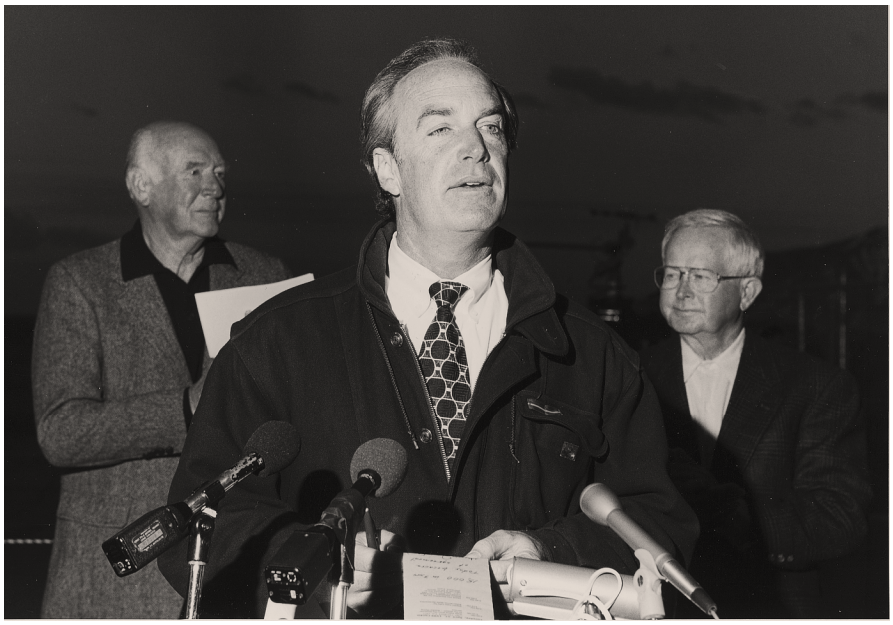
When DOE published for public review and comment the Draft EIS in June 1994, the governor's office was not happy with the document. It was not comprehensive, said Idaho, and it failed to evaluate the cumulative impacts of waste storage or to consider alternatives; its proposed action program was vague. In November, the Navy asked if Idaho would allow eight more containers. Andrus refused.[25]

But Andrus was about to leave the Idaho Statehouse, and the Navy's request fell into the lap of Phil Batt, the new governor. Batt allowed the additional containers. He told protesting Idaho citizens he was convinced that a court or Congress would decide that the Navy shipments were a matter of national security.[26]

The Final EIS was published in April 1995 and its subsequent Record of Decision in June. The Record of Decision identified which of the alternatives developed in the EIS that DOE intended to implement. It indicated that the INEL could receive nearly 2,000 shipments of (Navy and other) spent nuclear fuel and additional shipments of TRU waste, but mentioned no requirement that the material ever leave Idaho. Batt decided to try to fulfill Idaho's long-

INEEL99-237-1-27

At 7:00 a.m. on April 27, 1999, the first truckload of transuranic waste leaves the Radioactive Waste Management Complex for WIPP. Buildings in background store waste above ground.



INEEL 99-237-1-15

Former governors Cecil Andrus and Phil Batt stand behind Governor Dirk Kempthorne during ceremonies celebrating the first shipment of Rocky Flats waste to leave the Site.

time mission: to obtain from DOE a written schedule for removing waste—and now spent fuel—from the state. The citizens of Idaho had to be assured that INEL would not threaten the Snake River Plain Aquifer by transforming the Site into a "dump" for nuclear waste.[27]

The new governor and his staff still felt that eventually the court would force Idaho to allow Navy fuel into the INEL. The question was whether Idaho might obtain any concessions from DOE or the Navy. The Navy was running out of options to hold nuclear fuel at its shipyards, threatening its ability to defuel ships and support the fleet, and the conflict was inhibiting DOE from carrying out its missions at the INEL. All parties chose to negotiate.[28]

DOE representatives began making trips to neutral ground, cities like Chicago or Minneapolis, to meet their Navy and Idaho counterparts. They met in a law office or hotel rooms; sometimes the principals holed up together, sending their aides and lawyers outside to await developments. After one such session lasting several hours, one of them stepped outside and said, "We have a deal." The terms were refined throughout September, and an agreement was signed on October 16, 1995.[29]

The Idaho Settlement Agreement was a detailed import/export list itemizing what could enter the state and what must leave and by when. With many interim milestones—including shipments of Rocky Flats waste to WIPP—the fulfillment of the Settlement was set for 2035. The stored fuel and TRU waste would all be gone. Penalties for DOE failure would cost it $60,000 a day after 2035. At last, Idaho had it "in writing."[30]

After Batt signed the Agreement, those who opposed it attempted but failed to recall him from office. Opponents then gathered enough signatures to place on the ballot an initiative, Proposition Three, to nullify the Agreement and require voter approval for the receipt of radioactive waste. After a spirited campaign in which "Stop the Shipments" battled "Get the Waste Out," Idaho voters soundly rejected the proposition and supported Batt's action by a margin of nearly two to one.[31]

Throughout the Idaho campaign to open WIPP and to fend off the entry of additional waste and spent nuclear fuel for long-term storage in Idaho, the role of science, technical analysis, and risk assessment had been relatively minor. The heart of the problem had been one of public perception. Settling it—and restoring the credibility of the INEL as an environmentally sound neighbor—had required political risk and eventually a careful collaboration—a partnership—between the IDO managers and the governor's office. As of 1999, it seemed as if they may have succeeded. The DOE (and the Navy) were meeting their Settlement Agreement milestones. WIPP opened in 1999, and the first barrels of TRU waste left Idaho.

But a major question about the Site remained: With the United States no longer testing reactor concepts on the desert and the storage of spent fuel a mission with no long-term future, what exactly was the mission of the Site into the 21st century?

CHAPTER TWENTY-FIVE

MISSION: FUTURE

Opportunity knocks for future engineers.

–Editorial headline, iNews–

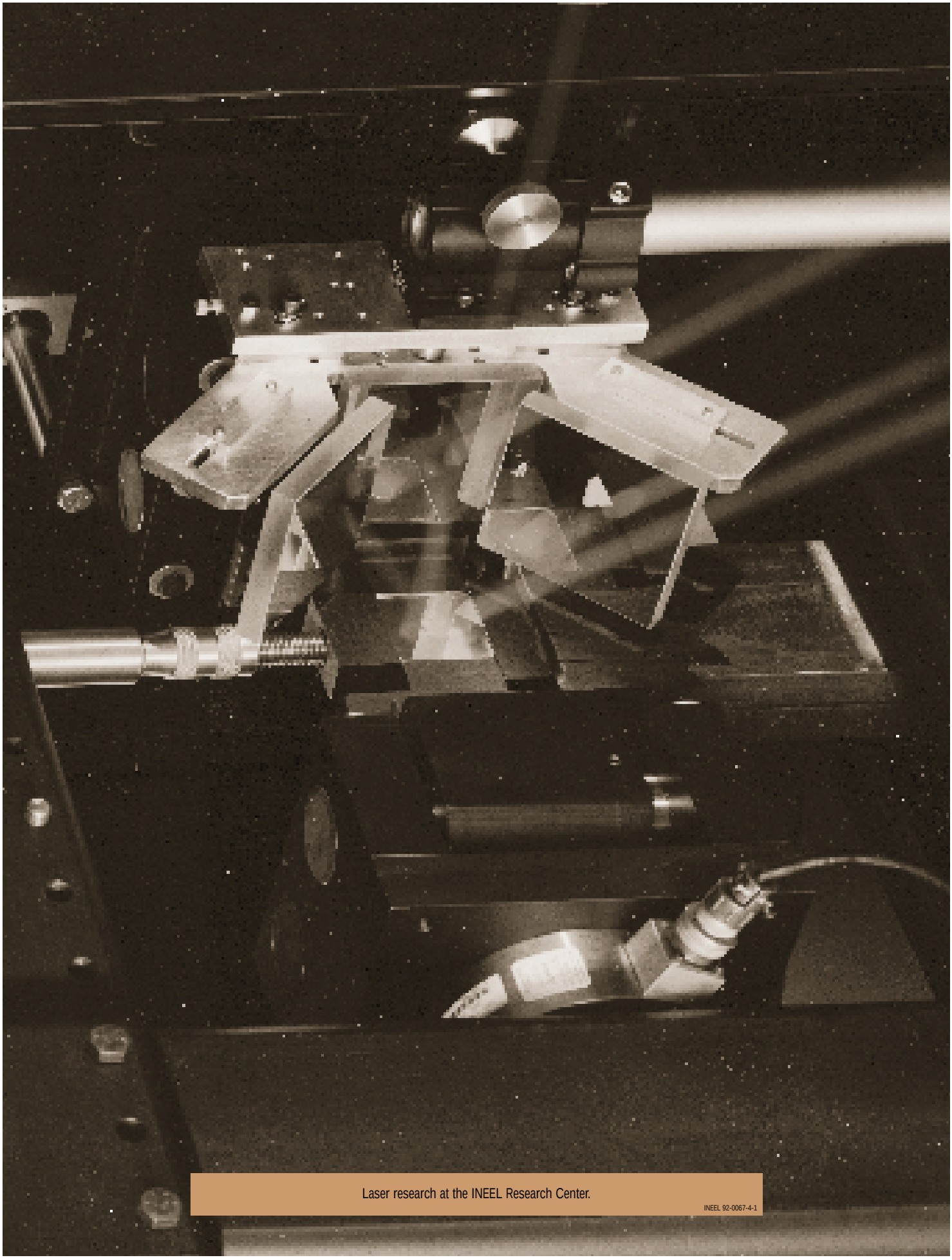
Dirk Kempthorne felt that INEL's future rested on the environment. As a United States senator from Idaho in 1993 he proposed that INEL change its name again by adding to it the word "environmental." He said, "the plain fact is that the INEL is now, will be, and must always be, known as an environmental lab. INEL should be recognized as the leader in solving tough environmental problems." But it took time for the name-change proposal to become official. Until 1997, the name continued as INEL, but then Site letterhead changed to Idaho National Engineering and Environmental Laboratory (INEEL), and the new logo assumed the environmental colors of green and tan.[1]

And indeed, the mission of the INEEL into the 21st century was going to involve—at the very least—a great variety of interaction with the environment. The industrial and nuclear history of the Site had left its mark on the desert, and the time had arrived to remediate or remove what DOE chose to call the environmental "legacy" of the Cold War. Although the struggle between Idaho governors and DOE over the storage of TRU waste and spent nuclear fuel had captured most of the headlines in Idaho after 1988, much else had been afoot at the laboratory in the last two decades of the 20th century.[2]

Not long after President George Bush appointed Admiral James Watkins as secretary of DOE in 1989, Watkins said he felt that "protecting the environment...is not at all inconsistent with advancing both energy security and national security needs." DOE funds committed to environmental cleanup began to rise. By January 1992, some of that funding was reflected in an employment level at the INEL of 12,700 people. In 1992 DOE's environmental restoration and waste management budget request increased by twenty-five percent. By 1995, sixty percent of the INEL budget was directed to waste management, cleaning up, dismantling obsolete buildings, and decontamination.[3]

Watkins appointed Augustine Pitrolo to succeed Don Ofte, who became eligible to retire from federal service and did so in 1989. In June 1989, the Federal Bureau of Investigation had raided the Rocky Flats plant in Colorado, suspecting that its managers had engaged in criminal negligence of national environmental laws. Reacting to this—and to what he regarded as the managerial "mess" of DOE's organizational structure—Watkins felt that DOE's field offices had to surrender a great deal of policy-making autonomy in the interest of more centralized control and implementation from Headquarters. Organizational charts changed, and once more an ex-Navy nuclear engineer attempted to impact the work and the culture of DOE and its labs.[4]

Pitrolo's responsibility was to assure that the INEL was in compliance with environmental regulations and to help Watkins achieve a disciplined response to DOE Headquarters initiatives. He set



Laser research at the INEEL Research Center.

INEEL 92-0067-4-1

Learning to Love D&D

Fred Tingey said to me, "I have a favor to ask of you. We're in the process of starting up a D and D program at the Site. It'll be the first new program that EG&G has started and not inherited from the previous contractor. We'd like it to look good, get it organized well and done right. I'd like you to set it up."

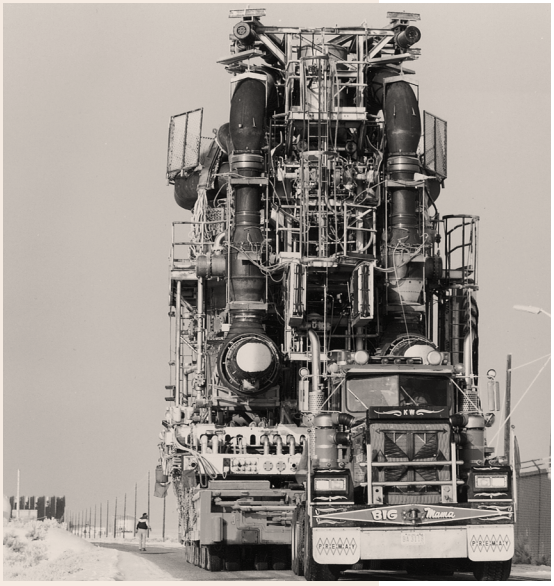
As he told me all this, my mind was racing a hundred miles an hour. I'd never heard of D and D and I didn't know what it meant. Finally I said, "Fred, I'm really embarrassed. You keep talking about D and D, and I'm not sure what that means."

He said, "Oh! Well, it's decontamination and decommissioning. It's in the waste management program." I just about died. In those days, waste management meant garbage. I had seen pictures of trucks hauling stuff and dumping it in a pit. How do you explain to your family—your parents especially—that they've invested all this money to get you trained as a scientist, and now I was going to leave the high-tech world of lasers and start dumping stuff in pits! I felt horrible.

By the time I got the program set up and operating, it was one of the more interesting things I'd ever done. There was lots of boom-boom stuff, and we had research money. It was fun figuring out how to decontaminate something. We looked at biodecontamination of soil and all kinds of explosive dismantlement techniques for structures.

When you got done with a job, it was very satisfying to walk away and see green grass growing there: a site returned to its natural conditions. Or we made a building useful for someone who needed a facility, and we provided it at a fraction of what it would cost to build new. I stayed fifteen years.

Richard Meservey



INEL88-0590-22-9

Not everything from historic programs was dismantled. In 1988, Big Mama hauled the two HTR experiments from the Aircraft Nuclear Propulsion program at Test Area North to a visitor center at the site of EBR-I.

in motion the analysis and procedures that would result in the 1994 consolidation of five major Site operating contracts under one contractor, Lockheed Martin Idaho Technologies Company. Henceforth, DOE announced, every incumbent contractor could assume that the next complex-wide contract would be competitive. New evaluation and selection criteria were expected to hold down costs and improve performance on well-defined tasks.[5]

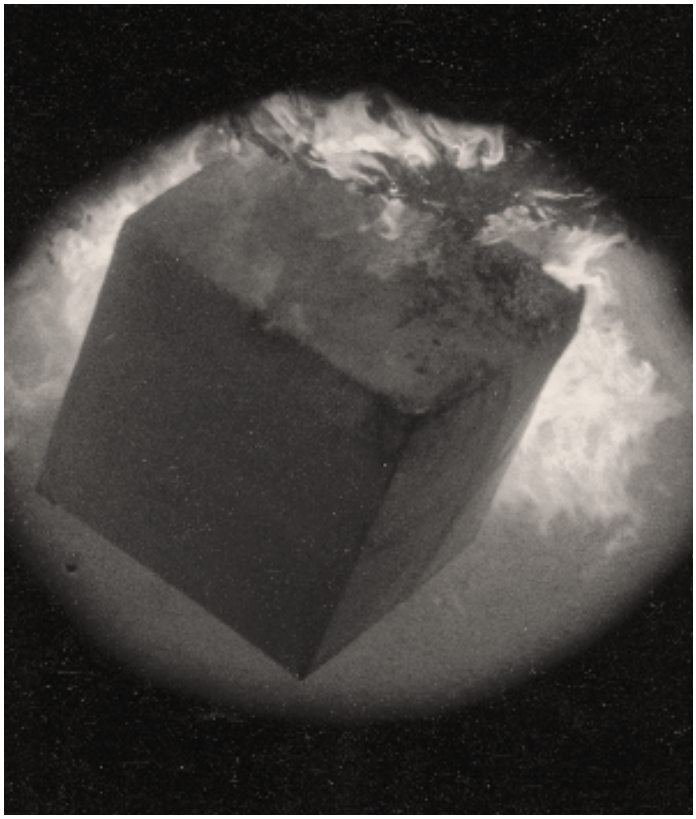
LOCKHEED MARTIN

Environmental compliance tasks were structured by a variety of laws pertaining to the removal of hazardous wastes. The INEL had been designated as a Superfund site under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This and several other laws required that lands and waters contaminated by hazardous substances be inventoried, evaluated, and remediated. The Environmental Protection Agency, DOE, and the Idaho Department of Health and Welfare mutually agreed in 1991 to work as partners in executing a consent order spelling out how each problem area at INEL would be prioritized and remediated.[6]

The laws laid a grid of regulatory compliance vocabulary over the entire Site. The familiar old names—Central Facilities Area, Test Reactor Area, Test Area North—took on additional labels as "Waste Area Groups (WAGs)." There are 10 WAGs at the INEL. Individual remediation targets within the WAGs became "Operable Units (OUs)." The CERCLA work was, however, heavily laced with checkpoints and consultations among the three agencies. The burden of interagency communication and public hearings sometimes seemed to the workers to exceed the actual work of removing and treating the hazardous materials. WAG 10 included the desert land beyond the fences of the Site's nine main activity complexes. In WAG 10, DOE combed the desert for—and found—unexploded ordnance and chunks of TNT from Naval Proving Ground detonation tests and bombing practice.

When seen through a CERCLA lens, the Site seemed to be a collection of wastewater ponds, sewage lagoons, burn pits, tank sites, spill sites, waste injection wells, leach fields, landfills, evaporation ponds, contaminated buildings, and once-leaky pipes. Traces of the industrial and radioactive materials that had been the ingredients of daily work for so many years had settled in patches of soil, on concrete walls, in lab drains and vents and sumps.

But a CERCLA lens was a feeble tool. When seen through the lens of science, the Site was something else entirely: the impact of human activity on the desert environment opened up a brand new laboratory. The theme of "waste management" became a new platform from which to leap into new frontiers of knowledge. Waste was an environmental problem all over the world, and the INEEL would, as Kempthorne had said, "lead." Scores of biologists, chemists, metallurgists, engineers, and the other specialists focused on the home ground.



INEEL 84-621-1-10

Box of waste is burned at the Waste Experimental Reduction Facility.

Ironically, the laboratory building to which many of these scientists reported for work was located in Idaho Falls, not out on the desert. The INEL Research Center (IRC) had been a growing part of the research and engineering mission since 1983. Idaho senator James McClure, who had been responsible for securing the funds for the lab from Congress, dedicated it in April 1984. Like so many other leaps into the future taken by Site employees, the IRC materialized because of a strategic assessment of the future that hit the bull's eye. Dennis Keiser was director of research and development and vice president of EG&G, the IDO's prime contractor in the early 1980s. Keiser said:

The major drive for the laboratory was the need to support the nuclear reactor safety program. We needed to develop diagnostic and instrumentation devices for LOFT, PBF, and other safety test reactors. At first, we planned to build the lab out on the desert, but energy conservation was a major issue at the time, and transportation was cheaper in town.[7]

The First IRC Building

The first structure on the IRC property was the fuel alcohol plant. During the Carter administration, DOE was promoting alternative energy sources such as making fuel alcohol from grain. This idea quickly caught the attention of farmers who hoped that making their own fuel might reduce their operating costs.

But a lot of scam artists picked up on the idea as well, and they started selling alcohol plants to farmers at a price around $50,000. These, of course, didn't work. Farmers began complaining to DOE or asking for help.

So DOE decided to build a reference standard plant here in Idaho Falls. The idea was for us to identify the kinds of operating criteria that the buyer of a plant should look for in making a purchase. For example, one of the criteria had to do with how many gallons of alcohol per hour the plant should produce, and another related to the number of hours per day that the plant could reasonably operate.

After we built and operated the plant according to the reference criteria, we found that a plant that would actually work had to cost around $1 million. And the operator had to be pretty sophisticated. The operation was, in fact, a chemical processing plant, and you couldn't allow contamination to affect the fermentation and distillation processes. If you did, productivity went way down, and the economics of it became marginal at best.

In the end, not a lot of fuel alcohol plants were built, partly because we managed to educate a lot of farmers about what it would really take to run one profitably. Senator Frank Church had been a big supporter of the fuel alcohol program. After he was defeated [1980], James McClure became Idaho's senior senator. He favored other research directions, and the alcohol plant went the way of the Raft River geothermal project. Eventually, the plant was dismantled and shipped to the Tennessee Valley Authority.

Because of the fuel alcohol plant, though, the INEL hired its first biochemist and microbiologist. We acquired a capability in these fields that we hadn't had before, and these continued to grow and evolve.

Tony Allen

The fuel alcohol plant at the INEL Research Center.

INEEL 81-3504

He found a thirty-five-acre farm at the north edge of Idaho Falls owned by an older couple whose children wished to relieve their parents of the rigors of farm management. EG&G bought the property and became the proud owner of a barn, farmhouse, and potato cellar. The first structure to go up on the property was a fuel alcohol plant, which sat on a concrete pad. A trailer containing the plant controls was parked nearby. Soon came another building. Keiser continued:

As we designed the laboratory, we thought twenty to twenty-five years into the future. We made an aggressive push for new research programs and we were very successful. The first major program, which was for the Bureau of Mines, proved to be the seed that took off in many other directions still working today. The Bureau was interested in the biological processing of ores, and the nation's earliest work in this field began here. Microbes live off of the sulphur in some ores and produce sulfuric acid, which dissolves the metal and makes it possible to selectively remove the metal. The technique is particularly effective with copper ores.

The Bureau also was looking for a substitute for chromium in metal alloys. The United States depended on other countries for chromium, but this was a strategic metal, and the Bureau did not wish to rely on South Africa or Russia for supplies. IRC scientists succeeded in developing new alloys, and this work led to the development of super-plastic alloy systems and better magnets now used in computers.

In connection with alloys, the Bureau also had a welding program. One of the criteria for any new alloy was whether or not it was weldable. So the IRC did welding research. Eventually, this work evolved toward the development of automatic—robotic—welding, in which a system monitors the welding process using complex interactions of computers, mathematics, and electronics. Without the decades of accumulated experience in hot cell work, this innovation might not have come about. Those successes attracted the attention of the Department of Defense, which came to the IRC with a number of classified projects. IRC work included membrane research, where the challenge was to separate hazardous ions from liquid solutions. This, too, continued as a major research activity.

It turned out that our vision was a good one. We deliberately went in new direc - tions that were uncharted by other DOE labs. We identified new areas where we thought American research and development would enter. We had little competition, and we continued to build on new knowledge and apply it in many different directions.

We did have to rename the lab, though. One day Troy Wade, the IDO manager, and I were showing Governor Andrus through the lab. At the time, the lab was named the Idaho Laboratory Facility. Andrus asked us if the lab was owned by DOE or whether it was a private facility. We realized immediately that we had to put "INEL" in the name. [8]

With laboratories for geophysics, chemistry, microbiology, and other sciences, the IRC was well-equipped to add the environmental cleanup mission to its many others. Cleanup technologies had to be safe for workers and be economical, which usually meant reducing the volume of the waste. Technologies tested and proven at the INEL were expected to benefit the rest of the globe, not just Idaho and the INEL.

For example, IRC scientists built on their mining microbiology experience and pioneered biodecontamination. While studying how microbes in the desert soil affect the stability of buried concrete, scientists discovered a microbe that might strip radioactive contamination from concrete floors, walls, and ceilings. After conducting experiments in the basement of EBR-I, IRC scientists perfected a means of applying the microbe so it would stick to a wall. They came up with a gel made of cellulose, elemental sulfur, and the microbes. The microbe metabolizes

INEEL 89-290-1-9

INEEL 97-438-1-5

INEEL 83-275-1-11

INEEL 96-667-3-5

INEEL 91-181-2-10

INEEL facilities in Idaho Falls in 1999 included, from top, DOE-ID South, Engineering Research Office Building (EROB), Willow Creek Building (WCB), the INEEL Research Center (IRC) and Technical Support Buildings A and B (TSA and TSB).

INEEL 99-233-1-25

Above. Concrete-eating microbe gel has removed as much as twelve millimeters of concrete per year in laboratory conditions. Below. Operator uses rapid geophysical surveyor at Bighorn Battlefield in Montana.

INEEL 95-234-1-15

the sulfur, creating sulfuric acid. The acid etches the concrete surface and loosens the top millimeters of the concrete. After a few months, a human comes along, vacuums the degraded concrete, and disposes of it. The method was safer than dressing up a team of people in anti-contamination gear to chip concrete. Besides, some radiation fields are too high to allow this, or contamination resides in areas hard to reach. The method was better than demolishing a whole building and treating the entire volume of rubble as a radioactive waste. As of 1999, the "eat and be merry" microbes were on their way to the United Kingdom to prove that they could clean up the concrete walls of the Windscale Pile 1 reactor in Sellafield.[9]

Other IRC researchers built upon the capabilities acquired during the Raft River geothermal project. They invented a "rapid geophysical surveyor," capable of "seeing" several feet beneath the surface of the old Burial Ground and differentiating the closely-spaced pits and trenches from one another. This tool was also taken to the Bighorn Battlefield in Montana to help find remains of twenty-eight soldiers who had perished, historians believed, somewhere in Deep Ravine. A private company in Idaho Falls went into business to market the surveyor. The gadget then served at a long list of Superfund sites and other DOE facilities requiring detailed characterization prior to cleanup.[10]

In short, the IRC labs tackled every aspect of waste management. Scientists monitored and characterized waste, counted it, moved it, prevented it, reduced it, analyzed it, modeled it. They treated, burned, biomassed, shredded, buried, and exhumed waste. Some of it they exploded, pumped, shrunk, calcined, or vitrified. Each activity was an opportunity for research, experiment, and a comparison of alternatives. And always, the cleanup of the Site was a route to new ideas, new customers, and new contracts. Every innovation was potentially a bridge to new opportunity.

In 1995, after DOE Headquarters convened a task force to consider the future of the national laboratory system, the group, chaired by Robert Galvin, recommended among other things that DOE more carefully coordinate and focus the work of all of its labs. It suggested that DOE identify "lead laboratories" whose responsibility it would be to take a broad national view of a specific problem, assess or characterize it, and coordinate an overall strategy that would exploit the strengths of all DOE resources in solving it most efficiently. DOE followed this recommendation. Designation as a "lead lab," naturally, brought with it a certain prestige. The system attempted to end duplicative and inappropriate competition among the national labs. While the system implied some reduction in autonomy for each lab in defining its mission, it also granted new opportunities for a single lab to have an impact on a national problem or mission.[11]

Thus, it was a moment of pride at the INEL when DOE named it as its Lead Laboratory for Environmental Management in 1994. Lead labs also were expected to be "test beds" for the improved methods and techniques that would tackle an environmental clean-up problem. The many enterprises of the resourceful teams of people at the IRC at its desert "test bed" had helped to shape the future of the INEL.[12]

The nuclear legacy of the Site offered paths to new missions *via* "technology transfer," a DOE program Pitrolo inaugurated in the early 1990s. The philosophy behind this program was to exploit the expertise acquired at nuclear laboratories as a benefit to society through private industry. Thus the "core competencies" acquired over the years were another bridge to new missions. For example, by building reactors with control rods able to scram a reactor in a microsecond, the engineers at the Site knew how to make a heavy object move very fast. The challenge of technology transfer in this case, is to adapt this know-how to other industries that needed to move heavy objects very fast.[13]

Evidence that the INEEL had capabilities valued by private industry accumulated in the form of a growing list of Cooperative Research and Development Agreements (CRADAs). These were partnerships in which private companies invested in an IRC research program aimed at perfecting a product for commercial application. By 1999 INEEL had 105 CRADAs to its credit. IRC scientists regularly won "R&D-100" awards presented by *R&D Magazine*, which recognized each year only a hundred research and development innovations in the country.

Nuclear research at the INEEL continued to be a presence amidst the ever-evolving continuum of ideas moving from some stage of theory to engineered hardware. Several dozen nuclear scientists worked in various laboratories around the Site. Considering the possibility that global warming (caused by the emissions of fossil fuel power plants) or other events might reawaken the nation's interest in nuclear power, some of these scientists continued to advance the case for socially responsible nuclear power plants. The IFR may have been ahead of the political and social market, but the notions that a reactor should—and could—be inherently safe, resist plutonium diversion,

Above. To learn how water flows through zones of fractured rock, INEEL did a field study of a fracture at Hell's Half Acre, a lava field west of Idaho Falls. Sensors record water dripping from an artificial pond through a fracture in an overhang. Right. INEEL cleaned up waste left by activities at the Naval Proving Ground. Soil contaminated with TNT was collected, mixed with acetone to dissolve the TNT, and the mixture composted. The process avoided accidental detonation and fugitive dust problems. Here, material goes into composter.

INEEL 99-0293-1-24

INEEL 87-0623-1-11

Don Ofte

INEEL 90-1-53-4

Augustine Pitrolo

INEEL 91-328-4

John Wilcynski

and minimize waste now were driving reactor research. Scientists considered concepts for gas-cooled or liquid-lead-cooled reactors and studied new ideas on corrosion-resistant materials and cladding that might allow higher temperatures and more-economical operation. Other analysts continued the tradition of reactor safety work for the Nuclear Regulatory Commission: updating safety codes for commercial reactors, improving the human interface with reactor control systems, analyzing steady-state and transient thermo-hydraulic phenomena in reactors.[14]

In 1997 DOE Headquarters established a Nuclear Energy Research Initiative (NERI), a program that invited scientists and engineers from all over the DOE complex to collaborate with each other, private companies, and universities. They were to propose their best ideas for nuclear research and request funds to carry it out. Three hundred bids entered the first round, forty were funded, and five of these went to the INEEL. The scale of the program was modest compared to the earlier thrusts to create a nuclear navy and a nuclear power industry, but it invited new concepts and proof-of-principle opportunities.

At Argonne-West, scientists likewise continued to promote the philosophy behind the IFR, if not the IFR itself. In the aftermath of the EBR-II shutdown, something had to be done with the IFR fuel that had been tested. It had been designed for burnup and recycling, not storage or chemical reprocessing. Argonne took five percent of the IFR fuel, developed a way of stabilizing it using an electro-metallurgical treatment, and proposed to apply the treatment to the rest of the fuel. Beyond their own "waste" fuel, Argonne scientists felt that an industry-wide concentration on the "tail end" of the fuel cycle was long past due, and they intended to promote it as important work that needed to be done well.[15]

At the Chem Plant, which changed its name in 1999 to Idaho Nuclear Technology and Engineering Center (INTEC), the mission continued to focus on the technologies of receiving and storing spent fuel or calcining the waste still remaining at the plant. The reprocessing facilities, in which so much had been invested, remained on standby in case a new mission for them should emerge. Because the Chem Plant engineers, scientists, and managers had acquitted themselves so well in their handling of high-level radioactive wastes, hazards and problems in Idaho were much less urgent than they were at other DOE reprocessing facilities. Money to deal with urgent problems went elsewhere in the DOE system, a fact that sometimes seemed to old Chem Plant employees an ironic reward for good behavior.[16]

With INEEL work roughly divided into sixty percent for waste cleanup and forty percent for other research missions, John Wilcynski, IDO manager from 1994-1999, summarized the path forward with the words, "Finish the sixty and grow the forty." The cleanup would eventually get done and the mission disappear. Dismantled buildings particularly symbolized this trend. By September 1999, the INEEL had cleaned up scores of sites and demolished 215 buildings or structures, and the next to go was the Experimental Organic Cooled Reactor, which had run out of scrounge value. After the Special Response Team appropriated the building in 1984 as a training center, security forces practiced hostage rescues and anti-terrorism tactics. Now the old building was surplus even for that mission.[17]

The research and development business would, on the other hand, have to grow. Whether it would grow absolutely or only as the larger portion of a shrinking whole was the question. Although INEEL would always rely on its work force to grasp opportunities to be brilliant, Wilcynski continued to refine the terms by which the INEEL related to the many potential allies among its Idaho neighbors.

The INEEL had, for example, recognized the Shoshone-Bannock tribe as a sovereign tribal nation. By virtue of a pact made with the tribe in 1992, INEEL provided training and equipment so the tribe would have an independent environmental monitoring capability. It also agreed to protect Native American artifacts on Site grounds. Wilcynski continued to consult with the tribe on matters of mutual importance.[18]

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Idaho National Engineering & Environmental Laboratory
BECHTEL BWXT IDAHO, LLC

Don Ofte had worked with the University of Idaho and the Idaho State University to improve higher education opportunities in nuclear engineering at those schools. The U of I opened a doctoral program in nuclear engineering, the first established in the United States since 1965. Ofte made the laboratories of the IRC available to graduate students. ISU initiated an independent environmental monitoring program, a way of validating Site data. Wilcynski advanced INEEL ties to higher education as he prepared the bid specifications for a new Site operating contract in 1999. The winner was a consortium of interests led by Bechtel BWXT of Idaho that included the Inland Northwest Research Alliance, a group of seven universities including the U of I and ISU.[19]

DOE established a policy of supporting a Citizens Advisory Committee at each of its field facilities. This group of citizen volunteers from across the state and a variety of professions reviewed waste management and other issues as a constructive path to greater public knowledge and information about INEEL operations. Wilcynski welcomed this

First convened in 1994 the INEEL Citizens Advisory Board is an independent panel of fifteen Idaho citizens. The board provides consensus advice to IDO and its regulators, and contributes in-depth public involvement for many IDO decisions.

group when it convened for the first time in 1994 and continued to receive its advice.[20]

The IDO continued to enjoy the support of its irrepressible eastern Idaho supporters, which never had abandoned the Site. Nuclear protesters had scorned the Idaho Falls Chamber of Commerce as a jobs-are-our-only-concern outfit, but the Chamber had in fact not ignored the findings of science in its reaction to events affecting the Site. In looking for a stable regional economy, traditional Site supporters were aided by new institutions, notably the Eastern Idaho Regional Development Alliance. Organized to distribute DOE Settlement Agreement grants intended to promote regional economic diversification, the Alliance hoped to retool part of the Site as a spaceport for launching rockets and space-travel vehicles.[21]

Another new organization, Coalition 21, worked to revitalize the nuclear research mission of the Site. The nonprofit group attracted Site retirees, ISU faculty members, business owners, and others who believed that nuclear technology had much to offer the nation and the world in the 21st century. The group had supported the Settlement Agreement and helped defend Governor Batt against Proposition Three in 1996. Coalition 21, whose motto was "supporting tomorrow's technologies with facts, not with fears," advocated continued research on the IFR and other technologies promoting safe nuclear reactors and innovative solutions to the management of spent fuel.[22]

The Snake River Alliance, continued as an INEEL "watchdog group." News reporters faithfully consulted its representatives in order to balance waste-related news stories. In 1999 the Alliance (among others) opposed INEEL's proposed Advanced Mixed Waste Treatment Project, a facility intended to treat certain Rocky Flats waste to prepare it for shipment to WIPP. A feature of the Settlement Agreement, the facility had the support of the governor's office, which was then staffed with a nineteen-member INEEL Oversight Office monitoring waste management.[23]

In 1999 a member of the generation that had arrived at the Site in the environmentally exuberant 1970s became the new and first woman IDO manager. Beverly A. Cook, metallurgical engineer, joined the INEL in 1975 with Aerojet Nuclear. She spent her first days on the job behind the glass shielding window of a hot cell, where she had some lessons to learn.

The technicians were prone to making each new engineer open a tool box and remove its contents using the remote manipulators—a procedure that took me, an amateur, all day. They taught me the concept of a "non-recoverable situation" in a hot cell, that is, a situation that cannot be fixed, like dropping a piece of radioactive material on the floor where it cannot be reached remotely. It was a valuable lesson: Analyze all of the job to completion before beginning, and do it right the first time.[24]

Secretary of Energy Bill Richardson addresses the crowd attending the INEEL 50th anniversary celebration.

INEEL 99-0409-3-13

INEEL 99-0365-1-15A

Beverly A. Cook

After fifteen years at the Site, Cook's career took her away from Idaho to the Defense Nuclear Facilities Safety Board and then to DOE's Office of Nuclear Energy in Washington, D.C. When she returned, appointed by Secretary of Energy Bill Richardson in 1999, she continued to believe that science and solid engineering techniques can and should be behind decisions that "do it right the first time." Aware that the nuclear skills like those possessed by her hot cell mentors were the kernel of the Site's present and future missions, she observed in an interview that "everything we do here at the INEEL can be tied to the historic expertise we developed." But her charter from Richardson also expressed the ideals of the Galvin task force: the talents at INEEL were to be applied not only at the home lab but at other places around the DOE complex. Corporate resources had to solve corporate challenges. With fifteen years of Site experience, she was well aware of its reservoir of talent.[25]

At INEEL's fiftieth anniversary ceremonies in the summer of 1999, Secretary Richardson named the INEEL, along with Argonne National Laboratory, as a DOE Nuclear Reactor Technology Lead Laboratory. DOE could see that the totality of nuclear expertise in the nation had been shrinking. Nuclear experts were retiring and not being replaced. Yet nuclear energy provided twenty percent of the nation's electricity and larger percentages in other countries. Nuclear safety and nuclear power were not local issues, as the Chernobyl accident made clear. The nuclear safety record in the United States—and the confidence to keep reactors running after the TMI accident—had depended in large part on the experiments and computer work of hundreds of Site scientists. Now DOE Headquarters needed an in-house consultant, as it were, to identify existing expertise, articulate nuclear research needs, and otherwise help the nation regroup and formulate energy technology strategies for the future.

INEEL—or rather, the people of the INEEL—had been moving the frontiers of knowledge and engineering forward for fifty years. The human potential to create ingenious experiments and pick at the edge of knowledge was still a force. The discipline of science—to make a prediction, design a test, carry it out, observe carefully, refine the next prediction—offered the same promise of discovery to a new generation as it had in the halcyon days of nuclear reactor research.

It is altogether possible, even probable, that in 2049, a new generation of retirees will recall their careers around the turn of the century and tell their grandchildren, "It was exciting then. It was all new."

Appendix A

INEEL Managers and Contractors

DOE-ID Managers

Leonard E. “Bill” Johnston	4/49-4/54
Allan C. Johnson	4/54-12/61
Hugo N. Eskildson	1/62-11/63
William L. Ginkel (Acting)	11/63-3/64
William L. Ginkel	3/64-9/73
R. Glenn Bradley	9/73-3/76
Charles E. Williams	5/76-6/83
Troy E. Wade	7/83-6/87
Don Ofte	6/87-12/89
Phil Hamric (Acting)	1/90-4/90
Augustine Pitrolo	4/90-2/94
John Wilcynski (Acting)	2/94-10/94
John Wilcynski	10/94-2/99
Warren E. Bergholz, Jr. (Acting)	2/99-5/99
Beverly A. Cook	5/99-

Prime Operating Site Contractors	
1950-1966	Phillips Petroleum Company
1966-1972	Idaho Nuclear Corporation (Allied Chemical Corporation, Aerojet General Corporation, and Phillips Petroleum Company)
1972-1976	Aerojet Nuclear Corporation
1976-1994	EG&G Idaho
1994-1999	Lockheed Martin Idaho Technologies Company
1999-	Bechtel BWXT Idaho, LLC
Argonne National Laboratory-West	
1949-	University of Chicago
Idaho Chemical Processing Plant (Idaho Nuclear Technology and Engineering Center)	
1950-1953	American Cyanamid Company
1953-1966	Phillips Petroleum Company
1966-1971	Idaho Nuclear Corporation
19712-1979	Allied Chemical Corporation
1979-1984	Exxon Nuclear Idaho Company
1984-1994	Westinghouse Idaho Nuclear Company
1994-1999	Lockheed Martin Idaho Technologies Company
1999-	Bechtel BWXT Idaho, LLC
Specific Manufacturing Capability	
1983-1986	Exxon Nuclear Idaho Company
1986-1991	Rockwell INEL
1991-1994	Babcock & Wilcox Idaho Inc.
1994-1999	Lockheed Martin Idaho Technologies Company
1999-	Bechtel BWXT Idaho, LLC
Naval Reactors Facility	
1950-1999	Westinghouse Electric Corporation
1999-	Bechtel Bettis, Inc.

Appendix B

Fifty Years of Reactors at the INEEL

After the first reactor at the National Reactor Testing Station (Experimental Breeder Reactor-I) went critical in 1951, scientists built and operated dozens more reactors in the next five decades. Since the 1970s, it has become accepted that 52 reactors operated at the Site.

But counting reactors at a reactor research facility is not as straightforward as it might seem, nor is accumulating vital statistics about each reactor. While considering the reactors that operated on the Idaho desert, the following thoughts might be kept in mind.

First, scientists in different programs did not seem to follow the same rules when it came to naming reactors. For example, the Aircraft Nuclear Propulsion (ANP) program modified the core of the reactor it called HTRE-1 and named it HTRE-2. These were subsequently known as two reactors. In another program, experimenters changed the core of the Organic Moderated Reactor more than once, but the reactor retained the same name and was counted as one reactor. When the Experimental Breeder Reactor-II operated as a prototype of the Integral Fast Reactor, the name did not change. Thus, any list of reactors very definitely understates and under-represents the actual complexity of reactor development at the Site.

Second, the list-maker must decide what to commemorate in a list of reactors. Should reactors that never went critical be given a place? If so, the list will include the Experimental Organic Cooled Reactor. No uranium fuel ever was loaded into the reactor and it never operated or went critical before the program was canceled. It was "a reactor," but never "an operating reactor." This was true as well for the Experimental Beryllium Oxide Reactor.

This list does not include simulated reactors such as Semiscale, which was part of the reactor safety testing program. The omission of facilities like this is another way in which a list can understate the variety and complexity of the INEEL's nuclear reactor history.

Finally, not all the information one might desire about the history of a reactor is easily found. For example, one goal for this list was to identify the day, month, and year of initial criticality for each reactor—and the date of its final shutdown. But the INEEL Technical Library's vast collection of archived reports did not yield this information for each reactor. Some report writers were content to report that a reactor went critical "in the summer of" a certain year and leave it at that. The same writers may have considered other milestones, such as its first operation at "full power," to be more meaningful in the progress of their particular reactor.

This alphabetical list of reactors contains the names of 52 reactors (the fifty that operated and the two that did not) as they have been known traditionally, their acronyms, selected milestone dates, and descriptive information about each reactor. All references to megawatts are "thermal" megawatts. Readers who examine this list are invited to contribute additional milestone dates and other vital statistics about the reactors so that future lists might be made more complete and more accurate.

Name	Acronym	Reactor Startup	Last Day of Operation
1. **Advanced Reactivity Measurement Facility No. 1** The ARMF-I, a reactor located in a small pool in a building east of the MTR in the Test Reactor Area, was used to determine the nuclear characteristics of reactor fuels and other materials subject to testing in the MTR. Together with the MTR, the reactor helped improve the performance, reliability, and quality of reactor core components. Until the next generation reactor, the ARMF-II, this was considered the most sensitive device for reactivity determinations then in existence.	ARMF-I	10-10-60	1974
2. **Advanced Reactivity Measurement Facility No. 2** The ARMF-II was built in the opposite end of the tank occupied by ARMF-I. It had a "readout" system which automatically recorded measurements on IBM data cards. This refinement over the ARMF-I meant that operators could process data quickly in electronic computers. Designers of the ARMF-II benefitted from previous experience with the ARMF-I and the Reactivity Measurement Facility (described below).	ARMF-II	12-14-62	
3. **Advanced Test Reactor** Located at the Test Reactor Area, the ATR, which continued to operate in 2000, is a materials testing reactor. It simulates the environment within a power reactor for the purpose of studying the effect of radiation on steel, zirconium, and other materials. The ATR produces an extremely high neutron flux up to 1 x 10^{25} neutrons per square centimeters per second. Target materials are exposed to the neutron flux for selected periods of time to test their durability within an environment of high temperature, high pressure, and high gamma radiation fields. Data that normally would require years to gather from ordinary reactors can be obtained in weeks or months in the ATR. The ATR can operate at a power level of 250 megawatts. Its unique four-lobed design can deliver a wide range of power levels to nine main test spaces, or loops. Each loop has its own distinct environment apart from that of the main reactor core. Therefore, nine major experiments can take place simultaneously. Additional smaller test spaces surrounding the loops allow for additional tests. In addition to materials testing, the ATR has made radioisotopes used in medicine, industry, and research.	ATR	7-2-67	Continuing
4. **Advanced Test Reactor Critical Facility** The ATRC performs functions for the ATR similar to those of the ARMF reactors in relation to the MTR. It was a valuable auxiliary tool in operation long before the ATR startup. It verified for reactor designers the effectiveness of control mechanisms and physicists predictions of power distribution in the large core of the ATR. Low-power testing in the ATRC conserved valuable time so that the large ATR could irradiate experiments at high power levels. The ATRC is also used to verify the safety of a proposed experiment before it is placed in the ATR.	ATRC	5-19-64	Continuing
5. **Argonne Fast Source Reactor** The Argonne Fast Source Reactor was a tool used to calibrate instruments and to study fast reactor physics, augmenting the Zero Power Plutonium Reactor research program. Located at Argonne-West, this low-power reactor—designed to operate at a power of only one kilowatt—contributed to an improvement in the techniques and instruments used to measure experimental data.	AFSR	10-29-59	Late 70s
6. **Boiling Water Reactor Experiment No. 1** BORAX-I was a pioneer reactor that tested the safety and operating parameters of reactors which used boiling water as a moderator and coolant. In this reactor type, water is allowed to boil in the core. Saturated steam drives the turbines and generates power. BORAX-I, like the later BORAX experiments, was located just north of EBR-I. It demonstrated that the boiling water moderated reactor concept was feasible for power reactors. Its design capacity was 1.4 megawatts. Operators destroyed it in July 1954 in a deliberately planned "destructive test," the purpose of which was to subject it to extreme operating conditions and learn more about the limits of its safe operation.	BORAX-I	1953	July 1954

Appendix B

Name	Acronym	Reactor Startup	Last Day of Operation
7. **Boiling Water Reactor Experiment No. 2** BORAX-II continued the testing program for boiling water reactors, this time at a power level capacity of 6 megawatts. Tests used fuels with varying enrichments of uranium-235.	BORAX-II	10-19-54	March 1955
8. **Boiling Water Reactor Experiment No. 3** The operating capacity of BORAX-III was 15 megawatts. The reactor was connected to a 2000-kilowatt turbine/generator set so that engineers could generate electricity, the ultimate objective of the reactor test program. On the night of July 17, 1955, the reactor produced sufficient power to light the city of Arco (500 kilowatts), the BORAX test facility (500 kilowatts), and part of the Central Facilities Area at the NRTS (1000 kilowatts).	BORAX-III	6-9-55	1956
9. **Boiling Water Reactor Experiment No. 4** BORAX-IV, with a power level of 20 megawatts, tested fuel elements made from mixed oxides (ceramics) of uranium and thorium. These materials had a high capacity to operate in the extreme heat of a reactor before they failed. The ceramic core demonstrated that a reactor loaded with this fuel could operate safely and feasibly. The fuel could operate in higher temperatures, was less reactive with the water coolant in case the cladding ruptured, was cheaper to manufacture, and burned a larger percentage of the fuel before loosing its reactivity. The reactor produced measurable quantities of the artificial thorium-derived fuel, uranium-233. One series of BORAX-IV tests involved operating the reactor with experimentally defective fuel elements in the core.	BORAX-IV	12-3-56	June 1958
10. **Boiling Water Reactor Experiment No. 5** BORAX-V could operate at a power level of 40 megawatts. This flexible reactor advanced the boiling water reactor concept by testing the safety and economic feasibility of an integral, nuclear superheat system. On October 10, 1963, it produced superheated (dry) steam entirely by nuclear means for the first time. The reactor demonstrated that improved efficiency from manufactured steam is obtainable by incorporating as a design feature a number of superheated fuel assemblies in the reactor core lattice.	BORAX-V	2-9-62	September 1964
11. **Cavity Reactor Critical Experiment** Located at TAN, CRCE was an outgrowth of a program begun by NASAin the 1960s to investigate the propulsion of space rockets by nuclear power, offering the possibility of much greater thrust per pound of propellant than chemical rockets. The concept for the cavity reactor core was that the uranium would be in a vapor, or gaseous, state. Hydrogen propellant flowing around it would theoretically attain much higher temperatures—up to 10,000° F—than in conventional solid core rockets. The experiments at TAN used simulated hydrogen propellant and produced data on the reactor physics feasibility of a gaseous core being able to go critical. The core was uranium hexafluoride (UF_6); the experiments were all done at the relatively low temperature of about 200° F. In the proposed ultimate application, the ball of uranium gas would be held in place by the hydrogen flowing around it, something like a ping-pong ball suspended in a stream of air. Uranium core temperatures as high as 100,000° F were considered possible.	CRCE	5-17-67	Early 1970s
12. **Coupled Fast Reactivity Measurement Facility** When the ARMF-II reactor was modified in 1968, it was given a new name, the CFRMF. A section of the core was modified to produce a region of high-energy neutron flux useful in comparing calculated and observed results. This tool provided physics information about the behavior of fast (ie, unmoderated) neutrons. Physicists studied differential cross sections and tested calculational methods. The CFRMF contributed to the development of fast neutron reactors.	CFRMF	1968	1991
13. **Critical Experiment Tank** The CET reactor produced a source of neutrons used to calibrate various types of neutron sensors and chambers. Part of the Aircraft Nuclear Propulsion program and located at Test Area North (TAN), the CETwas a low-power reactor (one of three in the ANP program) originally designed to mock-up the HTRE-I and HTRE-II reactors. Later, fuel test bundles intended for testing in HTRE-II were first evaluated for reactivity characteristics in the CET.	CET	1958	1961

Name	Acronym	Reactor Startup	Last Day of Operation
14. **Engineering Test Reactor** When the Engineering Test Reactor started up at the TRAin 1957, it was the largest and most advanced materials test reactor in the world. The 175-megawatt reactor provided larger test spaces than the older MTR and provided a more intense neutron flux. The ETR evaluated fuel, coolant, and moderator materials under environments similar to those of power reactors. In 1972 the ETR was modified by the addition of a Sodium Loop Safety Facility into the reactor core. With this, the reactor played a new role supporting DOE's breeder reactor safety program. ETR test programs related to the core design and operation of breeder reactors. As testing progressed, the reactor was again modified with a new top closure accommodating the irradiation loop. Other additions included a helium coolant system and sodium-handling system. The ETR was the first complete reactor facility to be deactivated and documented immediately after shutdown.	ETR	9-19-57	December 1981
15. **Engineering Test Reactor Critical Facility** ETRC was a full-scale, low-power nuclear facsimile of the ETR, similar in function to the ARMF and ATRC. It was used to determine in advance the nuclear characteristics of experiments planned for irradiation in ETR and the power distribution effects for a given ETR fuel and experiment loading. Since no two ETR loadings were identical, the ETRC allowed operators to predict the ETR's nuclear environment when completed experiments were removed or new ones added. This information was necessary to calculate the experiment irradiation and determine core life, control rod withdrawal sequences, reactivity worths, and core safety requirements. Proposed fuel and experiment loadings were first mocked up in ETRC and manipulated until a desired power distribution throughout the core was attained, satisfying pertinent safety requirements. The ETRC's low-power tests allowed the ETR to operate without interruption, saving time and money.	ETRC	5-20-57	1982
16. **Experimental Beryllium Oxide Reactor** Modifications of a former ANPbuilding at TAN, the Shield Test Pool Facility, began in May 1963 to house the Experimental Beryllium Oxide Reactor (EBOR). The objective of the reactor was to develop beryllium oxide as a neutron moderator in high-temperature, gas-cooled reactors. The project was canceled in 1966 before construction was complete. Among the reasons for the cancellation was the encouraging progress achieved, concurrent with EBOR construction, in developing graphite as a moderator. This reduced the importance of developing beryllium oxide as an alternate.	EBOR	Never operated	
17. **Experimental Breeder Reactor No. I** EBR-I, the first reactor built at INEEL, began operation in 1951. The reactor produced the first usable electricity from nuclear heat on December 20, 1951. It achieved full-power operation the next day. In 1953, the reactor confirmed that a nuclear reactor designed to operate in the high-energy neutron range is capable of creating more fuel than its operation consumes ("breeding"). The reactor, which used enriched uranium as fuel, was unmoderated. It used sodium-potassium alloy (NaK) as coolant. Ablanket of uranium-238 around the core provided the "fertile" material in which breeding took place. The liquid-metal coolant permitted the neutron energies to be kept high, thus promoting fissionable-material breeding. The coolant also enabled high-temperature and low-pressure operation, both conducive to efficient power production. President Lyndon B. Johnson dedicated EBR-I as a National Historic Landmark on August 26, 1966. It was subsequently opened to the public for visits and tours.	EBR-I	8-24-51	12-30-63
18. **Experimental Breeder Reactor No. II** Part of the continuing investigation of fast neutron breeding reactors, the EBR-II, located at Argonne-West inside a containment shell, was built to demonstrate the feasibility of on-site fuel reprocessing as an adjunct	EBR-II	9-30-61	9-30-94

Name	Acronym	Reactor Startup	Last Day of Operation
Experimental Breeder Reactor No. II (continued) to a liquid metal-cooled fast-breeder-reactor power plant. These objectives were met within the first few years of its operation. By September 1969, EBR-II operated at a capacity of 62.5 megawatts and supplied electricity to Argonne-West and the power grid at the Site until its shutdown in 1994. The reactor operated submerged in a tank of liquid sodium coolant. During recycle experiments between 1964-1969, spent fuel was sent by automated handling methods to the Fuel Cycle Facility adjacent to the reactor building, treated by pyrometallurgical techniques, and the useful fissile metal refabricated into new fuel pins. EBR-II also was used to irradiate reactor fuel and structural material samples, testing their durability in breeder-reactor environments. This information helped improve fuel and material performance for future breeder reactors.			
19. **Experimental Organic Cooled Reactor** Because the OMRE (see below) was built as a minimum-cost facility ($1,800,000) to test the feasibility of the organic-cooled reactor concept, it lacked test loops needed to investigate various organic coolants and experimental fuel elements. The EOCR was intended to extend and advance the OMRE studies. During the final stages of its construction, EOCR was placed in standby status in December 1962 when the AEC decided that the organic-cooled concept would not significantly improve nuclear power plant performance over what other reactor concepts already had achieved. The building, located east of the Central Facilities Area, was recycled for other (non-nuclear) uses.	EOCR	Never operated	
20. **Fast Spectrum Refractory Metals Reactor** This low-power critical facility operated at TAN to collect data for a proposed fast-spectrum refractory-metal reactor concept called the 710 Reactor. The concept involved using metals such as tungsten and tantalum in a compact, very high-temperature reactor for generating power in space.	710	March 1962	1968
21. **Gas Cooled Reactor Experiment** Built at the Army Reactor Experimental Area, later called the Army Reactor Area (ARA), the GCRE was a water-moderated, nitrogen (gas)-cooled, direct- and closed-cycle reactor. It generated 2,200 kilowatts of heat, but no electricity. The U.S. Army wanted to develop a mobile nuclear power plant, and the GCRE was the first phase of the program, proving the principle of this reactor concept. The reactor provided engineering and nuclear data for improved components. The GCRE was also used to train military and civilian personnel in the operation and maintenance of gas-cooled reactor systems.	GCRE	2-23-60	4-6-61
22. **Heat Transfer Experiment No. 1** Test Area North was opened in 1952 for the Aircraft Nuclear Propulsion program, which operated during the 1950s to develop for the U.S. Air Force a nuclear-powered jet airplane using direct-cycle heat transfer engineering. The program involved ground tests only, but proved the principle of nuclear-powered turbojet engine operation with a full-power test in January 1956, with Heat Transfer Reactor Experiment No. 1 (HTRE-I), which produced 20 megawatts of heat energy on a test stand at TAN's Initial Engine Test Facility. The water-moderated reactor used enriched uranium fuel clad in nickel-chromium.	HTRE-1	11-4-55	1956
23. **Heat Transfer Experiment No. 2** In order to irradiate fuel elements that were too large to fit in the MTR for materials tests, the ANP program drilled a hexagonal hole in the center of HTRE-1 and renamed it HTRE-2, converting it to a materials test reactor and subjecting test fuels to environments reaching 2,800° F. The ANP materials test program advanced the technology of high-heat ceramic reactor fuels.	HTRE-2	July 1957	3-28-61 (End of ANP program)

Name	Acronym	Reactor Startup	Last Day of Operation
24. **Heat Transfer Experiment No. 3** After substantial testing and experimentation, this new experiment arranged the reactor, engine, shielding, and heat transfer systems in a horizontal configuration anticipating final design in an airframe. President John F. Kennedy canceled the ANPprogram on March 28, 1961. Work on the project came to an abrupt and permanent end on that date. The two HTRE experiments were moved to the site of EBR-I, where they are on display at the visitors center.(See Heat Transfer Experiment No. 1)	HTRE-3	1958	December 1960
25. **High Temperature Marine Propulsion Reactor** The 630-Areactor, a low-power critical experiment, was operated at TAN to explore the feasibility of an air-cooled, water-moderated system for nuclear-powered merchant ships. Further development was discontinued in December 1964 when decisions were made to lower the priority of the entire nuclear power merchant ship program.	630-A	1962	1964
26. **Hot Critical Experiment** HOTCE was an elevated-temperature critical experiment designed to obtain information on temperature coefficients of solid-moderated reactors, to develop a theory consistent with this information, and to develop measurement techniques for high-temperature reactors. A part of the ANPprogram, it operated in the Critical Experiment cell of the Low Power Test Facility at TAN. HOTCE was one of three low-power reactors supporting the ANP program, along with the Shield Test Pool Facility Reactor (see below) and the Critical Experiment Tank (CET). The ANP program ended in 1961.	HOTCE	1958	3-28-61 (End of ANP program)
27. **Large Ship Reactor A** 28. **Large Ship Reactor B** The A1W (aircraft carrier, first prototype, Westinghouse) plant consisted of a pair of prototype reactors for *USS Enterprise*, a U.S. Navy nuclear-powered aircraft carrier. Located at the Naval Reactors Facility, the two pressurized-water reactors (designated A and B) were built within a portion of a steel hull. The plant simulated *Enterprise's* engine room. All components could withstand seagoing use. The A1W plant was the first in which two reactors powered one ship propeller shaft through a single-geared turbine propulsion unit. As the Navy program evolved, new reactor cores and equipment replaced many of the original components. The Navy trained naval personnel at the A1Wplant and continued a test program to improve and further develop operating flexibility.	A1W-A A1W-B	10-21-58 July 1959	1-26-94 1987
29. **Lost of Fluid Test Facility** The LOFTreactor, located at TAN within a containment building, was a centerpiece in the safety testing program for commercial power reactors. The reactor was a scale-model version of a commercial pressurized-water power plant built chiefly to explore the effects of loss-of-coolant accidents (LOCAs). Thirty-eight nuclear power tests were conducted on various accident scenarios, including the real accident at Three Mile Island, between 1978 and 1985. Among other goals, the program investigated the capability of emergency core cooling systems to prevent core damage during a LOCA. Experiments at LOFT simulated small-, medium-, and large-break LOCAs, sometimes complicated with other events such as "loss of offsite power." LOFT was inactivated in 1986, following completion of the LP-FP-2 experiment, the most significant severe-fuel-damage test ever conducted in a nuclear reactor. This test, which involved the heating and melting of a 100-rod experimental fuel bundle, provided information on the release and transport of fission products that could occur during an actual commercial reactor accident where core damage occurs.	LOFT	1973	7-9-85
30. **Materials Test Reactor** The MTR was the original reactor at the Test Reactor Area and the second reactor operated at the NRTS. Fueled with enriched uranium fuel, water-cooled and -moderated, the reactor was a key part of the Atomic Energy Commission's post-war reactor development program. It supplied a high neutron flux in support of a reactor development program subjecting potential reactor fuels and structural materials to irradiation. In	MTR	3-31-52	4-23-70

Name	Acronym	Reactor Startup	Last Day of Operation
Materials Test Reactor (continued) addition, its "beam holes" made it possible to perform cross-section and other physics research. The high-flux radiation fields available in this reactor made it possible to accelerate the screening of potential reactor materials. In its early years, the MTR contributed to the design of pressurized water, organic-moderated, liquid-metal-cooled, and other reactors. Successful operation of the MTR itself was a great experiment resulting in a family of plate-type reactors. The reactor operated at a power level of 30 megawatts until September 1955 when thermal output was increased to 40 megawatts. The MTR logged more than 125,000 operating hours and more than 19,000 neutron irradiations. During August 1958, the MTR became the first reactor to operate using plutonium-239 as fuel at power levels up to 30 megawatts. The demonstration showed that a plutonium-fueled reactor could be controlled satisfactorily. The materials testing workload of the MTR was taken over by the new and larger Advanced Test Reactor.			
31. **Mobile Low-Power Reactor No. 1** Following the operation of the GCRE, the ML-1 was the next major step toward the development of a mobile low-power power plant for the U.S. Army. The entire ML-1 plant was designed to be transported either by standard cargo transport planes or standard Army low-bed trailers in separate packages weighing less than 40 tons each. The reactor was operated remotely at the ARA-IVarea from a control cab at a distance of approximately 500 feet. It could be moved after a 36-hour shutdown. The reactor was designed for ease of operation and maintenance by enlisted technicians at remote installations, for reliable and continuous operation under extreme climatic conditions, and for the rigors of shipment and handling under adverse conditions. The ML-1 shut down for the last time after operating for a total of 664 hours. Before the ML-1 had reached all of its performance goals, the Army phased out its reactor development program around 1965.	ML-1	3-30-61	5-29-64
32. **Natural Circulation Reactor** The S5G (submarine reactor, 5th prototype, General Electric) was the prototype of a pressurized-water reactor for *USS Narwhal*. Located at the Naval Reactors Facility, it was capable of operating in either a forced or natural circulation flow mode. In the natural mode, cooling water flowed through the reactor by thermal circulation, not by pumps. Use of natural circulation reduced the noise level in the submarine. To prove that the design concept would work in an operating ship at sea, the prototype was built in a submarine hull section capable of simulating the rolling motion of a ship at sea. The S5G continued to operate as part of the Navy's nuclear training program until that program was reduced after the end of the Cold War.	S5G	9-12-65	5-1-95
33. **Neutron Radiography Facility** The NRAD, located in the Hot Fuel Examination Facility at Argonne-West, is a nondestructive examination tool. Using two collimated neutron beams produced by a 250-kilowatt reactor, NRAD produces neutron radiographs showing the internal condition of highly irradiated test specimens without physically cutting into the specimen. The reactor also has been used as a neutron source for isotope production, activation analysis, and the evaluation of radiation effects on materials.	NRAD		Continuing
34. **Nuclear Effects Reactor** The Nuclear Effects Reactor (FRAN) was a small-pulsed reactor, capable of supplying bursts of high-intensity fast neutrons and gamma radiation. FRAN was transferred to the NRTS in mid-1967 from the Nevada Test Site, where it had been operated by Lawrence Livermore National Laboratory. Located in the ARAbuilding formerly occupied by the ML-1 reactor, FRAN was used for a short time to test the performance of new detection instruments then being developed for reactor control purposes. The reactor was moved back to DOE's Lawrence Livermore National Laboratory in June 1970.	FRAN	8-28-68	June 1970

Name	Acronym	Reactor Startup	Last Day of Operation
35. **Organic Moderated Reactor Experiment** OMRE demonstrated the technical and economic feasibility of using a liquid hydrocarbon as both coolant and moderator, a reactor concept developed and partially financed by Atomics International. Located a few miles east of the Central Facilities Area, the reactor operated with a succession of cores. The waxy coolant was considered promising because it liquified at high temperatures but didn't corrode metal like water did. Also, it operated at low pressures, significantly reducing the risk of leaking. A scaled-up reactor, the Experimental Organic Cooled Reactor, was built next door in anticipation of further development of the concept.	OMRE	9-17-57	April 1963
36. **Power Burst Facility** Located southeast of the Test Reactor Area, the PBF was part of the reactor safety testing program. It was designed to simulate various kinds of imagined accidents caused by sudden increases in the operating level of a reactor. The PBF was the only reactor in the world that could perform rapid power changes (bursts) within milliseconds. It performed severe-fuel-rod-burst tests and also simulated loss-of-coolant accidents within a special assembly that fit inside the main reactor core. The initial mission for PBF was to test light water reactor fuel rods under representative accident conditions. Data from these tests were used to develop and validate fuel behavior computer codes for the Nuclear Regulatory Commission. After its test program ended in 1985, the PBF reactor was considered for use in defense-related programs or for use in a brain cancer treatment program called Boron Neutron Capture Therapy (BNCT). The BNCT program would have treated patients with glioblastoma multiforme—a form of brain cancer. However, neither of these missions materialized.	PBF	9-22-72	1985
37. **Reactivity Measurement Facility** RMF, a detector reactor that measured reactivity changes in materials irradiated in the MTR or ETR, was operated for more than eight years. The RMF was used to assay new and spent fuel elements and to assist in experiment scheduling by evaluating reactivity losses and flux depression caused by in-pile apparatus.	RMF	2-11-54	4-10-62
38. **Shield Test Pool Facility** The SUSIE reactor was used for bulk shielding experiments that were performed in support of the ANP Shielding Experimentation Program. The reactor, situated in a water-filled pool at TAN, could be operated safely, was adaptable to many forms of nuclear research, and was easy to operate at minimum cost. After the ANPprogram was discontinued in 1961, SUSIE continued in use by other programs at the NRTS.	SUSIE	1961	
39. **Special Power Excursion Reactor Test No. I** SPERT-I was the first in a series of four safety-testing reactors designed to study the behavior of reactors when their power level changed rapidly. Power runaways were produced deliberately by moving the control rods. The variables in the thousands of SPERT studies included fuel plate design, core configuration, coolant flow, temperature, pressure, reflectors, moderators, and void and temperature coefficients. All operations were conducted from a control building located a half mile from the reactors, situated a few miles east of the Central Facilities Area. SPERT-I was an open-tank, light-water-moderated and reflected reactor, originally using 92 percent enriched uranium fuel. The reactor tank, about 4 feet in diameter and 14 feet high, was filled with water to a level about 2 feet above the core. In general, SPERT-I tests demonstrated the damage-resistant capabilities of low-enrichment (4 percent enriched uranium-235) uranium-oxide fuel pins similar to those used in water-cooled reactors powering large central stations.	SPERT-I	6-11-55	1964
40. **Special Power Excursion Reactor Test No. II** This facility consisted of a closed pressurized water reactor with coolant flow systems designed for operation with either light or heavy water. The pressure vessel was 24 1/2 feet high by 10 feet inside diameter. Tests with heavy water (deuterium, an isotope of hydrogen) were desired because heavy water reactors were of growing	SPERT-II	3-11-60	October 1964

Name	Acronym	Reactor Startup	Last Day of Operation
Special Power Excursion Reactor Test No. II (continued) importance in Canada, Europe, and the United States. Also, heavy water tests allowed for the verification of various types of physics calculations on the effects of neutron lifetime on power excursions.			
41. **Special Power Excursion Reactor Test No. III** SPERT-III was considered the most versatile facility yet developed for studying the inherent safety characteristics of nuclear reactors. This reactor (which was planned as the third in the series of SPERTreactors, but was built second) provided the widest practical range of control over three variables: temperature, pressure, and coolant flow. The reactor sat in a pressurized vessel similar to those used in commercial power production. Water could flow through the vessel at rate up to 20,000 gallons per minute, temperatures up to 650° F, and pressures up to 2,500 pounds per square inch.	SPERT-III	12-19-58	June 1968
42. **Special Power Excursion Reactor Test No. IV** SPERT-IV was an open-tank, twin-pool facility that permitted detailed studies of reactor stability as affected by varying conditions including forced coolant flow, variable height of water above the core, hydrostatic head, and other hydrodynamic effects. The reactor, water-moderated and -reflected, used highly enriched, aluminum alloyed, plate-type fuel elements. The SPERT-IV facility was modified by the installation of a Capsule Driver Core (CDC), which permitted fuel samples to be inserted into a test hole in the center of the reactor core, where it could be subjected to short-period excursions without damaging the "driver" fuel in the rest of the core. The CDC work on fuel-destructive mechanisms continued until the Power Burst Facility replaced it.	SPERT-IV	7-24-62	August 1970
43. **Spherical Cavity Reactor Critical Experiment** SCRCE was the final experiment in reactor physics work for the NASA-sponsored program to determine the feasibility of a reactor going critical with a gaseous core of uranium. Previous work had been done with a cylindrical configuration because of its ease of construction. The spherical configuration was the culmination of the project, allowing for a comparison between theory and experimental results. The spherical shape was considered a more likely geometry for the ultimate application in a rocket to Mars.	SCRCE	November 1972	1973
44. **Stationary Low-Power Reactor** (Earlier name - Argonne Low Power Reactor) The SL-1 reactor, originally named Argonne Low Power Reactor (ALPR), was designed for the U.S. Army as a prototype of a low-power, boiling-water reactor plant to be used in geographically remote locations. The SL-1 was accidentally destroyed and three men killed on January 3, 1961.	SL-1, ALPR	8-11-58	1-3-61
45. **Submarine Thermal Reactor** With the S1W, also known as the Submarine Thermal Reactor (STR), the United States'nuclear navy was born. The purpose of a nuclear-powered submarine was to transform submarines into "true submersibles," vessels that could remain underwater powered by a fuel which did not require oxygen. The S1W (submarine, first prototype, Westinghouse) nuclear power plant was the first prototype built at the Naval Reactors Facility. Cooled and moderated by pressurized water, the reactor and its associated propulsion equipment were installed inside two hull sections duplicating the size and specifications of *USS Nautilus*, under construction at the same time in Connecticut. To facilitate shielding research, the hull sections were placed in a tank of water. After startup, the S1Waccomplished a simulated voyage nonstop from Newfoundland to Ireland, "submerged" and at full power most of the way during the 96 hour test. The simulation proved the principle and the feasibility of atomic ship propulsion long before *USS Nautilus* set out to sea. Later, the S1W tested advanced design equipment and operated as part of the Navy's personnel training program.	S1W, STR	3-30-53	10-17-89
46. **Systems for Nuclear Auxiliary Power (SNAP) 10A Transient No. 1** The SNAPTRAN program extended the SPERT reactor safety testing program to aerospace applications. Three test series, involving three reactors, investigated the behavior of SNAP10A/2 fuel under large-transient,	SNAPTRAN-1	Early 1960s	

Name	Acronym	Reactor Startup	Last Day of Operation
Systems for Nuclear Auxiliary Power (SNAP) 10A Transient No. 1 (continued) power-excursion conditions. SNAPTRAN-1, located at Test Area North, was subjected to non-destructive tests in conditions approaching but not resulting in damage to the zirconium-hydride-uranium fuel.			
47. **Systems for Nuclear Auxiliary Power (SNAP) 10A Transient No. 3** SNAPTRAN-3 was the first of two destructive tests on a version of the small space reactor (SNAP10A/2) designed to supply auxiliary power in space. The test, conducted at TAN's Initial Engineering Test Facility on April 1, 1964, simulated the accidental fall of a reactor into water or wet earth such as could occur during assembly, transport, or a launch abort. The test demonstrated that the reactor would destroy itself immediately instead of building up a high inventory of radioactive fission products.	SNAPTRAN-3	4-1-64	4-1-64
48. **Systems for Nuclear Auxiliary Power (SNAP) 10A Transient No. 2** This test version of the small space reactor, SNAP 10A/2, was intentionally destroyed on January 11, 1966. It provided information on the dynamic response, fuel behavior, and inherent shutdown mechanisms of these reactors in an open air environment. In normal operation, the control drums of the SNAP10A/2 were rotated to obtain criticality after the reactor had been placed in orbit. In case of a launch abort, however, impact on the earth might cause the drums to rotate inward, go critical, conceivably destroy itself, and release fission products to the surrounding environment. The test data contributed to an understanding of reactor disassembly upon impact and methods for assessing or predicting the radiological consequences.	SNAPTRAN-2	1965	January 11, 1966
49. **Thermal Reactor Idaho Test Station** THRITS was a low-power reactor located at TAN. Its nuclear core was arranged in two halves of a vertical, aluminum, honeycomb-like matrix. The reactor could not be operated until the two halves were brought together to form the critical fuel mass. Operators mocked up reactor design concepts for thermal and fast-neutron reactor systems to obtain basic physics and design data for such concepts.	THRITS Split-Table Reactor		1964
50. **Transient Reactor Test Facility** Part of the safety program for fast breeder reactors, TREAT was a uranium-oxide-fueled, graphite-moderated, air-cooled reactor designed to produce short, controlled bursts of nuclear energy. Located at Argonne-West, its purpose was to simulate accident conditions leading to fuel damage, including melting or even vaporization of test specimens, while leaving the reactor's "driver" fuel undamaged. Early studies determined the effect of extreme energy pulses on prototype fuel pins designed for EBR-II. TREAT tests provided data on fuel-cladding damage, fuel motion, coolant-channel blockages, molten-fuel/coolant interactions, and potential explosive forces during an accident. The data helped refine computer simulations of reactor accidents, and, ultimately, design reactors with greater inherent safety.	TREAT	2-23-59	April 1994
51. **Zero Power Physics Reactor** (Earlier name - Zero Power Plutonium Reactor) ZPPR, a low-power critical facility located at Argonne-West, provided reactor physics data for any type of fast neutron spectrum reactor, from tiny space-power reactors to large commercial breeder reactors. The (full-size) reactor core configuration to be studied was mocked up in two halves, the fuel loaded into a honeycomb lattice in each of the separated halves. Extrapolation from the zero-power measurements to full-power conditions was readily achievable. Upon moving the two lattice together, ZPPR was brought to a low power, critical state by control rods. Heat removal was by air flow over the fuel elements.	ZPPR	4-18-69	April 1992 Standby
52. **Zero Power Reactor No. 3** This was a low-power split-table reactor that achieved criticality by bringing two halves of a fuel configuration together. Alow-power reactor, ZPR-III was used to determine the accuracy of predicted critical mass geometries and critical measurements in connection with various loadings for makeup of fast-reactor core designs. The cores of EBR-II, Fermi, Rapsodie, and SEFOR reactors were originally mocked up in this facility. Experimental critical assembly results in this field were almost completely lacking before this reactor started up. The reactor was placed on standby in 1970 and later went on display in the EBR-I Visitor Center.	ZPR-III	October 1955	November 1970

Appendix C

Processing Runs, Idaho Chemical Processing Plant

Between 1953 and 1988 the Chem Plant recovered from spent reactor fuel 31,432 kilograms of uranium containing uranium-235. At times, the plant also recovered radioactive lanthanum (RaLa), neptunium, and radioactive krypton and xenon for use by private industry or other nuclear facilities.

Among the more frequent sources of fuel were the MTR, ETR, ATR, and STR (S1W), ZPR-III, EBR-I, and EBR-II—all NRTS/INEL/INEEL reactors. In addition, the plant processed SL-1 fuel, SNAPTRAN debris, and fuel from OMRE, BORAX, and SPERT reactors, and other test materials. The largest single source of reprocessed fuel was from naval nuclear propulsion reactors: prototype reactors, submarines, cruisers, and other vessels

Other sources included SRP (Savannah River Plant), Hanford, LITR (Low Intensity Test Reactor, Oak Ridge), SIR (Submarine Intermediate Reactor), OWR (Omega West Reactor, Los Alamos), GETR (General Electric Test Reactor), LPTR (Livermore Pool-type Reactor), BGRR (Brookhaven Graphite Research Reactor), ASTR (Aerospace Systems Test Reactor), JRR (Japanese Research Reactor), NRX (Nuclear Engine Reactor Experiment, Jackass Flats, Nevada), SER (Sandia Engineering Reactor), KUR (Kyoto University Reactor), STIR (Shielding Tests Irradiation Reactor), ORR (Oak Ridge Research Reactor), JANUS (Biological Research Reactor, Argonne National Laboratory), BMI Reactor (Battelle Memorial Institute of Columbus, Ohio) ML-1 (Mobile Low-Power Reactor), SFR (Segmented Fast Reactor), and many other university and research reactors.

Run Number	Fuel	Process Period
1	Hanford C and J slugs	2-53 to 8-53
2	MTR, LITR, NRX, ORNLshielding	10-53 to 12-53
	Cold test EBR-I Core 1	7-54 to 7-54
3	EBR-I Core 1, NPCold Run, MTR, LITR,	
	BORAX, BORAX scrap, Hanford C and J slugs	7-54 to 2-55

Run Number	Fuel	Process Period
4	Hanford J slugs, MTR, BORAX bulk shielding,	
	BORAX, LITR	3-55 to 7-55
Cold tests	Cold test SRPreject slugs	9-55 to 11-55
5	Hanford J and C slugs, Chem Dev Test SRP	
	reject slugs	12-55 to 3-56
6	MTR, LITR, BORAX, CP-3, CR	3-56 to 5-56
7	Hanford C and J slugs, CR, MTR, BORAX,	
	LITR, ANL plates, LM slugs, STR, RaLa MTR	5-56 to 3-57
	CPM cold start with LM slugs	8-57 to 9-57
8	LM slugs, RaLa MTR	10-57 to 12-57
9	STR	12-57 to 1-58
10	Hanford C slugs, RaLa MTR, SRP LM slugs	1-58 to 2-58
11	SRP LM slugs, SRP Tube, MTR, RaLa MTR,	
	Chalk River, SRP Tube	5-58 to 11-58
12	SRP slug, SRP Tube, NRX, RaLa MTR	12-58 to 4-59
13	SRP Tube, SRPslug, SRP Tube ends, Chalk River	4-59 to 8-59
14	SIR, OMRE, BMI, RaLa MTR	7-59 to 12-59
15	MTR, RaLa MTR, ETR, LITR, Convair (ASTR),	
	Hanford C, J, and KW slugs, SRPLM slugs	12-59 to 2-60
16	SIR, RaLa MTR	2-60 to 3-60
17	STR, RaLa MTR	3-60 to 4-60
18	ETR	1-61 to 2-61
19	MTR, ETR, BORAX IV, RaLa MTR, Hanford C and J	
	slugs, LITR, Chalk River, CP-5, LPTR, GTR (Convair),	
	OWR, SL-1 scrap	12-61 to 2-62
	SL-1	10-62 to 10-62
20	MTR, ETR, RaLa MTR, SPERT, GETR, BRR, SL-1,	
	BNL, LITR, CP-5, LPTR, GTR (Convair), OWR, WTR,	
	BORAX III, SUSIE, Hanford AEC, Hanford Rey, NRU	6-63 to 9-63

Appendix C

Run Number	Fuel	Process Period
21	BGRR, NRX, McMasters, NRU, NRL, SWE, IRL, University of Michigan—FNR, GTR, MTR, OWR, LPTR, LITR, UF, ETR, CP-5, STR, SPERT, NASA	6-64 to 12-64
	Cold Zr, unirradiated Zr scrap, PWR Core I Seed I, Zr, EBR-I Core 3 codissolution, EBR-I Core 3, SNAPTRAN 2/10A-3 core debris	1-65
22	VBWR, Atomics International UO_2SO_4	4-65 to 6-65
23	Cold from ATR, MTR, ETR, and SPERT; MTR, ETR, LITR, LPTR, OWR, SPERT, GTR, ASTR, GETR, EBR-II Vycor glass, EBR-I Mark 2, plastic-coated Al fuel plates	12-65 to 1-66
24	JRR-2 Core 1, NRX, NRU, BGRR, EBR-II Vycor glass, JRR-2 Cores 2 and 3	3-67 to 9-67
25	MTR, WSU, ETR, LITR, LPTR, OWR, GTR, CP-5, SER, IRL, GETR, NRL, graphite leaching, Zr, EBR-II Vycor glass	4-68 to 6-68
26	Zr, MTR, ETR, GETR, Korean, SER, LITR, AFNETR, JRR-2, KUR, LPTR, OWR, ATR, SPERT, ZPR-III, SNAPTRAN 2/10-2 debris	8-69 to 10-69
	ETR types	1-70 to 4-70
27	Zr, JRR-2 (6 batches), EBR-II scrap, WADCO	2-71 to 7-71
28	Zr, ETR, custom miscellaneous	6-72 to 9-72
29	EBR-II, EBR-II slurry and denitrator product	1-73 to 5-73
30	Zr, GETR, ATR, MTR, MTR 20%, TRAscrap, JRR, ETR, CP-5, OWR, JMTR, Juggernaut, KUR, UM, SER, LPTR, EBR-II Vycor glass, G.G.A. Thermionic, ETRC plates, University of Wyoming UO_2SO_4, Atomics International fission disc, HTRE scrap, Walter Reed Army Hospital, Nuclear Test Gauge/Split Table Reactor, HTGR secondary burner ash leaching, BMLfission disc	2-74 to 5-74
31	EBR-II, APPR cold fuel scrap	2-75 to 5-75
32	Zr, PWR	5-76 to 9-76
33	Godiva reactor fuel, HTRE, ATR, MTR, LPT, ETR, GETR	3-77 to 6-77

Run Number	Fuel	Process Period
34	EBR-II, OMRE, SPERT, ORNL-17-1, BMI, Kinglet, Sandia (Godiva reactors), PBF metallurgical samples	8-77 to 9-77
35	Zr, custom	7-78 to 3-79
36	Zr, Rocky Flats U_3O_8, GETR, OWR, STIR, LPTR, UCLA-MTR, ATR, ETR, ATR-XA	9-80 to 3-81
37	EBR-II, Los Alamos metal fuel scrap, Rocky Flats U_3O_8, Rover cold	8-81 to 11-81
38	ETR, BSR, ATR, OWR, ORR, HFR-PETTEN, SAPHIR, GETR, FRG, FRJ/FRM, SFR, UO_2SO_4	9-82 to 11-82
39	Rover, Sandia, Rocky Flats, cold FLUORINEL, FLUORINEL Phase 1 cold run	4-83 to 6-84
40	ITAL, FRG, DR-3, UCLA, MURR, OWR, HFBR, LPTR, TR-1, ATR, BSR, ORR, HMI, Triton, FRJ-2, HRF, BR-2, ORPHEE, ASTRA, SRF, R-2, JUNTA, McMaster, JRR-2, JMTR, JANUS, SR, UCSB UO_2SO_4, FLUORINELPhase II cold run, FLUORINEL pilot plant	8-85 to 1-86
41	FLUORINEL	10-86 to 10-87
42	FLUORINEL, EBR-II Vycor glass, BYU UO_2SO_4, EBR-II fuel scrap, ANL-E fuel scrap	12-87 to 7-88

Sources:

M.D. Staiger, *Calcine Waste Storage at the Idaho Nuclear Technology and Engineering Center*, Report No. INEEL/EXT-98-00455 (Idaho Falls: Lockheed Martin, June 1999), Appendix pp. A-163 to A-168.

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Leroy Lewis, Science and Engineering Fellow, Bechtel BWXT Idaho, contributed corrections to the lists published in the above two documents.

Appendix D

Criticality Accidents, Idaho Chemical Processing Plant

A criticality accident is an unintended amassing of a fissionable material (like uranium) which results in the fissioning of the material in a chain reaction. In such an event, fission products such as heat, gamma radiation, neutrons, gases, and other emissions are released by the nuclear reaction.

The designers of chemical processing, fuel fabrication, and other plants that handle fissionable material employ a variety of strategies to avoid accidental amassing of enough material to initiate a chain reaction. The examples below refer to uranium, but similar principles would apply to the management of any other fissionable material:

- Geometric control: the dimensions of the containers and conveyors of uranium make it impossible to reach a critical mass. At the Chem Plant, for example, certain dissolver vessels and storage vessels were no more than five inches in diameter. Spacing of vessels was also important, with two feet between vessels required to prevent a criticality.

- Concentration control: Where chemical processes involve evaporation or precipitation reactions which could result in the concentration of the uranium, vessels and containers are sized to prevent accidental accumulations of a critical mass. Appropriate dilution may also be used to keep the solution concentration below a minimum value to prevent criticalities.

- Mass control: In handling enriched uranium, the quantity that can be handled at any one time is limited to a specified, known-to-be-safe number of grams of material.

- Administrative control: Operational procedures may require two or more people to approve if a particular procedure could lead to a loss of control. Check-off points, guide limits, process alarm systems, color-coding of certain valve handles, key-only procedures, personnel training, and other controls accompany non-routine and many routine procedures.

1. Criticality Accident of October 16, 1959

A bank of storage cylinders containing a uranium solution was air-sparged (air was bubbled violently into the solution to mix it). The cylinders were geometrically safe, but the sparging initiated a siphon that transferred 200 liters of the solution to a 5,000-gallon tank containing about 600 liters of water. The resulting criticality lasted about twenty minutes.

No workers were exposed to gamma or neutron radiation, as the criticality occurred in a cell below ground when no one was in the vicinity. Airborne activity spread through the plant through vent lines and drain connections, triggering alarms and an evacuation. Two people who evacuated received significant beta doses (with no detectable medical consequences) as they passed areas where radioactive gas was being released into the room from floor drains.

The incident resulted in the placement of new valves, restrictions on air-flow lines when sparging, installation of water traps, and other measures before the plant restarted.

2. Criticality Accident of January 25, 1961

About 40 liters of uranyl nitrate solution (200 grams of uranium per liter) was forced upward from a 5-inch-diameter section of an evaporator into a 24-inch-diameter vapor disengagement cylinder, well above normal solution level. Analysts later assumed that air entered associated lines while operators were attempting to clear a plugged line and improve a pump. When the air bubble reached the evaporator, solution was expelled from the lower section, and a momentary criticality occurred in the upper section. Radiation triggered alarms, but no personnel received more than 100 mrem exposure. Concrete shielding walls surrounded the location of the criticality; the vent system prevented airborne activity from entering work areas; and equipment design prevented a persistent excursion. No equipment was damaged.

Management thereafter restricted the use of air pressure to move liquids and clear lines. A borated steel grid was installed in the disengagement cylinder. Boron is a nuclear “poison” that absorbs neutrons, helping prevent criticalities.

3. Criticality Accident of October 17, 1978

During the first solvent extraction cycle in the recovery of uranium from spent fuel, the uranium was extracted from the dissolution solution and then scrubbed, stripped, and washed in various process columns to separate the uranium from fission products. The criticality occurred in the scrub column (a long narrow, vertical tank). Water had leaked into the tank where the scrub chemical, aluminum nitrate, had been made up, and reduced the aluminum nitrate concentration. But this was

not known to operators because an alarm had not been repaired and was inoperable. Also, operators had not sampled the scrub solution to determine whether the aluminum nitrate was above the required concentration. As a result, the solution was too dilute to force the uranium into the organic phase and instead extracted small amounts of it out on the organic phase into the aqueous phase and accumulated it into the large-diameter disengaging head.

Over a period of a month, uranium continued to accumulate until it reached a concentration in the aqueous phase high enough to achieve criticality. It accumulated in a large-diameter part of the column designed to separate the organic phase from the aqueous phase. The criticality reaction continued for about a half an hour before the operators responded to the slight pressure build-up and took steps to terminate the reaction.

The criticality occurred in a well-shielded location inside a process cell and resulted in insignificant radiation exposures to personnel or damage to equipment.

The operation and management failures associated with this criticality led to a significant reassessment and evaluation of Chem Plant operations. A Plant Protection System (which consisted of a variety of changes in procedures, operating limits, sampling protocols, specifications, warning systems regarding analytical samples, and others) was installed to preclude this type of accident from happening again.

Appendix E

R&D 100 Awards

Cryogenic ZAWCAD • 1999

Research Team: Dennis Bingham, Russell Ferguson, Gary Palmer, Douglas Stacey, Richard Swainston, Carl A. Dunn, Gerald Decker

Description: Cryogenic ZAWCAD is a remarkable, patented cutting and cleaning tool that will make many industrial processes safer and more environmentally friendly by performing hazardous and non-hazardous cleaning and cutting operations while minimizing secondary waste. This unique system uses as its cutting/cleaning medium a harmless atmospheric gas that dissipates after use. As a result, there is no secondary wastestream and no cross contamination. Yet, it can cut with the precision of the most advanced cutting tool and clean or abrade surfaces with finer control, more aggressiveness, and greater efficiency than other cleaning technologies—all without creating a secondary waste to clean-up, dispose of or treat.

Cryogenic ZAWCAD is a highly controllable technology, adjustable for temperature, speed, and aggressiveness.

Tractrix Valve • 1999

Research Team: John Wordin, Pio Park

Description: The Tractrix Valve is a revolutionary, self-sealing valve that doesn't leak and doesn't wear out. Based on a geometric shape called a "tractrix curve," this innovative, plug-type valve wears less than competing plug and ball valves and seals tighter the more it wears—essentially "wearing in" each time it is opened and closed. It requires up to 90% less torque to actuate and can be made of any construction material for the most severe or simple applications. This cost-competitive new valve represents a leap in technology that could make common plug and ball valves obsolete for many applications—particularly those that are environmentally sensitive.

High Void-Fraction Multiphase Flowmeter • 1999

Research Team: James Fincke, Darrell Kruse, Daniel J. Householder, Bulent Turan, Doyle Gould, Charles Ronnenkamp

Description: The INEELHigh Void-Fraction Multiphase Flowmeter solves one of the natural gas industry's most difficult measurement problems: cost-effective measurement of "wet gas" (mixed-phase flows of ≤5% liquid by volume). This innovative flowmeter represents a major economic breakthrough that can impact over 300,000 natural gas wells in the U.S. alone. It offers extraordinary size and cost savings over existing technology, and is the only device to provide real-time wet-gas measurement at the wellhead. It brings better fiscal management to producers, maximizing gas recovery. Its compact size will simplify facilities design, and its low cost will reduce capital investment and total gas production costs. Most importantly, the INEEL Flowmeter gives producers a reliable, economical means of managing natural gas reservoirs for the first time, conserving a precious natural resource.

Maverick Tank Inspection Robot • 1999

Research Team: Thor Zollinger, Kerry Klingler, Charles B. Isom, Kerry Trahan, Scott Bauer, Don Hartsell

Description: The Maverick is a submersible, robot-based system that offers safe, practical, and cost-effective inspection of in-service, above-ground storage tanks (AST). This patented technology provides direct and indirect cost savings of 75% or greater over traditional manual inspection methods, reduces the inspection process from four weeks (or more) to a few days, eliminates worker exposure to hazardous conditions, and enables tank owners to continue using their tanks during inspections, saving them tens of thousands of dollars in previously "lost" revenue. Maverick also is the only robotic inspection system certified for use in hazardous and potentially explosive fuel environments (Class I, Division 1, Group D) such as gasoline and other fuel oils.

The robot's payload includes a multi-channel ultrasonic sensor system to map and correlate metal thickness data, an onboard video system to provide a detailed view of the tank bottom, and position-tracking sensors so technicians know the exact location of the Maverick, and any problem spots, at all times.

Supercritical Fluid Slashing System • 1999

Research Team: Mark Argyle and Alan Propp

Description: Before threads can be woven into fabric, they must be "sized," a process that adds a strengthening and smoothing coating to the thread. The INEELSupercritical Fluid Slashing System (SFSS) is a cheaper, faster, smaller, and more environmentally correct method for coating threads with size, one that replaces centuries-old technology. The INEELmethod transports the size (starch or polyvinyl alcohol) in a very high-pressure "supercritical fluid" that has properties of both a fluid and a gas. Individual threads pass through pressure gradient tubes, where the supercritical sizing mixture is forced into the threads. The efficient method reduces the amount of water, starch, and polyvinyl alcohol that textile manufacturers dispose of. The SFSS specifically addresses an industry "wish list" to provide uniform coating, reduce yarn hairiness, reduce the amount of sizing material, eliminate standing baths, and minimize drying. Because it significantly increases sizing efficiency, the SFSS can double production throughput for improved profitability.

Electro-Optic High-Voltage Sensor • 1998

Research Team: Thomas M. Crawford, James R. Davidson, Gary D. Seifert

Description: The Electro-optic High-voltage Sensor (EHVS) is a safe, small, non-electrical optical sensor that uses photons instead of electrons to measure high voltages on power lines. The most unique aspect of this technology is that the sensor does not have to be in electrical contact to effect a measurement, but simply within the conductor's electronic field, a key advantage over the large transformers conventionally used for voltage measurement at power distribution sites. The EHVS device offers substantial improvement over potential transformers in cost, ease of installation, range of response to voltage fluctuations, and richness of applications.

Rapid Solidification Process Tooling • 1998

Research Team: Kevin McHugh

Description: Rapid Solidification Process (RSP) Tooling technology is a fast, low-cost alternative to conventional fabrication of precision tooling used in the manufacture of nearly all mass produced products, from cell phones to automobiles. This new, molten metal spray-forming technology promises to reduce the cost and lead time for producing tooling by a factor of 5 to 10, substantially shortening the time it takes industry to get products to market. Unlike other alternative tooling approaches, RSPTooling technology makes it possible to create tooling from hard tool steels at the rate of 2,000 lb/hr or more, suitable for the largest auto industry tooling requirements.

Malt-Based Antimicrobial • 1998

Research Team: Karen B. Barrett

Description: The Malt-Based Antimicrobial is a naturally occurring biopesticide derived from malted cereal grains. Developed as an environmentally sound solution to agricultural crop protection, this product represents a major breakthrough in pesticide research. It offers an extraordinary taxonomic range—unrivaled by chemical fungicides, is easily and inexpensively produced, has an excellent shelf life; and can be used to protect crops in the field, in storage, and during transport. Most importantly, this new biopesticide is harmless to people, animals, and the environment; and is derived from a plentiful renewable resource: common cereal grain.

Nanocrystalline Composite Coercive Magnet Powder • 1997

Research Team: J.D. Branagan, J.A. Hyde, C.H. Sellers, K.W. Dennis, M.J. Kramer, R. W. McCallum

Joint entry: Ames Laboratory, Dr. R. William McCalum

Description: The development and application of a new alloying approach in rare earth-based permanent magnet systems resulted in the development of advanced alloys with a nanocrystalline composite microstructure. Atomization processing of these new alloys resulted in significant improvements in hard magnetic properties and processability over previous alloys, allowing the possibility of near term, high volume, low cost production of atomization materials.

Advanced Tensiometer • 1997

Research Team: Joel M. Hubbell, James B. Sission

Description: The Advanced Tensiometer is an instrument that measures how tightly water is held to soil in the unsaturated zone, a region that extends from the earth's surface to the aquifer. The Advanced Tensiometer's breakthrough design helps investigators determine the direction and rate of water movement at depths and with accuracies not possible before, ushering in a new era for monitoring waste disposal sites, safeguarding drinking water supplies, and controlling agricultural irrigation systems.

Gamma Neutron Assay System • 1995

Research Team: R. Aryaeinejad, J.D. Cole, R.C. Greenwood

Description: The Gamma Neutron Assay System (GNAT) is a new, nonintrusive, and unique patented technique of identifying fissile materials and their isotopic ratios in bulk quantities and in a field environment. It resolved, for the first time, problems of assaying and tracking special nuclear material (SNM) not previously possible, which are important in arms control, nonproliferation, and nuclear weapons dismantlement.

Biocube Aerobic Biofilter—A Biofilter for Treatment of Toxic Gases and Vapors • 1993

Research Team: W.A. Apel, F.S. Colwell, A.S. Espinosa, E.G. Johnson, B.D. Lee, M.R. Wiebe, W.D. Kant, P. Melick, B. Singleton

Joint entry: EG&G Roston, W.D. Kant

Description: The Biocube™ Aerobic Biofilter is a landmark product that ushers in a new era for degradation of toxic vapors and gases. It is novel, effective, and economical vs. conventional technologies, and is the first modular and mobile biofilter.

Portable Isotopic-Neutron Source Chemical Assay System • 1992

Research Team: A.J. Caffrey, J.D. Cole, L. Forman, R.J. Gehrke, R.C. Greenwood, K.M. Krebs, M.H. Putnam

Description: The Portable Isotopic-neutron source (PINS)-based non-destructive assay system distinguishes chemical weapons (e.g., nerve gas) from high-explosive munitions for treaty verification.

Pulsed Extraction Secondary Ion Mass Spectrometer • 1992

Research Team: D. Applehans, D.A. Dahl, J.E. Delmore

Description: This is a new type of Secondary Ion Mass Spectrometer using a patented secondary ion Pulsed Extraction technique that prevents sample charging and allows the positive and negative ion spectra to be collected simultaneously, making possible analyses that previously could not be performed.

Sulfur Poisoning Resistant and Regenerable Hydrogenation Catalysts • 1990

Research Team: Randy B. Wright

Description: This entry is a new, unique, and advanced method for the preparation of highly active, sulfur poisoning resistant and repeatedly regenerable hydrogenation catalysts. This method utilizes the controlled manipulation of chemically induced surface segregation processes in conjunction with intermetallic compounds and binary alloys to design and synthesize a wide range of

active catalysts. As specially applied to nickel-based intermetallic compounds, this approach provides a technique by which highly active hydrogenation catalysts can be prepared and regenerated by elevated temperature oxidation/reduction treatment of the starting material.

FiberOptic Moire Interferometry System • 1990

Research Team: V. Deason, M.B. Ward

Description: The FiberOptic Moire Interferometry System, Model FMI 1700, is a major advance in an important new technique—diffraction moire interferometry. Diffraction moire is used for the study and measurement of distortion, stress, and fracture. The FMI was developed at the INELin response to serious failings to the existing diffraction moire systems. The FMI utilizes advanced optical fiber components in a compact portable unit to replace an optical table full of standard optical devices. These fiber optic components are in all cases smaller, lighter, and more stable than the discrete components normally used. At the same time, the FMI greatly simplifies the experimental process, which until now has been complicated and tedious using conventional equipment.

Diffraction Moire Interferometry, for which the FMI was developed, allows the researcher to make highly accurate (better than one Micron resolution) measurements of deformation. This deformation could be the result of stresses on a ship's hull, an airplane's frame, bridge, piping in a nuclear plant, or other critical area. Understanding the relationship between stress, deformation, and such factors as aging, load, corrosion, and material properties is crucial to reducing the heavy burden on the economy and society of structural failures (estimated at tens to hundreds of billions of dollars annually, plus extensive loss of life and productivity).

Diffraction moire measures deformation in a specimen by creating full two-dimensional maps of the corresponding deformation in a diffraction grating bonded or marked on the surface of the specimen.

Finnigan MAK Gas Mass Spectrometer Model 271/251 • 1990

Research Team: R. Rankin, K.W. Guardapee, L.L. Dickerson

Joint entry: Finnigan MAT Corporation

Description: The 271/251 gas mass spectrometer defined the state-of-the-art in instrumentation for the analysis of noble gases in the environment. The unique aspect of this instrument is that it combines two diverse gas analysis functions, usually requiring separate instruments, into a single entity. The instrument performs both gas composition and gas isotope ratio analyses. In addition, typical isotopic precision capabilities with gas mass spectrometers were on the order of 0.03%. This product has been able to exceed these values by more than an order of magnitude (0.001%), thereby significantly extending the state-of-the-art in high precision gas isotopic analysis. Highly precise measurement of the concentrations of the gas isotopes in the atmosphere is indispensable to environmental studies involving nuclear facilities. This work has been recognized internationally; instruments based on these designs are now in use in Europe and Asia.

Simion PC/PS2 4.0 • 1989

Research Team: D.A. Dahl, J.E. Delmore, A.D. Applehans

Description: SIMION PC/PS2 4.0 is a personal computer program for designing and analyzing charged particle (ions and electrons) lenses, ion transport systems, and all types of mass spectrometers and surface probes that utilize charged particles. The program, which became available in June, 1988, has exclusive capabilities that significantly expand the number and types of problems that can be addressed, problems that heretofore were impossible to model with existing programs.

Neutral Molecular Beam Surface Probe • 1988

Research Team: J.E. Delmore, A.D. Apprelhans, and D.A. Dahl

Description: This device produces a well focused beam of high energy neutral sulfur hexafluoride molecules at energies ranging from 3 to 23 keV that can be transported many meters under vacuum while retaining sharp focusing, to probe the few molecular layers of a sample's surface. The primary function of the Neutral Molecular Beam Surface Probe is the analysis of surfaces of non-electrical-conducting materials. Asimilar technique has been used with charged atomic particle beams for many years to analyze surfaces of electrically conducting materials, although the technique is applied with great difficulty to insulating materials. Other techniques, notably fast neutral atom beams (FAB sources) have been used with some success, but the nature of their production precludes sharp focusing. In addition, the FAB source must be mounted quite close to the specimen, and that constrains the secondary ion source design. The new Neutral Beam is much easier to use, allows much sharper focus, and increases sensitivity about 1000 fold over systems using charged particle beams on insulating specimens.

Biodegradation System for Toxic Organic Waste Processing • 1988

Research Team: J.H. Wolfram, R.D. Rogers

Description: Disposing of hazardous waste is a high-priority item for every organization that produces it. Virtually every hospital, research university, and biotechnology company in the U.S. produces small quantities of hazardous wastes of organic compounds (e.g., toluene, xylene, and pseudocumene). The first two of these compounds are on the EPApriority pollutant list. A mixture of these compounds is know as liquid scintillation cocktail when the mixture also contains radioactive materials. The Biodegradation System presented here introduces organisms to the cocktail that detoxify it at very high levels of efficiency. The system includes a bioreactor (where living cells "feed" on the toxic materials and produce carbon dioxide), accessory hardware, and a supply of the detoxifying microorganisms. Once installed, the system will continually bioprocess an inflow of the cocktail, rendering it safe for conventional disposal through the sewer system if the radioactivity is within prescribed limits, or as low-level radioactive waste otherwise. This eliminates the high cost of packing and transporting the mixed waste to the very few authorized disposal sites. Sanctioned methods for handling the waste at present are incineration and long-term storage. Converting the waste at the site eliminates dependence on these methods and the cost associated with them.

Improved Iron-Based Alloys from Noble Gas Doping • 1988

Research Team: John E. Flinn

Description: The primary function of this product is to strengthen alloys for high-temperature applications. Noble gas atoms (e.g., those of helium or argon), when entrapped during the processing of iron-base powders, stabilize the microstructure and strengthen the alloy produced. The alloying addition forms numerous small and very stable clusters with vacancies (missing atom sites) during rapid cooling. The formation of the clusters is due to the high binding energy between the noble gas atoms and the vacancies that are created by high temperature exposure (i.e., heat treating). Because they retard microstructure coarsening, the clusters allow fine microstructures to be retained during exposure to high temperatures. Cluster presence provides a form of solid solution and dispersion strengthening. The strengthening is further enhanced during aging heat treatments because the clusters provide nucleation, or preferred, sites for the formation of precipitates such as carbides. The fine dispersion of a large number of precipitates significantly improves the strength of the alloy. This process is applicable to all iron-base alloys, particularly to stainless steels.

Oxynitride Braze Method for Joining Silicon Nitride Ceramics • 1988

Research Team: R.M. Neilson, D.N. Coon, S.T. Scheutz, R.L. Tallman

Description: Structural ceramics are potential substitutes for strategic and/or critical materials. However, many potential structural ceramic applications require components that are too intricate or too large to be fabricated with existing techniques. The invention is a method for joining silicon nitride ceramics to produce large parts and/or parts that have complex geometries in which the high-temperature mechanical properties of the joined part are comparable to that of the original ceramic components. For certain applications (e.g., aerospace, engines, chemical processing) ceramic parts, and complex shapes are preferred to metals. Reasons include: increased service operating temperatures, greater strength and increased corrosion resistance at the higher temperatures, greater thermodynamic efficiency in energy conversion devices, lower density and, therefore, lower inertia, lower cost of raw materials, and conservation of possibly strategic and/or critical materials in some applications. Structural ceramics are, however, difficult to form in either larger size parts or in complex geometries because the forming process usually requires some combination of high temperature and high pressure. Some method of joining the ceramics while maintaining the structural integrity and thermodynamic qualities of the ceramic is needed to produce the larger and/or more complex shapes required in many applications. The oxynitride braze method for joining silicon nitride ceramics presented here has been demonstrated to be an effective joining technique using either a hot isostatic press or a graphite resistance furnace with small nitrogen overpressure. In this process, oxynitride glass brazes are used to join silicon nitride ceramics. The glass uses are comparable in composition to the grain boundary phase present in the ceramic pieces that results from the densification process used to consolidate the silicon nitride powders.

Die-Target for Dynamic Consolidation of Powders • 1987

Research Team: John E. Flinn, Gary E. Korth

Description: Die Target for Dynamic Consolidation of Powders is a new and improved method of consolidating metal monoliths from rapidly solidified powders (RSP). The Die-Target controls dynamic stress waves produced by detonation of explosive charges to consolidate RSP alloys. With each detonation, the Die-Target produced four fully consolidated, fully dense, crack-free monoliths for test specimens. This process does not produce high generalized temperatures in the powders, which could seriously alter the microstructure and desirable properties for the RSP. Monoliths produced by the dynamic consolidation of RSPalloys (e.g., stainless steel) have improved mechanical properties, improved corrosion resistance, chemical homogeneity, extended solubility limits, very fine microstructures, and desirable metastable phases. At present, the primary use of the Die-Target is as a research tool. However, the theory and principles underlying the design hold promise for industrial and commercial applications of the DIE-Target where advanced materials that are harder and stronger are needed.

Vision System for High Luminosity Processes • 1986

Research Team: Jon Bolstad, M.B. Ward, C.L. Shull

Description: This system produces high-quality video imagery of industrial or experimental processes which are normally obscured by high luminosity of an electric arc, a plasma, or a combustion flame. It has particular application in electric arc welding where detailed vision of the welding pool, electrode, and liquid/solid interface is required. The welding site is illuminated by pulsed laser light transported to the welding torch by one or more optical fibers. The sensor assembly incorporates objective optics, a laser line filter, a microchannel plate image intensifier tube, and a CCD video camera. The intensifier tube is shuttered electronically in synchronism with the flash from the laser source, which occurs only once per video frame (or some multiple thereof). The shuttering interval (about 100 nanoseconds) is very small in comparison with the 33 millisecond integration time of a standard video camera. The welding arc light is almost totally eliminated from the video picture. Visibility through the arc is regained, and extreme variation in brightness across the picture is removed. The video imagery is much superior to standard video for interpretation by eye and by electronic image processing equipment.

Notes

Abbreviations

IHS Idaho Historical Society

BSU Boise State University Library Special Collections

HREX Human Radiation Experiments, Internet site: http://tis.eh.doe.gov/ohre/

Chapter One

Epigraph: Susan M. Stacy, *Conversations, A Companion Book to Idaho Public Television's Proceeding On Through a Beautiful Country* (Boise: Idaho Public Television, 1990), 47.

1. Mike Atwood, interview with author, January 22, 1999, recounted his story as retold in this chapter.
2. "Fourteen Stockmen Testify at AEC Land Hearing," *Post-Register*, May 3, 1950, 2.
3. See Dr. Bill Hackett, et al, *Geohydrologic Story of the Eastern Snake River Plain and the Idaho National Engineering Laboratory* (Idaho Falls: Idaho Operations Office, 1986), 11.
4. (Lava tubes) Hackett, *Snake River Plain*, 11; (date) personal communication from Dr. Richard P. Smith to Julie Braun, INEEL, March 9, 1999. Lava flows at Craters of the Moon National Monument west of the INEELmay be only 2,000 years old.
5. Mike Atwood, January 22, 1999.
6. E.S. Lohse, "Aviator's Cave," *Idaho Archeologist* 12 (Fall 1989): 23.
7. Susanne J. Miller, *Idaho National Engineering Laboratory Management Plan for Cultural Resources (Final Draft)* (Idaho Falls: Lockheed Idaho Technologies Company Report DOE/ID-10361, Revision 1, 1995), 2-17.
8. Lohse, "Aviator's Cave," 23-28.
9. Miller, *Cultural Resources Plan*, pp. 2-18 to 2-21.
10. (Homesteading) Miller, *Cultural Resources Plan*, pp. 2-21 to 2-22; (quotation) Hugh Lovin, "Footnote to History: `The Reservoir Would Not Hold Water,'" *Idaho Yesterdays* (Spring 1980): 14.
11. (Traditional routes) to Clayton Marler from Diana Yupe, Tribal Cultural Resources Coordinator, Shoshone-Bannock Tribes, June 21, 1999, copy at Cultural Resources Office, INEEL.

Chapter Two

Epigraph: Kay Lambson, interview with author, February 9, 1999.

1. Wyle Laboratories, *Interim Ordnance Cleanup Program Record Search Report*, hereafter, *Scientech Report* (Norco, California: Scientific Services and Systems Group, 1993), Reference 2, "History of the Naval Ordnance Plant, Pocatello, Idaho," p. 1. This report reprints documents found in Naval Historical Center and other archives. See also Arrowrock Group, *The National Environmental and Engineering Laboratory: A Historical Context and Assessment*, (hereafter *Context Report*) INEEL/EXT-97-01021, Revision 2 (Idaho Falls: INEEL, 1997), 29-30; and United States, *Building the Navy's Bases in World War II: History of the Bureau of Yards and Docks and the Civil Engineer Corps, 1940-1946*, Vol. 1 (Washington D.C.: Government Printing Office, 1947), 1-13.
2. *Context Report*, 29-30.
3. *Context Report*, 30.
4. *Scientech Report*, Reference 2, pp. 4-5.
5. *Context Report*, 30.
6. *Context Report*, 31. The letters on the concrete were still visible in 1999.
7. Margaret and Orville Larsen, interview with author, March 19, 1999; *Scientech Report*, p. 3-2 (road names).
8. Kay Lambson, Gloria Lambson, interviews with author, February 9, 1999; and *Scientech Report* Reference 1, "Register of Pertinent Information," p. 2.
9. *Scientech Report*, Reference 2, p. 22; Reference 85, p. 135; and map of Naval Proving Ground, p. 2-8. See also 1951 INEEL photo no. 02974; map U.S. Naval Proving Ground.
10. Stan Coloff, "The High and Dry Navy: World War II," *Philtron* (October 1965): 3, reprinted as "WWII: The Arco Naval Proving Ground" in *INEL News* (May 1989): 18; *Scientech Report*, p. 3-2 (road names), Reference 2, p. 5 (Scoville). Extant buildings from the Naval Proving Ground era in 1999 included the commanding officer's house (CFA-607), the Marine barracks (CFA-606), the pumphouse (CFA-642), a brick-veneer cottage (CFA-613), and a wood frame cottage (CFA-603). Three of the magazines were still in use: CFA-635 and -637 stored hazardous materials; and CFA-638 was used as a Dosimetry Calculation Laboratory.
11. Coloff, 3.
12. Gloria Lambson, February 9, 1999.
13. Gloria Lambson, February 9, 1999; *Scientech Report*, Reference 1, p. 6 (buoy repair).
14. Kay Lambson, Gloria Lambson, February 9, 1999.
15. *Scientech Report*, p. 2-6, 2-9, 2-10, 6-1.
16. One designated area was about five miles northwest of the INEEL's Radioactive Waste Management Complex; the other centered on what is today's U.S. Highway 20 between East Butte and the site of EBR-II. See *Scientech Report*, Reference 96, p. 2-74, 6-7.
17. (Quote, air-gap) to Captain M.A. Sawyer from Captain Walter E. Brown, August 11, 1944, in *Scientech Report*, p. 2-23 to 2-25.
18. *Scientech Report*, p. 2-22, 2-29, 2-35 to 2-38.

19. *Scientech Report*, p. 6-7, References 76-80, 82.
20. *Scientech Report*, p. 2-31.
21. *Scientech Report*, Reference 92.
22. *Scientech Report*, Reference 67, p. 7; Reference 88.
23. Depleted uranium was a byproduct of uranium enrichment plants at Oak Ridge, Tennessee. It contained less than the natural amount of the isotope of uranium-235. The material has several uses. In breeder reactors, it can be bred into Plutonium-239 and then fissioned. It is used in armor-piercing shells, in tank armor, and for counterbalances on aircraft control surfaces. For Elsie, Marsh see *Scientech Report*, p. 2-72.

CHAPTER THREE

1. Edward R. Landa and Terry B. Councell, "Leaching of Uranium from Glass and Ceramic Foodware and Decorative Items," *Health Physics* 63 (No. 3, September 1992): 343.
2. Raymond W.Taylor and Samuel W.Taylor, *Uranium Fever; or No Talk Under $1 Million* (New York: Macmillan, 1970), 79.
3. In some reactors, such as the fast-fissioning EBR-II, some U-238 atoms will fission.
4. Norman Polmar and Thomas B. Allen, *Rickover, Controversy and Genius, A Biography* (New York: Simon and Schuster, 1982), 118-120. Enrico Fermi observed uranium fission in a 1934 experiment. He thought the fission products were new elements and did not recognize them as krypton and barium. Four years later, Austrian physicist Lise Meitner realized that the uranium atom had actually split apart.
5. William Benton, *The Annals of America*, Volume 15 (Chicago: The Encyclopedia Britannica, Inc., 1968), 601-602.
6. Rhodes, *The Making of the Atomic Bomb* (New York: Simon and Schuster, 1986), 427; Stephane Groueff, *Manhattan Project: The Untold Story of the Making of the Atomic Bomb* (New York: Little, Brown, and Co., Bantam, 1967), 55-56; Taylor, *Uranium Fever*, 81; Polmar and Allen, *Rickover*, 120. The first two of these sources and Richard G. Hewlett and Oscar E. Anderson, Jr., *The New World, 1939-1946* (Philadelphia: Pennsylvania State University Press, 1962) are histories of the Manhattan Project.
7. Rhodes, *Atomic Bomb*, 711, 740. Estimates on TNT yield equivalent differ. Rhodes' source was the Committee for the Compilaton of Materials on Damage Caused by the Atomic Bombs in Hiroshima and Nagasaki, p. 21, in *Hiroshima and Nagasaki* (Basic Books, 1977, 1981).
8. Jack M. Holl, *Argonne National Laboratory, 1946-1996* (Urbana: University of Illinois Press, 1997), 40.
9. See Holl, *Argonne*, 62.
10. (Groves approval) Holl, *Argonne*, 40. For an account of the early deliberations of the AEC, see Richard G. Hewlett and Francis Duncan, *Atomic Shield, 1947/1952* (University Park: Pennsylvania State University Press, 1969).
11. Atomic Energy Act of 1954 (Public Law 79-585).
12. For a history of early corporate interest in nuclear energy, see Mark Hertsgaard, *Nuclear, Inc., The Men and Money Behind Nuclear Energy* (New York: Pantheon Books, 1983).
13. See Hewlett, *Atomic Shield*; Herbert York, *The Advisors, Oppenheimer, Teller, and the Superbomb* (San Francisco: W.H. Freeman and Company, 1976); and Herbert York, *Race to Oblivion* (New York: Simon and Schuster, 1970).
14. David Lilienthal, *Atomic Energy, A New Start* (New York: Harper and Row, 1980), 1.
15. John Tierney, "Take the A-Plane: The $1 Billion Nuclear Bird that Never Flew," *Science* 82 (Jan/Feb 1982): 47; Henry W. Lambright, *Shooting Down the Nuclear Airplane* (Syracuse, NY: Inter-University Case Program No. 104, 1967), 3; Susan M. Stacy, *Idaho National Engineering Laboratory: Test Area North, Hangar 629, Historic American Engineering Record ID-32-A* (Idaho Falls: Lockheed Martin Idaho Corporation, 1994), 10.
16. Susan M. Stacy, *Idaho National Engineering Laboratory, Army Reactor Experimental Area, Historical American Engineering Record ID-33-D* (Idaho Falls: Lockheed Martin Idaho Corporation, 1998), 5.
17. Hewlett, *Atomic Shield*, 196, 202-204. In 1948 the AEC research laboratories were Argonne, Chicago; Oak Ridge, Tennessee; Brookhaven, New York; and the new Knolles laboratory in Schenectady. The Los Alamos Science Laboratory in New Mexico focused on weapons research. The Radiation Laboratory at Berkeley, California, did not carry the title of "national laboratory." Other AEC production centers made plutonium and other weapons materials.
18. Pike quoted by Kevin Richert in "Original AEC Site Spawned Eastern Idaho's `Gold Rush,'" (Idaho Falls) *Post-Register*, May 15, 1994, H-20; (Hafstad) Hewlett, *Atomic Shield*, 210.
19. Hewlett, *Atomic Shield*, 196, 206.
20. Hewlett, *Atomic Shield*, 210.
21. Smith, Hinchman & Grylls, *Survey on Fort Peck, Montana, and Pocatello, Idaho, Sites* (Detroit: Smith, Hinchman & Grylls, March 1949), 1, 41 (fog).
22. Hewlett, *Atomic Shield*, 218.
23. Robert Smylie, interview with author, July 8, 1998, Boise; "Idaho Termed Top Favorite for Plant Site," (Idaho Falls) *Post-Register*, March 16, 1949, 1.
24. "Arco Area to Get West Atomic Plant," *Post-Register*, March 22, 1949, 1. See also letter to Mike Mansfield from David Lilienthal, March 29, 1949, IHS AR 2/22, Papers of Governor C.A. Robins, Box 1, Series 1, File: Arco Atomic Energy Plant/part 1; (hearings) Hewlett, *Atomic Shield*, 211.
25. "Station Manager Named," *Post-Register*, April 4, 1949, 1.

CHAPTER FOUR

1. "Who cares for letterheads?" *Arco Advertiser*, April 29, 1949, 1; "Arco Chief Wonders if Neighbor is Lacking in Brotherly Love," *Idaho Daily Statesman*, April 29, 1949; "Idaho Falls Pulls Back on Publicity as Atomic Capital," *Post-Register*, April 26, 1949.
2. "Station Manager Named," *Post-Register*, April 4, 1949, 1.
3. Because of the Navy's resistance to giving up the proving ground, the AEC discussed other locations for the MTR, EBR, and Navy reactors as late as mid-July; Hewlett, *Atomic Shield*, 218.
4. Jacqui Johnston Batie, interviews with author on October 14, 1998, and March 14, 1999; Bill Ginkel, interviews with author on October 13, 1998, and February 3, 1999; and undated news clipping supplied by Jacqui Batie, "Leonard E. Johnston, AEC Chief Here Takes New Job, Reports Say."

See Groueff, *Manhattan Project*, 381, for gaseous diffusion plant.

5. "Details Revealed for Plan to Build West Atomic Field Station," *Post-Register*, March 8, 1949, 1; "Arco Site Named for Atomic Plant," *Arco Advertiser*, March 25, 1949, 1; and "Leonard E. Johnston, AEC Chief Here Takes New Job, Reports Say," (see note no. 4 above).
6. "A Village Wakes Up," *Life* (May 9, 1949): 98-101; "Arco Site Named for Atomic Plant," *Arco Advertiser*, March 25, 1949, 1. See also Vardis Fisher, ed. *The Idaho Encyclopedia* (Caldwell, Idaho: Caxton Printers, 1938) entry for Arco.
7. "Village Alert to Problems" and "New Business Firms Move In," *Arco Advertiser*, 1; to Chet Moulton from Governor Robins, April 14, 1949, IHS AR2/22, Box 1, Series 1, File: Arco Atomic Energy Plant, part 1; and Federal Housing Administration, "A Preliminary Plan and Program for Arco, Idaho," 1949, in AR2/22, File: Arco Atomic Energy Plant, part 3.
8. (Quote) to Robins from Cy Davis, Idaho Falls Chamber of Commerce, March 28, 1949, IHS AR2/22, Box 1, Series 1, File: Arco Atomic Energy Plant, part 1.
9. (Quote) Robins from Cy Davis, March 28, 1949, cited in note above; to Robins from Joe Call, Idaho Falls Chamber of Commerce, March 28, 1949, IHS AR2/22, Box 1, Series 1, File: Arco Atomic Energy Plant, part 1. The towns were Island Park, Warm River, Ashton, St. Anthony, Rexburg, and Arco.
10. "Mayors Form Committee to Cooperate with Atomic Project," *Arco Advertiser*, April 8, 1949, 1.
11. Telegram to Robins from John Sanborn, April 12, 1949, IHS AR2/22, Box 1, Series 1, File: Arco Atomic Energy Plant, part 1.
12. "Who Cares for Letterheads?" *Arco Advertiser*, April 29, 1949, 1.
13. Robb Brady, interview with author, August 27, 1998.
14. Robb Brady, August 27, 1998.
15. "Blackfoot eyes Possibility of Atomic Future," *Post-Register*, April 3, 1949, 5. See also Ben Plastino, *Coming of Age: Idaho Falls and the Idaho National Engineering Laboratory* (Idaho Falls: Margaret A. Plastino, 1998), 7-8.
16. Marvin Walker, interview with author, March 15, 1999. Walker, Johnston's driver and document courier, heard Johnston remark several times that the NOPwould have been an ideal set-up for the AEC headquarters, except for the lack of commitment from Pocatello. See also Plastino, *Coming of Age*, 17.
17. AEC news release, May 18, 1949, IHS AR2/22 Box 1, Series 1, File: Atomic Energy Plant, part 1.
18. David Lilienthal, *The Atomic Energy Years, 1945-1950, The Journals of David E. Lilienthal, Volume II* (New York: Harper and Row, 1964), 513-514.
19. "Purpose of Arco Site Explained," *Arco Advertiser*, August 5, 1949, 1.
20. Jacqui Batie, Marvin Walker, and John Ray, interviews with author, March 14 and 15, 1999.
21. "Problems Mount as City Squares Off to Big Job," *Post-Register*, May 22, 1949, 4.
22. R.L. Polk and Co., *Polk's Idaho Falls City Directory* (Omaha: R.L. Polk, 1952), 13.

Chapter Five

Epigraph: Bill Johnston to C.A. Robins, July 13, 1949. See note no. 1 below.

1. "AEC Offices in New Location," *Arco Advertiser*, July 22, 1949, 1; letter to C.A. Robins from Bill (L.E.) Johnston, July 13, 1949, IHS AR 2/22, Box 1, Series 1, File: Arco Atomic Energy Plant, part 2; (bubble rumor) Hewlett, *Atomic Shield*, 219.
2. Hewlett, *Atomic Shield*, 218-219.
3. Holl, *Argonne*, 87.
4. "Gradual Expansion of Arco Plant Planned by AEC," *Arco Advertiser*, September 30, 1949, 1.
5. Marvin Walker, interview with author, March 15, 1999; Hewlett, *Atomic Shield*, 495; William Ginkel, interview with author, February 3, 1999.
6. Jack M. Holl, "The National Reactor Testing Station: The Atomic Energy Commission in Idaho, 1949-1962," *Pacific Northwest Quarterly* (Volume 85, No. 1, January 1994): 18.
7. John Horan, interview with author, July 29, 1997.
8. "Exploratory Surveys Start at Atomic Site," *Arco Advertiser*, July 1, 1949, 1.
9. John Horan, interview with author, July 29, 1997.
10. John Horan, July 29, 1997.
11. Smith, Hinchman & Grylls, *Survey*, 54, 70, 80. Harold T. Stearns and J. Stewart Williams, consulting geologists, were subcontracted by Smith, Hinchman & Grylls to summarize their understanding of the aquifer. See "Geological and Hydrologic Features of the Pocatello Site, Idaho," in the *Survey*.
12. "Gradual Expansion of Arco Plant Planned by AEC," *Arco Advertiser*, September 30, 1949, 1; Hewlett, *Atomic Shield*, 211; "Testing Proves Ample Supply," *Arco Advertiser*, August 19, 1949, 1.
13. Marvin Walker, March 15, 1999.
14. Hewlett, *Atomic Shield*, 218-220. For a history of the hydrogen bomb, see Richard Rhodes, *Dark Sun, The Making of the Hydrogen Bomb* (New York: Simon and Schuster, 1995).
15. "Gradual Expansion of Arco Plant Planned by AEC," *Arco Advertiser*, September 30, 1949, 1.
16. Rick Bolton, "USGS technician Rodger Jensen reflects on 30 years in the sagebrush" *INEL News* (May 19, 1992); "A Village Wakes Up," *Life* (May 9, 1949): 101; (Johnston quote) "Purpose of Arco Site Explained," *Arco Advertiser*, August 5, 1949, 1.
17. "AEC Given Custody of Naval Proving Ground," *Arco Advertiser*, December 9, 1949, 1.
18. Hewlett, *Atomic Shield*, 495; "Fresh Water Test Well Contract Bid" and "Batch Plant Equipment Moved to Atomic Site," *Arco Advertiser*, October 7, 1949, 1.
19. Deslonde deBoisblanc, interview with author, January 16, 1999.
20. Marvin Walker, March 15, 1999.
21. To Robins from Johnston, August 24, 1949, and September 9, 1949; to Johnston from Robins, September 2, 1949; all in IHS AR2/22, Box 1, Series 1, Arco AE Plant—1949, part 1.
22. To James Reid, Idaho Bureau of Highways, from J. Bion Philipson, November 22, 1949, IHS AR2/22, Box 1, Series 1, File: Arco Atomic Energy Plant 1949, part 1.
23. (Robins quotation) to Johnston from Robins, November 30, 1949, IHS AR2/22, Box 1,

Series 1, File: Arco Atomic Energy Plant, 1949, part 1; also see letter to J. Bion Philipson from James Reid, November 30, 1949, IHS AR2/22, Box 1, Series 1, File: Arco Atomic Energy Plant 1949, part 1.

24. "Dworshak and Welker in Blackfoot Today, Discussion on Highway 20 Construction; Irate as Johnson Bypasses the Meeting," *Blackfoot Daily Bulletin*, September 12, 1952.
25. "Groups Ready Dedication of Idaho Falls-Arco Highway," *Post-Register*, September 21, 1951; "Deal Dedicates New Arco, Idaho Falls Highway," *Post-Register*, October 8, 1951.
26. (Quotation) Lou Haller, "Johnston Explains AEC Position on the Road, Rich Sets 1954-'55 As Completion Date; Senator Dworshak Has Asked Federal Aid," *Blackfoot Daily Bulletin*, September 23, 1952; "Dworshak and Welker in Blackfoot Today; Discussion on Highway 20 Construction; Irate as Johnston By-passes the Meeting," *Blackfoot Daily Bulletin*, September 12, 1952; Plastino, page 13.
27. "State Engineer Says Highway 26 Serving AEC from Blackfoot Should Be Given First Priority," *Blackfoot Daily Bulletin*, November 21, 1952; "Sen. Dworshak Reports AEC and Bureau of Public Roads Have Assured Construction Money Aid," *Post-Register*, December 22, 1952.
28. "Sen. Dworshak Reports AEC and Bureau of Public Roads Have Assured Construction Money Aid," *Post-Register*, December 22, 1952; "Crews Start Plotting AEC-Rexburg Road," *Salt Lake Tribune*, January 27, 1952.
29. (Bus fare) William Ginkel, interview with author, February 3, 1999.
30. To Alton B. Jones, State Superintendent of Schools, from George Green, Superintendent of Schools for Bannock County, April 26, 1949, IHS AR2/22, Box 1, Series 1, File: Arco Atomic Energy Plant, part 1. See also Holl, *The National Reactor Testing Station*; Robb Brady, interview with author, August 27, 1998.
31. "L.E. Johnston Explains Purpose and Development of Reactor Plant," *Arco Advertiser*, December 9, 1949, 1.

Chapter Six

Epigraph: The occasion for the song was an AEC announcement that Oak Ridge would not be involved further in reactor development, but that such work would be centralized at Argonne. See Hewlett, *Atomic Shield*, 126.

1. Kirby Whitham, interview with author, October 14, 1998. The test was conducted in the EBR-I reactor. An organic compound is one which contains carbon.
2. William Ginkel, interview with author, February 3, 1999.
3. Holl, *Argonne*, 68-69.
4. In reactor technology, neutrons with energies above 100,000 electron volts are called fast neutrons. EBR-I neutrons moved with two million electron volts of energy.
5. For a general overview of fast reactors see Alan M. Jacobs, et al, *Basic Principles of Nuclear Science and Reactors* (D. Van Nostrand Company: Princeton, 1960), 171-175.
6. "New Pump to Aid AEC At Idaho Falls Plants," *Salt Lake Tribune*, April 14, 1952. Engineers also installed more conventional pumps in each of the main cooling systems.
7. Hewlett, *Atomic Shield*, 496.
8. Kirby Whitham, October 14, 1998.
9. "Dr. Walter Zinn Recalls Early Days," *Idaho National Engineering Laboratory EBR-I Review*, 1. This undated reprint with no other publication data is a collection of stories about EBR-I printed some time after December 13, 1971, possibly by the INEL employee newspaper. Copy found in Bechtel Cultural Resources departmental files at INEEL. Hereafter, *EBR-I Review*.
10. John H. Buck and Carl F. Leyse, *Materials Testing Reactor Project Handbook*, Report No. TID-7001 (Lemont, Illinois: Argonne National Laboratory and Oak Ridge National Laboratory, 1951), 356. For a brief description of nuclear physics research at the MTR, see NRTS, *1965 Thumbnail Sketch*, 16-17. Beam experiments did extend outside the MTR building, but not to distances of a quarter of a mile.
11. Buck and Lehse, *MTR Handbook*, 29.
12. For general history of MTR development, see Buck and Lehse, *MTR Handbook*, 34-43.
13. Donald J. Hughes. *The Neutron Story* (Garden City, N.Y.: Doubleday Anchor Books, 1959), 41; Buck and Leyse, *MTR Handbook*, 29.
14. Buck and Lehse, *MTR Handbook*, 37; Hewlett, *Atomic Shield*, 126, 419.
15. Hewlett, *Atomic Shield*, 186-188.
16. (Groundbreaking) Buck and Lehse, *MTR Handbook*, 43; (siting) John Horan, July 29, 1997.
17. Hewlett, *Atomic Shield*, 496.
18. (Quotation in previous paragraph and extended quote) John W. Simpson, *Nuclear Power from Underseas to Outer Space* (La Grange Park, Illinois: American Nuclear Society, 1995), 22 and 26-27, respectively.
19. Simpson, *Nuclear Power*, 27; (MTR contribution to STR) *1965 Thumbnail Sketch*, 13.
20. Accounts of Rickover and the Nuclear Navy include Richard Hewlett and Francis Duncan, *Nuclear Navy 1946-1962* (Chicago: University of Chicago Press, 1974); Polmar and Allen, *op cit*.
21. (Rickover quote) Ronald Schiller, "Submarines in the Desert," *Colliers Magazine* (February 5, 1954): 90. Polmar and Allen, *Rickover*, 149. The original name of the Idaho reactor was Mark I; the *Nautilus* reactor, Mark II. Rickover referred to the development shortcut as "Mark I equals Mark II."
22. Simpson, *Nuclear Power*, 43.
23. (McGaraghan's Sea) Schiller, *Colliers*, 88; (backscatter) Dr. John Taylor, communication with author, August 6, 1999. Taylor was responsible for the backscatter research.
24. *The Bluejackets Manual*, 19th edition (Annapolis, Maryland: Naval Institute Press, 1973), 153.
25. Simpson, *Nuclear Power*, 27, 224-337.
26. Simpson, *Nuclear Power*, 50.

Chapter Seven

Epigraph: Marion Thomas, "Recollections and Reflections," *Idaho American Nuclear Society Newsletter* (June 1989), 5.

1. Deslonde R. deBoisblanc, *Idaho ANS Newsletter*, 5-6. This issue contained several tributes to Dr. Doan by former associates.
2. Fred McMillan, interview with author, February 2, 1999.

3. deBoisblanc, *ANS Newsletter*, June 1989.
4. (Architects) Fred McMillan, February 2, 1999; (welcome) see for example "Two Join Phillips Petroleum Staff," *Post-Register*, August 1, 1951, 3.
5. "Atom Pioneer Directs Phillips Project Here," *Post-Register*, August 19, 1951. See also Virginia Doan Fanger, *ANS Newsletter*, June 1989.
6. Stephane Groueff, *Manhattan Project*, 80.
7. deBoisblanc, *Idaho ANS Newsletter*, June 1989; Richard Austin Smith, "Phillips Petroleum—Youngest of the Giants," *Fortune* (August 1954): 72; and Phillips Petroleum Company, *Phillips, The First 66 Years* (Bartlesville, Oklahoma: Phillips Petroleum Company, 1983), 86, 125-140.
8. Warren Nyer, *Idaho ANS Newsletter*, June 1989, 7-9.
9. *Ibid.*
10. (Pappy) John Byrom, interview with author, August 25, 1999; deBoisblanc, Miles Leverett, Warren Nyer, *ANS Newsletter*, June 1989, 6-9.
11. *Phillips, The First 66 Years*, 86, 125-140.
12. The study is described by W. Singlevich, et al, *Natural Radioactive Materials in the Arco Reactor Test Site*, Report No. HW-21221 (cover title: *Ecological and Radiological Studies of the Arco Reactor Test Site* (Richland: General Electric Nucleonics Division, Hanford Works, 1951), 1-49. See also "AEC Sets Radioactivity Study at Idaho Site; College Gets Contract," *Post-Register*, June 19, 1950, 3.
13. John Horan, in an interview with author, indicated that Health and Safety Division personnel in particular made use of the report: Singlevich, et al, *Natural Radioactive Materials in the Arco Reactor Test Site*, Report No. HW-21221. See note 12 for full citation.
14. (Nevada test site) Hewlett, *Atomic Shield*, 535; (malfunctioning, 10 mr/hr on truck) Phillips Petroleum Company, *Survey of Fall-out of Radioactive Material in South and South-East Idaho Following the Las Vegas, Nevada Tests of October and November, 1951*, Report IDO 12000 HPO (Idaho Falls: Site Survey Section of the Health Physics Division, NRTS, 1952), 11, 8; (truck, rainstorm explanation) John Horan, "Draft of Interview" with John K. Harrop and Joseph J. Shonka in Idaho Falls, Summer 1994, 2.
15. See for example, "Press Release, May 18, 1961: Annual Summary of Environmental Monitoring Data for 1960," in records of Senator Henry Dworshak, IHS, Ms. 84, Box 122 B, File: AEC-Id-Press Releases.
16. "AEC to Employ Top Safeguards Here," *Post-Register*, May 11, 1950, 15.
17. Henry Peterson, interview with author, February 22, 1999; (NCRPstandards) Elizabeth S. Rolph, *Nuclear Power and the Public Safety* (Lexington, Mass.: D.C. Heath and Co., 1979), 108; John Horan, interview with Baldwin and Bacchus, 1994. An exposure of 50 milirems per day was an allowable exposure, but alarms sounded at 80 percent of that value.
18. "AEC Sets Radioactivity Study at Idaho Site; College Gets Contract," *Post-Register*, June 19, 1950, 3; "Experts Test Weather Data," *Post-Register*, May 14, 1950, 14.
19. Idaho Department of Labor, *First Biennial Report of the Department of Labor, August 15, 1949—December 31, 1950*, 1.
20. To Governor Robins from W.L. Robison, March 22, 1950, IHS AR2/22, Box 1, File: Arco Atomic Energy Plant-1950, part II. See also "AEC to Organize Medical Program," *Post-Register*, June 21, 1950, 9.
21. (Accident rates) *First Biennial Report*, 25; (ceremony) Idaho Department of Labor, *Third Biennial Report of the Department of Labor, October 31, 1952 to October 1954*, 29.
22. "Committee to Advise AEC on Health in Area," *Arco Advertiser*, March 19, 1954, 3; "Idaho Board Approves AEC Health Safeguards, *Arco Advertiser*, March 26, 1954, 1; "State Committee Ends Meeting at AEC Plant," *Arco Advertiser*, July 22, 1955, 7.
23. (Hospitals) *Ninth Semiannual Report of the AEC*, January 1951, 31; (Idaho hospitals) Dr. Lawrence Knight, interview with author, April 20, 1999; "Mountain States Tumor Institute," supplement in *Idaho Statesman*, May 11, 1997, 2. St. Lukes Hospital in Boise organized an isotope laboratory in 1957 and began cobalt cancer therapy in 1960. (Shoes) Department of Health, Radiation Health Section, "Program for the Regulation and Control of the Use of Radiation in the State of Idaho, 1968," 5, IHS, Samuelson Papers, Box 50, File: Governor Samuelson Nuclear—Misc.
24. "Minutes of the Idaho State Board of Health, April 21-22, 1958; August 4-5, 1958," Minute Book at Idaho State Department of Health and Welfare, Director's Office, Boise, Idaho, p. 58 and 63, respectively. Among early industrial users of radioactive materials was the agricultural industry, which used tracers to help identify the uptake of pesticides or fertilizers in plants.
25. "Program for Regulation and Control... 1968," 5.
26. See, for example, letter to Smylie from Lyall Johnson, Acting Director of the Division of Materials Licensing, AEC-DC, May 13, 1964, in IHS AR2/23, Box 17, File: Atomic Energy.
27. To Governor Smylie from Terrell Carver, August 9, 1963, IHS, Smylie Papers, Box 20, File: Health Department, 1963. See also Minutes of the Board of Health, July 30-31, 1964, p. 241. The IDO/Phillips representatives were C. Wayne Bills, J. Weaver McCaslin, and Tabb O'Brien; "Minutes of the Governor's Committee on the Use of Atomic Energy and Radiation Hazards, February 19, 1964," held at the office of the Department of Labor, Boise. In IHS, Smylie Papers, Box 21, File: Labor Department 1962-1964.
28. To Clinton P. Anderson from T.O. Carver, February 18, 1959; IHS, Mss 84, Box 104, File: Legislative AEC Misc. 1959.
29. "Statement by the Honorable Robert E. Smylie, Governor of the State of Idaho, to the Natural Resources Subcommittee of the Committee on Government Operations," presented at a hearing held November 22, 1963, Seattle, Washington, IHS, AR2/23, Box 25, File: Len Jordan 1962-64. For a review of Idaho/AEC relations regarding housing, grazing, law enforcement, and other matters, see Jack M. Holl, "The NRTS: The AEC in Idaho," 85 *Pacific Northwest Quarterly* (January 1994): 15-24.

Chapter Eight

Epigraph: Idaho Department of Labor, *2nd Biennial Report*, 21. Thanks to Warren Nyer, from whom I first heard the term "reactor zoo."

1. Hewlett, *Atomic Shield*, 497. See also, Holl, *Argonne National Laboratory, 1946-1996*, 99. Holl reports the shortage as 12.5 kilograms of uranium-235, this being the

amount over Zinn's original estimate of 40 kilograms exclusive of the fuel in the extra fuel rods.

2. Kirby Whitham, communication to author, July 9, 1999. According to Whitham, the re-manufactured rods were .010 inches larger in diameter.
3. Hewlett, *Atomic Shield*, 497-98. The significance of the names on the wall is uncertain. According to Richard Lindsay of Argonne-West, not all of the crew members were present during the chalk ceremony; a few added their names later but others did not. The sensibilities of the era were such that the women who ran the EBR office were not included. In 1995 the names of the women were placed on a plaque and installed in the EBR-I building, but the names of missing men have not been so identified. See IDO News Release, March 20, 1995, and "Better late than never for EBR-I women," *Post-Register*, March 24, 1995.
4. "Reactor Staff Weary, Happy" and "Materials Testing Reactor Achieves Operation Stage Here," *Post-Register*, April 4, 1952, 1; and Fred McMillan, interview with author, February 2, 1999.
5. (Squirrels) Jack Clark, interview with author, July 16, 1998; (Doan) John Byrom, August 25, 1998. "Scram" was a slang word meaning, "let's get out of here." Its use as a term for emergency reactor shutdowns originated with CP-1, the first reactor. For safety backup, a man was stationed near a rope restraining a control rod. Should other controls fail, he was to cut the rope, letting the rod fall into place. Someone devised an acronym "Safety Control Rod Ax Man." Another acronym, according to Polmar in *Rickover*, p. 151, was "Super-Critical Reactor Ax Man."
6. John Byrom, August 25, 1998; Phillips Petroleum Company, *The Materials Testing Reactor,A Light Water Moderated Reactor* (Geneva, Switzerland: International Conference on Peaceful Uses of Atomic Energy, 1955) "Research Reactors," p. 352. See also Buck and Leyse, *MTR Handbook*, 352.
7. Buck and Leyse, *MTR Handbook*, 29-30.
8. John Byrom, interviews with author, August 25, 1998, and March 26, 1999. See also E. Fast, J.P. Byrom, and J.W. McCaslin, *A Survey of the Materials Testing Reactor Shield*, Report No. (IDO-16073) (Idaho Falls: Phillips Petroleum Co., n.d.) and Blaw Knox Construction Company, *Barytes Aggregate Concrete Applied to Reactor Shielding*, Report No. IDO-24003 (Idaho Falls: Blaw Knox Chemical Plant Division, 1952).
9. John Byrom, personal communication to author, October 29, 1998.
10. Fred McMillan, interview with author, February 2, 1999.
11. John Taylor, personal communication to author, August 6, 1999.
12. Fred McMillan, February 2, 1999.
13. Simpson, *Nuclear Power*, 47.
14. Simpson, *Nuclear Power*, 53.
15. Schiller, *Colliers*, 91.
16. Polmar and Allen, *Rickover*, 151-152.
17. Polmar and Allen, *Rickover*, 152.
18. Simpson, *Nuclear Power*, 55-56.
19. Polmar and Allen, *Rickover*, 153.
20. The original telegram is located in a Naval Reactors Facility historical scrapbook, 1958.
21. Polmar and Allen, *Rickover*, 615.
22. By the time the Navy laid the keel for *USS Enterprise* on February 4, 1958, it had launched or laid the keel for the submarines *Nautilus, Skate, Seawolf, Swordfish, Sargo, Seadragon*, and *Triton*; and the cruiser *USS Long Beach*.

CHAPTER NINE

1. "Industrial Radioactive Waste Disposal," *Hearings before the Special Subcommittee on Radiation of the JCAE* 86th Cong, 1st session, Volume 1, January 28, 29, and 30; February 2 and 3, 1959 (Wash, D.C.: GPO, 1959). Hereafter, *Radioactive Waste Hearings.*
2. (Quotation) Rafe Gibbs, "The World's Hottest Garbage," *Popular Mechanics* (April 1955): 124-125; (Argonne) Holl, *Argonne*, 57-58.
3. Holl, *Argonne*, 73.
4. B.C. Anderson, et al., *A History of the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory* (Idaho Falls: IDO Nuclear Fuel Cycle Division, 1979), 1. Hereafter, *History of the RWMC.*
5. Anderson, *History of the RWMC*, 2; (precipitation) 1971 *Thumbnail Sketch*, 3.
6. Anderson, *History of the RWMC*, p. 4, 16.
7. Henry Peterson, interview with author, February 3, 1999.
8. Henry Peterson, February 3, 1999; (diapers) Ronald Schiller, *Colliers*, 90; (sanitary pads) Beverly Cook, interview with author, September 7, 1999.
9. Edgar Juell, *A Short History of the Expended Core Facility, 1953 to June 1990* (Idaho Falls: Naval Reactors Facility Expended Core Facility, no date), 1.
10. (General procedures, liquids) Anderson, *History of the RWMC*, 16; (irradiated metal parts) Doan remarks in *Radioactive Waste Hearing*, 601.
11. (Native grasses) Byrom, personal communication; (practices) Anderson, *History of the RWMC*, 16. In current practice, cardboard boxes are no longer used. Waste is packaged in wooden boxes or metal drums, each lined with plastic.
12. For Rocky Flats history, see www.indra.com/rfcab/ FAQ.html#4.
13. Anderson, *History of the RWMC*, 19. The Rocky Flats area was later expanded to eleven square miles. Source: www.cdphe.state.co.us, April 26, 1999.
14. (Nevada/Idaho) Anderson, *History of the RWMC*, 19.
15. John Horan, interview with author, January 15, 1999.
16. John Horan, January 15, 1999. See also Anderson, *History of the RWMC*, 21.
17. *Radioactive Waste Hearing*, 582-583.
18. Anderson, *History of the RWMC*, 21-22. Also, see photo 58-1450. See "Alpha Decay" in John F. Hogerton, *The Atomic Energy Deskbook* (New York: Reinhold Publishing Corp., 1963), 21. Plutonium is highly ionizing and presents a hazard to human health when it is inhaled or ingested.
19. Clyde Hammond, interview with author, October 15, 1998. According to D.H. Card, *Waste Management Program History of Buried Transuranic Waste at INEL*, (Idaho Falls: EG&G Report No. WMP77-3, 1977), 9, Gulf Atomic sent 190 drums and 22 boxes of waste to the NRTS in 1962. Some drums were centered in boxes, and the boxes filled with concrete for shielding. These weighed between 12,000 to 14,000 pounds each.

20. Cass Peterson, "Rocky Flats: Risks Amid a Metropolis," *Washington Post*, December 12, 1988, 1.
21. Anderson, *History of the RWMC*, 22.
22. Clyde Hammond, October 15, 1998.
23. (Backfill) John Commander, personal communication to author, June 29, 1999; (strike) Anderson, *History of the RWMC*, 31; (efficiency) George Wehmann, interview with author, September 29, 1999.
24. Anderson, *History of the RWMC*, 28. According to EG&G, *Waste Management Program, History of Buried Transuranic Waste at INEL*, (Idaho Falls: EG&G Report No. WMP77-3, 1977), p. 8, waste arriving at this time included contaminated materials from other governmental experimental sites around the nation.
25. (Upper limits, flooding, guidelines, Interim Burial Ground) Anderson, *History of the RWMC*, 19, 33, 30, 27.
26. Anderson, *History of the RWMC*, 30; (quotation) *Radioactive Waste Hearing*, 584.
27. Anderson, *History of the RWMC*, 35.
28. Formal definitions of "high-level," "low-level," TRU, spent fuel, and other categories of radioactive waste have changed over time and have become more complex; recent definitions are found in the Energy Policy Act of 1992, Title 10 of the Code of Federal Regulations (CFR), Part 60 and in DOE Order 5820.2A. At the INEEL, high-level waste refers to the solid and liquid wastes resulting from chemical separations done at the Idaho Chemical Processing Plant. TRU waste contains alpha-emitting transuranic elements (like plutonium-contaminated waste from Rocky Flats) with half-lives of 20 years or more and concentrated at 100 nanocuries per gram of waste or more. Low-level waste, typically disposed or stored at the Burial Ground, in general contains lower concentrations of radionuclides per gram of waste than high-level and TRU waste. See DOE, *Linking Legacies* Report No. DOE/EM-0319 (Washington, D.C.: DOE Office of Environmental Management, 1997), pp. 31-70.
29. (Handbook) *Radioactive Waste Hearing*, 581. For the general AEC philosophy on concentrating and reducing volumes of waste, see remarks by Dr. Abel Wolman in the hearing on p. 8-10.
30. *Radioactive Waste Hearing*, 581, 589.
31. *Radioactive Waste Hearing*, 581.
32. Whether to measure the concentration of a contaminant at the point of discharge or at the point of its use downstream later became the subject of regulatory definition.
33. Bruce Schmalz, interview with author, February 1, 1999. See also *Radioactive Waste Hearing*, 589.
34. John Horan, "Draft of Interview, Mr. John Horan" with John K. Harrop and Joseph J. Shonka, Summer 1994, p. 4.
35. *Radioactive Waste Hearing*, 602.
36. John Byrom, personal communication to author.
37. Arrowrock Group, *Context Plan*, 146.
38. (Pellets) Leroy Lewis personal communication to author.
39. See INEELphotos 56-3201, -3203, -3205, -3206, -3207, and -3208.
40. INEL, *Idaho National Engineering Laboratory Historical Dose Evaluation*, Volume 1, Report No. DOE/ID-12119 (Idaho Falls: IDO, 1991), pp. iii, v-vii, 6-8. Later DOE expenditures on the removal of waste from below ground were justified on the basis that these pathways should not ever find a human population at any time in the long-range future.

Chapter Ten

1. Polmar and Allen, *Rickover*, 167.
2. Bettis Plant, *Expended Core Facility, Maintenance and Operations Guide* (Pittsburgh: Westinghouse, 1958), 3. Hereafter, *ECF Guide*.
3. *ECF Guide*, v. The ECF was designed by the AEC's Bettis Atomic Power Laboratory, managed by Westinghouse. Arthur G. McKee & Co. was architect/engineer; and Paul Hardeman, Inc., general contractor.
4. *ECF Guide*, 14. Later equipment allowed for the unloading of a cask without having to plunge the cask into the water.
5. Edgar L. Juell, *A Short History of the Expended Core Facility*, (Idaho Falls: Naval Reactors Facility, 1990), 9-11 (excerpt p. 10).
6. Juell, *A Short History of ECF*, 12.
7. (Three cores) *ECF Guide*, 15; (MTR irradiated fuel) Juell, *A Short History of ECF*, 9.
8. Juell, *A Short History of ECF*, 13.
9. (Early training) "Crews Train in Idaho for A-Submarine," *Idaho State Journal*, February 22, 1953. Thanks to Kenhi Drewes and Hal Paige, interviews with author, February 4, 1999, for discussions of training program.
10. Polmar and Allen, *Rickover*, 297-301.
11. (Rickover quote) Polmar and Allen, *Rickover*, 302; (cross-training) Kenhi Drewes and Hal Paige, February 4, 1999.
12. Ronald Schiller, "Submarines in the Desert," *Colliers* (February 5, 1954): 91.
13. Kenhi Drewes, Hal Paige, February 4, 1999; (cooling pond) Mary Freund, interview with author, February 2, 1999.
14. On aircraft carriers, cargo such as tanks of lubricating oil could be located to offer shielding opportunities around shipboard reactors. *USS Enterprise* was launched on September 24, 1960.
15. Clay Condit, interview with author, August 25, 1999.
16. To Governor from Henry Dworshak, April 8, 1961, IHS Mss 84, Box 122 B, File: AEC-Idaho Plant; to Robb Brady from Henry Dworshak, April 8, 1961, IHS, Mss 84, Box 122 B, File: AEC—Idaho Plant.
17. (Criticality date) *Naval Reactors Facility* pamphlet, no date, no page numbers. For more on the U.S. Navy's quest for silent submarines and the compromises made among silence, depth, and speed, see Tyler, *Running Critical, The Silent War, Rickover, and General Dynamics* (New York: Harper and Row, 1986). See Tom Clancy, *The Hunt for Red October* (Annapolis, Md.: Naval Institute Press, 1984) for a fictionalized account of the competition between the two superpowers; and "Submarines, Secrets, and Spies," a *NOVA* television program produced by the Documentary Guild for WGBH/Boston with Sveriges Television, copyright 1999.
18. Elizabeth S. Rolph, *Nuclear Power and the Public Safety*, 24-26.
19. (Sidebar) U.S. DOE and U.S. Department of Defense, *The United States Naval Propulsion Program* (Washington, D.C.: GPO), 19.
20. Rolph, *Nuclear Power and the Public Safety*, 26.
21. Clay Condit, August 25, 1999.

22. (Steno) Mary Freund; (preparations) Henry Peterson, February 3, 1999; (legend) Hal Paige, February 4, 1999.

CHAPTER ELEVEN

1. Don Reid, in undated transcript of taped interview named "Don Reid's Early CPP History, Cassette Tape # 1," p. 9-10. A second tape was named "Cassette Tape # 2." No copies of the tape were found, nor the name of the interviewer. Transcript supplied to author by Jeff Bryant of INTEC (Chem Plant).
2. Don Reid, Cassette Tape # 1, 14, 16.
3. (AEC plans) Don Reid, Cassette Tape # 1, 14-17. In a bomb detonation, tritium undergoes a fusion reaction with deuterium, producing a generous supply of neutrons which in turn promote the fissioning of plutonium atoms.
4. TWX from C. Vanden Bulck, Oak Ridge National Laboratory, to R. Cook, USAEC, Washington, D.C., August 31, 1953, HREX Doc. No. 0709671.
5. Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon and Schuster, 1986), 574. See also "Human Studies Project Team Fact Sheet, Bayo Canyon/The RaLa Program," January 10, 1994, HREX Doc. No. 0701316, p. 1.
6. To R. Cook, Washington, D.C., from C. Vanden Bulck, acting manager ORNL, August 31, 1953, HREX Doc. no. 0709671. See also John Horan, Summer 1994 interview by John K. Harrop and Joseph J. Shonka, pp. 1-2. Iodine is taken up by the human thyroid gland.
7. General Manager's Diary entry for April 18, 1950, HREX Doc. No. 0723885; to Carroll Wilson, General Manager, AEC, from George Brown, Director of Engineering, AEC, April 25, 1950, HREX Doc. No. 0720687; to George Brown from Ray Knapp, May 3, 1950, HREX Doc. No. 0720685.
8. The hexone process was called REDOX; the tributyl phosphate process, PUREX. In the history of the Chem Plant, there were three accidental criticalities.
9. Succeeding operators were Phillips Petroleum Company, 1953-1966; Idaho Nuclear Corporation, 1966-1971; Allied Chemical, 1971-1979; Exxon Nuclear Corporation, 1979-1984; Westinghouse Idaho Nuclear Corporation, 1984-1994; Lockheed Martin Idaho Corporation, 1994-1999. The Bechtel Corporation assumed responsibility in 1999.
10. Don Reid, Cassette Tape # 2, 6-9.
11. Mark L. Sutton, "ICPP Historical Data," September 8, 1988, 1. Copy supplied to author by Jeff Bryant. This also is source for sidebar, p. 98, "Memories of an Operator Helper at the Chem Plant."
12. R.B. Lemon and D.G. Reid, "Experience With a Direct Maintenance Radiochemical Processing Plant," *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* Volume 9 (Geneva: United Nations, 1956), 536.
13. Don Reid, Cassette Tape No. 2, 15. See also "Uranium Production—ICPPProcessing Runs," Revised 10-1-75, MPH, an ICPP history of production runs; and "AEC Chemical Processing Plant Begins Operation at Arco Site," *Idaho State Journal*, March 15, 1953.
14. Reid, Cassette Tape # 2, 11.
15. Reid, Cassette Tape # 2, 12-14.
16. For a more detailed description of the ICPP's modified PUREX process, see Brewer F. Boardman, *The ICPP (A Factsheet)* (Idaho Falls: Idaho Operations Office, 1957). For a general description of the plant and its operations, see R.B. Lemon and D.G. Reid, "Experience With Direct Maintenance Plant," 532-545.
17. L.A. Decker, "Significant Accomplishments in the History of the ICPP," paper presented at the 1972 National Meeting of the American Chemical Society, San Francisco, California, September 1, 1976, p. 5. In 1969 Idaho Nuclear Corporation designed a denitration facility to convert the liquid into UO_3, a granular solid, for which, see N.J. Rigstad, "ICPPEnvironmental Impact Statement," 1973, a draft manuscript supplied to author by Jeff Bryant, p. 17. The change was stimulated by more stringent packaging and shipping requirements.
18. Dieter Knecht, et al, "Historical Fuel Reprocessing and HLW Management in Idaho," *Radwaste Magazine* (May 1997): 40. See also Richard K. Lester and David J. Rose, "The Nuclear Wastes at West Valley, New York, *Technology Review* (May 1977): 20-21, for discussion of neutralization of acid wastes and its cost; (quotatation) John B. Huff, *Furnace Separations for Radioactive Liquid Wastes* Report No. PTR-241 (Idaho Falls: 1957, PPCo.), 8.
19. See Cyril M. Slansky and John A. McBride, "The Case for Small Reprocessing Plants, *Nucleonics* (September 1962): 43-56.
20. Knecht, "Historical Fuel Reprocessing," 40. The ratio of ten gallons of fission product to one million gallons of stored waste was noted in a letter from John B. Huff to Henry Dworshak, August 18, 1958, IHS, Ms. 84, Box 83, File: AEC-Idaho Plant. Geneva Conference *ICPP Report*, p. 534, says low-activity waste was "discharged directly to the ground." Boron is a neutron "poison," a material that absorbs neutrons and helps prevent accidental criticalities.
21. N.J. Rigstad, "ICPP EIS," 1973, p. 7, manuscript provided to author by Jeff Bryant. For a summary of how process chemistry progressed, see Dieter A. Knecht, "Historical Fuel Reprocessing," 35-47. Between 1953 and 1988, the Chem Plant recovered 31,432 kilograms of U-235.
22. Don Reid, Cassette Tape # 2, 17-18. See also Rigstad, 12. The fuel cutting facility was at CPP-603, the Fuel Storage Facility. It had to be modified to receive and unload fuel arriving in 75-ton casks, heavier than earlier casks.
23. (Dates of RaLa program) U.S. DOE, INEL Historical Dose Evaluation Report No. DOE/ID-12119 (Idaho Falls: DOE/IDO, 1991), Vol. 1, p. A-26. The program was under design and cold testing from March 1954 to November 1956. For a description of the RaLa cell, see Cyril M. Slansky and John A. McBride, "The Case for Small Reprocessing Plants," Nucleonics (September 1962): 44-45; (Operating practices) E.R. Ebersole, "RaLa Monitoring Experience" in A Compendium of Information for Use in Controlling Radiation Emergencies, delivered at a Conference in Idaho Falls on February 23, 1958, HREX Doc. No. 704450; (procedures in early years of RaLa runs prior to addition of filtration equipment) John Horan, interview with Harrop and Shonka, Summer 1994, pp. 2, 4-6; (iodine retention), Phillips Petroleum Company, Idaho Chemical Processing Plant (Idaho Falls: PPCo, n.d., but circa 1965), 33.
24. John Byrom, note to author, June 24, 1999. See also Horan, interview with Harrop and Shonka, Summer 1994, pp. 4-5; and Horan, interview with Baldwin and Bacchus, HREX Doc. No. 0726467, pp. 26-27.

25. John Horan, interview with Burton Baldwin and Thomas Baccus, August 18, 1994, p. 5-6, "redacted version" in HREX Doc. No. 0726467.
26. John R. Horan, *Annual Progress Report, Health and Safety Division, 1962*, Report No. IDO-12033, p. 43, HREX Doc. No. 702992.
27. *INELHistorical Dose Evaluation*, iii.

Chapter Twelve

1. "Johnson Leaves Position as Idaho AEC Manager, *Arco Advertiser*, April 30, 1954, 4. Also, Jacqui Johnston Batie and William Ginkel, interviews with author, October 14, 1998, and February 3, 1999, respectively.
2. (Consolidation) "AEC Contractors Study Merger Move," "Phillips Plans AEC Merger," "Phillips Ends Merger Soon," *Post-Register*, August 24, August 27, and October 8, 1953, respectively; (employee attitudes) Bernice Paige, April 8, 1999.
3. Eisenhower's policy domination is a central theme of Richard G. Hewlett and Jack M. Holl in *Atoms for Peace and War 1953-1961* (Berkeley: University of California Press, 1989), xxi; (defense spending) Harry S. Truman, *Memoirs, Years of Trial and Hope*, Volume 2 (Garden City, N.Y.: Doubleday and Co., 1956), 306-312; (quotation) Dwight David Eisenhower, *Mandate for Change, 1953-1956* (Garden City, N.Y.: Doubleday and Co., 1965), 452; (massive retaliation) Chester J. Pach, Jr., and Elmo Richardson, *The Presidency of Dwight David Eisenhower* (Lawrence: University Press of Kansas, 1991), 76-81. The Army's share of the budget shrank from 33 percent to 25 percent, and the Air Force's grew from 39 percent to 47 percent.
4. (Scare the country, Atoms for Peace quotations, Operation Candor) Herbert S. Parmet, *Eisenhower and the American Crusades* (New York: Macmillan Company, 1972), 386; (national objectives) U.S. AEC, *Major Activities in the Atomic Energy Programs, January—June 1953 U.S. Atomic Energy Commission* (Washington, D.C.: U.S. AEC, 1953), 18.
5. (Quotation) Hewlett, *New World,* 5.
6. Public Law 83-703 was adopted by the Second Session of the 83rd Congress and became effective August 30, 1954.
7. J.W. Henscheid, interview with author, December 10, 1998.
8. J.R. Huffman, *MTR Technical Quarterly Report, Second Quarter 1954*, Report No. IDO-16191 (Idaho Falls: PPCo, 1954), 17; and Huffman, *MTR Technical Quarterly Report, Third Quarter 1954*, Report No. IDO-209, 12.
9. Deslonde deBoisblanc, interview with author, January 16, 1999.
10. R.L. Heath, *Scintillation Spectrometry, Gamma-Ray Spectrum Catalogue*, 2nd edition, Report No. IDO-16880-1 (Idaho Falls: PPCo, 1964). Report number for the first edition was IDO-16408. According to D.R. deBoisblanc, Heath "pushed the resolution by more than a factor of sixteen using lithium-drifted germanium and silicon, plus low noise amplifiers employing liquid nitrogen-cooled field effect transistors. He also introduced the use of digital computers to reduce the data."
11. *1965 Thumbnail Sketch* (Idaho Falls: Idaho Operations Office, 1965), 17; deBoisblanc, July 14, 1999.
12. (Hydraulic rabbit) US AEC, *Major Activities in the Atomic Energy Program July—December 1953*. (Washington, D.C.: US AEC, January 1954), 25; (Argonne loop) L.W. Fromm, *Design Evaluation of In-Reactor Tube for Argonne Water Loop at MTR*, Report No. ANL-5403 (Lemont, Illinois: Argonne National Laboratory, 1955), 5.
13. W.E. Nyer, et al. *Proposal for a Reactivity Measurement Facility at the MTR*, Report No. IDO-16108 (Idaho Falls: PPCo, 1953), 6-8.
14. J.W. Henscheid, personal communication to author, December 10, 1998.
15. J.R. Huffman, *MTR Technical Branch Quarterly Report for First Quarter 1955*, Report No. IDO-16229 (Idaho Falls: PPCo, 1955), 24.
16. Pamphlet, *Gamma Irradiation Facility, A Fact Sheet*, no author, p. 3-5, found attached to *1957 Thumbnail Sketch*.
17. Walter C. Sparks, interview published in Susan M. Stacy, ed., *Conversations, A Companion Book to Idaho Public Television's "Proceeding On Through A Beautiful Country)* (Boise: Idaho Educational Public Broadcasting Foundation, 1990), 266-267.
18. Walter C. Sparks, interview with author, May 13, 1999.
19. Sparks, May 13, 1999; George A. Freund, *Suitability of Potato Products Prepared from Irradiated and Chemically Inhibited Potatoes* and Freund, *Current Status and Potential of Irradiation to Prevent Potato Sprouting*, Reports No. IDO-10042 and IDO-11300-Addendum, respectively, both (Idaho Falls: Western Nuclear Corporation in cooperation with Engineering Committee, Potato Processors of Idaho, February 1965); and "Commercial Interest Increasing Rapidly in Food Irradiation, *Nucleonics* (December 1963): 23.
20. (40 megawatts) IDO-16254, 6; (questions) see series of Phillips Technical Branch quarterly reports for 1955 through 1957.
21. W.P. Connor, *MTR Technical Branch Quarterly Report*, Report No. IDO-16297 (Idaho Falls: PPCo, 1956), 5.
22. "Test Reactors—The Larger View," *Nucleonics* (March 1957): 55.
23. Philip D. Bush, "ETR: More Space for Radiation Tests," *Nucleonics* (March 1957): 41-42. The extra depth required for the control rods meant that a portion of the foundation had to be blasted through lava rock. See also R.M. Jones, *An Engineering Test Reactor for the MTR Site (A Preliminary Study)*, Report No. IDO-16197 (Idaho Falls: PPCo, 1954), 7.
24. *1965 Thumbnail Sketch*, 14; J.W. Henscheid, December 10, 1999. For more information on the ETR, see "ETR: More Space for Radiation Tests," *Nucleonics* (March 1957): 41-56.

Chapter Thirteen

1. Horan, Baldwin and Baccus 1994 interview, HREX Doc. No. 0726467. Bracketed inserts within quotation are from *INELHistorical Dose Evaluation*, Volume 2, pp. A-180 to A-182.
2. (Johnston announcement) "AEC to Add Aircraft Unit Here," *Post-Register*, July 29, 1952, 1; See "AEC Announces Preliminary Plans for Airplane Reactor Will be Ready Around November 15," *Arco Advertiser*, November 7, 1952, 1; "AEC Sets January 30 as Bid Opening Date for $6,000,000 Facilities at Aircraft Reactor Site," *Post-Register* (assumed), January 3, 1953, 1; "Utah Construction Low Bidder on AEC Aircraft Reactor," *Arco Advertiser*, February

20, 1953; "Contact Let for AEC Aircraft Propulsion Reactor," *Arco Advertiser*, March 27, 1953, 1; "AEC Announced Bids for the Construction of an Access Road to the Prototype Aircraft Propulsion Reactor," *Post-Register*, August 31, 1952.

3. "Allan C. Johnson Gets Idaho AEC Post; Bowden Goes to FOA," *Post-Register*, May 13, 1954, 1; "Allan Johnson Named New AEC Manager, *Arco Advertiser*, May 14, 1954, 1.
4. William Ginkel, February 3, 1999. For detailed history of Aircraft Nuclear Propulsion Program, see Susan M. Stacy, Historical American Engineering Record, *Idaho National Engineering Laboratory, Test Area North, Hangar 629*, HAER NO. ID-32-A(Idaho Falls: LMITCO, 1995).
5. Hewlett, *Atomic Shield*, 71-74, 106.
6. John Tierney, "Take the A-Plane: The $1 Billion Nuclear Bird that Never Flew," *Science 82* (January/February 1982): 49; also Henry W. Lambright, *Shooting Down the Nuclear Airplane* (Syracuse, N.Y.: Inter-University Case Program, No. 104, 1967), 5.
7. To Senator William F. Knowland from Henry Dworshak, November 24, 1956; IHS Dworshak Papers, Box 59, File: Legis AEC Miscellaneous.
8. Among the public relations documents produced by General Electric in 1959 was *Idaho Test Station, Idaho Falls, Idaho*, a pamphlet describing GE's activities concerning the ANP program. It includes explanations and diagrams explaining the direct cycle concept. Copy in Dworshak Papers, Box 112 File: AEC Idaho Plant. Pratt and Whitney contracted to develop the indirect cycle, but got a late start due to contract disputes.
9. Carl Gamertsfelder, "Oral History of Health Physicist Carl C. Gamertsfelder," January 19, 1995, Report No. DOE/EH-467 *Human Radiation Studies: Remembering the Early Years*.
10. (ANPmanagement structure) Kenneth Gantz, ed., *Nuclear Flight* (New York: Duell, Sloan and Pearce, 1960); John Horan, interview with author, July 14, 1998.
11. General Electric, *Nuclear Power Plant Testing in the IET*, Report No. APEX-131 (Cincinnati: Aircraft Nuclear Propulsion Program, Aircraft Gas Turbine Division, May 1953), 5.
12. For description of HTREs, see G. Thornton, A.J. Rothstein, and D.H. Culver, ed. *Comprehensive Technical Report, General Electric Direct-Air-Cycle Aircraft Nuclear Propulsion Program, Program Summary and References*, Report No. APEX-901 (Cincinatti: GE ANP Department, Atomic Products Division, 1962),
19. See also news release, "General Electric ANPDepartment Completes Testing of Heat Transfer Experiment No. 3," issued by AEC IDO, January 27, 1961, Dworshak Papers, Box 122-B, File: Atomic Energy Commission, Idaho Press Releases.
13. General Electric, *ANPP Engineering Program Progress Report No. 18*, Report No. APEX-18 (Cincinatti: GE ANP, 1955), 7; APEX-901, 37; Tierney, "Take the A-Plane," 50.
14. (Shield weight) Tierney, "Take the A-Plane," 50; APEX-18, 195.
15. Gamertsfelder, "Oral History," Report No. DOE/EH-0467.
16. Comptroller General of the United States, *Review of Manned Aircraft Nuclear Propulsion Program, Atomic Energy Commission and Department of Defense, Report to the Congress of the United States* (Washington, D.C.: General Accounting Office, 1963), 138. Congress authorized construction of the FET(hangar), support buildings, and a runway in July 1955. Detailed design commenced in March 1956, and groundbreaking occurred in September 1957. The facility was ready in July 1959. Hereafter, Comptroller General.
17. Richard Meservey, interview with author, October 12, 1998.
18. AEC/IDO news release, "General Electric ANPDepartment Completes Testing of Heat Transfer Experiment No. 3," January 27, 1961, IHS, Dworshak Papers, Box 122-B, File: Atomic Energy Commission, Idaho Press Releases. See also "HTRE - 3 Completes 120 Hours of Operation," *GE News, Idaho Test Station, Aircraft Nuclear Propulsion Department* (April 1, 1960): 1. Issue found in IHS, Dworshak Papers, Box 112, File: AEC Idaho Plant; and APEX-901, p. 50, 57.
19. John Horan, interview with Baldwin and Baccus, HREX Doc. No. 0726467, p. 7. See also Gamertsfelder, DOE/EH-0467.
20. APEX-18, 196.
21. (Runway) "Proposed ANPRunway Area," Drawing No. 7-ANP-001-2 2/2, and "ANP Runway Profile," 7-ANP-001-3, shown to author by Bud White, INEL; copies available at Record Storage Center, Central Facilities Area, INEEL; (quote), Comptroller General, 39, 52.
22. Gantz, *Nuclear Flight*, 175, 178.
23. D.J. Blevins, et al. *Flight Engine Test Facility Design Criteria*, Report No. APEX-225 (Idaho: GE ANPDepartment Idaho Test Station, 1955), 15-21.
24. See samples of mail to Henry Dworshak: telegram from Robb Brady, Idaho Falls *Post-Register*, January 29, 1961; letter from (Idaho State Senator) C.A. Bottolfsen, March 2, 1961; IHS Dworshak Papers, Box 122-B, File: AEC Idaho Plant.
25. David F. Shaw, "General Manager's Report" and "GE Ready to Perform First Experimental Flight in 1963,"*Aircraft Nuclear Propulsion Department News* (March 31, 1961): 1.
26. Letter to Bottolfsen from Henry Dworshak, March 7, 1961; dayletter to J. Robb Brady from Henry Dworshak, March 8, 1961; IHS Dworshak Papers, Box 122-B File: Atomic Energy Commission Idaho Plant.
27. Arthur M. Schlesinger, Jr., *A Thousand Days, John F. Kennedy in the White House* (Boston: Houghton Mifflin, 1965), 300-301, 307. See also Herbert York, *Race to Oblivion* (New York: Simon and Schuster, 1970), 29.
28. "Kennedy Asks $2 Billion Defense Insurance Hike," and "A-Plane Work Halt Asked by JFK in Defense Message," *Idaho Daily Statesman*, March 29, 1961, p. 1, 6 respectively.
29. To President John F. Kennedy from Governor Robert E. Smylie, March 29, 1961; IHS Dworshak Papers, Box 122-B, File: Atomic Energy Commission Idaho Plant.
30. "Kennedy Wants A-Plane Junked, New GE Effort," *Post-Register*, March 28, 1961, 1.
31. Jay Kunze, interview with author, February 5, 1999.
32. (Expense) Comptroller General, 113; "ANP Termination Leaves Vast Facilities, Big Technical Legacy," *Nucleonics* (August 1961): 26-27. See also letter from John W. Morfitt, Manager, ANPD, to Henry Dworshak, September 26, 1961; both in

Dworshak Papers, Box 122 B, File: AEC Idaho Plant.

Chapter Fourteen

Epigraph: "Transient Studies," *Nucleonics* (June 1960): 115.

1. Plastino, *Coming of Age*, 64; Holl, *Argonne*, 118. The acronym comes from the letters BOiling water Re Actor eXperiment.
2. Holl, *Argonne*, 118; Andrew W. Kramer, *Understanding the Nuclear Reactor* (Barrington, Illinois: Technical Publishing Co., 1970), 37, 70.
3. J.R. Dietrich and D.C. Laymans, *Transient and Steady State Characteristics of a Boiling Reactor: The Borax Experiments, 1953*, Report No. ANL-5211, February 1954; Holl, *Argonne*, 118; Plastino, *Coming of Age*, quoting Ray Haroldsen, 64.
4. Holl, *Argonne*, 118.
5. Holl, *Argonne*, 119.
6. Holl, *Argonne*, 120; (talk of dynamite), Clyde Hammond, interview with author, October 15, 1998.
7. Plastino, *Coming of Age*, quoting Haroldsen, 64.
8. For account of 1955 Geneva Conference, see Laura Fermi, *Atoms for the World: United States Participation in the Conference on the Peaceful Uses of Atomic Energy* (Chicago: University of Chicago Press, 1974).
9. Plastino, *Coming of Age*, 64-65. The addition of the generating equipment earned BORAX-II its new designation as BORAX-III. BORAX-IV was BORAX-III with a new core made of a fuel containing Thorium Oxide and Uranium Oxide.
10. "Arco First City in United States Lighted by Atomic Power," *Arco Advertiser*, August 12, 1955, 1; "Arco Gets Premier Showing of AEC Film, *Arco Advertiser*, August 19, 1955, 1; Plastino, *Coming of Age*, 65.
11. (Borax tests) Argonne National Laboratory, *Annual Report for 1959*, ANLReport No. ANL-6125 (Chicago: ANL, 1959), 94. See also J.O. Roberts, "Selected Operating Experience of Commission Power Reactors," a paper presented to the American Institute of Electrical Engineers, June 18, 1961, in IHS, Ms 84, Box 122 B, File: AEC-Press Releases; (EBWR) Holl, *Argonne*, 150; Robert L. Loftness, *Nuclear Power Plants: Design, Operating Experience, and Economics*, (Princeton, N.J.: Van Nostrand (Nuclear Science Series), 1964), 167-213; to Senator Dworshak from Francis K. McCune, GE, September 25, 1958; IHS, Ms 84, Box 104, File: Legislative AEC Misc 1959.
12. Reactor safety programs also took place at other national labs; ie, Kinetic Energy Water Boilers (KEWB) were safety tested at Los Alamos.
13. Richard L. Doan, "Two Decades of Reactor Safety Evaluation," Memorial Lecture in honor of Dr. C. Rogers McCullough prepared for Winter Meeting of the American Nuclear Society, Washington, D.C., November 15-18, 1970, p. 3. For general histories of reactor safety, see George T. Mazuzan and J. Samuel Walker, *Controlling the Atom* (Berkeley: University of California Press, 1984) and J. Samuel Walker, *Containing the Atom* (Berkeley: University of California Press, 1992).
14. Jack M. Holl, et al., *United States Civilian Nuclear Power Policy, 1954-1984: A History* (Washington, D.C., U.S. DOE, 1985), 4.
15. Warren Nyer, interview with author, February 1, 1999.
16. (Location) T.R. Wilson *An Engineering Description of the SPERT-1 Reactor Facility*, Report No. IDO 16318 (Idaho Falls: ANL, 1957), 8. (vocabulary) to Glenn Seaborg from Senator Dworshak, November 16, 1961, IHS MS 84, Box 122 B, File: AEC-Idaho Plant.
17. "SPERT-2 Features Versatility," Nucleonics (June 1960): 120; pamphlet, "Special Power Excursion Reactor Tests" (Idaho Falls: Phillips Petroleum Company, n.d.), 18.
18. Nyer, February 1, 1999.
19. "Special Power Excursion Reactor Tests," (Idaho Falls: Phillips Petroleum Company. n.d.); Warren Nyer, February 1, 1999.
20. Detroit Edison led a consortium of utility companies called the Power Reactor Development Company.
21. Holl, *Argonne*, 115-116.
22. J.O. Roberts, "Selected Operating Experience," 37.
23. Holl, *Argonne*, 141-143.
24. "AEC Tells How Reactor Failed," *Business Week* (April 14, 1956): 34; Jerome D. Luntz, "Nuclear Accidents Are Everybody's Business, *Nucleonics* (May 1956): 39.
25. Argonne National Laboratory, *Annual Report for 1957*, Report No. ANL-5870 (Chicago: ANL, 1958), 83.
26. Loftness, *Nuclear Power Plants*, 339; ANL-West, *EBR-II since 1964* (Idaho Falls: ANL-W, 1983).
27. For design and other details, see George Freund, et al, *Design Summary Report on the Transient Reactor Test Facility, TREAT*, Report No. ANL-6034 (Chicago: ANL, 1960).
28. ANL, *Annual Report 1959*, 102; Edmund S. Sowa, "First TREAT Results—Meltdown Tests of EBR-II Fuel," *Nucleonics* (June 1960): 122-124.
29. These were the Argonne Fast Source Reactor (AFSR) and Zero-Power Reactor Three (ZPR-III). ZPR-I and -II were not located at the NRTS.
30. "About the Idaho Division..." (Idaho Falls: Argonne Idaho Facilities, 1964), Fact Sheet EBR-II, page 1-2. The approach to design-level power production was gradual, attained on September 25, 1969.

Chapter Fifteen

Epigraph: Interview of George Voelz, "Remembering the Early Years," Report No. DOE/EM 0454, November 29, 1994, HREX Doc. No. 0727845.

1. Lawrence H. Suid, *The Army's Nuclear Power Program, The Evolution of a Support Agency* (New York: Glenwood Press, 1990), p. 3-8, 82. For technical detail on the SL-1 reactor and artist's renderings of DEWLine packages, barge-mounted reactors, and other applications, see "Army Reactor Program," *Nucleonics* (February 1969): 53-54 and insert. See also ANL *Annual Report 1958*, Report No. ANL-5980 (Lemont, Illinois: ANL, 1959), 53-55.
2. For a history of the Army Reactor Program at the NRTS, see Susan M. Stacy, Historical American Engineering Record, Idaho National Engineering Laboratory, *Army Reactor Experimental Area, HAER No. ID-33-D*.
3. Suid, *Army's Nuclear Program*, 83.
4. See "Description of ALPR," *Nucleonics* (February 1958), and pull-out section following p. 54.
5. Argonne had named the reactor "Argonne Low Power Reactor," or ALPR.

6. The GCRE was the eighth reactor type developed by the AEC Nuclear Reactor development program, selected for both military and civilian potential. The name of the AREAreactor complex was changed later to ARA(Army Reactor Area) and still later to ARA(Auxiliary Reactor Area). U.S. AEC press release, June 6, 1956; IHS Dworshak Papers, Mss 84, Box 55, File: AEC—Idaho Plant.
7. Norman Engineering Co., *Master Plan Study for the Army Reactor Experimental Area*, Report No. IDO-24033 (Idaho Falls: Norman Engineering, 1959), Section II (no p.n.).
8. R.T. Canfield, *SL-1 Annual Operating Report, February 1959-February 1960*, Report No. IDO 19012 or CEND-82 (Idaho Falls: Combustion Engineering, 1960), 7. SL-1 was the first power plant reactor in the country to use aluminum-clad fuel elements, which heretofore had been used only in test reactors like the MTR. A new alloy overcame the low melting point of aluminum, and after SL-1, aluminum alloys were used widely. See Suid, *Army's Nuclear Program*, 83.
9. "SL-1 Explosion Kills 3; Cause and Significance Unclear," *Nucleonics* (February 1961): 17.
10. See drawing in *Nucleonics*, (February 1969): 54 ff. The fuel zone was 27.8 inches long.
11. (Water hammer) General Electric, *Final Report of SL-1 Recovery Operation* (Idaho Falls: GE Report No. IDO-19311, 1962), p. I-6.
12. Staff of the JCAE, "Summary of the SL-1 Reactor Incident at the National Reactor Testing Station in Idaho on January 3, 1961," January 10, 1961, IHS, Dworshak Papers, Box 122 B, File: AEC Id Press Releases. Other details of the accident were reported in *Nucleonics* (February 1961): 17-23; and in a series of press releases from the Idaho Operations Office after the accident, copies in Dworshak papers.
13. "Sequence of Events Related to the SL-1 Accident at the National Reactor Testing Station, Idaho, on January 3, 1961." HREX document #0715561. No author or date. This report was an appendix to an unidentified AEC document. See also *Nucleonics* (February 1961); and "Detailed Events Chain at SL-1 Reactor Told," *Post-Register*, January 12, 1961.
14. A Class II event would impact other facilities on the site; a Class III, territory beyond the boundaries of the Site. A road block was not required. C. Wayne Bills recalled that the HPs may have stopped one or two autos in order to determine whether their tires had picked up any contamination.
15. SL-1 Report Task Force, *IDO Report on the Nuclear Incident at the SL-1 Reactor on January 3, 1961, at the National Reactor Testing Station*, Report No. IDO-19302 (Idaho Falls: Idaho Operations Office, 1962), 54.
16. "Big Hazard at Idaho Atom Site? Traffic Accidents, Says Nurse," *Post-Register*, February 23, 1961.
17. Dr. George Voelz, "Remembering the Early Years," Oral History Interview, November 29, 1994, HREX Doc. No. 0727845.
18. The men were Specialist 5 John A. Byrnes, 27, U.S. Army; Specialist 4 Richard L. McKinley, 22, U.S. Army; and Construction Electrician Richard C. Legg, 26, U.S. Navy. Byrnes had been certified at SL-1 in February 1960; Legg, in September 1960. McKinley was a trainee.
19. John Horan, interview with author, July 16, 1998.
20. Horan, July 16, 1998.
21. "Findings of the Board of Investigation," *Nuclear News* (July 1961): 15.
22. *INELHistoric Dose Evaluation, Volume 2*, p. A-83 to A-85. See also *Volume I* map, p.27.
23. (Squad rescue) Staff of the JCAE, "Summary of the SL-1 Reactor Incident," 2-3; (GCRE decontamination, logbook, neutron detector) film "The SL-1 Accident," (Idaho Falls: Idaho Operations Office).
24. The General Manager's Board of Investigation, *Report on the SL-1 Incident, January 3, 1961,* Press Release No. 61-24 (SL-1), (Idaho Falls: Idaho Operations Office, June 11, 1961), 31.
25. (Team recovery) IDO Press release, January 9, 1961, Dworshak Papers, box 122 B; (Dugway, mockup, procedures) film "The SL-1 Accident."
26. George Voelz, M.D., November 29, 1994; John Horan and Wayne Bills, "What Have We Learned? Health Physics at SL-1," *Nucleonics* (December 1961): 48.
27. (Luedecke proposal) John Horan, July 16, 1998; (caskets) "Blast Victim's [sic] Rites Await AEC Action," *Salt Lake Tribune*, January 17, 1961; (lead wrap) C. Wayne Bills, February 3, 1999; "Military Gets Bodies of NRTS Victims," *Post-Register*, January 23, 1961; "Atom Victim is Buried in Lead Vault," *Utica Observer-Dispatch*, January 25, 1961; "ACatastrophe New to Man," *New York Herald Tribune*, January 29, 1961. The AEC required that the cemeteries accepting the caskets must have perpetual care, that the graves not be disturbed without AEC permission, and that the graves be shielded with concrete and dirt.
28. Jay Kunze, February 5, 1999. The AEC contracted General Electric to disassemble and analyze the reactor on May 5, 1961; (Dugway) C.W. Bills, personal communication, June 25, 1999.
29. Kunze, February 5 and July 6, 1999.
30. Kunze, February 5, 1999.
31. (Crane) Wayne Bills, interview with author, February 3, 1999; (vessel in transit) General Electric, *Final Report of SL-1* p. II-37, II-39. See also "SL-1 Reactor Core Trucked to Hot Cell for Study," *Arco Advertiser*, December 8, 1961, 3.
32. General Electric *Final Report*, ii.

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1. (Monster quote) Robert F. Alkire, "'Monsters'Huddle in Weird Stillness," Associated Press story published in *Salt Lake Tribune*, January 8, 1961, and as "Moon-like Eastern Idaho Desert Scene of Nuclear 'Monster' Runaway," in *Idaho Daily Statesman*, same date, 5; (sleeping quote) "A-Reactors Won't Blow Us Up," *The Deseret News and Telegram*, January 6, 1961.
2. (Mishaps) "NRTS Marks First Fatal Atomic Mishap," *Idaho Daily Statesman*, January 5, 1961; (instructed) Frank Carey, "Chemical Explosion in Nuclear Reactor Potentially More Perilous than A-`Blast,' *Idaho Daily Statesman*, January 5, 1961.
3. The IDO compiled 154 press clippings from around the country in a document "The SL-1 Accident, Press Clippings." A copy is extant at the IDO public information office in Idaho Falls, Idaho.
4. (Siting) John W. Finney, "Blast Stresses A-Question," *Salt Lake Tribune*, January 5, 1961; (set back) "What Happened in

Nuclear Blast," *Business Week*, January 7, 1961.

5. (Reuther quote) "Press Release from Industrial Union Department of AFL-CIO, January 5, 1961, at IHS, Ms 84, Box 122 B, File: "AEC-Idaho Plant;" (defeat) "AMonth After the Idaho Accident," *Oak Ridger*, February 6, 1961.

   The forty-item list included incidents such as the MTR fuel rod with a pin-hole leak (described in Chapter 12) and similar events that had occurred in other AEC facilities across the country. The information was available for review in unclassified AEC literature.

6. To Senator Henry Dworshak from Donald E. Seifert and George Dragich, May 11, 1061, in IHS, Mss 84, Box 122 B, File: AEC-Idaho Plant.

7. To Senator Dworshak from John T. Conway, June 20, 1961, IHS, Mss 84, Box 122 B, File: AEC Miscellaneous.

8. (Wilson) To Senator Dworshak from John T. Conway, acting executive director of JCAE, June 1, 1961, in IHS, Mss 84, Box 122 B, File: AEC-Idaho Plant.

9. Atomic Energy Commission Investigation Board, *SL-1 Accident* (Washington, D.C.: Joint Committee Print, U.S. Government Printing Office, 1961), ix.

10. "Johnson Resigns at AEC," *Arco Advertiser*," December 8, 1961, 1; John Horan, C. Wayne Bills interviews with author, July 16, 1998, and February 2, 1999, respectively.

11. To Ramey from A.R. Luedecke, January 12, 1961, in IHS, Mss 84, Box 122 B, File: AEC-Idaho Press Releases; "AEC Surveys Safety of Licensed Reactors," *Post-Register*, January 13, 1961; "Safety Survey Launched for all Reactors Licensed by AEC," *Idaho Daily Statesman*, January 13, 1961; "AEC Asks U. Bolster Reactor Safety," *Salt Lake Tribune*, January 13, 1961.

12. J.W. Henscheid, interview with author, December 10, 1998.

13. David Okrent, *On the History of the Evolution of Light Water Reactor Safety in the United States* (Los Angeles: University of Los Angeles, 1978), pp. 6-102 to 6-106. Okrent reproduces a letter from the ACRS to A.R. Luedecke, December 31, 1962.

14. (Greenland) To Ramey from Luedecke, January 12, 1961, op cit.; (ML-1) AEC/Idaho Operations press release, February 11, 1961, IHS, Dworshak Papers, Box 122 B, File "AEC—Press Releases." Also, Hogerton, *Atomic Energy Desk Book*, 33. The Army operated SM-1 at Fort Belvoir; SM-1Aat Fort Greeley, Alaska; PM-2Aat Camp Century, Greenland; PM-1 at Sundance Air Force Base, Wyoming; PM-3Aat McMurdo Sound, Antarctica; PL-3 at Byrd Station; and *Sturgis*, a barge.

15. (Power dates) Suid, *Army's Nuclear Program*, 91.

16. T.L. Murphy, *Final Disassembly and Examination of the ML-1 Reactor Core*, IDO-171-90, (Idaho Falls: PPCo, 1966), 110-111; "Economic Military Power Arrives, But Pentagon Hesitates," *Nucleonics* (April 1960): 27; Suid, *Army's Military Reactors*, 92-93. See also Stacy, *Army Reactor Experimental Area, HAER No. ID-33-D*.

17. The SL-1 Burial Ground was regraded and recontoured in 1997 after a 1996 "Record of Decision" signed by the Department of Energy, the Environmental Protection Agency, and the State of Idaho. The new natural-material "cap" was to improve the isolation of hazardous materials from humans and the surrounding environment. Erik Simpson, "Agencies agree to cap reactor burial grounds," *INELNews* (February 6, 1996): 7.

18. "Reactor Safety: Accident Control Study," *Nucleonics* (April 1964): 28. See John R. Horan and C. Wayne Bills, "What Have We Learned? Health Physics at SL-1," *Nucleonics* (December 1961): 48; Voelz, November 29, 1994. The film, "The SL-1 Accident," produced by Idaho Operations Office circa 1962, was in three parts, Phase 1, 2, and 3. All were converted to video format.

19. C. Wayne Bills, personal communication to author, June 25, 1999.

20. (Exposures) *IDO Report on the Nuclear Incident at the SL-1*, 27; John R. Horan and C. Wayne Bills, "What Have We Learned? Health Physics at SL-1," *Nucleonics* (December 1961): 43.

21. "Rescue, Control Crews Honored for Service After SL-1 Blast," *Post-Register*, March 6, 1962, 12; "AEC Honors Participants in SL-1 Reactor Emergency," March 6, 1962, IDO Press Release, IHS, MS 84, Box 124, File: AEC Idaho Plant.

22. See for example Harvey Wasserman and Normon Solomon, *Killing Our Own, The Disaster of America's Experience with Atomic Radiation* (New York: Delacorte Press, 1982); John Fuller, *We Almost Lost Detroit* (New York: Reader's Digest Press, 1975); John May, *The Greenpeace Book of the Nuclear Age* (New York: Pantheon Books, 1989); Leslie J. Freeman, *Nuclear Witnesses: Insiders Speak Out* (New York: W.W. Norton and Co., 1981).

Chapter Seventeen

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1. "Johnson Resigns at AEC," *Arco Advertiser*, December 8, 1961, 1; C. Wayne Bills, interview with author, February 3, 1999.

2. William Ginkel, interview with author, October 13, 1998.

3. Warren Nyer, "Recollections and Reflections," *Idaho ANS Newsletter* (June 1989): 9.

4. The following quotations and information regarding the ATR not otherwise noted are from Deslonde deBoisblanc, interviews and personal communications with author, August-September 1999.

5. D.R. deBoisblanc, *The Advanced Test Reactor—ATR—Final Conceptual Design*, Report No. IDO-16667 (Idaho Falls: Phillips, 1960), 11-13; and Deslonde deBoisblanc, personal communications.

6. Deslonde deBoisblanc, personal communications to author, August 23 and September 2, 1999.

7. Deslonde deBoisblanc, communication to author, August 23, 1999.

8. For additional information on the ATR, see D.R. deBoisblanc et al, *The Advanced Test Reactor—ATR Final Conceptual Design*, Report No. IDO-16667 (Idaho Falls: PPCo, 1960). See pamphlet, *Advanced Test Reactor* (Idaho Falls: Idaho Nuclear Corporation, no date) for addition description of the reactor.

9. "Idaho Rites Start Record Atom Job," *Post-Register*, no date, p. 1, 12, clipping in IHS, Ms. 84, Box 124, File: AEC-Idaho Plant, 1961.

10. Letter to Senator Dworshak from Richard Donovan, November 7, 1961, IHS, Ms. 84, Box 122 B, File: AEC Miscellaneous; (Geneva) IDO Press Release, September 11, 1958, at IHS, Ms. 84, Box 83, File: AEC-

Idaho Plant; R.L. Doan, "MTR-ETR Operating Experience," *Nuclear Science and Engineering* (January 1962): 23-24, 26; Idaho Operations Office, *1965 Thumbnail Sketch* (Idaho Falls: Idaho Operations Office, 1965), 15.

11. R.L. Doan, "MTR-ETR Operating Experience," 24.
12. *1965 Thumbnail Sketch*, 16-18.
13. "Bid opening for AEC Tech Services Center," *Arco Advertiser*, June 5, 1962.
14. J.O. Roberts, "Selected Operating Experience of Commission Power Reactors," 32 (full citation in Chapter 14).
15. *November 1958 Thumbnail Sketch*, 23; (gauges) Jack Clark, interview with author, July 16, 1998.
16. For more on OMRE and EOCR, see Arrowrock Group, *Context History*, 85-88.
17. (Melting point) C. Wayne Bills, communication to author, circa August 20, 1999. Piqua was one of the "Second Round" of demonstrations initiated by AEC invitation in September 1955. See Holl, Anders, and Buck, *Civilian Nuclear Power Policy*, 5; *Controlled Nuclear Chain Reaction: The First 50 Years* (La Grange Park, Illinois: American Nuclear Society, 1992), 41; and numerous editions of *Thumbnail Sketch*.
18. William R. Corliss. *SNAP Nuclear Space Reactors* (Washington, D.C.: U.S. AEC Division of Technical Information, 1966), 11.
19. *July 1971 Thumbnail Sketch*, 34.
20. Richard Meservey, interview with author, October 12, 1998. See also letter to J.W. McCaslin from G.L. Cordes, January 20, 1965, "Monthly Report of TAN-SPERT HP Section for December 1965," HREX Doc. No. 0721415.
21. "Idaho's Atom Mission in Space," *Post-Register*, April 14, 1965, 4; Corliss, *SNAP Nuclear Space Reactors*, 35-38. *1965 Thumbnail Sketch*, 32. See also AEC/ID news release No. 63-11, "AEC Schedules Deliberate Reactor Destructive Test for November," September 17, 1963, HREX Document No. 721416. See also John Horan, "Memo to File," January 14, 1966, HREX Document No. 727305. The tests were named SNAPTRAN (SNAP Transient).
22. R. (Dick) Smith, "The Breeder Reactor Concept," Idaho National Engineering Laboratory *EBR-1 Review* (cited in Chapter Six notes.)
23. "EBR-II Fact Sheet," copy found in IHS, Ms. 400, Box 43, File: Legislative JCAE—20th Anniversary.
24. *EBR-II since 1964*, 24. The first loading of fuel was enriched to 48 percent U-235.
25. For more detailed description, see *EBR-II Since 1964*, 67-70.
26. (Burnup rate), *EBR-II since 1964*, 26. Burnup rate reached 2.6 percent in 1975.
27. Holl, Anders, and Buck, *Civilian Nuclear Power Policy*, 10.
28. Holl, *Argonne*, 230; "AEC Kills Argonne's FARET in favor of Fast Flux Test Facility," *Nucleonics Week*, December 2, 1965.
29. J. Newell Stannard, *Radioactivity and Health, A History*, Report No. DOE/RL01830-T59 (Hanford: Pacific Northwest Laboratory, 1988), 1299; C.A. Hawley, et al, *Controlled Environmental Radioiodine Tests, National Reactor Testing Station*, Report No. IDO-12035 (Idaho Falls: IDO, 1964), 1; John Horan, interview with author, January 15, 1999.
30. Clyde Hawley, interview with author, September 22, 1999.
31. John Horan, July 14, 1998; Hawley, *Controlled Environmental Radioiodine Tests*, 2.
32. (Location), C.A. Hawley, ed., *Controlled Environmental Radioiodine Tests at the National Reactor Testing Station 1965 Progress Report*, Report No. IDO-12047 (Idaho Falls: IDO, 3; (grid) D.F. Bunch, *Controlled Environmental Radioiodine Tests Progress Report Number Two*, Report No. IDO-12053 (Idaho Falls: IDO), 3; (bids) IDO News Releases, April 21, 1966; April 25, 1967; May 6, 1967; April 2, 1970; April 13, 1970; in BSU, Ms. 6, Box 155, File 1.
33. George Voelz, "Remembering the Early Years," HREX Doc. No. 0727845. Other sources indicate that from six to ten people were involved in the experiments. See U.S. DOE, *Human Radiation Experiments: The Department of Energy Roadmap to the Story and the Records*, Report no. DOE/EH-0445 (Washington, D.C.: DOE, 1995), 239.
34. In a 1994 interview with researchers investigating human radiation experiments, John Horan expressed his belief that the NRTS might have been the only AEC laboratory to follow the protocol of obtaining approval of the AEC and developing consent forms. See transcript of interview by Baldwin and Baccus, HREX Doc. No. 0726467, p. 16. For a summary of CERT test dates, see *INEL Historical Dose Evaluation*, Volume 2 (Idaho Falls: Idaho Operations Office Report No. DOE/ID 12119, 1991), page A-72 through A-77. A copy of the Nuremburg Code was found at www.geneletter.org/0197/nuremburg.htm.
35. (Sensitive counters) Hawley, *Controlled Environmental Radioiodine Tests*, 14; for an account of personal experiences, see *Idaho Press Tribune*, January 19, 1987.
36. Stannard, *Radioactivity and Health, A History*, 1,300, 1,302; (laboratory experiments) J.D. Zimbrick and P.G. Voilleque, *Controlled Environmental Radioiodine Tests at the National Reactor Testing Station Progress Report Number Four*, Report No. IDO-12065 (Idaho Falls: IDO, 1969), 2.
37. "Uranium Production—ICPPProcessing Runs," Revised 10-1-75, M.P.H., and "CPP 601 Processing History," both provided by Jeff Bryant of INTEC (ICPP).
38. See W.S. Ginnell, J.J. Martin, and L.P. Hatch, "Ultimate Disposal of Radioactive Wastes," *Nucleonics* (December, 1954): 14-18; "Outlook for Waste Disposal," *Nucleonics* (November 1957): 155-164; *The Waste Calcining Facility at the Idaho Chemical Processing Plant*, pamphlet, no date, no author, p. 2; Joseph A. Lieberman, "Treatment and Disposal of Fuel-Reprocessing Waste," *Nucleonics* (February 1958): 86; and J.I. Stevens, et al, *Preliminary Process Criteria and Designs for Waste Calcining Facilities at the Idaho Chemical Processing Plant*, Report No. PTR-177 (Idaho Falls: PPCo, 1957), 5.
39. See C.E. Stevenson, et al, *Waste Calcination and Fission Product Recovery Facilities—ICPP, A Conceptual Design*, Report PTR-106 (Idaho Falls: PPCo, 1956); and D.R. Evans, *Pilot Plant Studies with a Six-Inch Diameter Fluidized Bed Calciner*, Report No. IDO-14539 (Idaho Falls: PPCo), 2.
40. Argonne National Laboratory, *Annual Reports* for 1955 (p. 21-23), 1956 (p. 65), 1957 (p. 95-97). See also C.E. Stevenson, et al, *Waste Calcination and Fission Product Recovery Facilities—ICPP,A Conceptual Design*, Report PTR-106 (Idaho Falls: PPCo, 1956); and D.R. Evans, *Pilot Plant Studies with a Six-Inch Diameter Fluidized*

Bed Calciner, Report No. IDO-14539 (Idaho Falls: PPCo, 1961)). Studies of the two-foot model are reported in B.P. Brown, E.S. Grimmett, and J.A. Buckham, *Development of a Fluidized Bed Calcination Process for Aluminum Nitrate Wastes in a Two-Foot Square Pilot Plant Calciner, Part 1, Equipment Development in Initial Process Studies*, Report No. IDO-14586 (Idaho Falls: PPCo).

41. See INEELphotos NRTS-59-709 and NRTS-59-925. For a history of the old Waste Calcining Facility, see Susan M. Stacy, *Idaho National Engineering and Environmental Laboratory, Old Waste Calcining Facility HAER No. ID-33-C*, Report No. INEEL-97-01370 (Idaho Falls: LMITCO, 1997).
42. L.T. Lakey, et al, *Development of Fluidized Bed Calcination of Aluminum Nitrate Wastes in the Waste Calcining Facility*, Report No. IDO-14608 (Idaho Falls: PPCo, 1965), pp. ii-5.
43. (Merit badge sidebar) "Boy Scouts Atomic Energy Merit Badge," *Nuclear News* (August 1963): 34; to Len Jordan from Robert L. Shannon, March 14, 1966, BSU, Ms. 6, Box 148, File 1.
44. D.R. Evans, *Pilot Plant Studies*, 3. See also Robert D. Thompson, *Ruthenium Behavior during Fluidized Bed Calcination of Radioactive Waste Solutions: Problem Review and Program Suggestions*, Report No. PTR-743 (Idaho Falls: PPCo, 1965). The calciner's first waste feed came from aluminum-clad fuel. With the aluminum nitrate from the waste stream and aluminum nitrate from the process, most of the nitrate salt being processed was aluminum nitrate. Calcining turned this into aluminum oxide, which is known as the mineral *alumina*. The calcined product of zirconium-clad fuel is *zirconia.*
45. Stacy, *Old Waste Calcining Facility HAER No. ID-33-C*.
46. (500 years) Allied Chemical, *The Waste Calcining Facility, Idaho Chemical Processing Plant* (Idaho Falls: Idaho Chemical Programs, circa 1974), 13. Towards the end of life for the WCF, the bends in the pipe did become a concern. The abrasion of the calcine particles eroded a hole in an elbow of the transport line; Leroy Lewis, personal communication to author, August 31, 1999.
47. R.E. Commander, et al, *Operation of the Waste Calcining Facility with Highly Radioactive Aqueous Waste*, Report No. IDO-14662 (Idaho Falls: PPCo, 1966), 1-4; and L.T. Lakey, *Fluidized Bed Calcination*, iii. Lakey, IDO-14608 contains a summary of test-runs.
48. Richard K. Lester and David J. Rose, "The Nuclear Wastes at West Valley, New York," *Technology Review* (May 1977): 20-23.

Chapter Eighteen

Epigraph: William Ginkel, Remarks at Chamber of Commerce Breakfast Meeting, Westbank Motel, Id Falls, May 16, 1967, p. 2. Copy provided by Bill Ginkel.

1. J.W. Henscheid, interview with author, December 10, 1998. See also *Nuclear News* (October 1969): 17, which described a failure of the primary coolant heat exchangers early in the hydraulic testing program (1965) from excessive tube vibrations and which had to be rebuilt.
2. J.W. Henscheid, December 10, 1998.
3. (Shaw quotation) William Lanouette, "Dream Machine," *Atlantic Monthly* (April 1983): 45. For a summary of safety philosophy, see Elizabeth Rolfe, *Nuclear Power and the Public Safety*.
4. Chuck Rice, interview with author, October 15, 1998.
5. Joint Committee on Atomic Energy, *Hearings on AEC Authorizing Legislation, Fiscal Year 1968* (Washington: Government Printing Office, 1967), 762.
6. (Shaw views) Robert Gillette, "Nuclear Safety (I): The Roots of Dissent", *Science* (September 1, 1972): 774-776.
7. "Martin, U.S. Rubber to Run Hanford '200 Area,' Build Isotope Plant; Diversification at NRTS," *Nucleonics* (March 1965): 21; "A New Contractor to Manage NRTS in place of Phillips," *Nuclear Industry* (February 1965): 12.
8. (Thirty companies) "NRTS Breakup: AEC Seeks New Contractor," *Nucleonics* (June 1965): 27; "AEC Invites Proposals for Operation of Certain Facilities at Idaho Site," May 3, 1965, BSU Ms. 6, Box 141, Folder 10; (titan firms) "Titan Firms to seek Idaho AEC Contract," *Post-Register*, circa May 9, 1965, in BSU Ms. 6, Box 141, Folder 10; "General Atomics Here to Study Contract," *Post-Register*, undated clipping, BSU Ms. 6, Box 141, Folder 9; Bill Ginkel, "Welcome. The NRTS—What It Is and What It Does...," remarks at "Pre-Proposal Information Meeting," Elks Club, May 20, 1965.
9. (AEC liked Aerojet) Aerojet Nuclear Company, *A Historical Brief of the LOFT Reactor at the Idaho National Engineering Laboratory* Report No. ERDA/IDO CI-1275 (Idaho Falls: ANC, 1975), 14; (Aerojet investments) Robert Gillette, "Nuclear Safety (II): The Years of Delay," sidebar "The Fall of Phillips Nuclear," *Science* (September 8, 1972): 868; "Aerojet Commemorates 25th Anniversary March 20," *Idaho Nuclear News* (March 1967): 1; (Johnson) to Jordan from Allan C. Johnson, February 22, 1966, BSU Ms. 6, Box 148, Folder 1. Aerojet was a subsidiary of the General Tire Company; Charles Rice, interview with author, October 15, 1998.
10. IDO news release, "Idaho Nuclear Assumes Major Operating Role at NRTS in Idaho," July 1, 1966, BSU Ms. 6, Box 147, Folder 36; (shot-gun marriage) Charles Rice, October 15, 1998.
11. (Quotation) Robert Gillette, "The Fall of Phillips Nuclear" sidebar, *Science* (September 8, 1972): 868.
12. For discussions of the "Bandwagon Market" that began with the Oyster Creek project, see Richard Rhodes, *Nuclear Renewal* (New York: Viking, 1993); Elizabeth Rolfe, *Nuclear Power and Public Safety*; J. Samuel Walker, *Containing the Atom*.
13. The Brookhaven Study was WASH-740, a report originally prepared in 1957, when the JCAE was preparing the Price-Anderson Act and contemplating the monetary value of severe accidents.
14. Aerojet Nuclear Company, *AHistorical Brief of the LOFT Project*, 1.
15. Aerojet Nuclear Company, *AHistorical Brief of the LOFT Reactor*, 1.
16. Roger Anders, unrevised preliminary unpublished manuscript, "Safety Research: An Impossible Task," copy supplied to Stacy by author, p. 48.
17. Walker, *Containing the Atom*, 147.
18. (Zircaloy) Aerojet Nuclear Company, *A Historical Brief of the LOFTProject*, 2; (gas pressure) Anders, "Safety Research," 6.

19. (Regroup quotation) JCAE, *Hearings on AEC Authorizing Legislation, Fiscal Year 1968*, 761.
20. Samuel J. Walker, *Containing the Atom*, 144. For a review of Advisory Committee on Reactor Safety views on China Syndrome, see David Okrent, *On the History of the Evolution of Light Water Reactor Safety in the United States* (Los Angeles: Okrent, circa 1978), p. 2-173 ff.
21. (Quotation) Bill Ginkel, "Presentation, to Consolidation Study Group," March 11, 1969; Gillette, "The Fall of Phillips Nuclear," *Science*, p. 868.
22. (Breeder) Robert Gillette, "Nuclear Safety (III): Critics Charge Conflicts of Interest," *Science*, (September 15, 1972): 970; (quotation) to Jordan from T.G. Taxelius, September 18, 1970, BSU, Ms. 6, Box 174, File 31; to Edward J. Bauser from Donald Kull, November 17, 1970, BSU Ms. 6, Box 174, File 31.
23. Robert Gillette, "Nuclear Safety (I): The Roots of Dissent," *Science* (September 1, 1972): 773; (*Post-Register* quotation) "The Layoff and Our Deeper Throes," editorial, *Post-Register*, circa 1970, p. 4, undated news clipping in IHS Ms. 400, Box 16, File 9/I Atomic Energy Commission; (Andrus quotation) to Jordan from Andrus, November 2, 1971, BSU Ms. 6, Box 181, File 11.
24. To Orval Hansen from Chuck Rice, Sept 22, 1970, IHS, Ms. 400, Box 16, File 9/I AEC.
25. Walker, *Containing the Atom*, 177. U.S. DOE, *Comprehensive Facility and Land Use Plan, INEL*, Report No. DOE/ID-10514 (Idaho Falls: IDO, 1995), 185.
26. Gillette, "Nuclear Safety (III): Critics Charge Conflicts of Interest," *Science*, 974.
27. Rolfe, *Nuclear Power and the Public Safety*, 93. See also letter to Robert Hollingsworth from Orval Hansen, Nov 19, 1971, IHS Ms. 400, Box 16,21, File: Dept Atomic Energy Commission. The Union of Concerned Scientists attacked the Interim Criteria and the Semiscale tests that supported them because they were not conservative enough.
28. Aerojet Nuclear Company, *A Historical Brief of the LOFT Reactor*, 4.
29. (No fabricators) Gillette, "Nuclear Safety (II): The Years of Delay, *Science*, 870; Aerojet Nuclear Company, *A Historical Brief of the LOFT Reactor*, 5; to John Hough, governor's office, from Nolan Hancock, Oil, Chem and Atomic Workers International Union, Dec 30, 1971, BSU Ms. 141-3, Box 91, File 6.
30. (Blame Phillips) Gillette, "Nuclear Safety (II): The Years of Delay," 869; (early research independence) Rolph, *Nuclear Power and the Public Safety*, 68.
31. (Stake) Bill Ginkel, personal communication to author, July 13, 1999; (name change) Gillette, "The Fall of Phillips Nuclear," 868.
32. (Gillette quotation) "Nuclear Safety (I): The Roots of Dissent," *Science*, p. 773; (Leeper quotation), same article, p. 774. In addition to the four-part series published in *Science* on September 1, 8, 15, and 22, 1972, Gillette wrote "Nuclear Reactor Safety: At the AEC the Way of the Dissenter is Hard," which appeared in *Science* (May 5, 1972):492-498, and discusses the hearing underway at the time on LOCAs and ECCS.
33. EG&G, *Five Year Report, 76/81* (Idaho Falls: EG&G, 1982), 14; EG&G News Release, "New ATR Operation Record Established," December 23, 1981.

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Epigraph: "Governor, Commission Size Atom Goals," *Post-Register*, September 20, 1967.

1. (FARET canceled) "AEC Kills Argonne's FARET in favor of Fast Flux Test Facility," *Nucleonics Week* (December 2, 1965).
2. Holl, Anders, Buck, *Civilian Nuclear Policy*, 6. The Price-Anderson amendment to the Atomic Energy Act capped the coverage for a nuclear accident at $560 million. The government supplied $500 million of the insurance at a nominal cost, while private companies supplied the remaining $60 million at standard rates.
3. See *EBR-II Since 1984*, p. 26-29 for operating data on EBR-II reactor. According to Richard Lindsay, a water cooled reactor can make plutonium, but not with enough efficiency to make recycling economic for more than about one recycle.
4. William Lanouette, "Dream Machine," *Atlantic Monthly* (April 1983): 45.
5. There were several types of breeders. Using combinations of uranium and thorium, the concepts had in common the conversion of otherwise useless metals into new fissionable fuel. See Lanouette, "Dream Machine," 36.
6. Holl, *Argonne*, 230-231.
7. Holl, *Argonne*, 231.
8. "AEC Reports on Current Fast Reactor Technology," *Nucleonics* (April 1966): 19.
9. Holl, *Argonne*, 231-32.
10. (Brady editorials), Orval Hansen, interview with author, July 1, 1998.
11. Telegram to Frank Church, Len B. Jordan, and Ralph Harding from Governor Robert Smylie, April 16, 1964, IHS, Ms. AR2/23, Box 17, File: Atomic Energy 63-64.
12. IDO news release, September 15, 1965, BSU, Ms. 6, Box 141, File 9; (long shot) "The Research Yeast," editorial, *Post-Register* (May 9, 1965), 4.
13. To Governor Smylie from N.K. Sowards, Asst. Mgr, Aerojet, June 7, 1965; and to Governor Smylie from Fred Rooney, May 25, 1965, IHS, Papers of Gov. Samuelson, Box 50, File: Nuclear File from Smylie, 1965.
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Chapter Twenty Four

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Acronyms

630-A	High Temperature Marine Propulsion Reactor
710	Fast Spectrum Refractory Metals Reactor
A1W	Aircraft carrier, first prototype, Westinghouse (Also known as the Large Ship Reactor A and B)
A/E	architect/engineering
ACRS	Advisory Committee on Reactor Safeguards
AEC	Atomic Energy Commission
AFSR	Argonne Fast Source Reactor
AI	Atomics International
ANC	Aerojet Nuclear Corporation
ANP	Aircraft Nuclear Propulsion
ARA	Army Reactor Area, (Later Auxiliary Reactor Area)
AREA	Army Reactor Experimental Area
ARMF	Advanced Reactivity Measurement Facility
ATR	Advanced Test Reactor
ATRC	Advanced Test Reactor Critical Facility
ATWS	Anticipated Transients Without Scrams
BORAX	Boiling Water Reactor Experiment
BPA	Bonneville Power Administration
CE	Combustion Engineering
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERT	Controlled Environmental Radioiodine Tests
CET	Critical Experiment Tank
CFA	Central Facilities Area
CFRMF	Coupled Fast Reactivity Measurement Facility
CP-1	Chicago Pile Number One
CPP	Chemical Processing Plant
CRADA	Cooperative Research and Development Agreement
CRCE	Cavity Reactor Critical Experiment
DEW	Distant Early Warning System
DoD	Department of Defense
DOE	Department of Energy
DOE-ID	Department of Energy-Idaho Operations Office
EBR	Experimental Breeder Reactor
EBOR	Experimental Beryllium Oxide Reactor
EBWR	Experimental Boiling Water Reactor
ECCS	Emergency Core Cooling System
ECF	Expended Core Facility
EINIC	East Idaho Nuclear Industry Council
EIS	Environmental Impact Statement
EOCR	Experimental Organic Cooled Reactor
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
EROB	Engineering Research Office Building
ETR	Engineering Test Reactor
ETRC	Engineering Test Reactor Critical Facility
FARET	Fast Reactor Test Facility
FCF	Fuel Cycle Facility
FET	Flight Engine Test
FFTF	Fast-Flux Test Facility
FLECHT	Full-length Emergency Core Heating Tests
FPC	Federal Power Commission
FRAN	Nuclear Effects Reactor
FRAP	Fuel Rod Analysis Program
FWPCA	Federal Water Pollution Control Administration
GCRE	Gas Cooled Reactor Experiment
GE	General Electric
HOTCE	Hot Critical Experiment
HP	health physicist
HTRE	Heat Transfer Reactor Experiment
ICPP	Idaho Chemical Processing Plant
IDO	Idaho Operations Office
IDWR	Idaho Department of Water Resources
IET	Initial Engine Test
IFR	Integral Fast Reactor
INC	Idaho Nuclear Corporation
INEC	Idaho Nuclear Energy Commission

INEL	Idaho National Engineering Laboratory
INEEL	Idaho National Engineering and Environmental Laboratory
INFCE	International Nuclear Fuel Cycle Evaluation
INTEC	Idaho Nuclear Technology and Engineering Center
IRC	INEEL Research Center
ISC	INEEL Supercomputing Center
ISU	Idaho State University
JCAE	Joint Committee on Atomic Energy
KAPL	Knolls Atomic Power Laboratory
LMFBR	Liquid Metal Fast Breeder Reactor
LOCA	Loss-of-Coolant Accident
LOFT	Loss of Fluid Test
MIT	Massachusetts Institute of Technology
ML-1	Mobile Low-Power Reactor
MTR	Materials Testing Reactor
NaK	eutectic alloy of sodium (Na) potassium (K)
NAS	National Academy of Science
NASA	National Aeronautic and Space Administration
NEPA	National Environmental Policy Act
NERI	National Energy Research Initiative
NERP	National Environmental Research Park
NOAA	National Oceanic and Atmospheric Administration
NPG	Naval Proving Ground
NPR	New Production Reactor
NRAD	Neutron Radiography Facility
NRC	Nuclear Regulatory Commission
NRF	Naval Reactors Facility
NRTS	National Reactor Testing Station
NSF	National Science Foundation
NWCF	New Waste Calcining Facility
OAC	operating area confinement
OMRE	Organic Moderated Reactor Experiment
OU	operable unit
PBF	Power Burst Facility
RAF	Remote Analytical Facility
RaLa	radioactive lanthanum
RIA	reactivity-initiated accidents
REM	roentgen equivalent man
RMF	Reactivity Measurement Facility
RWMC	Radioactive Waste Management Complex
S5G	submarine reactor, 5th prototype, General Electric (Also known as the Natural Circulation Reactor)
SCRCE	Spherical Cavity Reactor Critical Experiment
SDI	Strategic Defense Initiative
SIS	Special Isotope Separations
SL-1	Stationary Low-Power Reactor
SM-1	Stationary Medium-Power Reactor
SMC	Specific Manufacturing Capability
SNAP	Systems for Nuclear Auxiliary Power
SPERT	Special Power Excursion Reactor Test
STEP	Safety Test Engineering Program
STR	Submarine Thermal Reactor (Also known as S1W or, Submarine reactor, 1st prototype, Westinghouse)
STR	Split Table Reactor
SUSIE	Shield Test Pool Facility
TAN	Test Area North
THRITS	Thermal Idaho Reactor Test Station
TMI	Three Mile Island
TRA	Test Reactor Area
TSA/B	Technical Support Building
TREAT	Transient Reactor Test
TRU	transuranic
U of I	University of Idaho
UAW	United Auto Workers
UP&L	Utah Power and Light
USGS	United States Geological Survey
USSR	Union of Soviet Socialist Republics
WAG	Waste Area Group
WBRR	Western Beam Research Reactor
WCB	Willow Creek Building
WCF	Waste Calcining Facility
WERF	Waste Experimental Reduction Facility
WIPP	Waste Isolation Pilot Plant
WOW	Woman Ordnance Worker
ZPR	Zero Power Reactor
ZPPR	Zero Power Physics Reactor (Previously known as the Zero Power Plutonium Reactor)

Glossary

Activation product

Upon bombardment with neutrons, some materials absorb neutrons into their nuclei, forming new and usually radioactive isotopes.

Alpha particle

A positively charged nuclear particle identical with the nucleus of a helium atom. It consists of two protons and two neutrons. Alpha particles can be stopped by a sheet of paper.

Anti-Cs

Slang speech meaning "anti-contamination," referring to special clothing worn by people requiring protection from radiation.

Atom

The smallest particle of an element that can exist either alone or in combination with other elements. Atoms are made up of electrons, neutrons, and protons.

Atomic energy

Energy that can be liberated by changes in the nucleus of an atom, such as by fission or fusion. Contemporary scientists prefer to use the term "nuclear energy."

Atomic number

A characteristic of an element, the number of protons in the nucleus.

Aquifer

A water-bearing stratum of permeable rock, sand, or gravel.

Background radiation

The radiation in an ambient environment. It includes cosmic rays from outer space, radon gas, and other forms of radiation from natural sources (such as granite) and human-made sources (dental X-rays, fallout from nuclear explosions).

Beta particle

An electron or positron ejected from the nucleus of an atom during radioactive decay. The mass of an electron is equal to 1/1837 that of a proton. It can be stopped by an inch of wood or a thin sheet of aluminum.

Bin set

A cluster of storage containers at the Idaho Nuclear Technology Engineering Center built to store solid calcine waste. The waste is highly radioactive, and the bin sets are heavily shielded.

Blowdown

A term used to describe sudden depressurization upon the breaking of a pipe carrying pressurized water.

Boiling water reactor

A nuclear reactor concept in which the coolant, water, is permitted to boil as it absorbs the heat of the nuclear reaction. The resultant steam drives a turbine and generates electricity.

Breeder reactor

A nuclear reactor concept in which the operation produces a net increase in fissionable material. That is, more fissionable material is produced than is consumed.

Calcine

As a noun, the dry solid (grainy or granular) product of a chemical process removing liquids from a solution. As a verb, the heating of a material at a high temperature to drive off volatile materials.

Cerenkov radiation

A blue-white light produced when gamma rays hit electrons in water. The energy of the gamma rays is sufficiently great that the electrons move through the water faster than light moves through water.

Cesium-137

A radioactive isotope of the element cesium, which emits gamma radiation. It is an important fission product.

Chain reaction

A self-sustaining sequence of events occurring when a neutron splits a fissionable atom (of uranium, for example) and releases sufficient neutrons to cause other atoms to split in the same way.

China Syndrome

A figure of speech referring to a theoretical melting of nuclear reactor fuel which would occur upon a loss of coolant to the fuel. The fuel would melt, penetrate the reactor vessel, drop to the concrete floor of the building, and reach the soil below. The phrase comes from the expression "dig a hole all the way to China," a fantasy of (American) children who believe China to be on the opposite side of the globe from their own playground.

Chicago Pile-1

The name of the first nuclear reactor to go critical, so called because graphite blocks were piled upon each other to construct the reactor.

Cladding

The outer layer of metal over the fissionable material in a nuclear fuel element, typically aluminum or zirconium. Cladding promotes the transfer of heat from the fuel to the coolant and contains fission products and activation products within the fuel element.

Cold run

A test of a chemical process and equipment using non-radioactive materials.

Cold shutdown

A reactor condition in which the coolant temperature has been reduced to 200° F or below, the pressure has been reduced to atmospheric pressure, and the chain reaction has stopped.

Cold War

A conflict over ideological differences between the United States and the Soviet Union and their respective allies lasting from the late 1940s until early in the 1990s. It was carried on by means other than sustained or direct military action.

Containment building

A safety feature of most commercial nuclear reactor power plants. The airtight building, typically engineered to contain gases and pressures that might be released in an accident, houses the reactor, pressurizer, coolant pumps, and other equipment.

Control rod

A device within a nuclear reactor made of materials which absorb neutrons. Control rods help dampen or permit the reactor's chain reaction.

Contamination, radioactive

Unintentional or undesirable contact of a person, object, or material with radioactive substances.

Control room

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

Coolant

In a nuclear reactor, a gas or fluid (such as water or liquid metal) sent past the fuel elements to collect and carry away the heat generated by the nuclear reaction.

Core

That part of the nuclear reactor consisting of the fuel and control elements, the coolant, and the vessel containing these.

Criticality

The point at which a nuclear reactor is just capable of sustaining a chain reaction.

Critical mass

The minimum amount of nuclear fuel necessary to sustain a chain reaction.

Curie

A measure of radioactivity, a curie is that quantity of material that decays at a rate of 3.7×10^{10} disintegrations per second.

D&D

An abbreviation for "decontamination and decommissioning," particularly of a building or structure that once housed active nuclear activities and may have been contaminated in the process. Historic uses of the term may also have referred to "dismantling" or "demolishing."

Decontaminate

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

Decay

The spontaneous ejection of particles by radioactive materials. Synonym for radioactive disintegration.

Depleted uranium

Uranium that, through the process of enrichment, has been stripped of most of the uranium-235 it once contained. It has more uranium-238 than natural uranium, but is referred to as "depleted."

Dose

A specific amount of ionizing radiation or a toxic substance absorbed by a living being.

Dosimeter

A device such as a film badge which can be worn by a person (or placed somewhere in the environment) and is used to measure the radiation dose received over a period of time.

Electron

An elementary particle consisting of a charge of negative energy. Electrons are said to circle the nucleus of an atom.

Emergency Core Cooling System

An emergency backup system designed to inject cooling water into the core of a reactor in the event that the normal cooling system fails. This safety requirement is intended to prevent the overheating of the fuel and subsequent melting.

Enriched uranium

Uranium which has been modified from its natural state to contain a higher concentration of the isotope uranium-235 than natural uranium.

Excursion

A term used to describe an unexpected or accidental increase in the power level of a nuclear reaction.

Fallout

Radioactive particles and gases resulting from a nuclear explosion which gradually descend to earth.

Film badge

A piece of masked photographic film worn by nuclear workers. The film is darkened by radiation and can be analyzed to indicate how much exposure the film and the badge wearer received over a period of time.

Fission

The splitting of an atomic nucleus resulting in the creation of lighter elements, heat, free neutrons, and other particles.

Fission product

Any of several lighter elements or particles created by the nuclear fission of a heavy element such as uranium.

Flux

The flow or stream of neutrons emanating from nuclear fission.

Fossil fuels

Coal, oil, and natural gas are referred to as “fossil” fuels because they are the remains of plants and animals that lived on earth millions of years ago.

Fuel cycle

The life cycle of a fuel including the complete sequence of steps beginning with mining and refining an ore and ending with the disposition of the waste products after the fuel has been beneficially used.

Fuel reprocessing

A chemical process, usually involving several steps, that recovers uranium-235 and other fissionable products from spent fuel.

Fuel assembly

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

Fusion

The union of atomic nuclei to form heavier nuclei resulting in the release of enormous quantities of energy. The process usually requires conditions of extreme heat and pressure.

Gamma radiation

High-energy, high penetrating electromagnetic radiation emitted in the radioactive decay of many radionuclides. They are similar to X-rays.

Geiger counter

An instrument used to detect and measure beta and gamma radiation.

Half-life

The time it takes for one-half of any given number of unstable atoms to decay (disintegrate). Half-life is unaffected by temperature, pressure, or chemical conditions surrounding the substance.

Hot cell

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

Hot run

An operational (or test) run of a chemical process and equipment using radioactive materials.

Hot settlement Pond

An outdoor basin, usually lined at the bottom with clay, in which liquids containing radioactive particles are sent to evaporate. Solids settle to the bottom, where they are adsorbed onto the clay.

Interim storage

A concept in the management of nuclear waste in which the waste is moved to an intermediary location between its point of origin and its "final" or ultimate storage location.

Iodine-131

Also called radioiodine or radioactive iodine, an isotope of the element iodine, which has a half-life of about eight days. This (and other iodine isotopes) are released when the cladding surrounding spent fuel is dissolved or breached.

Ion exchange

A chemical process in which a substance dissolved in water is exchanged with another.

Ionization chamber

A device used to measure radioactivity.

Irradiate

To expose a substance to ionizing radiation in a nuclear reactor. The substance so exposed may be referred to as the target.

Isotope

Any of two or more species of atoms of a chemical element distinguished by different quantities of neutrons in their nuclei. For example, hydrogen has three isotopes: protium (one proton), deuterium (two protons), and tritium (three protons).

Linear accelerator

Adevice in which charged particles are speeded up in a straight line by successive impulses from a series of electric fields.

Manhattan Engineer District/Manhattan Project

Created by President Roosevelt in 1939, the Manhattan Engineer District of the U.S. Army Corps of Engineers was commissioned to build an atomic bomb. The effort was referred to as the Manhattan Project.

Maximum permissible dose

A regulatory limit on the radiation exposure that a nuclear worker or a member of the general public may legally receive due to radioactive releases from a nuclear power plant or other nuclear activity.

Megawatt

A measure of electrical power equal to one million watts.

Meltdown

The accidental melting of nuclear reactor fuel caused by a failure of the coolant to carry away heat.

Millirem

A unit of radiation equal to one thousandth of a "rem." See rem.

Microcurie

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

Mixed waste

Waste that contains both chemically hazardous and radioactive waste.

Moderator

A material used in a nuclear reactor to reduce the natural speed of neutrons ejected from fissioning atoms. Typical moderators are water or graphite.

Natural uranium

Uranium that has not been through an enrichment process to separate its uranium-235 isotopes. It is made of uranium-238 (99.3 percent) and uranium-235 (0.7 percent).

Neutron

An uncharged particle, a part of an atomic nucleus, having a mass nearly equal to that of a proton. One or more neutrons are present in every known element except hydrogen.

Noble gases

Elemental gases which do not generally combine chemically with other materials. They are helium, neon, argon, krypton, xenon, and radon.

Nuclear power plant

An electrical generating facility using nuclear fuel.

Nuclear energy

Energy released in a nuclear fission or fusion reaction.

Nuclear reactor

A complex device designed to contain a controlled nuclear fission chain reaction. A reactor may function for testing and experimentation (Materials Test Reactor), for the generation of electricity (any commercial nuclear power plant), for the production of weapons-related materials such as tritium or plutonium (N Reactor at Hanford), as a breeder of nuclear fuel (Experimental Breeder Reactor), for propulsion (Submarine Thermal Reactor), or as a combination of these functions.

Nuclear waste

A general term including high-level, transuranic, low-level, mixed low-level, and byproduct material. Each of these terms is further defined for regulatory purposes.

Nucleus

Center of an atom consisting of a cluster of neutrons and protons. It contains nearly all of the mass of the atom.

Plutonium

A metallic element most typically created by irradiating uranium in nuclear reactors (although small amounts have been found in nature). The fissionable isotope plutonium-239 can be used as reactor fuel.

Pressurized water reactor

A reactor concept in which water is used to cool the reactor core. It is pressurized to prevent it from boiling. Heat is transferred from a "primary" coolant pipe to a "secondary" pipe.

Primary loop

A closed system of piping through which coolant flows past the nuclear fuel in a reactor.

Prompt critical

Astate of criticality derived from the fact that a small percentage of neutrons in a chain reaction are not emitted as soon as the atom splits, but are "delayed" for as long as a few minutes. "Prompt" neutrons are emitted immediately upon fission. If a reactor goes "prompt critical," it indicates that reactivity has increased to the point that prompt neutrons alone are sufficient to maintain the chain reaction. Rapid multiplication of neutrons can occur after this point. In the SL-1 reactor accident, the rapid withdrawal of the control rod is presumed to have brought about a state of prompt criticality, in which the chain reaction did not require the emission of the "delayed" neutrons to begin or continue.

Proton

An elementary atomic particle that is identical with the nucleus of a hydrogen atom. Along with neutrons, it is a constituent of all other atomic nuclei.

PUREX

An acronym for plutonium-uranium extraction, the name of a chemical process used to reprocess spent nuclear fuel and irradiated targets.

R&D 100 Award

Research and development awards presented by *R&D Magazine*. Only one hundred R&D innovations are recognized in the country each year.

Radiation

Energy transferred through space or some other media in the form of particles or waves. If the particles or waves are capable of breaking up atoms or molecules, then the radiation is said to be ionizing radiation.

R

An abbreviation meaning "roentgen." One roentgen (R) measures the power of gamma or X-rays to produce ionization (ie, strip an electron from an otherwise stable atom) in one gram of air.

Radioactive waste

By-products of nuclear processes which are radioactive and have no useful recyclable purpose.

Radioactivity

The spontaneous emission of particles or waves from the nucleus of an atom. The emissions may include alpha and beta particles, and gamma rays.

Radionuclide

A radioactive species of an atom. For example, strontium-90 is a radionuclide (also called a radioisotope) of strontium.

RaLa

An abbreviation for Radioactive Lanthanum, one of the fission products of a nuclear reaction. It was useful to scientists developing a plutonium bomb.

Reactor vessel

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

Reflector

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

Rem (or REM)

An abbreviation meaning "roentgen equivalent man," a measure of the amount of exposure (dose) of radiation that takes into account the biological effectiveness of the exposure on the particular organ exposed.

Retention basin

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

Roentgen

An international unit of measurement of gamma or X- radiation. See "R" above.

Secondary loop

In a reactor coolant system, heat carried away from the reactor core in a "primary" system is transferred to a second loop. Water in the second loop does not become radioactive and its steam is used to spin turbines for electrical generation.

Semiscale

The informal name of a scale model of a nuclear reactor operated as part of the Nuclear Reactor Safety Test Engineering Program at the NRTS/INEL. Instead of using nuclear fuel, the "core" simulated the heat of a nuclear reaction by electrical means. The device was used to study the behavior of water and steam in accidents involving the loss of coolant caused by a broken pipe.

Scram

A sudden shutting down of a nuclear reactor, usually by dropping safety rods, when a predetermined neutron flux or other dangerous condition occurs.

Shielding

Material such as lead, concrete, water, paraffin, and other materials used to prevent the escape of radiation into the ambient or working environment of people and equipment.

Spent nuclear fuel

Nuclear fuel containing fission and activation products that can no longer economically sustain a chain reaction and is withdrawn from a reactor.

Spent fuel storage basin

A pool or pit made of reinforced concrete containing water and used to store spent nuclear fuel. The water acts as a shield preventing radiation from harming workers near the pool.

Transuranic waste (TRU)

Waste materials contaminated with human-made elements heavier than uranium, such as plutonium. Also called TRU (transuranic waste). This term also implies a regulatory definition in which the waste contains substances with a half-life over twenty years in concentrations of more than one ten-millionth of a curie per gram of waste.

Triga

The brand name of a small, low-power reactor manufactured by General Atomics for use in universities and laboratories. The reactor was in a small pool of water used as both coolant and moderator. Similar reactors are often called "triga-type" reactors.

Tritium

An isotope of hydrogen containing three protons. Tritium gas is produced in nuclear reactors and used to boost the explosive power of most modern nuclear weapons. It is also a constituent of irradiated water associated with reactor operations.

Uranium-235

A fissionable isotope of the metallic element, uranium. In nature, only 0.7 percent of all uranium mined from the ground consists of this isotope.

Uranium-238

The most common isotope of uranium. It does not generally fission, but can be irradiated in a reactor and transformed to an isotope of plutonium which does fission.

Uranium oxide

A metallic compound of uranium and oxygen, a useful form of uranium for use as nuclear fuel because it has a higher melting point than metallic uranium and can survive the high temperatures inside a reactor more readily. However, its heat transfer properties are not as efficient as those of metallic uranium.

Water-moderated reactor

A reactor concept which is designed so that water slows down the speed of neutrons ejected from fissioning atoms. Includes boiling water and pressurized water reactor concepts.

Warm run

The operation of a chemical process using materials that are slightly radioactive. A "warm" run is contrasted with "cold" or "hot" runs.

Waste storage tank

A holding tank for liquid or gaseous wastes which may or may not be radioactive.

Zirconium

A metallic element highly resistant to corrosion and used to make cladding for nuclear fuel elements. It is sometimes alloyed in small amounts in the fuel itself.

Zero power

Also called "low power," a mode of operating a reactor so that it maintains a chain reaction at extremely low power levels. It produces very little heat. Zero power reactors are used as sensitive laboratory tools to pre-test experimental loadings of test reactors and for other analytical purposes.

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