Idaho National Engineering Laboratory,
SPERT-III
(Idaho National Laboratory, SPERT-III)
Scoville Vicinity
Butte County
Idaho

HAER No. ID-33-I
DOE/ID-11455

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historical American Engineering Record
National Park Service
Pacific West Regional Office
Department of the Interior
Seattle, Washington 98104

HISTORIC AMERICAN ENGINEERING RECORD

IDAHO NATIONAL ENGINEERING LABORATORY, SPERT-III
(Idaho National Laboratory, SPERT-III)

HAER NO. ID-33-I

Location: Within Idaho National Laboratory, approximately 50 miles west of Idaho Falls, Idaho, in Butte County, T 3 N, R 30 E, Section 27 (Reactor Area), Boise Meridian

Date of Construction: 1957-1958

Conceptual Design and Reactor System: Phillips Petroleum Company

Architect/Engineer: Stearns-Roger Manufacturing Company

Builder: Paul Hardeman, Inc.

Present Owner: United States Department of Energy

Present Use: Decommissioned, demolished

Significance: Anticipating the necessity for safe and reliable operation of commercial reactors, the Atomic Energy Commission (AEC) began the Nuclear Safety Program in 1954 at the National Reactor Testing Station with a series of reactors called Special Power Excursion Reactor Test (SPERT).

Several reactor concepts were under study as potentially feasible for commercial power plants. SPERT-III tested the kinetic behavior of reactors moderated and cooled by pressurized water.

The program studied excursions: unintended and sudden increases in the reactor's power level. The objective was to understand intrinsic shut-down mechanisms and thus design (and license) safe reactors that took the best advantage of them.

SPERT-III operated between 1958-1968. Test results were compared with predictive computer models (to improve the models). Upon completing its kinetic studies, the AEC decommissioned SPERT-III and modified the building for the Waste Experimental Reduction Facility (WERF), which operated between 1981-2000 to reduce the volume of low-level radioactive waste disposed of at the Idaho National Laboratory.

The SPERT-III research lives on in the safety record of operating American nuclear reactors.

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Date: July 29, 2011

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PART ONE

INTRODUCTION TO SPERT-III

In 2004, the then-named Idaho National Engineering and Environmental Laboratory (INEEL), prepared to demolish two reactor facilities that had been part of the Nuclear Safety Program initiated by the Atomic Energy Commission in 1954. These reactor facilities, known as SPERT-I (Special Power Excursion Reactor Test I) and PBF (Power Burst Facility) had been identified as historically significant in the context of American nuclear and technological history.[1]

As part of its agreement with the National Park Service, INEEL prepared Historic American Engineering Report (HAER) No. ID-33-F, which included both facilities. The report was entitled *SPERT-I and Power Burst Facility Area* to recognize that the "area" at the National Reactor Testing Station dedicated to the safety program was a single, coherent site, comprehensively planned from its inception. The reactors built there shared the same history, purpose, and siting philosophy. When selecting identifying letters and numbers for buildings in the area, site managers abbreviated "power excursion reactor" area as PER and affixed numbers accordingly.[2]

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[1] See The Arrowrock Group, Inc., *The Idaho National Engineering and Environmental Laboratory, A Historical Context and Assessment, Narrative, and History*, INEEL/EXT-97-01021, Rev. 1 (Idaho Falls: DOE/ID November 2003).

[2] Susan M. Stacy, *Idaho National Engineering and Environmental Laboratory, SPERT-I and Power Burst Facility Area*, HAER No. ID-33-F (Idaho Falls: Idaho Completion Project, 2005); Julie B. Braun, *INEEL Historic Architectural Properties Management Plan for U.S. Department of Energy, Idaho Operations Office*, INEEl/EXT-02-1338 (Idaho Falls: Bechtel BWXT Idaho LLC, October 2003); and letter from Teresa Perkins to Susan P. Pengilly, May 29, 2009.

Early in 2009, the United States Department of Energy (DOE) undertook to demolish SPERT-III, another of the reactor buildings at the area. This demolition continued DOE's long-term goal to "clean up" the nuclear residue at the laboratory and eliminate obsolete buildings for which no further mission was expected.[3] SPERT-III was (despite its name) the second reactor to operate in the SPERT area, built in the location specified by the original site plan.[4]

The name of INEEL changed in 2005 to Idaho National Laboratory (INL).[5] For simplicity, this report will hereafter use the acronym NRTS (National Reactor Testing Station) for events occurring before 1974, and INL for events occurring between 1974 to present.

This report continues the history of the PER area begun with HAER No. ID-33-F by describing and identifying the particular contribution of SPERT-III, operated by Phillips Petroleum Company, to the safety testing program. The reader is invited to consult the earlier report for an account of the historic evolution of the program, its setting and site plan, and the general significance of the SPERT/PBF program.

PART TWO

SPERT-III MISSION AND FACILITY REQUIREMENTS

SPERT-I had been, to use the language of nuclear physicists,

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[3] U.S. Department of Energy, Idaho Operations Office, *Environmental Management Performance Management Plan for Accelerating Cleanup of the Idaho National Engineering and Environmental Laboratory*, DOE/ID-11006 (Idaho Falls: DOE/ID, July 2002), p. i, 21-23.

[4] See Appendix A and Appendix B respectively for SPERT area vicinity map and SPERT-III plot plan.

[5] The chronology of name changes at INL is as follows:
(NRTS) National Reactor Testing Station: 1949-1974;
(INEL) Idaho National Engineering Laboratory: 1974-1997;
(INEEL) Idaho National Engineering and Environmental Laboratory: 1997-2005;
(INL) Idaho National Laboratory: 2005-present.

a "simple" reactor.[6] Its *raison d'etre* was to examine the kinds of accidents and mishaps that might occur in the operation of non-pressurized water-cooled and -moderated reactors. The investigations dealt chiefly with safety concerns about nuclear "excursions," sudden and uncontrolled power increases caused by too-rapid and out-of-control fissioning in the chain reaction. SPERT-I had generated no electricity and ran for lengths of time too brief to build up sustained high temperatures or large inventories of fission products in the fuel. Most of its program explored excursions in startup conditions. Therefore, the reactor generated little heat and needed no complex coolant piping, pumps, or other highly engineered water management devices and processes.

By 1956, government and industry already were planning reactors that were to be moderated and cooled by pressurized water. The United States had decided upon pressurized-water reactors as its choice for the Nuclear Navy. *USS Nautilus*, the Navy's first nuclear powered submarine, had demonstrated the concept successfully; and construction was underway for the concept at the Shippingport Atomic Power Station in Pennsylvania, another Navy-influenced project. That reactor, built as a demonstration, went critical for the first time in December 1957.

The Operations Manager of the SPERT program, Clyde Toole (since retired), recalled that the operating parameters for SPERT-III's performance specifications came from the needs of pressurized-water reactor industry. As the chief consumers of the safety and design studies of the SPERT program, they asked that the operating limits for SPERT-III emulate conditions of propulsion and other commercial power reactors, which meant operating temperatures at 650 degress F., and coolant water under 2500 psig.[7]

The AEC program for nuclear power development was rapidly expanding. While basic safety and engineering requirements were understood, much remained to be learned about nuclear reactor behavior undergoing accident scenarios under various conditions. "Kinetic studies" sought to understand the dynamic forces acting upon fissioning neutrons in the reactor both during startup and

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[6] T.R. Wilson, *The SPERT-III Reactor Facility Preliminary Design Report*, IDO 16341 (Idaho Falls: Phillips Petroleum Co., May 1957), p. 7.

[7] Clyde Toole, personal telephone communication with author, October 11, 2009.

steady-state power operation. Findings were expected to help design safe commercial reactors.[8]

The Atomic Energy Act of 1954 had given the Atomic Energy Commission authority to license commercial reactors. To evaluate safety concerns, the AEC appointed and consulted an Advisory Committee on Reactor Safeguards (ACRS). This body reviewed license applications and advised the AEC on the engineering and procedural safeguards to be required. In these early years, the safeguards typically called for very large margins of safety, which added to the cost of the reactor. One ultimate purpose of the SPERT program was to clarify appropriate margins of safety, reducing reactor costs where possible.[9]

A reactor's kinetic behavior is a predictable phenomenon despite many dynamic variables. During the 1950s and 1960s, the computing power of IBM computers became available to nuclear scientists. As these decades unfolded, computers became increasingly powerful, able to handle programs with more and more variables, subroutines, and other refinements. Scientists could model a particular type of reactor under various conditions, "run" an accident scenario, and predict its outcome. They could see the day when these models, called "codes," would help the ACRS evaluate reactor designs and the sufficiency of their safety features. But first, the task at hand was to develop reliable codes.

A code, among other things, needed to account for the condition of the reactor when the sudden increase in reactivity and subsequent power level -- the "excursion" -- occurred. An excursion produces different effects if it occurs when the reactor is just starting up compared to when it has been operating for a long time. In the first case, water temperatures are still at room temperature; in the latter case, the "system temperature" may be at 600 degrees F. The "burst" of power resulting from the incident will be different, and the time it takes for the reactor to shut itself down will be different.[10]

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[8] C. Rogers McCullough, *Safety Aspects of Nuclear Reactors, The Geneva Series on the Peaceful Uses of Atomic Energy* (Princeton, N.J.: D. Van Norstrand Co., 1957) p. 144.

[9] Personal communication with author by Warren Nyer, Idaho Falls, July 22, 2009.

[10] See HAER No. ID-33-F, p. 6-7, for ACRS hopes for the safety ideal of "automatic fuses" in reactor design. These would be inherent and natural responses in a reactor that would prevent runaway reactors from reaching dangerous conditions.

The objective of SPERT-III was to investigate a wide range of system temperature, pressure, and flow conditions.[11] These were particularly descriptive of pressurized-water reactors. Codes had been created, but were they reliable? How well would they compare with "real" excursions that occurred when temperature, water pressure, water flow, and power level were different? The only way to find out was to create the excursion, record the data in precise detail, and compare results with what the code had predicted. If the code was not predictive, the challenge was to understand why and amend the code.

In addition, physicists hoped to learn whether the interactions between a nuclear core and supercritical water would be similar to or different than what they had learned with SPERT-I.[12] SPERT-I had confirmed that when moderating water became hot enough to boil and create bubbles, the decrease in its density tended to shut down the reactor. Now they wanted to operate closer to the high-temperature zone where liquid and steam merge into one fluid unlike either liquid water or steam.[13]

These research questions dictated what was required of the reactor and its vessel, what accessories it needed, and what features were required of the building that would house them.

Foremost, the reactor required a pressurized water system. Such systems relied on water flowing through all the fuel assemblies and past each fuel rod element within each assembly. The water was confined in a closed-system pipe, called a "loop," to carry away heat generated by the fissioning of the uranium fuel. The heat collected in this "primary" loop passed *via* a heat exchanger to a "secondary" water circulation loop that, in a commercial reactor, would then produce the steam to spin turbine blades and generate electricity. To prevent the primary coolant from boiling within the reactor, it was kept under significant pressure.

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[11] J.C. Haire, Jr. "A Summary Description of the SPERT Experimental Program" in *Nuclear Safety, A Review of Recent Developments*, Volume 2, Number 3 (Oak Ridge: Oak Ridge National Laboratory, 1961), p. 15.

[12] "Supercritical" water has reached at least 705 degrees F. under pressure of 3208 pounds per square inches. At this stage, the liquid and vapor densities are identical and the two phases merge into one "supercritical" fluid unlike either liquid water or its vapor state, steam.

[13] Warren Nyer, July 22, 2009.

The other function of water in the primary loop was to moderate (slow down) neutrons released by fissioning uranium-235 atoms. Slower neutrons had an improved chance of fissioning additional U-235 atoms, which was necessary to continue the chain reaction.

To simulate excursions occurring during high temperature conditions, water heaters and heat exchangers were part of SPERT-III's equipment. Flow rates were controlled by pumps and valves. Instrumentation was an integral part of all operation and design. The state of the water -- levels, temperatures, pressure, flow rates -- had to be instantly communicated to data-recording devices and control consoles.

Thus equipped, SPERT-III could simulate accidents safely. The reactor and its vessel had to allow for rapid increases of "excess" reactivity, which was one way to simulate a control rod that failed to operate correctly. For any given test, researchers could hold all but one variable constant, thus isolating its impact on the progress of the excursion. As always, the goal was to understand what inherent self-limiting mechanisms would quench a chain reaction -- or do the opposite. Disturbances that could generate dangerous oscillations in reactor power needed to be found out.[14]

PART THREE

THE SPERT-III REACTOR

As a "test" reactor, SPERT-III had to be versatile and tough enough to withstand and support the desired ranges of extreme heat, pressure, and flow. Researchers wanted to operate at a maximum power level of 60,000 kilowatts.[15] Since they planned to test different types of fuel, it had to accommodate different core designs. Its control system had to tolerate deliberate reactivity increases. It had to be biologically safe for workers adjusting instrumentation, loading and unloading fuel assemblies, and managing process water equipment.

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[14] W.E. Nyer, G.O. Bright, and R.J. McWhorter, "Reactor Excursion Behavior" in *Proceedings of the Third International Conference on the Peaceful Uses of Atomic Energy, Geneva, August 31-September 9, 1964*, Volume 13 (New York: United Nations, 1965) p. 13.

[15] Heffner and Wilson, *SPERT III Reactor Facility*, p. 12.

The Reactor Vessel

Gamma heat generation within the reactor vessel, plus sudden changes in water flow, temperature, and pressure, would stress

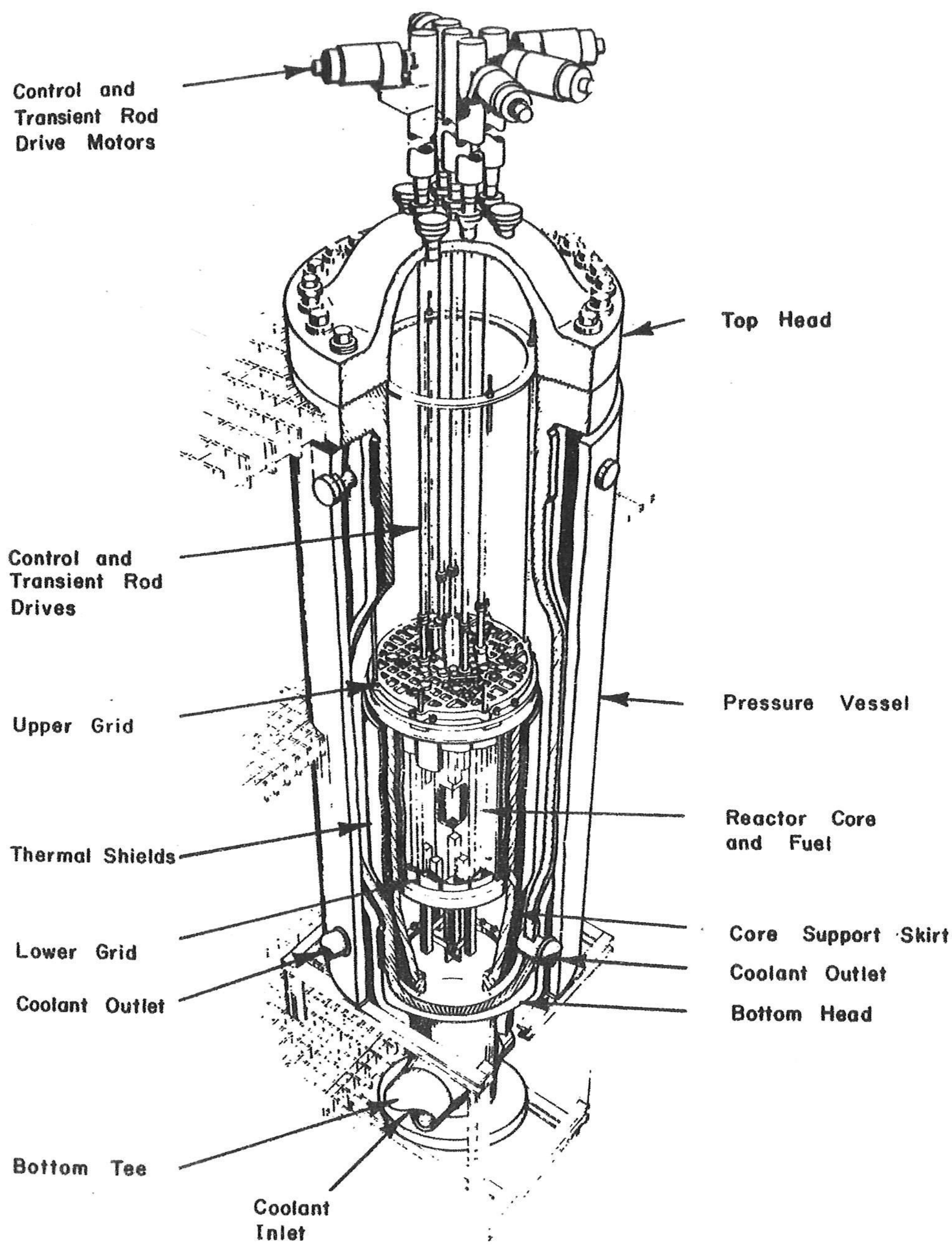

Figure 1. Cutaway view of SPERT-III reactor vessel. Control and transient rods are shown inserted into the core and fuel zone.

the vessel considerably. Design standards for such vessels had been promulgated by the American Society of Mechanical Engineers but didn't account for SPERT-III's role as a test reactor in an isolated location. Research would feature short run times, a relatively brief lifetime, and access to instruments. These considerations dominated the specifications.[16]

The vessel shell consisted of eleven layers of thin steel plate, built up by wrapping it around an inner pressure-tight cylinder, tightening it, and welding the sheets to one another. The top head was removable. The bottom was shaped as a hemisphere, below which was a thick support referred to as "the bottom tee." The inner diameter of the vessel was 48 inches. Its full length was 23 feet/9 inches. Prior to fuel loading, it weighed 42 tons.[17]

The top head, which had to be removed when operators needed to work on the reactor, fastened to the shell by means of 28 bolts. A pair of gaskets made of steel and "Canadian asbestos" lay between the faces of the flange. The top head accommodated five control-rod nozzles and four others for the insertion of measuring instruments. The nozzles were welded into the head forging and lined with stainless steel.

The cylindrical-shell section of the vessel, with its half-inch-thick inner pressure shell and eleven quarter-inch sheets of steel plate, was 3 1/4 inches thick. The inner shell was clad with stainless steel, while the layers surrounding it were carbon steel. Six coolant outlet nozzles, 8 inches in diameter and equally spaced, were near the bottom of the vessel shell and above the inlet ports.

The opening for the water coming from the pressurizer vessel was four inches in diameter and located below the six coolant nozzles. Six other access ports, designed like the access ports on the top head, also were in the lower part of the vessel. Thermocouples, instruments measuring heat, penetrated the reactor vessel to measure the temperature of water leaving the core, the vessel wall at various depths, and fuel plates.

The bottom tee supported the vessel and its contents. Two thermocouples penetrated the forged head to measure the temperature of coolant as it entered the vessel in either of the

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[16] Heffner and Wilson, *SPERT III Reactor Facility*, p. 11-13.

[17] This and the following description of the reactor vessel and its thermal shields are from Heffner and Wilson, *SPERT-III Reactor Facility*, p. 11-22.

two inlet ports. Because of rapid heating and cooling, the vessel would expand and contract. The vessel was given sufficient space in which such changes could occur without constraint. Beneath the bottom head was a curved support "cradle," shaped to hold the bottom head and welded to a base plate. The base plate was then bolted to the I-beam framework of the building at an elevation about 11 feet above the floor of the reactor pit. To keep the vessel from rocking or swaying while the reactor was operating, spring-loaded braces were anchored to the reactor pit wall to exert even pressure around the circumference of the vessel.

Before Phillips placed the vessel in the reactor pit, it tested whether the vessel could withstand pressures of 1 1/2 times the design specification. The crew placed 78 strain gauges on the outside surface of the vessel, increased the pressure gradually to 3750 psig, held it for eight hours, and then gradually reduced it. They concluded that strain was distributed uniformly. During maximum pressure, the vessel grew by 1/8 inch in circumference and 1/16 inch in length, a satisfactory result. To reduce heat loss from the vessel, four inches of foamglass insulation covered it, attached to the vessel by steel mesh and metal bands.[18]

Biological and Thermal Shields

To shield people from radiation, a wall of curved lead bricks was stacked by hand around the vessel. The bricks began at the bottom-head bolting flange and rose the full length of the vessel to the underside of the top flange. Openings were left for piping and access nozzles. Lead wool plugged gaps between the bricks. An air gap was left between the wall of bricks and the reactor vessel to allow cooling air to be blown into the space, should this ever be necessary. In the region of the vessel that was to be occupied by the reactor core, a structural steel "window" of 3x3 feet was created in the shield wall. Bricks in this section could be removed and replaced if operators ever needed to access thermocouples and strain gauges on the vessel wall. General support for the heavy bricks was provided by extending the vessel's I-beam supports.[19] Drawings in HAER Photo No. ID-33-I-63 show how the shaped bricks fit around the circular vessel.

The vessel itself required "thermal" shields. When a chain reaction is in progress, gamma radiation is thrown off in the direction of the vessel's inner wall, heating it up and weakening it. To attenuate this problem, four concentric cylinders of

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[18] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 15.

[19] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 16.

stainless steel were fitted between the reactor core and the inner wall, each separated by a water annulus. These shields constricted the 48-inch diameter of the vessel by several inches.[20]

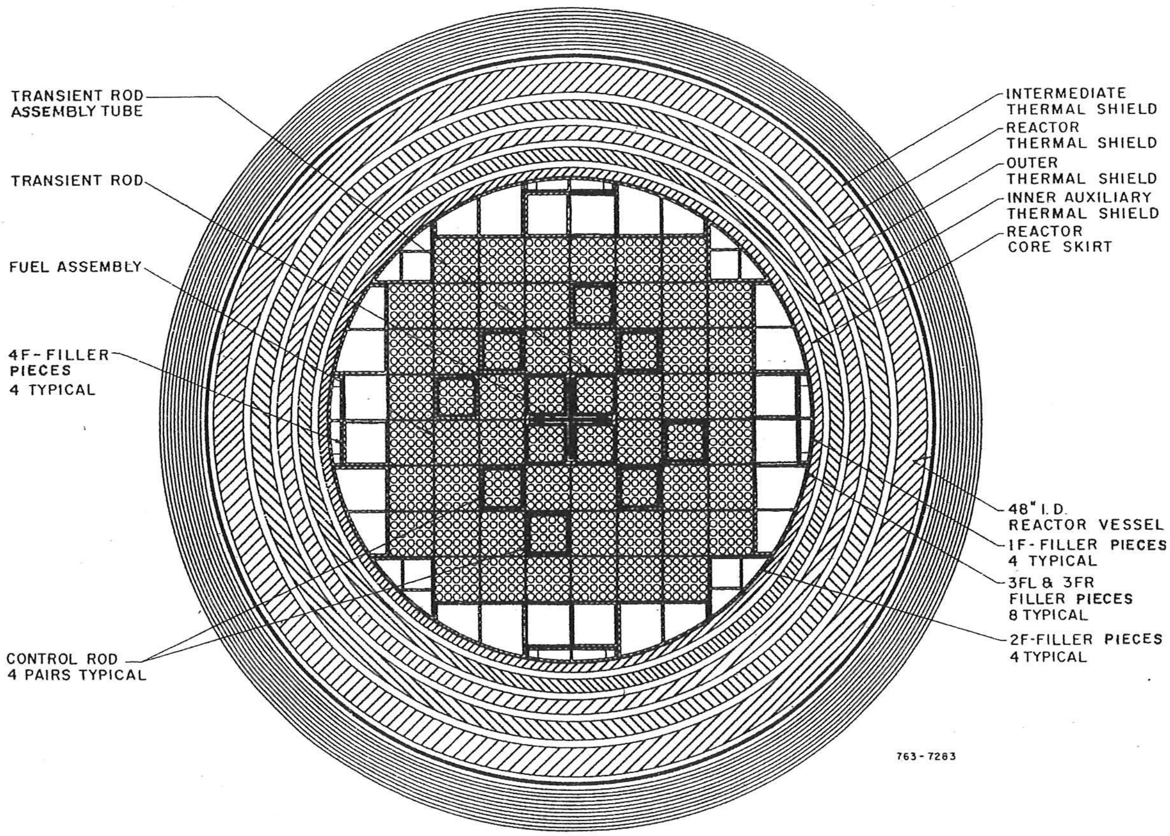

Figure 2. Cross section of SPERT-III vessel and C-core.

Flow Skirt

"We had ways of making water go where we wanted it to go," recalled Reactor Safety Program Director for Phillips Petroleum, Warren Nyer. After entering the reactor vessel it had to flow upwards through all four fuel quadrants uniformly -- and return downward into the annuli between the four heat shields. The "flow

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[20] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 21-22.

skirt" was a somewhat funnel-shaped metal plate located in the lower end of the vessel and arranged to direct the water accordingly.[21]

Control-Rod Assemblies and Drives

The loading of fuel and control rods in each quadrant of the reactor was symmetrical. The control material, Boron-10 (an absorber of neutrons that "poisoned" or dampened the chain reaction), was packaged into stainless steel "assemblies," the support structure for which consisted of a lower grid, upper grid, and guide tubes for control rods. The lower grid, when fully loaded with the reactor's fuel, could support 2500 pounds. HAER Photo No. ID-33-I-50 shows the top grid plate.

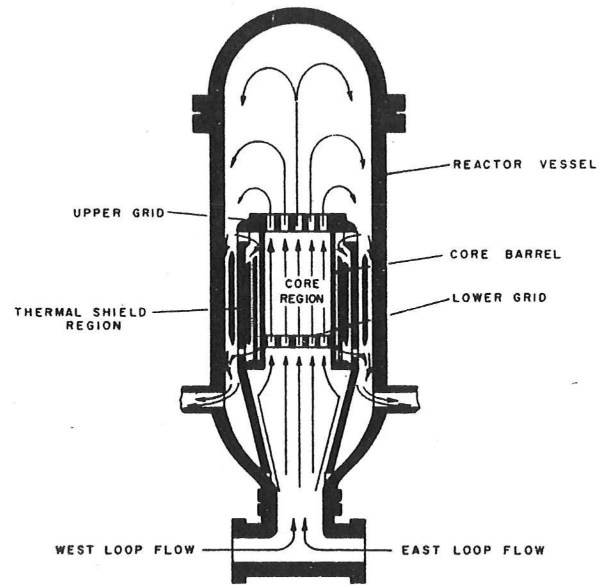

Figure 3. Coolant water entered the reactor from the bottom, flowed past the fuel plates in the core,and returned downward through the annuli of the thermal shields.

The upper grid positioned the core elements in their correct vertical orientation. Its outer diameter was 42 inches, and it was 7 inches thick. Its design allowed for some assemblies to be "removable" without removing the grid, while other assemblies could not be removed until the grid came off. Each assembly fit securely into its place by a locking collar.[22]

Control rods aided in starting up the reactor and maintaining the chain reaction at the desired power level. Each quadrant in the grid had a place for two control rods, which were yoked together at the top and moved together. One special rod, called the "transient rod," was placed at the center of the grid.

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[21] Warren Nyer, July 22, 2009.

[22] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 23-26.

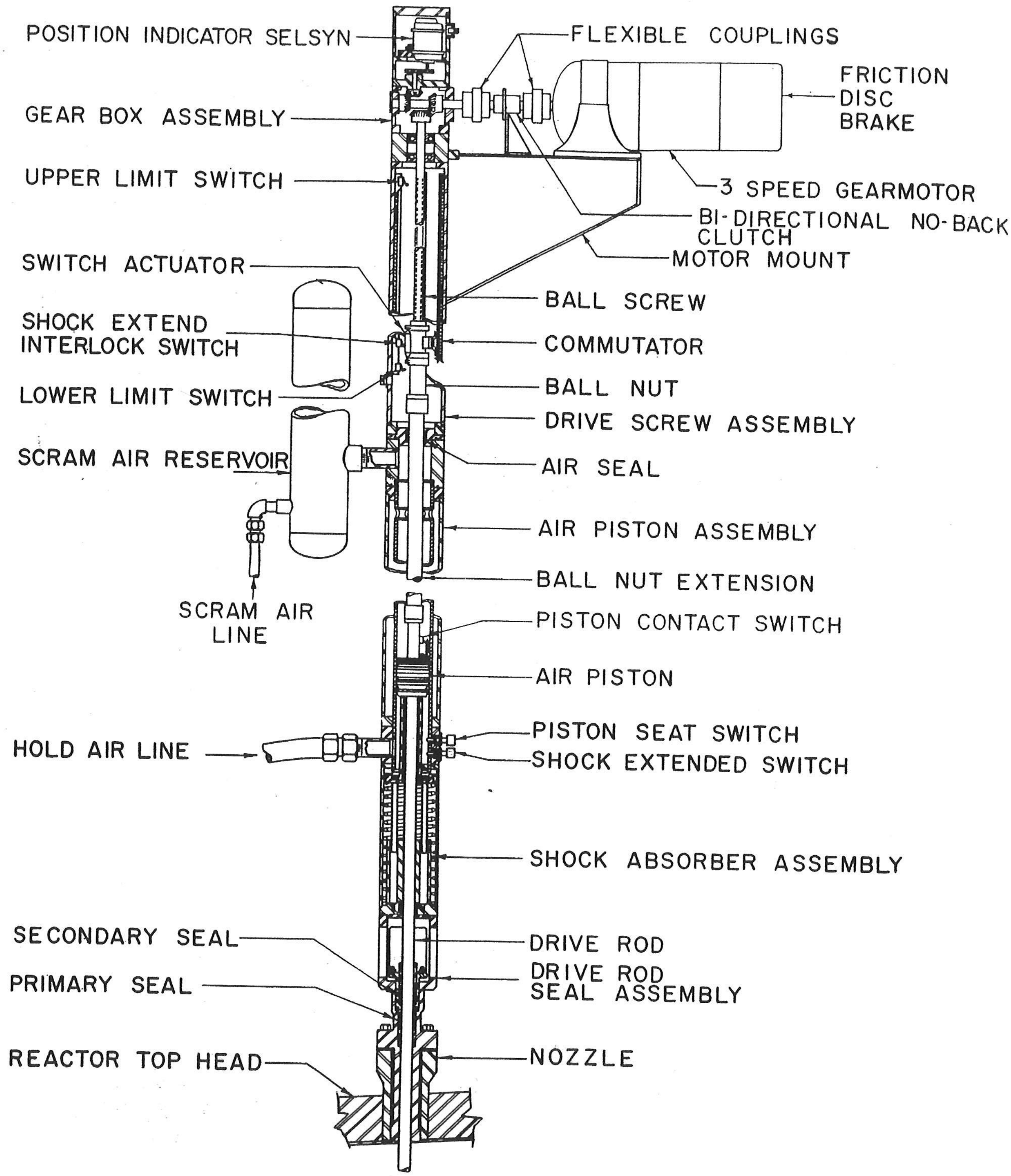

Figure 4. Schematic drawing of SPERT-III control rod drive assembly. Compare with HAER Photo Nos. ID-33-I-52 and -53, which show air pistons and three-speed drive motors atop the reactor.

Like the SPERT-I transient rod, it was cruciform in cross-section, having four "blades" each 2 5/8 inches long. For versatility, the control rods were fabricated so that they could be adapted for variations in length of the fuel zones. It will be recalled that SPERT-I had ten different cores, and it was assumed that SPERT-III would likely have multiple cores as well.[23]

The performance of the complicated mechanisms moving or "driving" the rods in and out of the fuel zone of the reactor core were of great importance to the safety of the reactor and its operating personnel. Much depended on the reliable and instant release of energy stored in air pistons whenever the operator called for it. Each drive apparatus consisted of hundreds of parts: switches, screws, commutators, nuts, extensions, lock assemblies, seals, shock absorbers, motor gears, rings, rods, solenoids, latches, gaskets, sensors, cylinders, pistons, and other engineered specialties of the mechanical arts.[24]

Conventional reactors scram when the reactor reaches a preset power level or doubling period (a measure of the rate at which the power level is increasing). For SPERT-III, the point of the work was to identify processes at work beyond these conventional parameters, so the reactor had no "automatic" scram. Nevertheless, it was still possible to run the reactor in an unwise fashion and damage the core unintentionally. Mechanical interlocks were built into the control system to prevent such unintended or premature excursions.[25]

In addition to Boron-10, the control rods also contained fissionable fuel below the poison. One method of increasing reactivity was to withdraw the poison section from the core while at the same time adding additional reactivity in the "follower" section, a useful tool for both experiments and control.

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[23]Possibly a "zirconium core" was anticipated. Nuclear calculations for same were prepared in 1956. See G.A. Cazier and B.L. Hanson, *Nuclear Calculations for SPERT III Zirconium Core*. Idaho Falls: Phillips Petroleum Company, 1956.

[24]For performance and safety specifications concerning control and transient rod performance, see Heffner and Wilson, *SPERT-III Reactor Facility*, p. 27-41.

[25]Heffner and Wilson, *SPERT-III Reactor Facility*, p. 5.

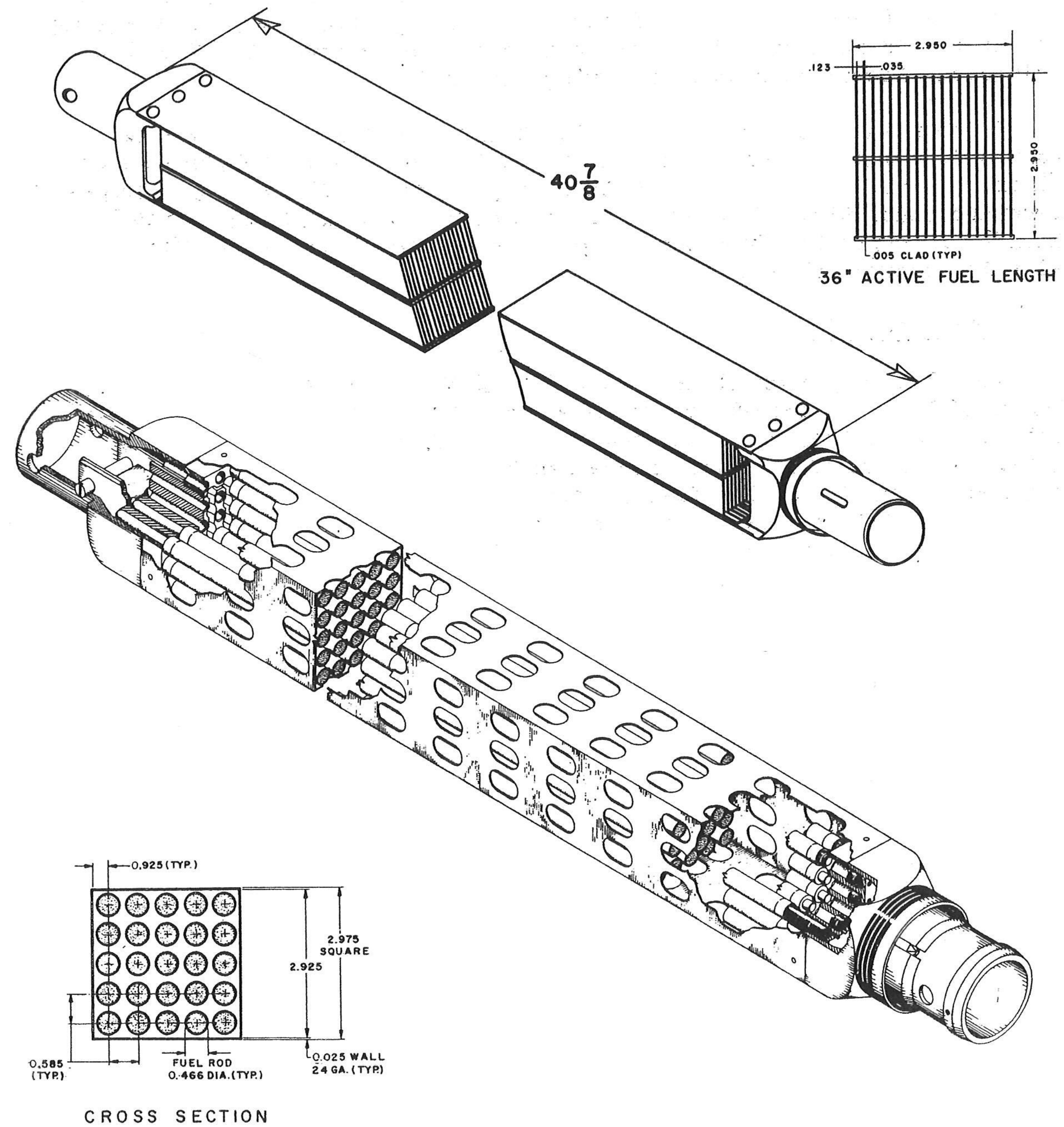

Figure 5. Two Fuel rod assemblies. C-Core fuel was packed within thin plates clad in stainless steel. E-Core fuel was formed as pellets stacked within a stainless steel rod.

Fuel Assemblies

Like control assemblies, SPERT-III's stainless steel fuel assemblies were made to fit the length of the reactor vessel. The fuel, however, occupied only about three feet of each assembly at the center of the vessel. The assembly packaged many small fuel plates or rods together in one long "box." Coolant/moderator water flowed in the small spaces between each element to carry away the heat of fission.[26]

PART FOUR

SITING AND BUILDING SPERT-III

The safety philosophy for running SPERT-III tests was similar to that governing SPERT-I: that the reactor be managed and controlled remotely from a control center. Most experiments were of short duration -- rarely more than a few hours; frequently, much less. Operators and technicians prepared experiments and instruments in the reactor building and then withdrew to the SPERT Control Center to run the experiment. Visual contact between Control Center and the Reactor Room was available with the aid of several closed-circuit televisions connected by cable across the intervening desert.[27] At SPERT-I once, when the program called for a series of severe reactor experiments that were deliberately destructive, operators had dismantled the Butler-building roof and walls before the test series.

The SPERT Area site plan arranged its reactor buildings roughly in a semi-circle a half-mile from the Control Center and

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[26] For descriptions of SPERT-III C-Core and fuel assemblies, see C.M. Condit, J.F. Scott, and R.L. Johnson, *The Effects of Coolant Temperature and Initial Power Level on the Excursion Behavior of a Highly Enriched Plate Core in SPERT III -- Experiment and Analysis*, IDO-17138 (Idaho Falls: Phillips Petroleum Co., 1967), p. 49-52. For similar E-Core data, see McCardell, R.K., D.I. Herborn, J.E. Houghtaling, *Reactivity Accident Test Results and Analyses for the SPERT III E-Core -- a Small Oxide-Fueled, Pressurized-Water Reactor*, IDO-17281 (Idaho Falls: Phillips Petroleum Company, 1969), p. 85-89.

[27] Clyde Toole, October 11, 2009. At first, the TV cables lay atop the desert covered with a soft rubber-like coating of a light brown color to hold the cables together. Upon losing the signal one day, operators discovered that small desert animals had eaten through the cover and then into the cable insulation, shorting out the cable.

a half-mile from each other.[28] SPERT-III took its position east and slightly north of the Control Center. The site planners had calculated these relationships with the understanding that prevailing winds blew towards the northeast. Should an accidental release of radioactivity occur, the position of the Control Center upwind of the reactors would (most of the time) minimize the danger to people working there.[29]

As we have seen, SPERT-III required more elaborate water accessories than SPERT-I: the primary and secondary coolant loops with piping and pumps; water treatment processes for softening and purifying (deionizing); pressurizer and heat exchangers. The building shell for these items -- and the reactor -- required a significant upgrade from SPERT-I's detachable roof and walls.

The Idaho Operations Office (IDO) of the NRTS hired Stearns-Roger Company of Denver, Colorado, to complete an excavation study and develop the architectural and engineering drawings for the SPERT-III building and site. Working with Phillips Petroleum Company, the designer and operator for SPERT-III, Stearns-Roger's upgrade was a steel-frame building with masonry walls made of concrete blocks. See elevations on HAER Photo No. ID-33-I-59.

By September 1956, Stearns-Roger had completed its survey of the SPERT-III site. Test-hole drilling sought the depth to bedrock at five-foot intervals. This work illuminated an uneven lava flow below the soil, none of it as deep as thirty feet below grade, the depth of the proposed reactor pit. Phillips and Stearns-Roger selected an optimum placement, nevertheless, a spot where some rock would have to make way for the reactor pit, but not for the shallower pits. See section profiles in HAER Photo No. ID-33-I-56.

Late in 1956, IDO awarded the prime construction contract to the Paul Hardeman Company, Inc., of Stanton, California, and extended a 12.5 KV power line to the construction area. On the flat, snow-covered site, Hardeman set up a small heated trailer as a construction office and began to excavate a 30-foot hole for the SPERT-III reactor pit. "Bedrock" was an ancient basalt lava flow that underlay the wind- and water-borne sediments of the desert. When the excavation had exposed the uneven layer of

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[28] See HAER No. ID-33-F-93, a drawing of the site plan that also shows a modification to accommodate the Power Burst Facility. The SPERT-III site was not affected by the modification.

[29] See Part Three of HAER Report ID-33-F for other environmental and site characteristics of the SPERT area.

"cinder-type" lava, as the engineers called it, IDO site photographers recorded the fissures typical of magma that had long ago cooled and cracked. See HAER Photo No. ID-33-I-24.[30]

The excavators turned to the other pits, removing soil only to the necessary depth for each. Accommodating each pit resulted in the particular floor-area dimensions of the building. The main one was the "process pit," its floor level about 12 feet below the main floor level. It contained the pressurizer vessel, water pumps, and their associated piping. The floor plan oriented this pit just north of the reactor pit along the north/south axis of the building with both pits centered equidistant from the east and west walls. See floor plan at HAER No. ID-33-I-58.

Shaping the several pits was an exercise in erecting forms and placing rebar and concrete in a series of lifts, or pours. Future locations for conduit, piping, and other "negative space" penetrations (block outs) through concrete gradually materialized as the lifts approached grade level. See HAER Photo Nos. ID-33-I-25 and -26. Some floors required extra steel to support the heavy weight of the equipment that was to rest upon them. HAER Photo No. ID-33-I-30, for example, shows closely spaced steel beams anticipating the heavy heat exchangers.[31]

After the concrete work reached the main operating floor, approximately at grade level, the steel frame of the building went up, followed by pumice-block walls and a metal roof, all typical low-bid conventional construction. The specifications for a bridge crane determined the roof height. The crane was an essential aid for raising and lowering the reactor's long control, fuel, and instrument rods into the vessel from the top. Drive mechanisms for these assemblies also were situated above the reactor. During preparations for a test run, the top head itself, an item weighing 10,606 pounds, would be unbolted and lifted from the vessel and set down on the floor out of the

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[30] Photographer's "cinder-type" remark appears on envelope containing INL Negative No. 57-361. Snow at construction site appears on INL Negative No. 57-374. SPERT-III construction progress photos are available from records created by IDO photographers, who were dispatched regularly to construction sites. They are stored and available at INL's Records Storage Warehouse in Idaho Falls. Several are reproduced in the Index to Photographs for this report.

[31] See also Drawing 102349, S 5, which identifies the location of structural steel in the operating floor.

way.[32] The air space required for these lifting activities dictated that the crane hook reach to the floor, lift an object 21 1/2 feet above it, and have access to the complete length and width of the reactor room. After accommodating the crane and its travel rails, the roof was about 30 feet above the floor. See HAER Photo Nos. ID-33-I-31 and -59 respectively for construction photograph and roof elevation.

Not all of the building's activities required crane assist or a high ceiling. Workers needed an office area, instrument control room, bathroom with showers and lockers, and a utility room for process water treatment. Such rooms needed only a conventional roof elevation suited to the human scale, a height of twelve feet above the floor. The designers placed all these "low-bay" functions in a row along the full length of the west wall. See HAER Photo Nos. ID-33-I-32 and -35, and -47.

In all, the floor area required to serve the reactor and its operators produced a rectangular building 80 feet long by 60 feet wide. The high-bay reactor room took up 40 feet of the width. Phillips operators came to refer to the 20-foot-wide low-bay section as the "west wing." See HAER Photo No. ID-33-I-58.

By the end of September 1957, the pressurizer vessel had been delivered to the site and placed in its future location between the reactor and process pits. This early arrival was necessary because, other than the reactor vessel, it was the only equipment mounted in a fixed position on structural steel. Other water-related equipment and piping was mounted on spring supports and bearing plates to allow for the expansion and contraction of metal upon heating or cooling.[33] The top of the pressurizer vessel is seen in HAER Photo Nos. ID-33-I-33 and -36. HAER Photo No. ID-33-I-60 illustrates the arrangement of the process layout.

With the pressurizer in position, the concrete work progressed around it. Water-system equipment such as the 20,000-gallon tank that would store deionized water, began arriving. The steel frame and masonry walls enclosed the reactor room and the four west-wing rooms. The bridge crane was installed. Accessories outside the building, such as waste-water leach ponds, the substation, pipe trenches, a guard house, and cable runs, went under construction.

The reactor vessel arrived in late November 1957. The manufacturer, A.O. Smith, shipped it by train from Milwaukee,

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[32] Heffner and Wilson, *SPERT III Reactor Facility*, p. 75.

[33] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 53.

Wisconsin, to the Central Facilities Area of the NRTS. Workers loaded it onto a flatbed trailer and hauled it to the south rollup door at the SPERT-III building. The door was 16 feet wide and 19 feet high while the reactor vessel was a fraction of an inch short of 20 feet long.[34] The roof of the building already had been installed, so the movers angled the heavy vessel inside the door with the help of an outside crane and an A-frame support. See HAER Photo Nos. ID-33-I-39 and -40.

After that, inside work shifted to the welding of pipe, the checkout of pumps and other equipment, and the assembly of the reactor's many attachments. The laydown yards outside, piles of materials, and construction clutter gradually disappeared and the site took on an orderly appearance. Most of the interest and action thereafter was focused inside the reactor room. See HAER Photo No. ID-33-I-46.

In September 1958, the Hardeman contract was 99 percent complete, and the SPERT physicists already had been preparing for the reactor's first criticality. The contractors demonstrated to Phillips that the water control systems were working, so Phillips accepted the building on October 23, 1958, and took the reactor critical nine weeks later.[35]

In a 2009 interview, Warren Nyer remarked that, "We didn't care all that much about the layout and arrangement of the process water pit. We just wanted the results at the reactor to meet our specs. How they did it was up to them. This was standard industrial design; we weren't asking for anything new to be invented."[36]

PART FIVE

THE SPERT-III FACILITY: DESCRIPTION

A half-mile dirt road connected the Control Center to the SPERT-III reactor building, which in turn was surrounded by its supporting utilities, a fence, and leach ponds. Other than the electrical substation and a fuel-oil storage tank for an

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[34] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 75. The reactor, including top head was 19 feet, 11 and 1/8 inches long. Its total weight was 83,400 pounds.

[35] *Quarterly Progress Report*, IDO-16537, December 1958, p. 50.

[36] Warren Nyer, July 22, 2009.

emergency electrical generator, the features supporting the building all dealt with the management and processing of water. See plot plan for relation to Control Center at HAER Photo No. ID-33-I-57 and also Appendix B.

The fence surrounding the building was mainly for safety, keeping unsuspecting people and wandering deer from harm during experiments. Two leaching ponds lay outside the fence. Night security lights were installed on poles every 110 feet or so along the fence line. See HAER Photo No. ID-33-I-46 and -47.

The SPERT-III Reactor Building, PER 609

As noted above, the rectangular floor-area footprint of 80 feet by 60 feet accommodated the reactor system and the adjoining west-wing suite of service rooms. The reactor room contained no partitions or smaller rooms. The west wing rooms, from south to north, were the Transient Instrument Room, the Office and Locker rooms, the Control Room, and the Utility Room.

The following description begins with the four exterior facades, then the interior layouts of the wing rooms, and finally, the reactor room's main-floor and lower-level layouts. The descriptions use the past tense to distinguish them from the many modifications made after 1980 when the building went into use as the Waste Experimental Reduction Facility (WERF).

The south facade contains the 16x22 feet rollup steel door (opening 16x19 feet) through which the reactor vessel and other hardware had entered the building for installation.[37] It was centered in the high-bay section and topped by a steel beam lintel. To its west was a personnel door of an industrial steel style with the top half glazed. The flat unadorned roof line was marked by a galvanized metal gravel stop and closure. The skin of the building consisted of 41 courses of grey pumice block. On the south facade of the west wing, a six-pane steel-frame window centered in the wall gave light into the Transient Instrument Room. See HAER Photo No. ID-33-I-46.

The north facade was similar to the south, except that the steel rollup door was a smaller model at 12x12 feet. Each door operated by means of a motorized chain gear. The Utility Room's north wall had a louvered register instead of a window. See HAER Photo No. ID-33-I-47.

The east facade was the east wall of the reactor room and had no windows or doors. Attachments on the outside wall,

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[37] See HAER Photo No. ID-33-I-58. Reference to the size of the rollup door may vary in different reports.

however, included a vent, security wires and insulators, and alarm sirens. See HAER Photo No. ID-33-I-46.

The west-wing facade had four doors, one each into four interior rooms, along with windows and other openings. The Instrument Control Room had no windows other than the one from its south exposure. The next door opened into the Locker Room. A pair of four-paned steel windows (5 feet by 2 feet/8 inches) were situated high enough for privacy. The next door was to the Control Room, a double-wide, double-swing door, the extra width desirable when moving control panel consoles in and out. A pair of windows, each 5 feet by 2 feet/9 inches and controlled from either inside or outside, was just north of the door. Access into the Utility Room was also by a double door, this one made of wood, designed to be removable, with two panes of glass on top and louvers at the bottom. Above this door and to its south was an air inlet register. The roof line of the west wing was as plain as that of the reactor room -- galvanized metal gravel stop and closure. Like all of the other facades, siding on the wing was pumice block in 15 courses. See HAER Photo No. ID-33-I-59.

The flat roof of the high bay, covered with gravel, sloped for drainage about two inches from west to east. The wing roof sloped slightly from east to west. The finished floor was six inches above grade, requiring a six-inch concrete sill for the several entry doors.

The Transient Instrumentation Room was 15 feet/7 inches wide (north to south) and 19 feet deep. The chief interior feature of this room was the conduit trench installed in the floor, the destination for communication and power cables originating at the Control Center and running on the desert floor for the half mile between. The cables entered the room just below grade level. The trench was arranged parallel to each of the four walls so that its leads could connect to instrument panels along each wall. The trench was covered with an open-mesh grate flush with the floor. This was the only room cooled by air conditioning, a concession to heat-sensitive equipment, not its human occupants. An industrial steel door opened into the reactor room. Construction of the trench, seen in HAER Photo No. ID-33-I-32, reflects the drawing, HAER Photo No. ID-33-I-58.

The equipment in the Transient Room received signals from thermocouples and other measurements and sent them to the Control Center. Here, technicians performed the signal conditioning necessary to calibrate or amplify signals, for example, before tests. They made certain that instrumentation was working correctly and that signals received at the Control Center were accurate.

A partition wall with no doors or windows separated the Instrument Room from its next-door neighbors. The Locker Room and Office each had their functional space defined by a wall between the two. Entering from the outside door, personnel -- obviously expected to be male persons only -- found themselves in the Locker Room, which was equipped with a double tier of lockers and a shower room against the west wall. Along the north/south wall separating the locker area from the office were the urinals, toilets, two lavatory sinks, a 40-gallon water heater, and a clothes closet. A door, louvered at the bottom, at the north end of the locker room opened to a short hallway containing a water cooler (drinking fountain). A person could either continue down this hallway and open a door into the reactor room or turn into the Office doorway on the right, the only door into the Office. The Office was 14 feet along its north/south axis and 7 feet wide, the only space in the west wing with no window to the outside. An industrial-steel fixed window about 5 feet wide by 4 feet high gave visual access into the reactor room. The combined Locker Room, Office, and connecting hall measured about 19 feet square.

The dividing wall between the Locker/Office module and the Control Room also was solid, with no connecting interior doors or windows. Cable trenches in the floor were covered with open-mesh floor grating. This, the largest of the four wing rooms at about 24 feet by 19 feet, contained recording equipment and data cabinets along its south wall, in the center of the room, and along its north side. The function of the equipment was to operate and regulate the pumps and pressurizer equipment before each test, bringing temperature and other parameters to the desired conditions for the given test. The door into the reactor room was near the corner at the south wall. Like the Office next door, it had an interior window into the reactor room, where it looked directly across the process pit.[38]

Finally, the Utility Room, about 19 feet square at the north end, contained a furnace (for heating and ventilating), pumps, and water-processing supplies: a brine tank, zeolite softener, mixed-bed demineralizer, and tanks of acid and caustic. An air-inlet register was situated above and southward of the outside entry door. Its interior access into the reactor room was next to the north wall, an industrial steel door with glazing on top. HAER Photo No. ID-33-I-45 shows water process equipment along north wall of Utility Room.

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[38] For a simplified diagram showing process instrumentation, indicators, and controls, see Heffner and Wilson, *SPERT-III Reactor Facility*, p. 45.

Inside the Reactor Room, the most prominent architectural features were the two large rectangular pits and their contents. The reactor pit contained the reactor vessel, most of which was below the floor. The top head and its many piped, cabled, and instrumented attachments and control-rod drive mechanisms projected above the floor. The concrete floor of the pit was 26 feet below, beneath which was a sump. At floor level, the pit was 18 feet square and covered by removable metal grating with a mesh of 1.25 inch. The center of the reactor (bird's eye view) was located at the center of the pit, 20 feet from the east and west walls. Conduit emanating from their fittings on the reactor proceeded south beneath the concrete floor, and turned a 90-degree angle towards the Transient Instrumentation Room. Views of the "naked" reactor vessel, HAER Photo Nos. ID-33-I-39 and -40, on the day it moved into the building illustrate the reactor's many openings for coolant, control, and instrumentation connections. The layout for the major equipment in the two pits is shown in Figure 7 and HAER Photo No. ID-33-I-60.

The process pit was a rectangular space 32 feet/5 inches along the north/south axis and 20 feet/8 inches across.[39] Its floor was 12 feet below the main floor and provided space for the loops (piping) of primary and secondary coolant water and their associated motorized valves, pumps, and drains. Two built-in ladders, made of reinforcing metal (rebar) and set into the concrete, gave access directly from the main floor into the pit. The construction scene in HAER Photo No. ID-33-I-27 shows these ladders. On the main floor, a concrete safety curb surrounded the process pit, as did removable handrails.

The two pits were separated by 3 feet/6 inches of concrete, which acted partly as a biological shield between the two areas. At the south end of the process pit, the Pressurizer Vessel had its own 7-foot-wide niche.

The purpose of the pressurizer vessel, which contained sixteen 12-kilowatt immersion heaters, was to maintain a constant-pressure steam dome in the vessel. The vessel was

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[39] Heffner and Wilson, in *SPERT III Reactor Facility*, p. 10, reports the process pit dimensions as 27x12 feet.

Figure 6. Process flow diagram

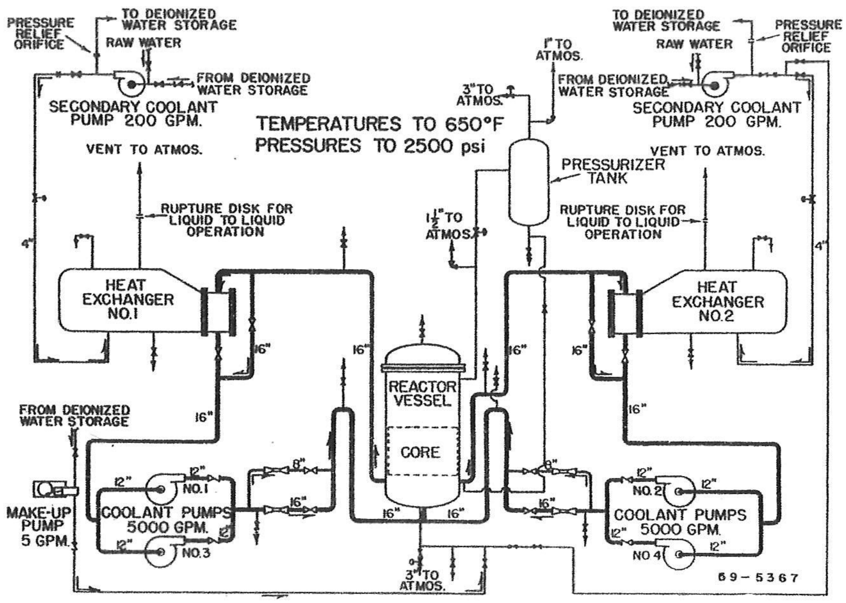
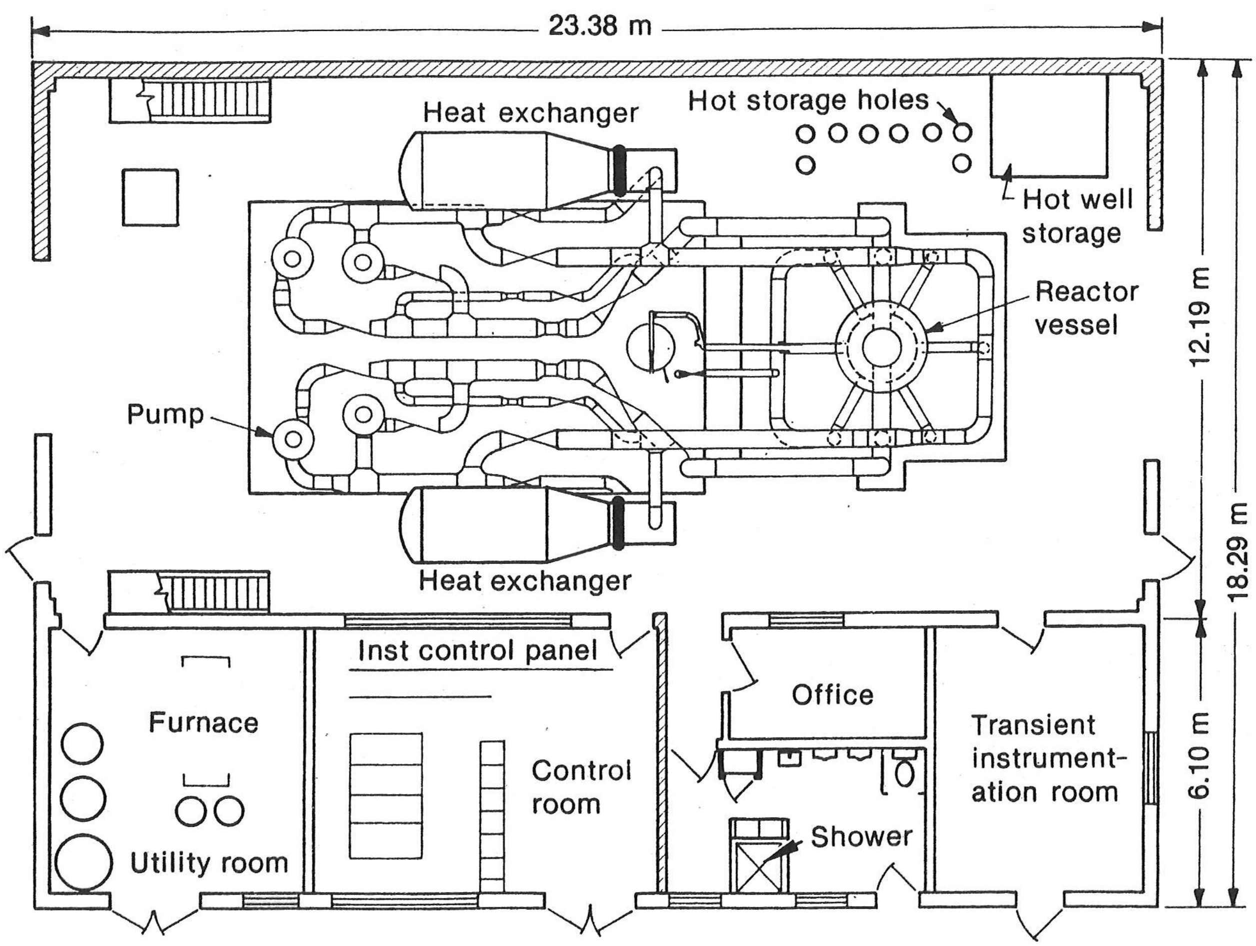


Figure 7. SPERT-III floor plan shows location of main process water features.



connected to the reactor outlet piping by a 4-inch static water leg. The dome in the upper half of the vessel served as a cushion to absorb pressure surges in the primary system.[40] The vessel was designed to sustain pressures of 2500 psig and temperatures up to 668 deg. F. It was 16 feet/8 inches long, with an outer diameter of 4 feet/3 inches. The vessel volume was about 83 cubic feet; it weighed about 20,000 pounds.

Along the east side of the reactor pit was a series of seven ion chambers. Such features detect the presence of ionizing radiation by measuring the electrical charge resulting from an interaction between the radiation and suitable gases, liquids, or solids. These penetrations through the concrete floor were lined with carbon-steel pipes, 11 feet long. At the bottom of each was a hemispherical weld cap and below that, a pipe drain.

Dominating the floor space next to the process pit were the two Heat Exchangers, one on each side of the pit near its respective wall. These were located purposely on the main floor for future convenience in studies involving natural convection circulation of the coolant. They were so heavy -- 43,200 pounds when full, not counting the 11,600 pound tube bundle -- that their concrete support pads were given extra steel-beam reinforcement. Within the heat exchangers, the reactor's hot primary coolant circulated through U-shaped tubes surrounded by the secondary water and gave up about 200 degrees F. of its heat.[41] Both streams were under pressure to prevent boiling. Thus, all loops (pipes) led to the heat exchanger.

The steam heat collected by the secondary coolant would, in a commercial reactor, power a turbine and generator to make electricity. As SPERT-III was not intended to do this, the secondary heat from steam was vented from the heat exchangers to the atmosphere; hot water drained to the leaching pond.[42]

Other cavities built into the reactor room floor occupied space near the east wall. At the south end in the southeast corner was a Hot Storage Well, 8 feet long (north/south axis) and 6 feet wide, and 16 1/3 feet deep. The pit was lined with 16-gauge stainless steel and had a removable aluminum cover. At floor level, it was surrounded by a concrete curb of 4 inches by 4 inches and a removable safety handrail. This pit was filled

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[40] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 53.

[41] Wilson, *Preliminary Design Report*, p. 13; Heffner and Wilson, *SPERT-III Reactor Facility*, p. 76.

[42] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 63.

with deionized water, which acted as a biological shield for the radioactive items placed in the pit. Deionized water arrived at this pit upon operation of a one-inch valve located at the southeast corner of the process pit. When this water needed to be drained, it went to the building sump through a two-inch valve operated by a handwheel.[43]

Immediately adjacent to the Hot Well's north curb were eight Hot Storage Wells (or holes), designed for the temporary storage of radioactive fuel elements. These were dry, containing no water. Embedded in the floor, the holes were six-inch diameter pipes, lined with carbon steel, each 16 feet deep and plugged with lead covers. See HAER Photo No. ID-33-I-62. The carbon steel pipe stepped down from 14 inches in diameter near the floor to 10 inches and finally to 6 inches. This design provided width at the top for a lead plug for biological shielding. At the bottom of each hole was a pipe drain leading to the building sump, anticipating water drips or leaks from whatever assembly was placed there. Operators could store hot, infrequently used fuel elements in these holes. As it happened, the dry wells were used infrequently, as fuel assemblies rarely required removal. Clyde Toole recalled that when the first SPERT-III core was removed from the reactor, the assemblies were stored on racks in the larger "wet" pool to cool and, perhaps, be available conveniently should the experimental program ever require it again.[44]

When operators removed the reactor's top to refuel or re-instrument for the next experiment, they needed a place to set it down out of the way and distant from people. The chosen spot was over a hole four feet square in the floor near the northwest corner, north of the Heat Exchanger. The hole was curbed by 2x8 timbers. This arrangement allowed personnel to go below the ground floor and inspect the bottom side of the head from there, a job best not done while it was hanging from a crane hook. Small holes in the floor allowed for the erection of a removable safety handrail around this floor opening. See HAER Photo No. ID-33-I-58, section B1.[45] Operators sometimes called it a "dry dock."

Two stairways led to the floor of the process pit, one each at the northeast and northwest corners. The stairs, three feet wide, were adjacent to the east and west walls respectively, made

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[43] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 72.

[44] Clyde Toole, October 11, 2009.

[45] Heffner and Wilson, *SPERT III Reactor Facility*, p. 10. Inspections from below: Clyde Toole, personal communication with author, November 16, 2009.

of grate metal and equipped with hand rails and a concrete curb around each stairwell. HAER Photo No. ID-33-I-33 contains a view of one of the stairways; HAER Photo No. ID-33-I-58 shows them in the floor plan.

The 10-ton bridge crane moved north/south over the floor on steel rails secured on the east and west walls, spanning the entire 40 feet width of the reactor room. It moved the reactor's top head, helped install and remove fuel and control assemblies, and was on hand for moving equipment in and out of the Process Pit. HAER Photo No. ID-33-I-50 shows a technician holding a crane-control device to lower equipment into the reactor vessel.

Guard House, PER-610

The first construction photo to show the Guard House was taken in October 1957. See HAER Photo ID-33-I-35. It was located south of the building between the roadway from the Control Center and the security fence.

This structure seemed not intended to stand the test of long-term or even daily use. It was a wood-frame shed-roof structure 9 feet square and sided with half-inch plywood sheets. Battens two inches wide covered the plywood joints. The flat wood-frame roof was 12 feet square, allowing an overhang on all sides of 1 1/2 feet. For drainage, the roof sloped slightly from north to south. It was built up with gravel, specified on the drawing as "20-year." See HAER Photo No. ID-33-I-65, *Section AA*. The eaves were lined with 1x8 facia board and topped with a galvanized metal gravel stop. The Guard House foundation was a thin concrete slab with reinforced sills 1 1/2 feet wide around its perimeter.

The north and south facades each contained one double-hung window and one standard wood door with a single pane of glass on the top half and three wood panels below. The east and west elevations each had one window, the tops being 6 feet/5 inches from the floor line. See HAER Photo No. ID-33-I-46.

The Guard House was to be equipped with telephone, fire alarm, gong, safety switch, transformer, overhead light, and heater. Interior furnishings were intended to include a frisker and counter. However, the SPERT scientists interviewed for this report recalled that the Guard House was never manned or occupied during the daily life of SPERT-III. The actual "exclusion" barriers for reactor experiments were closer to the Control Center.[46]

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[46] Clyde Toole, October 11 and October 29, 2009; Warren Nyer, July 22, 2009.

The structure was still standing in 1982, when it appeared in HAER Photo No. ID-33-ID-55, a photograph documenting a WERF-related addition to the building's east side. No record of it exists in the *Comprehensive Facility and Land Use Plan*, a document published in 1996 that contained an inventory of extant buildings at each Site area.[47]

Deionized Water Storage Tank

Raw water originated from a deep well at the Control Center, where it was stored in a 20,000-gallon storage tank and then pumped under pressure of 70 psi as needed to each of the SPERT areas. At SPERT-III, the well water arrived inside the Utility Room, where it flowed first through the water softener, then a mixed-bed demineralizer, and finally to a storage tank as pure, deionized water.

The 12,000-gallon storage tank was located just outside the Utility Room on the north side of the building. It had been one of the early deliveries at the construction site; its massive horizontal bulk was first photographed in 1957. See HAER Photo No. ID-33-I-31. Made of carbon steel, the tank was lined with natural rubber inside. Outside, it was insulated with two inches of fiberglass for defense against the desert's winter cold. Additional defense came from two 6-kg electric immersion heaters located in each end of the tank. Elsewhere in the west wing, one of the control panels indicated the level of the liquid in the tank and provided controls to refill it. This level was sufficiently important that an alarm was set to sound (hi-low) at the Control Center should it fall to a pre-set indicator level.[48] See Figure 7 for diagram showing flow of process water.

Deionized water circulated in both the primary and secondary coolant loops. The primary loop passed directly through the reactor, where any impurities or metal ions in the water could potentially absorb neutrons released by the chain reaction. It was important, therefore, to minimize or eliminate this possibility as much as possible. Deionizing the secondary coolant helped to minimize corrosion.

Process Waste Leach Pond

Had there been a river or stream near the SPERT-III site, non-radioactive or low-level radioactive waste water might have drained to it. Instead, such water went to an old borrow pit

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[47] Idaho National Engineering Laboratory, *Comprehensive Facility & Land Use Plan*, DOE/ID-10514 (Idaho Falls: IDO, March 1996), p. 171-172.

[48] Heffner and Wilson, *SPERT-III Reactor Facility*, p. 66.

newly excavated as a rectangular pond located about 450 feet southeast of the reactor building. Here water percolated through the soil at an estimated rate of two gallons per square foot of surface per day. The pond's total surface area was 10,000 square feet. It was fenced to prevent large animals or unauthorized humans from entering the area.[49] The buried pipe leading from the reactor building to the pond can be seen under construction in HAER Photo No. ID-33-I-34. For topography of the leach pond, see HAER Photo No. ID-33-I-56.

Hot Waste Storage Tank

The reactor designers considered the possibility that fuel-element cladding could rupture or develop a pinhole leak and release fission products into the primary coolant. Should this occur and the radiation level exceed the tolerance level for disposal to the Process Waste Leach Pond, the coolant would go to the Hot Waste Storage Tank.

The reactor building was plumbed so that all drains or sumps that might receive high-activity water could flow or be pumped to the Hot Waste Storage Tank. This tank lay on its side five feet below-ground on a layer of sand and gravel at the east side of the building. It had a capacity of 8,000 gallons and diameter of 9.5 feet, sufficient to accept all of the primary coolant in the reactor system should it become necessary.

To deal with the possibility that the tank might leak, a monitoring station (manhole) was positioned next to it. A person could lift a wooden cover, climb down via ladder rungs, and assess the situation at the bottom.

Water could be held in the tank until radioactivity had decayed enough to qualify the water for the Leach Pond. If that was not practical, two 30-kw immersion heaters inside the tank could warm the water and evaporate it to concentrate the waste. Operators could then choose either to leave it in the tank or to send it to the Idaho Chemical Processing Plant (elsewhere at the NRTS) for permanent storage.[50]

During SPERT-III's ten years of nuclear operations, it was never necessary to divert coolant into the Hot Waste Tank.[51]

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[49]Heffner and Wilson, *SPERT III Reactor Facility*, p. 71.

[50]Heffner and Wilson, *SPERT III Reactor Facility*, p. 71.

[51]This conclusion derives from the accumulated record of SPERT Quarterly Progress Reports. At least one minor episode concerning gaseous radioactivity in the primary coolant was

Auxiliary Leaching Pond

In the west wing Utility Room, the water softener and deionizer (ie, demineralizer) both had drains which were piped to a pond north of the reactor building and just outside the area security fence. To preserve the pipe from the dilute acids and caustic, it was made of vitrified clay. This pond, roughly 30 feet square, had a surface area of about 1000 square feet. It is seen in HAER Photo ID-33-I-34.[52]

Electric Substation

An NRTS distribution loop delivered electrical power for the SPERT area to the Control Center. A 13.8-kv feeder from there to SPERT-III led to a substation on the west side of the building across from the Utility and Control rooms. The two outdoor transformers were rated at 2000 Kva and 750 Kva.[53]

Fuel Oil Storage Tank

One of the safety procedures at SPERT-III required that a standby electrical power generator be on line any time the reactor was operating. If the main commercial power supply failed, the immediate switch-over to standby power was effectuated by a bus transfer unit. If all power sources failed, the system was rigged so that the reactor scrammed: the control rods were driven at full speed into the reactor core.[54]

The generator was fueled by gasoline stored in an outdoor tank just north of the substation on the west side of the building.

The Cable Runs

A pair of parallel cable "trenches" ran between the Control Center and SPERT-III, separated from each other by at least fifteen feet. They lay above the ground on a two-inch bed of pea gravel, its sides sloped. The cable was covered with three inches more of sand or soil. The easterly run was for instrumentation cables, the westerly for control cables. Phillips provided most of the cable to Hardeman for installation. Every twenty feet, the cables were bound together with one-inch cotton tape.

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reported in the December 1967 report, IDO-17279. However, an event significant enough to require transfer of coolant to the tank would have interrupted research and been noted.

[52] Heffner and Wilson, *SPERT III Reactor Facility*, p. 72.

[53] Heffner and Wilson, *SPERT III Reactor Facility*, p. 7.

[54] F. Schroeder, *SPERT-III Hazards Summary Report*, IDO-16425 (Idaho Falls: Phillips Petroleum Company, 1958), p. 44.

Someone driving a car over the road from the Control Center to the reactor building would meet with a short section of road covered with wood planks. This was the point where the cable course crossed the access road. At this spot, the two runs dipped below the road in reinforced concrete boxes, 12 inches wide by 8 inches deep. Covers made of creosoted wood in 6-foot lengths protected the box and were removable. Within the box, the cables lay on a 2-inch bed of coarse aggregate. Weep holes spaced every six feet allowed for drainage.

At the reactor building, the cables entered conduits along the west side of the building and then entered the Control or Transient Instrument room through several penetrations in the concrete foundation approximately at grade, observable in HAER Photo No. ID-33-I-32. Inside, cables ran to control panels, instrumentation devices, and ultimately to some particular point in the reactor or process-water system where they took the measure of a particular indicator or communicated an instruction or other sequence of actions.

The Pump and Cooling Tower

The four pump motors that circulated the primary coolant water through the reactor were themselves cooled by water. For this water, a small cooling tower functioned to remove the heat generated by the motors as they operated. It was located east of the reactor building's southeast corner with its below-ground discharge and return lines arranged parallel to each other. See HAER Photo No. ID-33-I-37.

The tower was made of weather and corrosion-resistant materials and mounted on a concrete basin. Manufactured by the Marley Company of Chicago, it was an induced-draft, double-flow, single cell unit with a rated capacity of 300 gallons per minute. When the wet-bulb air temperature was 60 degrees F., it could cool 100-degree water to 80 degrees.[55] Cool water returned to the pumps. During weather cold enough to freeze the water, it was possible to by-pass the cooling tower and simply pump the water from the discharge line directly to the return line.

The cooling tower pump was located on the tower's north side. It started automatically whenever the primary coolant pumps were started and also could be started manually.[56]

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[55] Heffner and Wilson, *SPERT III Reactor Facility*, p. 66.

[56] Wilson, *Preliminary Design Report*, p. 13.

PART SIX

RUNNING SPERT-III

The care with which Phillips undertook the runup to the reactor's first criticality underscores why the SPERT program was able to make a lasting contribution to the safety of nuclear power industry. All tests would have to be repeatable and demonstrate the same results; therefore, the initial materials and their standard of fabrication had to be known and quantified.

The engineers installed remaining hardware, checked out all the valves, immersion heaters, meters, thermocouples, interlocks, relays, and other equipment. They modified, replaced, or repaired anything that didn't perform as expected or required. They placed strain gauges on the pressurizer to determine how much it would expand under high heat and pressure. They designed and tested handling tools and checked out equipment such as fuel racks and working tables.[57] They conducted hydraulic tests to make certain that the flow skirts were sending water equally through each quadrant of the core.[58]

Physicists took each of the fuel- and control-rod assemblies to the Materials Testing Reactor (MTR) and passed them over one of its vertical beam holes on top of the MTR. The neutron beam fissioned some of the U-235 in each assembly, which produced a measurable pulse of heat. These were counted. If all was well, the fuel assemblies would each contain a uniform quantity of U-235. The control assemblies, on the other hand, were expected to contain a uniform quantity of the Boron-10 poison. Findings were good: the assemblies varied in content between two to four percent, an acceptable standard.[59]

The Engineering group, meanwhile, had been testing designs for a control-rod drive mechanism that could be used interchangeably for either control rods or the transient rod. The

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[57] F. Schroeder, F., W.J. Neal, C.R. Toole, and R.A. Zahn, *The SPERT III Reactor Nuclear Startup*, IDO-16586 (Idaho Falls: Phillips Petroleum Company, 1960), p. 22. Tools and fuel racks: *Quarterly Progress Report*, IDO-16512, September 1958.

[58] *Quarterly Progress Report*, IDO-16512, September 1958, p. 67.

[59] See Schroeder, SPERT III Startup, p. 22. For a history and photographs of the Materials Testing Reactor, see Susan M. Stacy, HAER No. ID-33-G, *The Test Reactor Area*; and Stacy, *Proving the Principle*.

drive mechanism consisted of a drive motor, gear box, air cylinder, shock absorber, and drive-rod seal unit. The goal was to reduce the friction as the rod traveled into the reactor core and to measure the elapsed time it took for the rod to fall from different heights above the reactor head. Tests achieved elapsed times of 0.18 seconds, which the engineers considered sufficient.[60] These items are visible above the reactor head in HAER Photo Nos. ID-33-I-52 and -53.

Nuclear startup began on December 15, 1958. The crew loaded the fuel and other assemblies into the reactor in such as way to keep it "cold," that is, to prevent the mass of fuel from initiating a sustained chain reaction. This procedure revealed that one of the assemblies did not seat properly in its bottom grid. They removed the small burr creating the problem. Then a control-rod drive required last minute repair. These items delayed proceedings somewhat, but the team achieved the reactor's first criticality on December 19, 1958, just before midnight. On January 26, 1959, they repeated the process and concluded that the smallest amount (mass) of U-235 required in the core for a sustained chain reaction was 14.6 kilograms.[61] Knowing this, they could determine what additional fuel was needed to perform "excess reactivity" experiments.

Finally, the researchers had to learn the unique nuclear characteristics of the reactor core, named the C-Core. The core was composed of fuel-rod assemblies loaded with uranium dioxide fuel, enriched to 93.2 percent Uranium-235 and arranged in a flat plate design. The fuel, a powder, was packed within stainless steel plates and steel-clad on all sides and edges. Each fuel wafer was about 36 inches long, about 1.55 inches wide, and .02 inches thick. The fuel assemblies were of two sizes and contained either 38 or 32 of these plates within a rectangular stainless steel box slightly less than three inches square. They were affixed within the assembly so that water could flow between all the plates.[62]

The fuel and control assemblies were each loaded into the reactor from the top, where they fit snugly into the top grid, slid to the bottom where they were supported by a matching bottom

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[60] *Quarterly Progress Report*, IDO-16416, September 1957, p. 72-78.

[61] Schroeder, *SPERT III Reactor Startup*, p. 29-31.

[62] Heffner and Wilson, *SPERT III Reactor Facility*, p. 17-19.

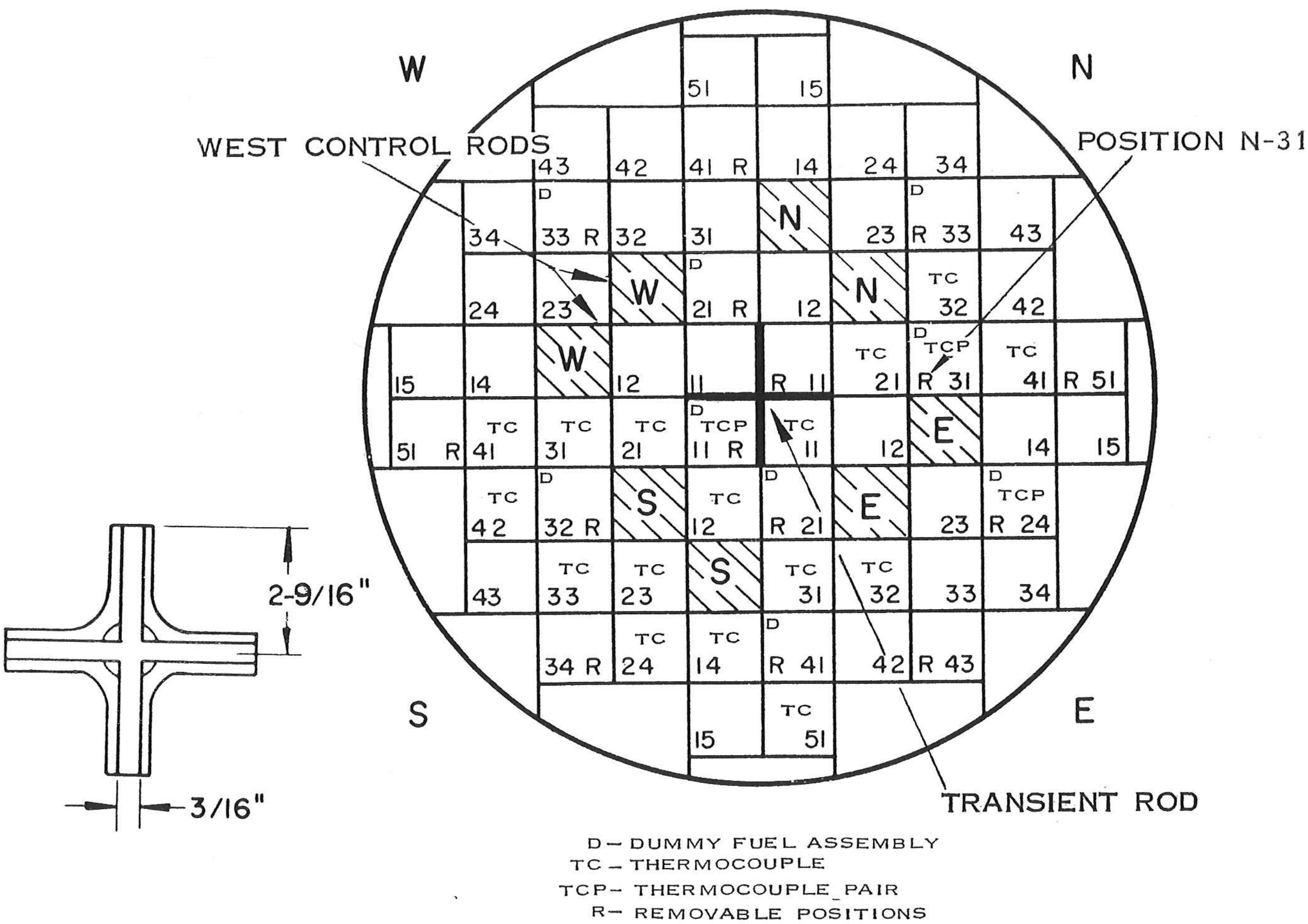

Figure 8. C-Core had 68 lattice positions. The cruciform Transient Rod divided the grid into four quadrants, named North, South, East, and West. Appropriately shaped filler pieces occupied positions near the vessel wall.

grid. The circular grid was thought of as having four quadrants -- north, south, east, and west -- and each position had its own coordinate numbers.

The operators learned how much a control rod was worth with a given loading of fuel. That is, how much of a quenching effect would it have if its poison was introduced into the core's fuel zone by one inch? two inches? all 36 inches? The more boron entering the fuel zone, the more power the rod had to suppress reactivity. How did these "worths" change when additional fuel was introduced into the grid?

These investigations were performed under both ambient and hot running temperatures. When the system ran hot, the water expanded, reducing the density of atoms in the water and reducing the moderating effect on neutron speed. Neutrons were less likely to fission, and reactivity went down. To balance the effect of the higher operating temperature, the reactor required more fuel to balance this effect and sustain the chain reaction.

Each quadrant had a pair of control rods. They were made with a fuel section at the lower end and poison in the upper end. Each pair was operated as one unit, yoked at the top. By "noodling" the reactor -- moving the control rods slowly up or down -- the operator could either increase or decrease reactor power.

The center position in the grid was reserved for the cruciform Transient Rod. This was the chief tool for initiating reactivity excursions. The upper section, the fuel section, was 56 inches long. Its 38-inch long poison section, also called the absorber section, in rest position was normally below the reactor core. When criticality conditions were established for the given experiment, the operator would "fire it out," that is, eject the rod rapidly from the core.[63]

Having gotten to know the reactor and what temperature and other conditions would cause reactivity to increase or decrease, the experimenters were ready in earnest for test excursions and power bursts. An excursion was caused by a rapid increase in the rate at which the number of fissions doubled. The higher this rate (ie, the shorter the millisecond interval) the more heat the fissioning process created, and the higher the power level of the reactor. When the Transient Rod had been ejected, the choice part of the experiment immediately unfolded: to measure the various parameters and follow the progress and reasons for the reactor's self-shutdown. SPERT-III scientists aimed to record and understand the dynamics of self-limiting factors, and how they depended on conditions of flow, temperature, pressure, and initial power.

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[63] Heffner and Wilson, *Spert-III Reactor Facility*, p. 20; Clyde Toole, October 11, 2009.

The basic discipline of SPERT-III research was similar to that of SPERT-I. An experiment always began with a computerized run of the reactivity accident. An analyst inserted appropriate variables into the code and ran the program. The output would describe the result. Then operators primed the reactor with the same variables and ran the accident. Then they compared the two runs to determine how well the code had predicted the characteristics of the actual event.

PART SEVEN

SPERT-III C-CORE AND E-CORE RESULTS

SPERT-III's C-Core was in the reactor from 1958 to the end of 1964. Every three months, the scientists and engineers documented their research and the problems that sometimes interrupted it. In 1967, they wrote an account of the overall program that included charts and graphs of each run. That account describes the conclusions and analysis.[64]

The SPERT-III group had done low-initial-power tests, high-initial-power tests, ramp tests (rapid), step tests (slow), and loss-of-flow tests. They compared results with the calculations of a code name ART-04, which had been developed by Bettis Atomic Power Laboratories to predict transient outcomes in reactors fueled by plate cores, and offered reasons as to why the code underpredicted certain values. They identified the conditions in which the code could reliably assess the safety of other reactor systems.[65]

They observed the impact of temperatures approaching two-phase flow (supercritical fluid) on the self-limiting tendency of the reactor. The high-temperature fluid resulted in a reduced pressure in the coolant flow. The density of the fluid decreased; fissioning decreased. The high temperature of the fuel plate also contributed to reduce fissioning. Its temperature stopped rising before it or the fuel could melt. With the help of a new IBM-704

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[64] C.M. Condit, J.F. Scott, and R.L. Johnson, *The Effects of Coolant Temperature and Initial Power Level on the Excursion Behavior of a Highly Enriched Plate Core in SPERT-III -- Experiment and Analysis* IDO-17138 (Idaho Falls: Phillips Petroleum Company, 1967). See Bibliography for SPERT Quarterly Progress Reports.

[65] Condit, *Highly Enriched Plate Core*, p. 1, 39-40.

computer, they revised the code to reflect these data.[66] The scientists had suspected that supercritical fluid would be a negative coefficient of reactivity, and now they felt more confident of it.[67] The next generation of safety testing reactors, the Power Burst Facility and the Loss of Fluid Test reactor, which used test loops within the core of the reactor, could, with less risk, experiment with supercritical temperature ranges. A loop could sustain conditions more severe than those of the mother core surrounding it.[68]

The work on the C-Core was interrupted for several months after October 26, 1961, when the pressurizer vessel failed. An exposed immersion heater superheated the steam in the upper part of the vessel and ruptured it.[69] Kinetic testing resumed in June 1963. In the interim, analysts evaluated the data thus far collected and improved equations and calculations in the codes.

The final test runs, numbers 92 through 117, pushed the C-Core to its highest ranges of temperature, pressure, and flow rate. With the reactor running at high power, they simulated accidents caused by the rapid withdrawal of a control rod (a "ramp-type" insertion of reactivity). They imitated loss-of-coolant-flow accidents by shutting off electrical power to all four coolant pumps and scramming the reactor about five seconds later. Regarding this latter test, the analyst reported what happened to the power burst and fuel-plate temperature while the reactor was running at 27 megawatts:

> In this test, the reactor power level decreased rapidly for the first two seconds to approximately 66 percent of the initial power level, then decreased at a slightly slower rate for three seconds more until the control rods were scrammed. The maximum measured fuel plate surface temperature rose from 550 to 636 degrees F. over the total five-second time interval. The other loss-of-flow tests performed exhibited a similar type of behavior.[70]

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[66] *Quarterly Progress Report*, IDO-16677, September 1960, p. 15-16.

[67] Warren Nyer, July 22, 2009.

[68] Clyde Toole, October 11, 2009.

[69] *Quarterly Progress Report*, IDO-16750, December 1961, p. 21.

[70] *Quarterly Progress Report*, IDO-17084, December 1964, p. 8-9.

As these conclusions were being reported, the group prepared to begin all over again with a new core, the E-Core. E-Core fuel was composed of slightly enriched uranium oxide, and it was to undergo a similar suite of preliminary investigation and testing as had the C-Core.

E-Core fuel was enriched with U-235 to only 4.8 percent. It was fabricated in the form of pellets (each less than an inch long) that were encased in stainless steel tubes, or rods, along with a "filler gas" of Helium, which kept the pellets from touching the inner sides of the tubes. The stacked height of the pellets in the rods was 38.3 inches. The rods fit into assemblies of two sizes, containing either 25 or 16 rods. Coolant/moderating water flowed between the rods. The assemblies were just under three inches square.[71]

The fuel rods had been made originally for the PL-2 Natural Circulation Boiling Water Reactor, a zero-power reactor operated previously by the Combustion Engineering Company and in storage since 1962. As reactor fuel goes, it was "lightly used," having seen relatively few hours of fission at low temperatures and atmospheric pressure.[72] To test its safety for the SPERT tests, researchers needed to know how much heat and pressure the fuel could sustain before its shape distorted, the cladding breached, or something else failed. Fuel samples went into an autoclave, and the researchers learned the limits of the fuel. They determined they would not run transients above certain temperatures and pressures.

Control rods and the transient rod for E-Core were similar to C-Core's: four pair of yoked control rods, one in each quadrant; and the cruciform transient rod in the center.

Nuclear testing began in the first quarter of 1966. After the preliminary exploration of critical mass, flux mapping, control-rod worths, and shut-down mechanisms, transient tests began in the last quarter. These were interrupted when a small part within one assembly (a flux suppressor) broke loose and was free to slide up and down within the assembly, causing shifts in reactivity as it moved. Upon finding this trouble, SPERT engineers repaired it with a special weld and retrofitted the

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[71] *Quarterly Progress Report*, IDO-17179, December 1965, p. 1

[72] *Quarterly Progress Reports* IDO-17179, December 1965, p. 1; and IDO-17271, September 1967, p. 11.

other assemblies.[73] Displaying a faint sliver of emotion in the quarterly report describing this episode, the author wrote:

> It is apparent, therefore, that dependence on a fabricator's quality control during the process of fabrication is insufficient for such critical items as control rods. To preclude future occurrences of this nature, it will be necessary to provide detailed quality control procedures, with an in-plant inspection to verify compliance with the procedures.[74]

The predictive computer code for oxide fueled core dynamics was called PARET, which had been produced by the Phillips' group. Given the helium-filled gap between the fuel and its clad, the analysts developed a model to predict heat conductance and convection across this gap. Heat from the fuel jumped the gap to the cladding and then transferred to the moderating water. As rising moderator temperature was one of the compensations for increased reactivity, it was important to know how long the transfer of heat would take.[75]

High temperatures forced the SPERT group to do incidental research on thermocouples, instruments that measured temperatures at the surface of the fuel cladding. Obviously, the environment was harsh and rugged. Instruments that were tough enough to hold up under corrosive heat and water pressures didn't always respond quickly enough to the rapid changes in fuel-plate temperature. Consequently, the information was "late" getting to the reactor operator.

Newer thermocouples were more responsive, but also more delicate, being sheathed in nylon rather than steel. The engineers placed pairs of both new and old models in similar flux regions of the core. They recorded the run data from both,

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[73] *Quarterly Progress Report*, IDO-17245, December 1966, p. 3-7.

[74] *Quarterly Progress Report*, IDO-17245, December 1966, p. 9.

[75] Discussing safe reactor design, C. Rogers McCullough pointed out how important it is that fuel elements be in close thermal contact with the water. Since the transfer of heat to the water causes it to vaporize and lose density, the plate has to have enough surface to allow this transfer to occur quickly enough to influence shutdown before the fuel melts, after which it is too late to avoid damage. See *Safety Aspects of Nuclear Reactors*, p. 147.

compared them, corrected for the time difference in reporting heat changes, and wrote a program (on an IBM 7040) to "correct" the data and get accurate values for the maximum temperature tests.[76]

By the middle of 1967, researchers were finding that their tests verified the PARET model. Its predictive power was "excellent."[77] By this time, Phillips had acquired enough insight to know that if the operator of a commercial reactor some time into the future were to monitor the output temperature of water, neutron flux, and the temperature of the fuel plates, any *one* of those indicators could supply evidence of trouble, most likely in time to do something about it.[78]

After about the 86th transient test, the instruments reported the presence of a radioactive gas in the coolant water that proved to be I-131. The steel cladding of a rod had sprung a pinhole leak. It was a minor episode, and the tests continued.

On February 27, 1968, an unplanned reactor excursion occurred while operators were approaching criticality for the next test. The operator scrammed immediately, and the power started falling four seconds later. Self-limiting mechanisms had worked. In the search for the cause, the scientists discovered how an operator could select the wrong speed for withdrawing a control rod. It was possible for one of the control buttons to remain partially depressed.[79]

Somewhat abruptly, the June 1968 Quarterly Report announced that the SPERT-III reactor had completed the essential parts of the Oxide Core program and that budget limitations required suspending the program. The AEC's Headquarters controller, John Abidessa, described for SPERT managers a budget shortfall and told Warren Nyer that a choice had to be made between the proposed Loss of Fluid Test (LOFT) Reactor and part of the SPERT program. The impact fell largely on the SPERT-III program; funds were not available for both. The reactor was deactivated, but not

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[76] *Quarterly Progress Report*, IDO-17097, March 1965, p. 7-10. See also quarterly report IDO-17260, March 1967, p. 4-6.

[77] *Quarterly Progress Report*, IDO-17271, September 1967, p. 1.

[78] Warren Nyer, July 22, 2009.

[79] *Quarterly Progress Report*, IDO-17289, June 1968, p. 1.

decommissioned. Should funds eventually materialize, Phillips wanted the reactor ready for work on short notice.[80]

Funds did not materialize. Among other experiment ideas, natural convection studies were not undertaken at SPERT-III. The building was used for a few months in 1968-69 for the non-radioactive testing of components from the Loss of Fluid Test facility. DOE decommissioned the reactor in the summer of 1980 so that its building could be re-cycled for another kind of project entirely.[81]

PART EIGHT

RECYCLING SPERT-III BUILDING FOR WERF PROGRAM

When historians began in 1997 to conceptualize the broad historic trends influencing the activities, research, mission, and programs operating at the INL during its first fifty years, they proposed that "remediation of waste" be identified as the most recent of those trends. Its emergence, they suggested, might be marked at 1970, the first year of the national Environmental Protection Act. It was also the year that the NRTS ended the practice of burying plutonium waste from Rocky Flats, Colorado, in favor of storing it above-ground.[82] The original name of NRTS's solid waste depository, the "Burial Ground," changed that year to Radioactive Waste Management Complex (RWMC), symbolic of a growing "environmental conscience" and new approaches to radioactive waste.[83]

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[80] *Quarterly Progress Report*, IDO-17289, June 1968, p. iii; Warren Nyer, July 22, 2009. For a summary of E-Core results, see R.K. McCardell, D.I. Herborn, J.E. Houghtaling, *Reactivity Accident Test Results and Analyses for the SPERT III E-Core -- a Small Oxide-Fueled, Pressurized-Water Reactor*, IDO-17281 (Idaho Falls: Phillips Petroleum Company, 1969.)

[81] Clyde Toole, personal telephone communication, October 29, 2009. J.L. Bogue, *Recommendations for Potential Energy Conservation at SPERT III Facility*, RE-A-82-063 (Idaho Falls: EG&G, 1982), p. 1.

[82] The Arrowrock Group, *A Historical Context and Assessment*, p. 172-173.

[83] Name change: Stacy, *Proving the Principle*, p. 203. "Environmental conscience": J.D. Dalton, H.A. Bohrer, and G.R. Smolik, *Performance History of the WERF Incinerator*, EGG-M-36687 (Idaho Falls: EG&G, circa 1988), p. 1.

From the vantage point of 2010, it appears that this contextual theme has been highly justified and continues in full flower as of 2011. In the *Concept Plan* report detailing this theme, the historians noted that:

> Resource expenditures at the INEEL in the 1990s are dominated by the prevention of waste, the cleanup of waste sites created in the past, and research into better ways of handling waste, eliminating waste, reducing waste, transporting waste, and transforming waste from one form into another.[84]

Some of the expenditures sought to reduce the large volume of radioactive wastes being sent for disposal to the RWMC. This effort gave the SPERT-III building its second life. During the 1970s, the building had been vacant, the reactor vessel resting quietly in its pit.

During that decade, federal and state regulations governing the disposal of hazardous and radioactive waste became more complex and comprehensive. It was increasingly difficult for NRTS/INL managers to feel confident that they would be able to open new waste disposal sites at the RWMC. Land area at the existing facility was running out, but waste streams containing low-level radioactive hazards continued to flow.[85] One way to extend the life of the facility was to reduce the volume of the waste. For that, INL needed to research and develop techniques that would be safe, efficient, and effective.[86]

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[84] The Arrowrock Group, *A Historical Context and Assessment*, p. 29.

[85] The Nuclear Regulatory Commission defines "low level waste" to consist of items that became radioactive because of exposure to neutron radiation. The degree of radioactivity may range between levels just above natural background to very high levels, in the case of reactor parts. Examples of low-level waste include shoe covers, mops, filters, tools, and equipment. "High-level" wastes, in contrast, include spent nuclear reactor fuel, by-products of reactions occurring inside a fissioning nuclear reactor, and wastes left from the reprocessing of spent reactor fuel.

[86] J.D. Dalton, *Informal Report: Second Progress Report for the WERF Incinerator*, EGG-WM-8154 (Idaho Falls: INEL, EGG-Idaho, June 1988), p. 1.

In 1980, DOE approved a proposal to create an experimental "contaminated metal volume reduction melter" at INL.[87] It selected the SPERT-III building for the project -- it was economical to use an existing building -- and authorized a decontamination study and partial demolition of the building in the summer of 1980.[88] Other buildings in the PER area also became part of the program. The area once dominated by SPERT reactors was officially renamed the "Waste Reduction Operations Complex/Power Burst Facility."[89]

Demolition activities included removing the reactor vessel and the entire suite of water-process equipment that had served it. Operators cut a hole in the building's metal roof, hoisted the vessel from its pit, and set it outside on a pad designed to take its weight temporarily. Heat exchangers, pumps, pressurizer vessel, and piping soon joined it on their way to permanent disposal elsewhere at INL. The heating system was removed. Upon testing indoor surfaces for radioactive contamination, most registered levels below the threshold criteria that would have restricted the building for further use.[90]

The remodel of PER-609 commenced in 1981. Its new name was Waste Experimental Reduction Facility (WERF). Many of several remodels, then and in later years, consisted of exterior attachments to the older building shell. Inside the reactor high-bay room, the pits were covered with a new floor. A scissor-lift elevator communicated between the main and "basement" floors. The basement was restructured into several operating and observation rooms. The entire roof was removed and replaced with a new one.

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[87] Robert E. Hine, *Decontamination and Decommissioning of the SPERT-II and SPERT-III Reactors at the Idaho National Engineering Laboratory*, EGG-2074 (Idaho Falls: EG&G, 1981), p. 1.

[88] L.A. Crews, *SPERT-III Characterization of External Building Components*, WM-F1-82-018 (Idaho Falls: EG&G Idaho, Inc., December 1982), p. 1. Economic expediency: Dalton, *Second Progress Report*, p. 2.

[89] As described on p. 44 of HAER Report No. ID-33-F Narrative, SPERT-I was decommissioned for nuclear operations so that it would not interfere with the 1965 construction of the Power Burst Facility, a considerably more advanced safety test reactor than SPERT-I.

[90] Photographs showing crane lifting reactor from roof are in Hine, *Decommissioning of SPERT-III Reactor*, p. 17. See p. 12 for post-D&D radiological surveys.

The new arrangement of space eventually housed a 5.5-million BTU/hour incinerator (with oil-fired burners for startup), a 200-ton compactor, and a 960-square-foot sizing shop where waste materials could be cut up. Accessories to these processes included an off-gas system to control radionuclide emissions, ash solidification room, waste storage both indoors and outside. Also outdoors was an above-ground 4000-gallon fuel storage tank.[91]

Some WERF operations began in 1982. Radioactive waste processing began in September 1984. By 1985, all of INL's combustible waste was going to WERF. Between 1984-1988, WERF reduced 151,110 cubic feet of waste to 594 cubic feet, a reduction ratio of 254:1. Ash volume was so low, its volume was not calculated.[92] In later years and for some "burns," volume reduction ratios went as high as 300:1.[93]

With operating experience, WERF moved beyond its original "experimental" function and became a "complete low-level beta/gamma volume reduction center." Plasma torches cut metals, allowing closer, denser packing for disposal. Compactors gave way to "super compactors." Over half of the low-level waste generated at INL had its volume reduced at WERF. Similar waste came to WERF from DOE laboratories elsewhere in the country.[94]

The HAER photographs taken for this report (perforce) illustrate the many WERF features that obscured the exterior walls of the original building. See HAER Photo Nos. ID-33-I-1 through -11. Waste began its incineration process via a vertical loading chute and airlock. After boxed waste was characterized on a conveyor belt, monitored for radiation levels, and X-rayed to inspect for undesirable wastes, it went through the airlock and up the elevator to a waste-loading chute. The incinerator had two chambers, the lower partially burning the waste; the upper

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[91] *Waste Reduction Operations Complex/Power Burst Facility*, found at http://mceris.inel.gov/plan/cflup/html/pbf.htm on July 9, 2004. "Cflup" referred to "Comprehensive Facility and Land Use Plan." Oil-fired burners and tank: Dalton, *Second Progress Report*, p. 3, 21.

[92] Dalton, *Performance History*, p. 1-2.

[93] Dalton, *Second Progress Report*, p. ii.

[94] Dalton, *Performance History*, p. 1. Waste from elsewhere: Dalton, *Second Progress Report*, p.ii.

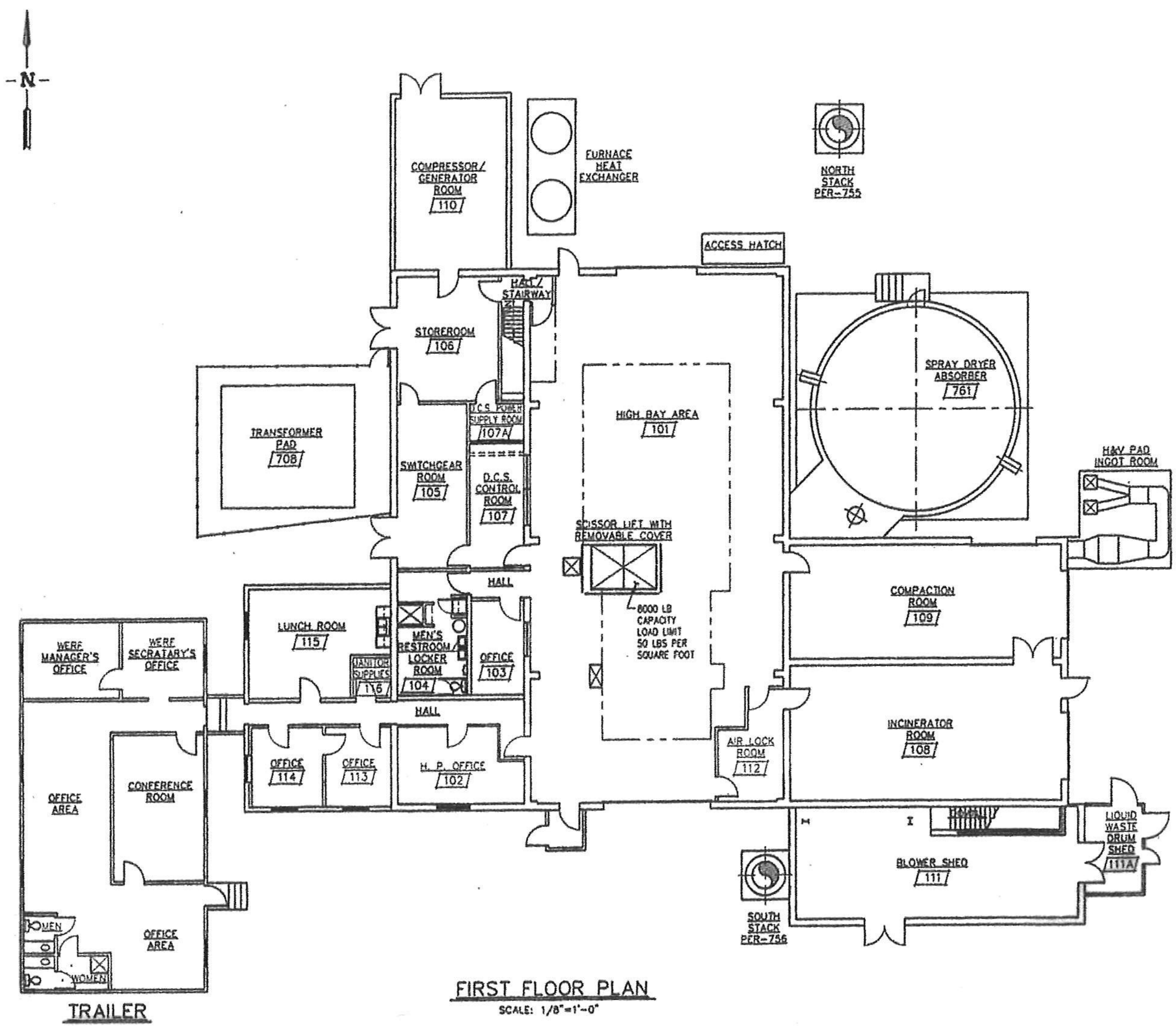

Figure 9. First floor layout for WERF circa 1991. Most of the original facades of the simple rectangular SPERT-III were covered by WERF accessories and additions.

serving as an afterburner for volatile gases generated below. Ash was cooled and swept into a hopper.[95]

Later additions allowed for the combustion of liquid wastes, for which the Environmental Protection Agency's Resource Conservation and Recover Act (RCRA) required a permit. The scope of waste materials entering the system expanded to include halogenated wastes and "mixed" wastes, which combined hazardous and radioactive qualities.[96] Off-gases generated by incineration were air-cooled in a shell-and-tube heat exchanger, filtered in a baghouse *via* a high-efficiency particulate air (HEPA) filter bank. Radionuclide releases to the environment were considerably lower than those allowed by regulatory standards. Incinerated materials included wood, non-halogenated plastics, paper, and cloth.[97]

Solidification of flyash took place in the main floor high-bay section (the SPERT-III reactor room) of the building. Drums that collected hearth and flyash were only partially filled, allowing for the addition and mixing of wet cement. The resulting monolith reduced the leachability of the ash, and therefore, its hazard.[98]

Burn operations at WERF were suspended on February 14, 1991, to upgrade equipment and improve operating procedures. Regulators had increased incinerator standards since the 1980s. This closure lasted until July 12, 1995, when low-level radioactive wastes were once again incinerated. On September 20 the same year, WERF began incinerating mixed low-level wastes and sought to reduce the backlog of low-level wastes that had accumulated during the suspension.[99]

Regulatory conditions for air emissions governed by the Clean Air Act as amended in 1990 became progressively more difficult. To qualify for an operating permit, WERF had to comply

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[95] Dalton, *Performance History*, p. 3.

[96] Dalton, *Second Progress Report*, p. ii.

[97] Dalton, *Performance History*, p. 5, 13. This report covered the operating period between 1984-1987.

[98] Dalton, *Second Progress Report*, p. 25.

[99] Dennis Conley and Shannon Corrigan, *Facility Status and Progress of the INEL's WERF MLLW and LLW Incinerator*, INEL-95/00549. (Idaho Falls: Lockheed Idaho Technologies Company, 1995), p. 1, 3.

with Maximum Achievable Control Technology (MACT) standards. These applied mainly to the incinerator and were more restrictive than what had governed WERF to date. The regulations gave the DOE until June 30, 2000, to decide whether to comply with the new standards or shut down the facility.[100]

After reviewing the cost to comply, its commitments to the State of Idaho for waste cleanup, and other alternatives for the processing of low-level and hazardous wastes, the DOE decided to shut down WERF. Idaho's Department of Environmental Quality had preliminarily denied a Resource Conservation and Recovery Act operating permit for the incinerator in July 2000.[101] Additionally, the Office of the Inspector General had in 1999 conducted an audit of WERF operations and concluded that other alternatives, including commercial facilities, would be cheaper and more effective than attempting to upgrade and continue operating the WERF incinerator.[102]

DOE evaluated PER-609 and its accessories for radioactive contamination and cleaned it up. The incinerator, air pollution control system, and most of the other equipment were dismantled. The building closure was required to meet federal and state standards for the safe closure of such facilities.[103]

During the response to a national economic recession in 2008, the United States Congress granted the DOE "stimulus funds" to inspire employment and other expenditure useful to slow the recession. DOE decided to use some of these funds to complete the demolition of PER-609, the SPERT-III/WERF building.

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[100] Citizens Advisory Board, INEEL, "The Future of the Waste Experimental Facility at the Idaho National Engineering and Environmental Laboratory," Recommendation No. 71, March 22, 2000, p. 1.

[101] Citizens Advisory Board, INEEL, "Operation of the Waste Experimental Reduction Facility Incinerator," Recommendation No. 77, September 20, 2000, p. 1.

[102] *INEEL Reporter*, February-March 2000, "Future of Facility being Evaluated."

[103] Donald N. Rasch, et al, "WERF Incinerator Operations: Upgrade for MACT or Shutdown and Find Treatment Alternatives," (WM '01 Conference, February 25-March 1, 2001, Tucson, Arizona), p. 3-4.

PART NINE

THE SIGNIFICANCE OF SPERT-III

On the Internet in 2011, one can find on the World Wide Web a Department of Energy book entitled, *DOE Fundamentals Handbook, Nuclear Physics and Reactor Safety.*[104] It explains -- in language not so difficult for non-scientists to understand -- how shut-down mechanisms work in a nuclear reactor, and why.

More properly called "negative coefficients of reactivity," the principles are set forth in a summary only two pages long in Volume 2 of the *Handbook.* One of them says:

> The fuel temperature coefficient is more effective than the moderator temperature coefficient in terminating a rapid power rise because the fuel temperature immediately increases following a power increase, while the moderator temperature does not increase for several seconds.[105]

This sentence, asserted so simply and confidently, was made possible by programs like SPERT-I and SPERT-III. The combined work of physicists, engineers, instrumentation specialists, computer programmers, and their associated technicians brought their reactors to criticality over and over again, month after month, year after year. They accumulated the data and experience to understand the margins of safety in reactor operations.

The practical impact of the SPERT empirical program was evident by the mid-1960s, when Warren Nyer and his SPERT colleagues wrote that "the reactivity accident in power reactor systems can, through proper design, be reduced to secondary importance in the consideration of the maximum credible accident."[106] This had been the desired goal.

In evaluating a commercial design, it became possible to identify a standard approach to safety evaluations: establish the general excursion characteristics of the system; set limits on permissible reactivity increments in the control and fuel units;

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[104] Found in August 2009 at http://www.hss.doe.gov/nuclearsafety/ns/techstds/standard/hdbk1019/h1019v1.pdf. In two volumes, the second volume has the same url, but ends with "h1019v2.pdf."

[105] *DOE Fundamentals Handbook*, Volume 2, p. 28.

[106] Nyer et al, *Reactor Excursion Behavior*, p. 13.

determine the mechanical and procedural controls that will prevent exceeding such limits.[107]

The SPERT-III data was published, never a government secret or "classified" in its distribution. In fact, international agreements between the United States and other nations made it possible for nuclear scientists from around the world to work at SPERT-III and the other reactors in the SPERT complex for lengthy periods of time, some up to two years. People came from France, Germany, Japan, Italy, Canada, and other nations. Most of the participating countries did not possess the capability -- or large expanses of isolated land -- to do the kinds of safety testing being done at the NRTS. It was in the best interest of the United States that all nuclear reactors operating anywhere in the world be operated safely. When the people trained at SPERT returned to their homes, they continued career paths leading them to authoritative and influential positions in nuclear safety in their own countries.[108]

SPERT-III data continues to be available to reactor designers and researchers all over the world. Computer "codes" continue to serve the cause of safety in nuclear-reactor design. In 2009, for example, the *Journal of Nuclear Science* published an article entitled "Analysis of the SPERT-III E-Core using ANCK Code with the Chord Weighting Method."[109] The Japanese authors used SPERT-III data to "confirm" the adequacy of their predictive codes. As of 2009, SPERT-III was still working.

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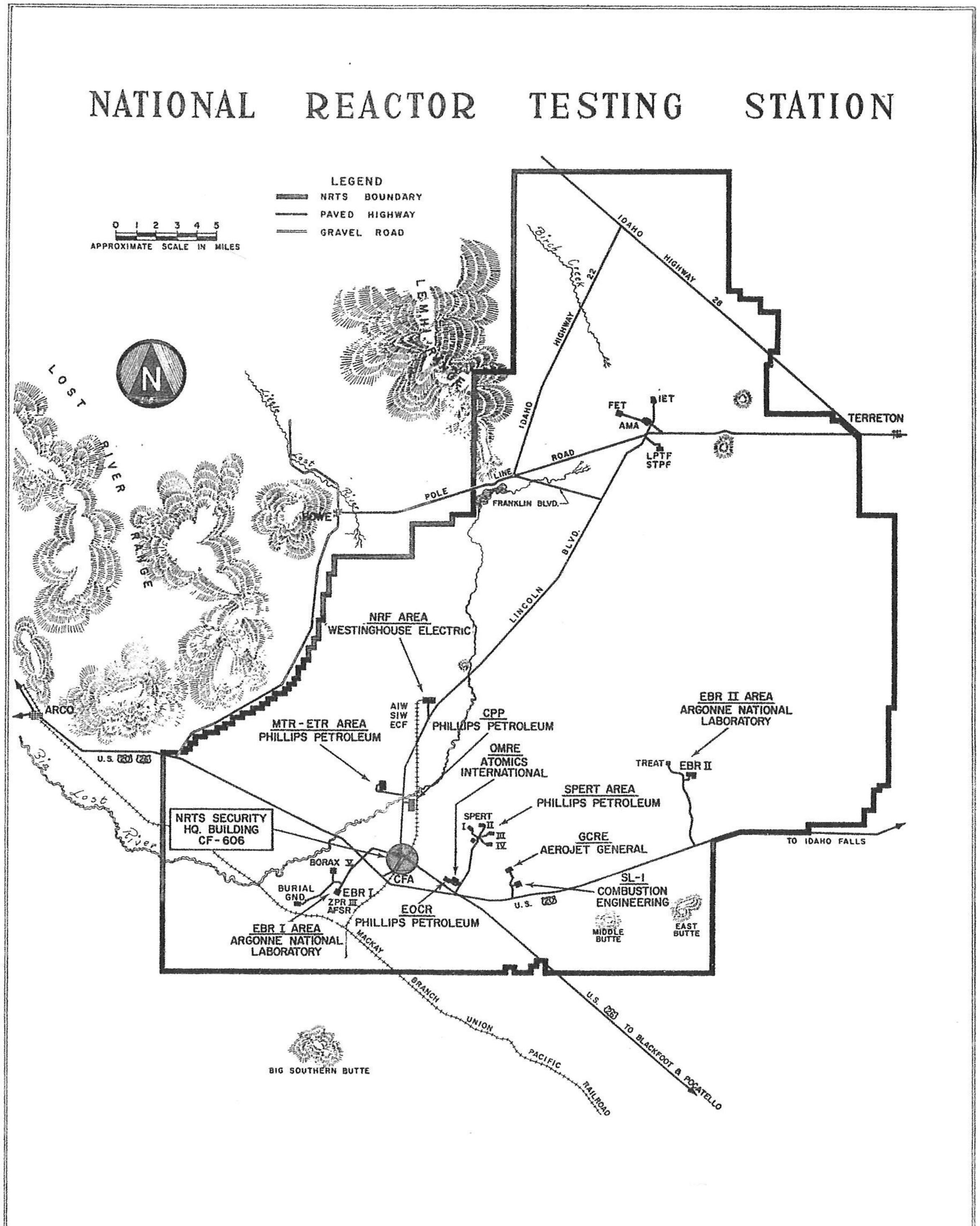
[107]Nyer et al, *Reactor Excursion Behavior*, p. 18-19.

[108]Clyde Toole, October 11, 2009.

[109]Shigeaki Aoki et al, "Analysis of the SPERT-III E-Core using ANCK Code with the Chord Weighting Method," *Journal of Nuclear Science* (Volume 46, No. 3): 239-251.

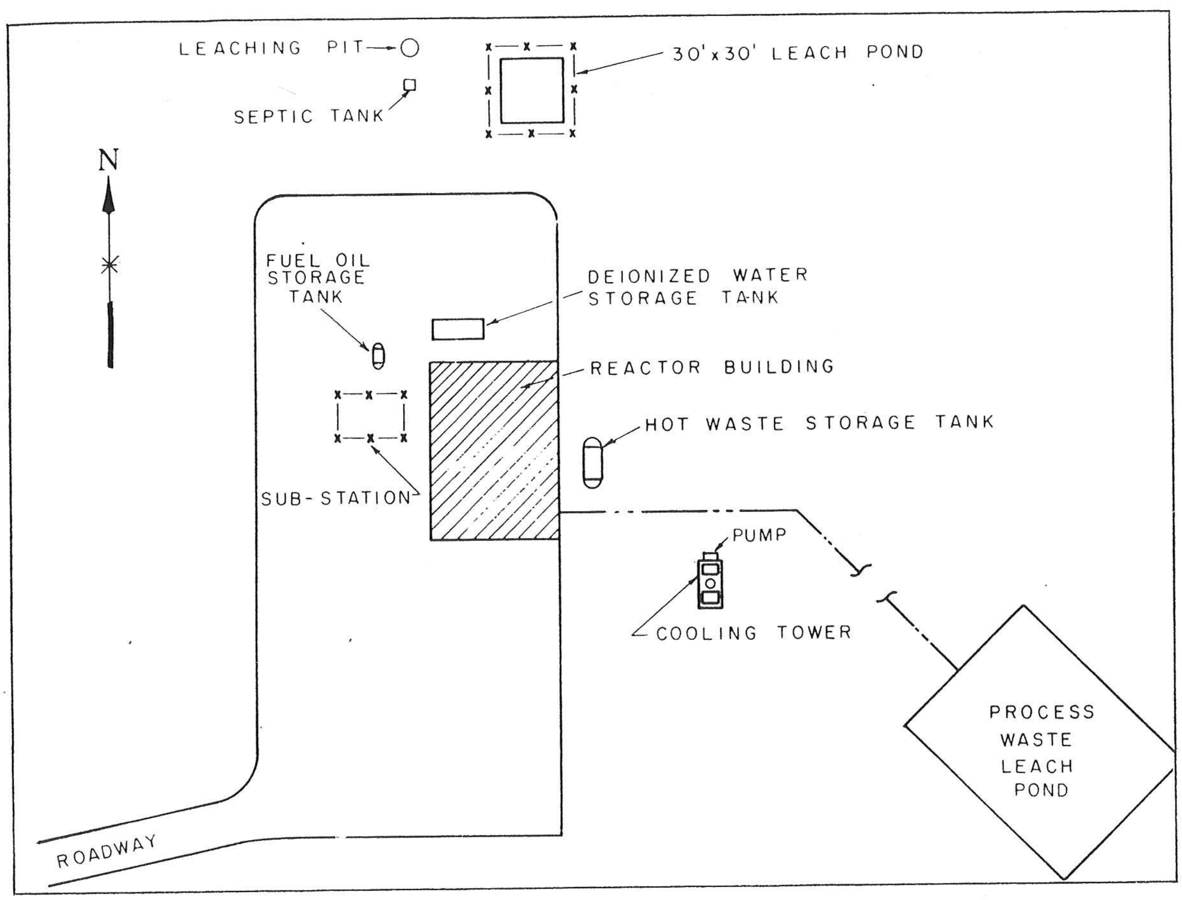
APPENDIX A

SPERT Area Vicinity Map



APPENDIX B

SPERT-III Plot Plan



APPENDIX C

STEARNS-ROGER DRAWING LIST

Source: Stearns-Roger Drawing No. 809-PER-INDEX, INL Drawing No. 763-9999-80-812-102300.

SPERT III REACTOR FACILITIES

NATIONAL REACTOR TEST STATION

IDAHO

DWG. NO.	TITLE
809-PER-101-U-1	PLOT PLAN
809-PER-609-A-1	ARCHITECTURAL-PLANS
809-PER-609-A-2	ARCHITECTURAL-ELEVATIONS & SECTIONS
809-PER-610-A-1	ARCHITECTURAL-GUARD HOUSE DETAILS
809-PER-609-E-1	ELECTRICAL-LEGEND / ID SYMBOLS
809-PER-401-E-1	ELECTRICAL-PLOT PLAN
809-PER-609-E-2	ELECTRIC POWER ONE LINE DIAGRAM
809-PER-609-E-3	ELECTRICAL-CIRCUIT SCHEDULE
809-PER-609-E-4	ELECTRICAL-CIRCUIT SCHEDULE
809-PER-609-E-5	ELECTRICAL-CIRCUIT SCHEDULE
809-PER-401-E-2	ELECTRICAL-GROUNDING PLAN AND DETAILS
809-PER-609-E-6	ELECTRICAL-POWER PLAN
809-PER-609-E-7	ELECTRICAL-POWER SECTIONS & DETAILS
809-PER-609-E-8	ELECTRICAL-POWER SECTIONS & DETAILS
809-PER-609-E-9	ELECTRICAL-480 V. LOAD CENTER SCHEMES
809-PER-609-E-10	ELECTRICAL-480 V. M.C.C. SCHEMES & CONNECTIONS
809-PER-609-E-11	ELECTRICAL-480 V. M.C.C. SCHEMES & CONNECTIONS
809-PER-401-E-3	ELECTRICAL-AREA LIGHTING PLAN
809-PER-609-E-12	ELECTRICAL-REACTOR BLDG. LIGHTING PLAN
809-PER-609-E-13	ELECTRICAL-REACTOR BLDG. LIGHTING SECTIONS & DETAILS
809-PER-609-E-14	ELECTRICAL-REACTOR BLDG. LIGHTING SECTIONS & DETAILS
809-PER-609-H-1	HEATING & VENTILATION-PLAN
809-PER-609-H-2	HEATING & VENTILATION-SECTIONS & DETAILS
809-PER-609-T-1	INSTRUMENTATION-BLOCK DIAGRAM
809-PER-609-T-2	INSTRUMENTATION-BLOCK DIAGRAM
809-PER-609-T-3	INSTRUMENTATION-PLAN AND DETAILS
809-PER-609-T-4	INSTRUMENT PANEL REACTOR BLDG.
809-PER-601-T-1	INSTRUMENTATION-CONTROL PANEL

DWG. NO.	TITLE
809-PER-609-M-7	MECHANICAL-SPECIAL 2500 LB. FLANGE & REDUCER
809-PER-609-M-12	MECHANICAL-SPECIAL MIXING NOZZLE IN 16" X 10" REDUCER
809-PER-609-M-1	MECHANICAL-PROCESS GENERAL ARRANGEMENT PLAN
809-PER-609-M-2	MECHANICAL-PROCESS ELEVATIONS
809-PER-609-M-3	MECHANICAL-PROCESS SECTIONS
809-PER-705-M-1	MECHANICAL-DEIONIZED WATER STORAGE TANK
809-PER-609-M-4	MECHANICAL-RADIATION SHIELD
809-PER-609-M-5	MECHANICAL-PIPING HANGERS & SUPPORTS
809-PER-609-M-6	MECHANICAL-EQUIPMENT SUPPORTS
809-PER-609-P-1	PIPING-PROCESS FLOW DIAGRAM
809-PER-609-P-2	PIPING-WATER TREATING FLOW DIAGRAM
809-PER-609-P-3	PIPING-WATER SUPPLY & WASTE DIAGRAM
809-PER-609-P-4	PIPING-DRAINS, BLOWLINES & RELIEF PIPING - PLAN
809-PER-609-P-5	PIPING-DRAINS, BLOWLINES & RELIEF PIPING - SECTIONS
809-PER-609-P-6	PIPING-INSTRUMENT PIPING
809-PER-609-P-7	PIPING-PROCESS AREA FLOOR DRAINS
809-PER-609-P-8	PIPING-COMP AIR, DEIONIZED & RAW WATER SYSTEMS-PLAN
809-PER-609-P-9	PIPING-COMP AIR, DEIONIZED & RAW WATER SYSTEMS-SECTIONS
809-PER-209-P-10	PIPING-COOLING TOWER PIPING & DETAILS
809-PER-609-P-11	PLUMBING-PLAN & SECTIONS
809-PER-609-P-12	REVISED PRESSURIZER ARRANGEMENT
809-PER-001-1	STRUCTURAL-EXCAVATION STUDY & PROCESS WASTE DISPOSAL
809-PER-609-S-1	STRUCTURAL-FOUNDATION PLAN
809-PER-609-S-2	STRUCTURAL-GROUND FLOOR PLAN
809-PER-609-S-3	STRUCTURAL-FOUNDATION SECTIONS
809-PER-609-S-4	STRUCTURAL-REACTOR PIT & MISC. FOUNDATIONS
809-PER-609-S-5	STRUCTURAL-STEEL PLANS
809-PER-609-S-6	STRUCTURAL-STEEL ELEVATIONS & SECTIONS

PER-706-100-1	ELECTRICAL SUBSTATION - PLANS & SECTIONS
PER-708-100-2	ELECTRICAL SUBSTATION - SERVICE POLE

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IDO-16584 Quarter ending June 1959
IDO-16606 Quarter ending September 1959
IDO-16616 Quarter ending December 1959

IDO-16617 Quarter ending March 1960
IDO-16640 Quarter ending June 1960
IDO-16677 Quarter ending September 1960
IDO-16687 Quarter ending December 1960

IDO-16693 Quarter ending March 1961
IDO-16716 Quarter ending June 1961
IDO-16726 Quarter ending September 1961
IDO-16750 Quarter ending December 1961

IDO-16788 Quarter ending March 1962
IDO-16806 Quarter ending June 1962
IDO-16829 Quarter ending September 1962
IDO-16890 Quarter ending December 1962

IDO-16893 Quarter ending March 1963
IDO-16920 Quarter ending June 1963
IDO-16931 Quarter ending September 1963
IDO-16992 Quarter ending December 1963

IDO-17010 Quarter ending March 1964
IDO-17030 Quarter ending June 1964
IDO-17055 Quarter ending September 1964
IDO-17084 Quarter ending December 1964

IDO-17097 Quarter ending March 1965
IDO-17123 Quarter ending June 1965
IDO-17146 Quarter ending September 1965
IDO-17179 Quarter ending December 1965

IDO-17206 Quarter ending March 1966
IDO-17207 Quarter ending June 1966
IDO-17228 Quarter ending September 1966
IDO-17245 Quarter ending December 1966

IDO-17260 Quarter ending March 1967
IDO-17270 Quarter ending June 1967
IDO-17271 Quarter ending September 1967
IDO-17279 Quarter ending December 1967

IDO-17287 Quarter ending March 1968
IDO-17289 Quarter ending June 1968