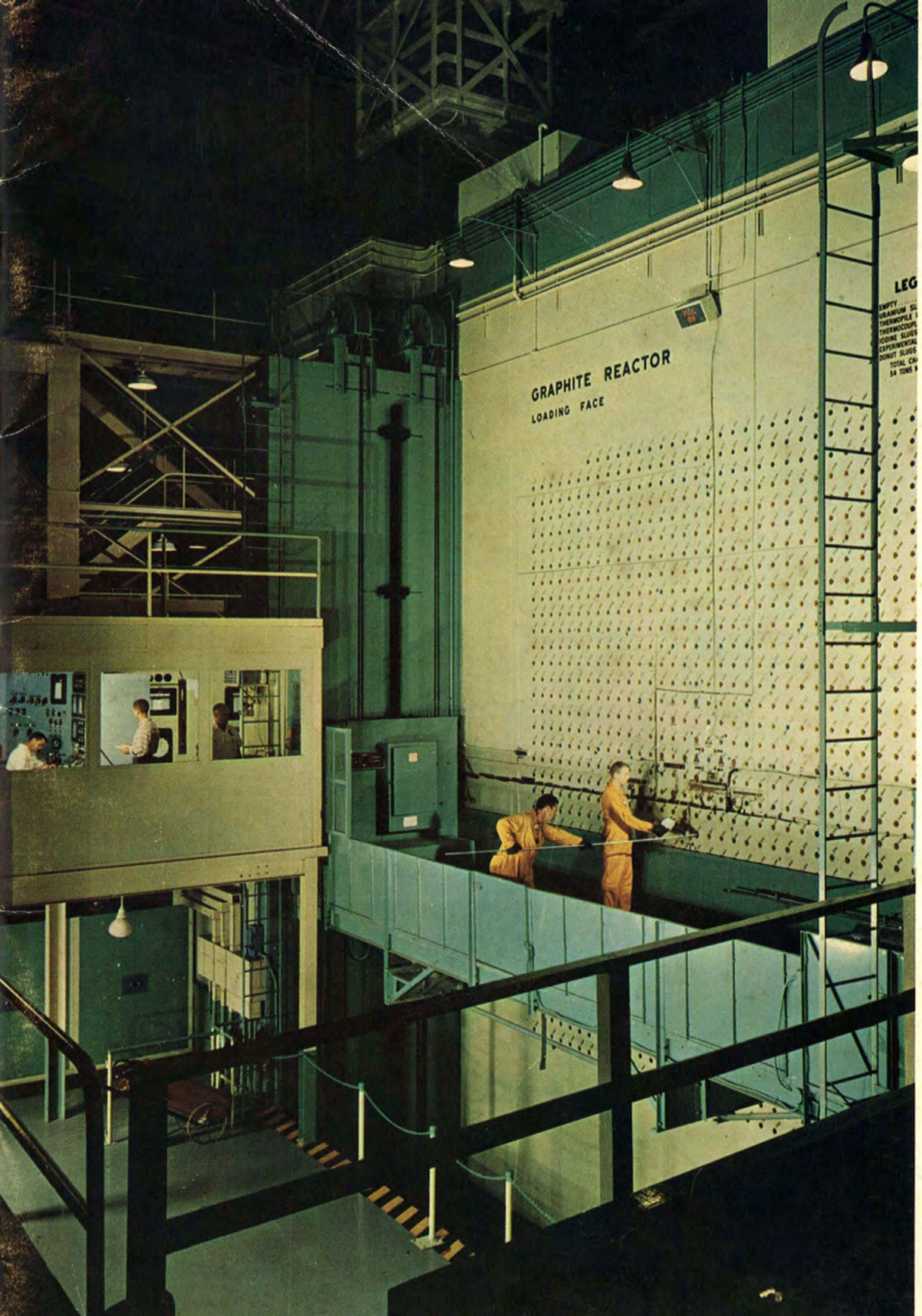


1943

X-10 PILE

ORNL GRAPHITE REACTOR

1963

RESEARCH REACTOR

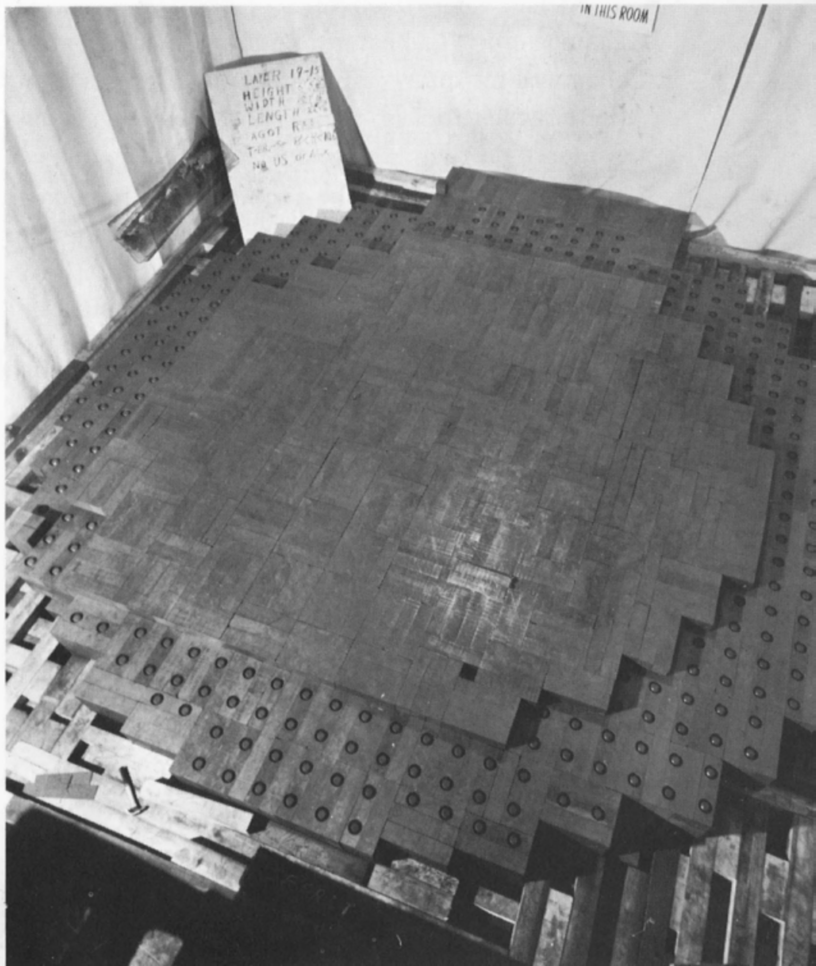
FOREWORD

The Oak Ridge National Laboratory's Graphite Reactor will have operated 20 years on November 4, 1963. During this time nuclear energy has changed from a closely held military art to a widely used technology whose impact on society will certainly grow. The story of the X-10 Pile, which played so important a role in the change, is presented in this brochure.

That the X-10 pile is to be retired after 20 years of faithful service may bring sentimental regrets to those of us who saw its birth. But this is the inevitable fate of all scientific equipment in an age of rapidly advancing technology. Many of those who were responsible for bringing the X-10 reactor into being have also been responsible for the magnificent technical advances which have made it obsolete. We must therefore look upon the retirement of our reactor not with regret, but with a sense of pride at the many technical achievements over the past 20 years which have made this occasion possible.

November 4, 1963

Alvin M. Weinberg, Director
Oak Ridge National Laboratory



In the Chicago Pile, the uranium was fitted into holes in the graphite so as to minimize air spaces. Initially, it was thought that the pile might have to be encased in a balloon which could be evacuated to reduce neutron absorption by air. The graphite and uranium were machined closely to make the components fit tightly.

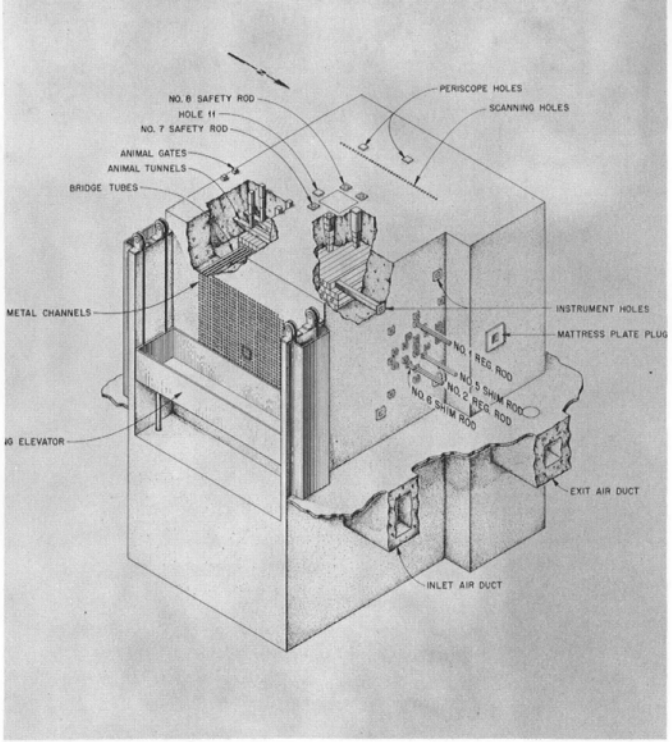
LOOKING BACKWARD BY NEWCOMER

To Newcomer in 1945, the center of the Clinton Laboratories was the pile. Around it were neutron and shielding experiments belonging to physicists and to engineers; from its fuel came radioisotopes for Los Alamos, for Rochester and for Chicago; standing on its top, radiation chemists let quartz ampoules down on strings to study decomposition of the aqueous fuel of the proposed Homogeneous Pile. And, from any spot outdoors on the glaring, dusty X-10 site, one could hear a steady, D-sharp above high-C whine, the sound of the fans cooling the Graphite Pile—the sound of "Atomic Energy". Not even the prosaic truth (probably the belittling remark of some engineer) that the fans used more power than could ever be extracted from the pile spoiled one's pleasure in this audible token of the new era. Now, after 20 years, it is gone.

For all its impact on a susceptible newcomer, the Graphite Pile was a routinely-operating device in 1945. The interesting part of its history was behind it, and the attention of the Laboratory was already shifting to new reactors and to the problems of a new kind of laboratory. For 18 more years, however, it operated routinely, producing radioisotopes, supplying beams of neutrons for nuclear measurements and for diffraction, and supporting major experimental programs on radioactivity and on the effects of radiation on matter. For many purposes, it is still the reactor of choice—stable, accessible, flat of flux.

For the occasion of its final shutdown, it seems fitting to go back into that interesting part of its past and collect in one place the story of its origin, construction and earliest operation.

On December 20, 1943, the reactor and chemical pilot plant in the background had been operating almost two months. In the foreground is the chemistry building.



NUCLEAR CHAIN REACTION COULD BE ACHIEVED

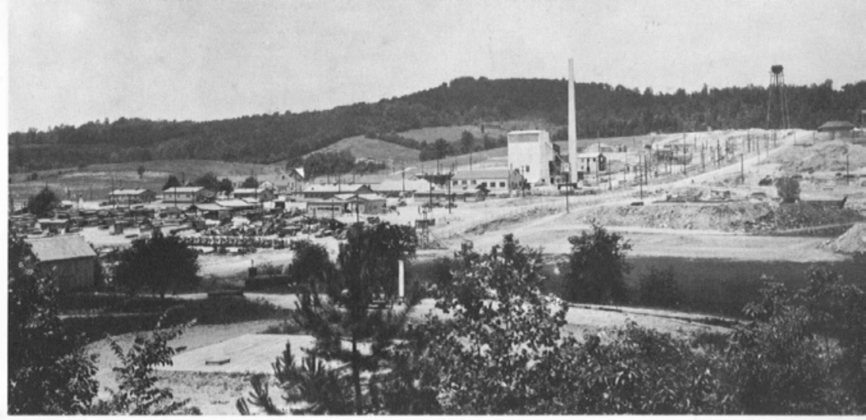
The West Stands experiment at Chicago on December 2, 1942 showed that a pile of natural uranium and graphite would work—that the separate measurements of neutrons per fission, fission cross section, and other nuclear parameters were indeed correct and could give valid predictions of bulk behavior. The production of plutonium for a nuclear explosive required then only a scaling up—a megawatt of fission power for each gram per day desired.

From 200 watts to many megawatts in a single step was risky. Fermi's pile tested only the physics and the purity of the ingredients. Problems of cooling, of radiation damage, of startup and shutdown—all of the engineering details normally studied in successively larger pilot plants—were unresolved. Risk, in those days, however, yielded to urgency, and the final commitment to the full-scale Hanford plant was taken.

The Clinton Pile was a last-minute hedge on the Hanford decision. For the Hanford reactors themselves it was only a feeble hedge, for the major decisions as to coolant, configuration and materials had to be taken before the Clinton Pile was even built. Hopefully, however, Clinton might reveal, in time to be useful, unsuspected quirks in operating Hanford.

For the Hanford chemical process, it was a slightly better hedge. That process had been worked out with only micrograms of plutonium—the Clinton plant would soon provide many milligrams, and the chemical plants, although built in concrete canyons, still were susceptible to considerable change if experience with milligrams did not match that with micrograms.

PILE HELPED TO TRAIN OPERATIONS STAFF



In one respect the Clinton Pile served as a normal pilot plant. Its operation provided training for the operating staff consigned to Hanford, an important function in view of the new techniques and peculiar hazards of atomic energy. Perhaps, too, the experience of living for a time in Oak Ridge helped prepare the Hanford trainees for the rigors of project life.

Shown above is the status of construction on June 27, 1943. The large structure next to the stack is the steam plant. The Health Division building and some shops, already complete, are seen to the left of the steam plant. In a photo (below) taken two months later, the concrete shielding for pilot plant processing cells are to the left of the reactor building. The openings indicate the size and location of the cells. The physics building is to the left of the water tank.

The major design parameters for the Clinton Pile were set by its function and by the state of knowledge at the end of 1942. Graphite was the only feasible moderator, as was likewise true for Hanford. Heavy water was too far in the future. The configuration had to allow for cooling and for removal of fuel for processing without taking down the graphite structure. There was a strong incentive to minimize, by the detailed design, the quantities of uranium and graphite; in the requisite purity, both were in critically short supply.

The choice of coolant lay between helium, water and air. Water would require an elaborate and untried coolant circulating system. Helium was expensive and also required elaborate circulating equipment. In the end, air was chosen. The choice turned out to be a happy one.

The design power level of 1,000 kw was a compromise. Lower power gave slower production of plutonium; higher power gave too high a fuel temperature. The use of aluminum as the fuel cladding set the fuel temperature at about 200°C, and the largest available fan would handle only about 650 kw if the fuel had to be held below that temperature. A larger fan, if it became available, or parallel operation of two would permit operation at the design level.

CLINTON LABORATORIES CONSTRUCTION PROGRESS

A little less than a year passed between the freezing of the design and the loading of the pile with uranium. The diary of a well-informed observer of that year has been reconstructed from the official records:

Jan. 18, 1943—Field engineer appointed by du Pont. They are contractors for the pile and other facilities at X-10.

Jan. 28—Field office opened in Knoxville. Will try to find site again tomorrow. (Note by Newcomer: In 1945, there were still packing cases in the storerooms marked "E. I. du Pont de Nemours and Co. Plant site near Byington, Tennessee".)

Feb. 22—Field offices at X-10 finished. Power lines, water supply, roads, field shops completed in next several weeks.

Mar. 9—Excavation for radiochemical processing plant begun.

Mar. 23—Construction started on buildings for graphite machining and testing.

Apr. 27—At last! Excavation for pile building begun.

May—Graphite buildings finished. Machining and testing begun. Guess these are first nuclear measurements (neutron diffusion length) at X-10.

Excavation for pile building delayed. Unexpected conformation of rock. Must dig 10 feet deeper. A little more time on core drilling would have paid off now.

Excavation for air ducts and for the slug-transfer canal went okay, but the pile stack sits right in a mess of soft clay. Have to increase foundation to keep stack from sinking.

Foundations for four of the cells of the processing building were completed. The other stack (process off-gas) is going up satisfactorily and waste-tank foundations are on schedule.

June—Graphite machining and testing 50-60% complete. Some trouble with 5-mil tolerance. Big joke being so careful if Wigner's radiation effect turns out to be big.

Equipment for hydrogen-testing of fuel slugs set up. Intended building not ready, but can't wait.

Pouring of cell walls for processing building started. Concrete for reactor charging face poured and tubes inserted. Tubes were blistered in galvanizing and had to be reamed.

Chemists finally made up their minds on bismuth phosphate over lanthanum fluoride process. Equipment design full speed ahead.

July—Graphite machining complete except for the keying strips to lock the stacked blocks. Graphite testing finished, except for rechecks on several layers.

Hydrogen testing of welded fuel cans proceeding; rejects averaging only 8%.

Side walls, back and top of pile being poured. Waterproof membrane inserted inside shield to cut down evaporation.

August—Now we're getting down to business. Two sub-critical piles assembled, one to standardize indium foils and the other to check out the eight-inch Clinton lattice. Training classes for pile operators. And operating manuals.

Big construction news is fans. Main blower (30,000 cfm, electric) and emergency blower (5,000 cfm, steam) installed. Concrete for process building finished.

September—Graphite going up. First layer inside shield on September 2, last (73rd) on the 22nd. Six hundred and seventy-six tons. Metal sleeves for fuel channels grouted into shield holes at same time.

Third fan installed, 50,000 cfm, electric. Maybe we'll make 1,000 kw after all. First two started up. Run okay.

Water tanks not okay. Several leaks. Install waterproof membrane. Won't have to last long.

Process piping started in canyon. Equipment testing manuals put together for pile and separation areas.

Much trouble testing fuel slugs. Tuballoy hydride forms by diffusion on hydrogen through jacket. Seventy tons already tested. Deflection testing tried—nitrogen pressure on welded end, measure dimensions of opposite end. Retest of accepted batch always shows up some more rejects. Abandoned. New test. Heat in air, 500° C. If holes, oxidation of fuel gives weight change.

October—Triangular graphite strips into empty fuel channels to direct more air past fuel. Operating Department got pile building on October 16 to test equipment. Control rod drives ready a week later.

Charging tubes in front face damaged fuel jackets—reamed all 1,252 tubes. Trouble at rear of pile also. Discharged slugs hit graphite in falling if they hang up at all. Grooves cut below exit holes on back face. Discharge chute lined with neoprene to cushion fall.

Testing in process canyon begun. Instrument tubing all saran to save copper. Many leaks. Change to copper. Maybe we are what they're saving copper for. Lots of piping changes. What do they think the drawings are for?

November—Got letter from draft board on Monday, November 1. Guess they don't know how important this project is back in Gary.

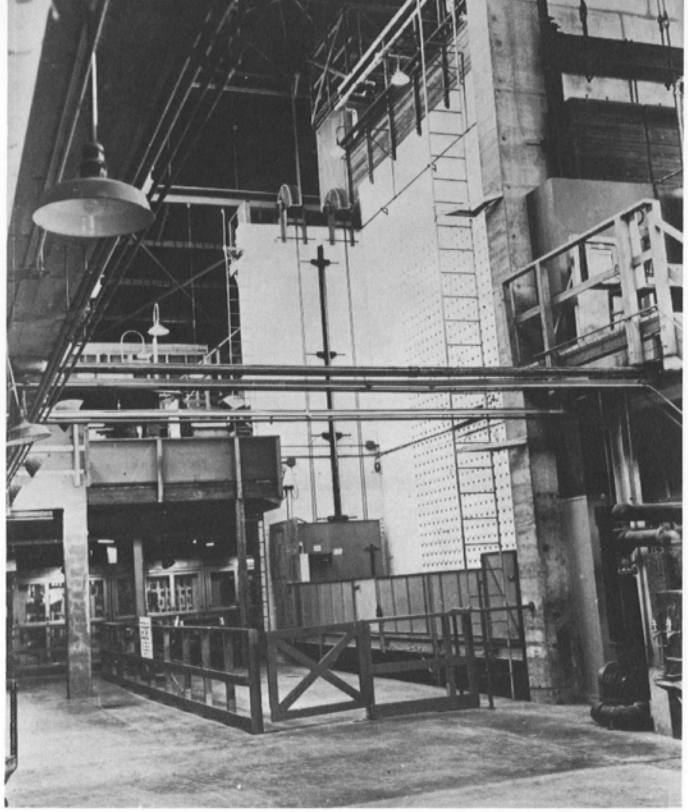
(Note by Newcomer: Rest of diary refers to other matters and other places. However, the next few months seem to have been exciting enough to inspire other, more extensive accounts, which, with some editing, are added at this point.)

The pile building had been completed on October 16, 1943, and was turned over to Operations Division for final check-out of the building and its equipment. The graphite was in place inside the concrete shield of the reactor, but no fuel had been loaded. Equipment testing procedures were carried out and minor modifications were made as necessary during the last two weeks in October.

On November 3 at 4:30 P.M., the loading of fuel slugs into the reactor was started under the general supervision of Enrico Fermi. Because it was expected that 50 to 60 tons of fuel would be loaded by hand, two loading crews were assembled, one at each end of the elevator. Each crew was subdivided into two groups of four men each, one group working on the elevator, the other on the building floor handing boxes of slugs up to the elevator. The crews loaded about one fuel channel per minute when they were fresh, but about half that as they tired. In 12 hours they loaded 31 tons of fuel, with frequent stops during the last few hours to check the neutron multiplication in the pile.

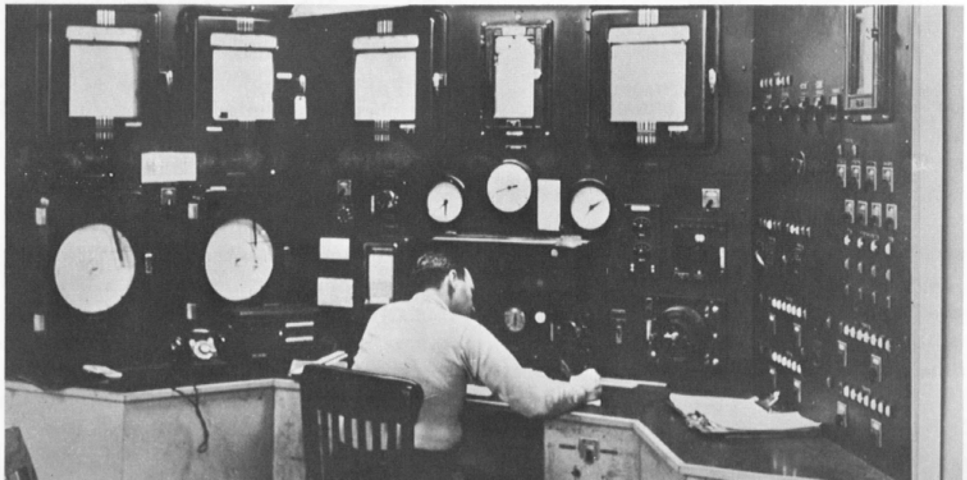
By 2:30 in the morning of November 4, the neutron counting data extrapolated to a critical size only about 10% larger than that reached. The laboratory director, M. D. Whitaker, and other interested staff were sent for, and loading was resumed. At 5:00 A.M. the indicated critical loading was reached, 31 tons in 367 tubes. Withdrawal of a control rod gave not a simple step in neutron counting rate but a step followed by a further exponential increase. The Clinton Pile was critical.

The next six days were spent in determining operating characteristics and loading more fuel. On November 11, the power level was raised to 300 kw



REACTOR GOES CRITICAL

The face of the Clinton Pile (above) where the loading of the fuel took place. The uranium was inserted into the center openings, with the outer channels left vacant. At the left is the reactor control room which was the hub of activity as personnel established the operating characteristics of the pile that went critical in 1943.



Fuel slugs, irradiated at the Clinton Pile in a simulated Hanford fuel channel, are examined inside the heavy shield. The fuel was irradiated to check its performance under actual operating conditions, and to determine the effects of radiation on water corrosion of the aluminum which jacketed the natural uranium metal.

EARLY PILE EXPERIMENTS

which gave a temperature of 100°C in the fuel. In December, the power level reached 700 kw with a fuel temperature of 115°C. On December 20, 1943, the first batch of irradiated fuel slugs was delivered to the chemical pilot plant for the first run with significant quantities of radioactivity. The 65 fuel slugs contained an estimated six milligrams of plutonium. The first shipment from the pilot plant was 1.54 mg of plutonium to the Metallurgical Laboratories on January 3, 1944. By the end of January, 110 mg had been sent to Chicago. The first shipment to Los Alamos was between one and two grams on February 26.

The first concern after startup was with control rod effect, temperature of fuel, neutron intensity as a function of position, and with calibration of the power, flux and radiation measuring instruments. The first major experiment was a test of the laminated steel and masonite shield planned for use at Hanford. A section of this was tested in a special hole in the top of the Clinton shield. Since the hole looked directly at the graphite, it was important to conduct the test early in the life of the pile before much radioactivity built up to hamper the work of installation and removal.

A second test, using a Hanford shield section with a charging tube, was done on the west face of the pile where a hole had been left for emergency access to the center section of the graphite. This hole was plugged with a steel tank ordinarily filled with water. Removal of the water allowed exposure to pile radiation with attenuation only by the tank walls. Both tests showed the Hanford shield to be adequate.

The intense radiation expected in the Hanford Piles was a matter of considerable concern. In early experiments many ordinary construction materials such as aluminum, steel, graphite, masonite, brass, neoprene, bakelite, concrete and rubber were exposed to Clinton Pile radiations. Although neither time nor radiation intensities permitted extensive tests, some reassurance on the performance of materials in the Hanford Piles was gained and a few materials were ruled out.

Because the Hanford Piles were to be water-cooled, pile-radiation effects on water were examined and found, as expected, to cause no significant problems. The effects of radiation on the corrosion of aluminum were checked more extensively, using a simulated Hanford water-cooled fuel channel in the Clinton Pile. Here again no significant problems were indicated.

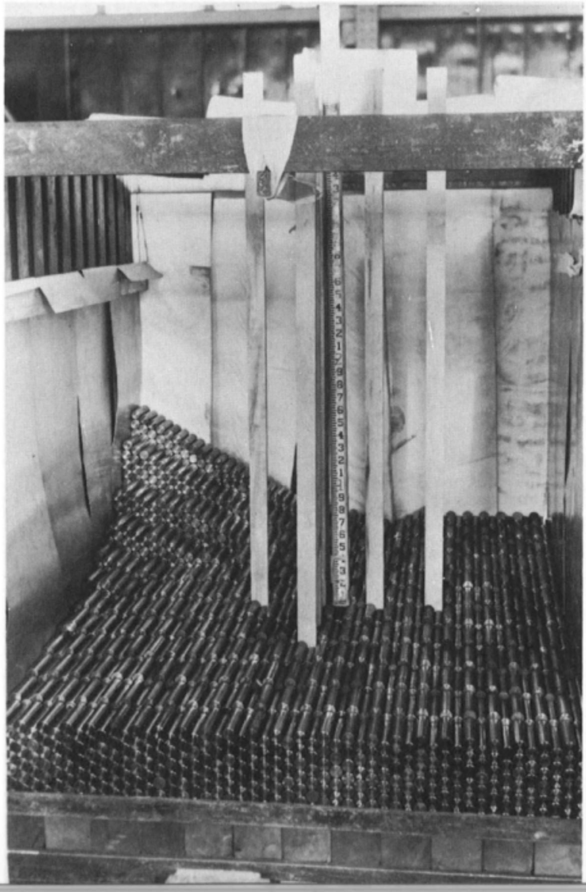
CONCERN ABOUT CROSS SECTIONS

Poisoning of the piles by accumulation of the fission products was a serious possibility because some of the fission products were already known to have large neutron absorption cross sections. The rare earths were given first attention since they were among the most abundant fission products and because some of them had high cross sections.

Samples of samarium and gadolinium were exposed in the Clinton Pile to get estimates of the cross sections, not only of the natural elements, but also of the radioactive isotopes formed from them by neutron capture. The estimated cross sections, although large, were not so large as to cause difficulty in pile operation. However, shortly after startup at Hanford it was found that the reactors would not be restarted after shutdown, presumably because of the presence of a very high cross section fission product. Emergency experiments at the Clinton Pile confirmed that xenon-135, with a cross section some thousand times higher than any previously measured, was the unexpected poison.

The physicists at Los Alamos urgently needed information on the capture-to-fission ratio of unmoderated neutrons in uranium metal. One of the experiments performed, as soon as sufficient quantities of pure uranium were available, was the so-called "Snell Experiment" at the Chicago Cyclotron, in which five tons of uranium metal were used with cyclotron-produced neutrons in an unmoderated assembly. This experiment was repeated at the Clinton Pile using 34 tons of uranium fuel slugs placed in the hole which had previously been used for the Hanford shield experiments. The results verified those of the earlier cyclotron experiments.

To verify the Snell experiment at Chicago, 34 tons of fuel were stacked in the opening atop the Clinton Pile as a check on data for the weapons development groups.



Perhaps the most acute of the developmental problems of the Clinton Pile were those associated with canning the uranium in aluminum and testing the integrity of the cans. The cans for the first slugs used were sealed with a stitch weld. The first test for these was to heat them at 300°C under two atmospheres of hydrogen for 10 hours. This test was used until it was found that some of the slugs passing the test nevertheless contained uranium hydride, apparently formed by diffusion of hydrogen through the can.

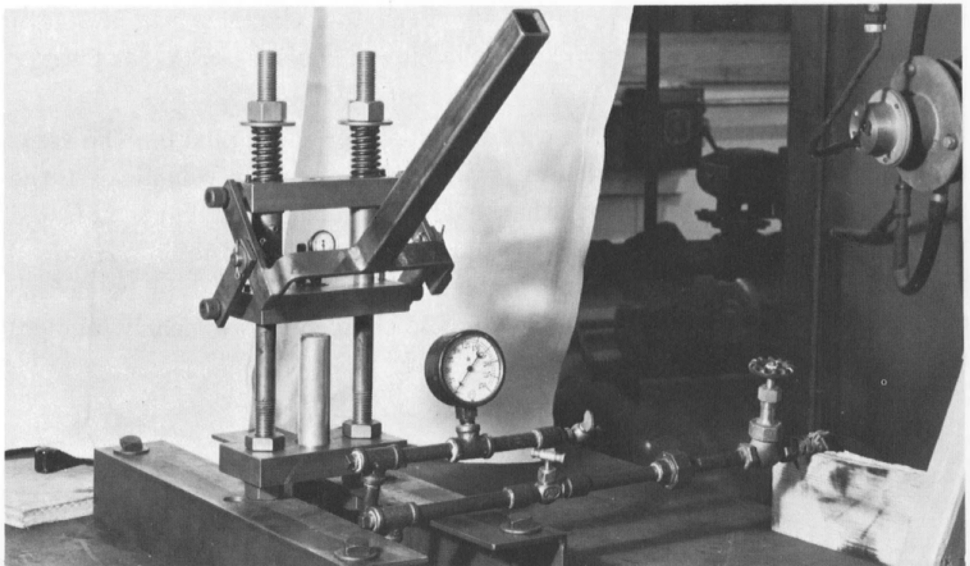
The next test tried was called the deflection test. The welded end of the can was exposed to nitrogen at 200 pounds per square inch, and the opposite end of the can was measured for any change in dimension. The changes were apparently too small to be measured reproducibly under production conditions, and this test was abandoned after it was found that re-tests of batches already accepted always gave some further rejects.

The test which finally proved adequate was to heat the slugs for considerable time in oxygen at high temperature and use weight changes (from uranium oxidation) to indicate defective cans. With the first jackets 200°C was the temperature of the test; with improved jackets the final test was heating at 500°C for about 10 days.

The testing of the complete production of the improved jacketed slugs (argon arc welded) was finished in February, 1945. Of the approximately 104,000 slugs tested, less than 4% were rejected.

FUEL JACKETS A PROBLEM

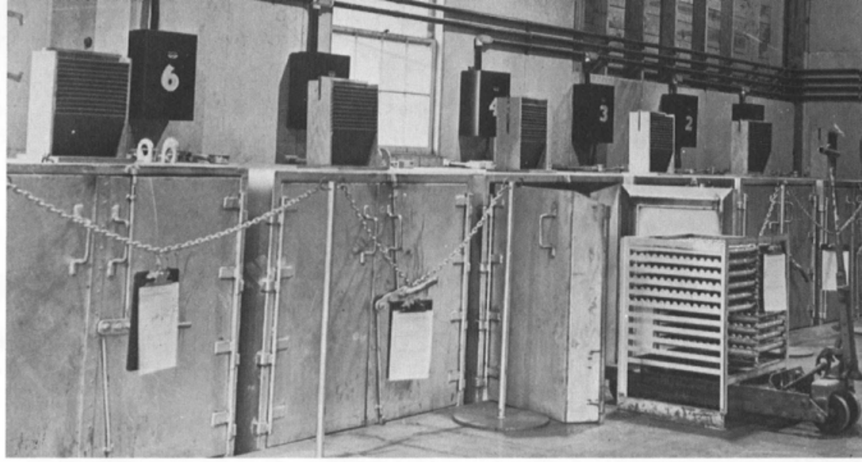
The jacketing of fuel was a difficult process. Shown above are some of the slugs which ruptured after a 12-hour autoclave test at 175°C. At right is a slug-testing machine. The welded end of the can was subjected to gas pressure. A leak in the weld would create pressure inside the jacket and cause the opposite end to bulge. The micrometer indicated the extent of bulging.



SLUG RUPTURES

The problems encountered in making suitable aluminum jackets for fuel slugs and in testing and inspecting them made the pile operating group acutely conscious of slug ruptures in the pile. It was considered vital to detect a ruptured slug as soon as possible. For this purpose, a "sniffer" was made with a snout fitting in the end of a fuel channel to draw air from the channel past a radiation detector. The presence of radioactive materials in the air stream would indicate a ruptured slug.

Although the sniffer was used for a number of years after startup, it gradually became insensitive to new slug ruptures because of the background of radioactive dust built up in the channels from previous ruptures. In the end, the sniffer was abandoned in favor of visual inspection to detect the swelling that characterizes a ruptured slug.

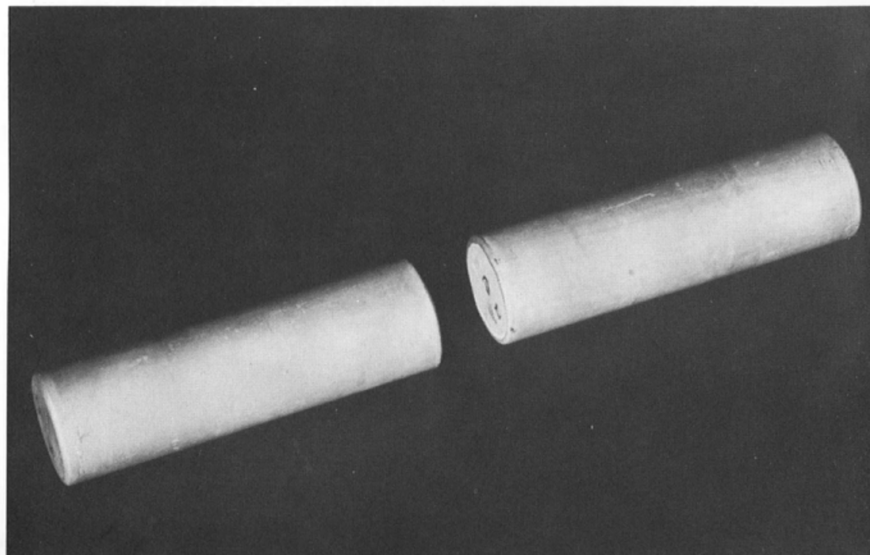


The final method of testing slugs was one in which the fuel was subjected to 500°C temperatures for 10 days in the ovens shown above. If the jackets leaked, the uranium would oxidize and the defect would be detected by a weight change. Two fuel slugs of the type most recently used in the Graphite Reactor are shown below.

CHARGING MACHINES CONSIDERED

During design, it was expected that after a period of operation the loading of new fuel would be complicated by radiation streaming through the hole in the shield when a channel was opened for the insertion of new fuel. Considerable development went into a charging machine designed to permit the insertion of new fuel slugs without exposing personnel to radiation leaking out the open channel. When actual operating experience showed that the radiation leaking out of the fuel channels was not dangerously high, the charging machine, cumbersome and slow, was never used.

A much more complex machine was developed for accomplishing the same purpose at the Hanford reactors, where water-cooling complicated the problem. Its doom was sealed when extrapolation of test runs indicated that this machine would require three months to load the fuel in a Hanford reactor. By that time, radiation problems had been found to be not so acute as originally expected, and a much simpler, more nearly manual operation was devised for the Hanford fuel.

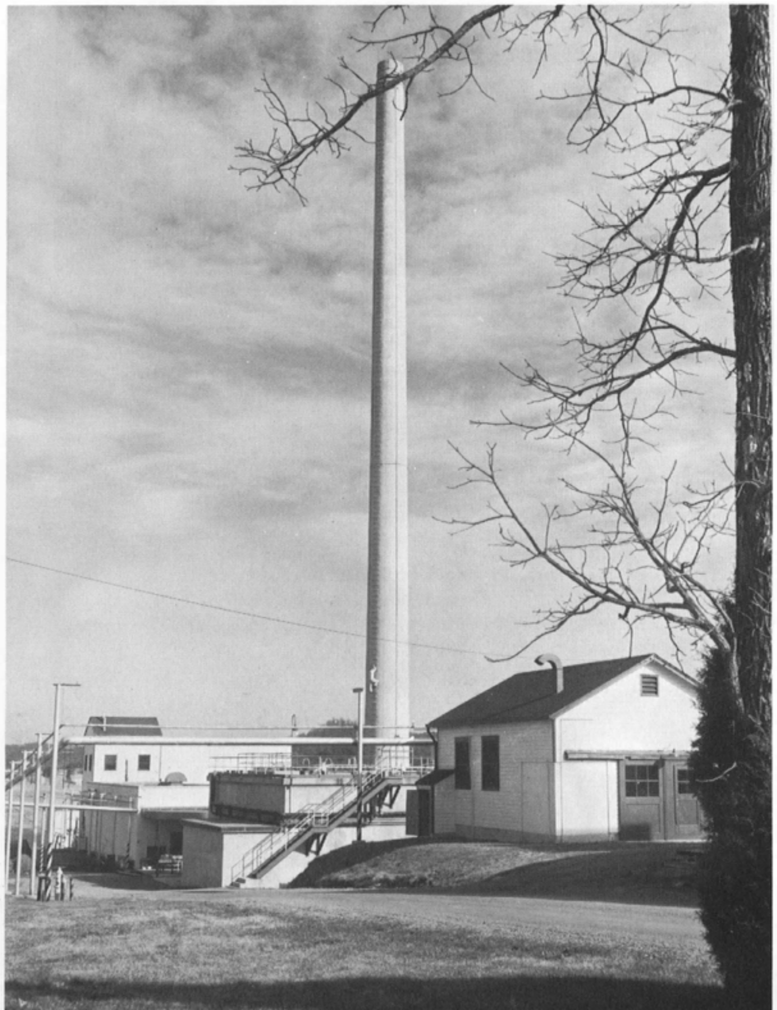


LEVEL RAISED TO 4,000 KW

The design power level of 1,000 kw was based on a fuel temperature of 200°C and a cooling air flow between 30,000 and 50,000 cfm. Soon after startup, an 800 kw power level was attained with a maximum fuel surface temperature of 150°C. A slight change in loading, reducing the amount of uranium near the center, gave a substantial increase in power.

Slugs with improved jackets also became available, allowing temperatures of 200°C and a total power of 1,800 kw which was reached in May, 1944. Two larger fans (55,000 cfm each) were installed in June and July, raising the power level to 4,000 kw. Considerable difficulty was at first experienced with fan bearing failures at these high levels, but careful maintenance made 4,000 kw the standard power for most of the pile life.

The discharge stack of the Graphite Reactor is 200 feet high. After passing through the reactor, the air is filtered before being expelled into the atmosphere.

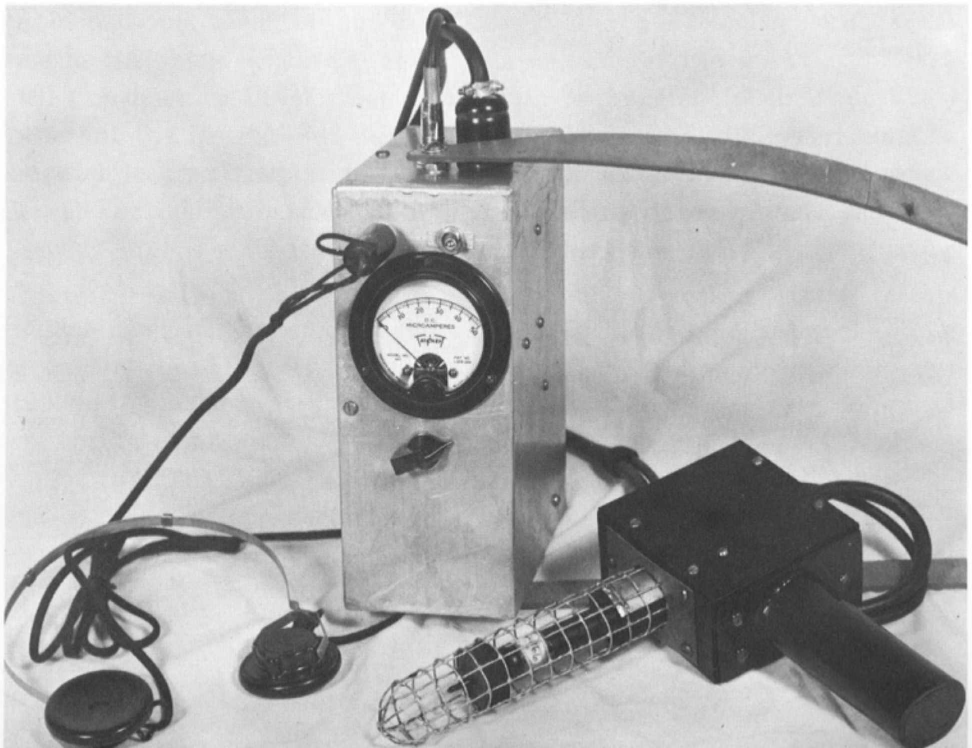


PLUTONIUM PRODUCTION RECORD

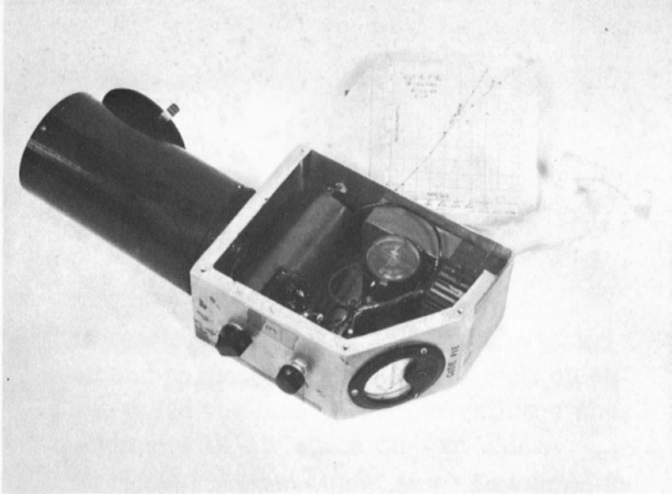
MONTH	EST. PROD.	ACTUAL PROD.	LOS ALAMOS	MET. LAB.	BERKELEY	CLINTON LABS.	HANFORD	AMES	TOTAL SHIPPED
Dec. '43		.00154		.00154					.00154
Jan. '44	.5	.21367	.10527	.1084					.21367
Feb.	1.3	2.98100	2.475	.350	.031	.110		.015	2.981
Mar.	7.0	7.29600	2.768	3.578	0.050	.900			7.296
April	7.0	7.54500	4.485	0.965		2.095			7.245
May	12.0	12.70000	9.710			2.990			12.700
June	16.0	15.37500	12.175			3.200			15.375
July	14.0	28.33000	13.930	1.0	0.10	13.300			28.330
Aug.	15.0	10.89400	10.894						10.894
Sept.	22.0	14.46800	16.764			-5.616	3.320		14.468
Oct.	40.0	37.42600	35.07				2.356		37.426
Nov.	45.0	41.28700	41.287						41.287
Dec.	85.0	92.89700	92.897						92.897
Jan. '45	25.0	54.99400	44.901	4.315	0.473	5.305			54.994
Total	289.8	326.40821	287.46127	10.31794	.654	22.284	5.676	.015	326.40821

NEW INSTRUMENTS NEEDED

The problems introduced by work with radioactive materials and with radiation entered every scientific and engineering effort at Clinton Laboratories. Since instrumentation for the detection and measurement of radiation was not commercially available, major efforts went into the development and manufacture of many types of radiation instruments.



At the left is the Walkie-Talkie, a portable instrument for detecting radiation which was developed in 1944. The earphones provided an audible indication of the radiation area. Above is a 1944 version of a hand and foot counter, an improvement over earlier instruments.

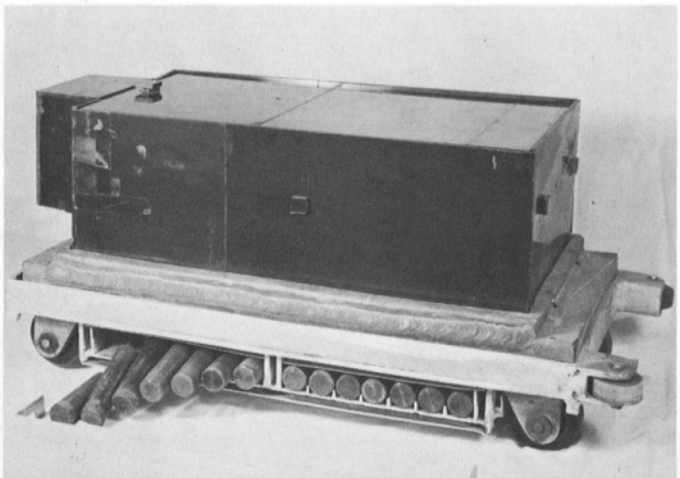


The Cutie Pie (above), developed in 1945, was the most popular and widely used radiation instrument. In the apparatus shown at the right below, mice were lowered into the animal tunnel for exposure. Another animal irradiation apparatus (below) utilized irradiated fuel.

BIOLOGICAL EFFECTS STUDIED

The biological effects of radiation and of radioactive materials had to be evaluated to establish safe working standards. Early biological experiments included not only external radiation and ingested radioactive materials, but also the possible hazards of unknown radiations which could not be detected with the instruments then available.

Some 10,000 animals were employed in these experiments. Some were given high exposures to reveal quickly the type of damage to be expected, and some were scattered around the site (in cages) to test the effects of the general radiation environment, known and unknown, to which the human workers were exposed. The lack of abnormalities in these animals, exposed 24 hours to the humans 8 to 12, gave reassurance about the lack of any unsuspected hazard.

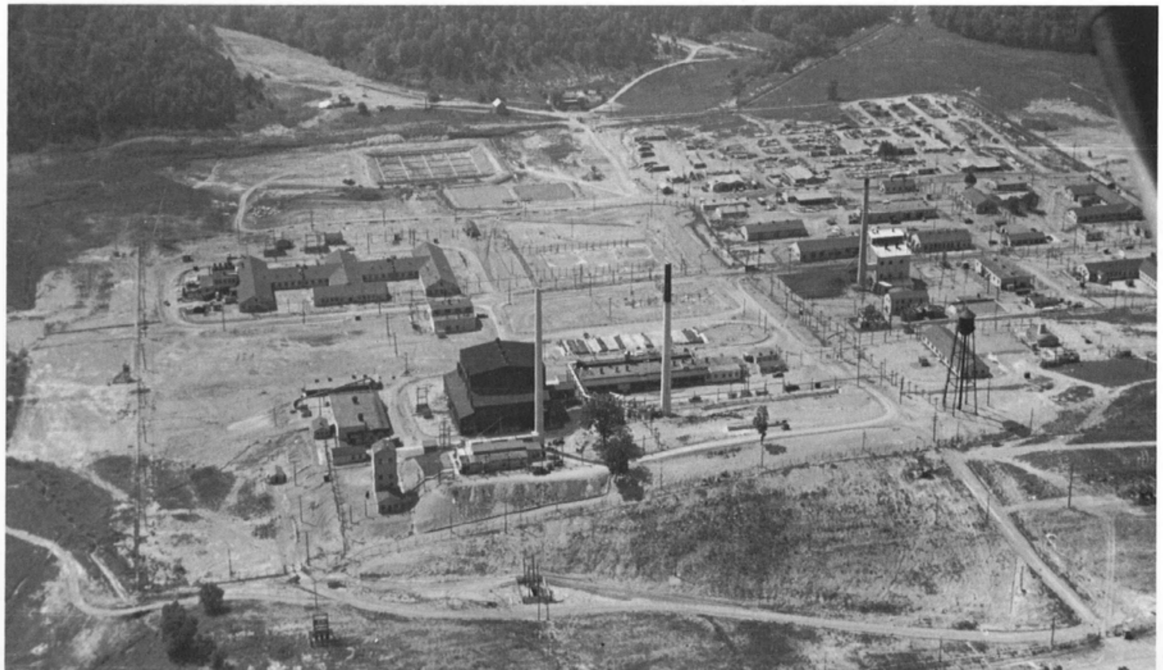


ORGANIZATION AND PERSONNEL

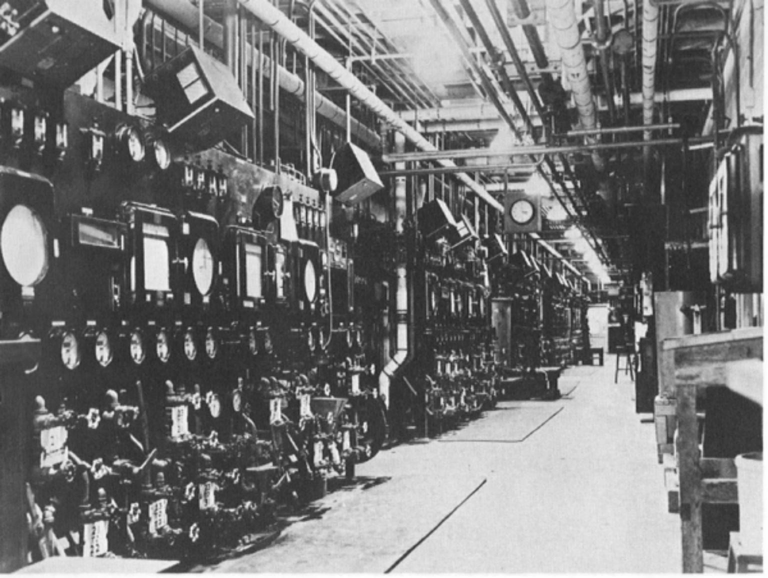
The operation of the Clinton Laboratories was the responsibility of the Metallurgical Laboratories. The first group of 11 scientific personnel moved from Chicago to Oak Ridge in April, 1943. It was augmented each month as housing, laboratory facilities, and office space became available. By August, 1943 the framework of the technical operating organization was on the site.

In August, 1943 the technical staff on site was formally organized as the Clinton Laboratories for the operation of the pile, separations plant and associated activities. The Laboratory roll was 236 persons. The number of employees was gradually increased, reaching a maximum of 1,513 in June, 1944. The Hanford trainees, included in that total, began to transfer out to Site W in July. By the end of 1944, a relatively stable organization of about 1,300 was reached.

Because of the urgency of the work and the scarcity of well-trained and qualified technical civilian personnel, arrangements were made to have technically trained men of the Special Engineer Detachment transferred to Clinton Laboratories for duty. The first group consisted of 10 men who reported during the month of January, 1944. As qualified men became available, additional enlisted men were assigned to Clinton Laboratories until the number finally reached a maximum of 113. Several of this group were given specialized training in certain phases of the work and were then transferred to other locations on the project where the necessary training facilities were not available.

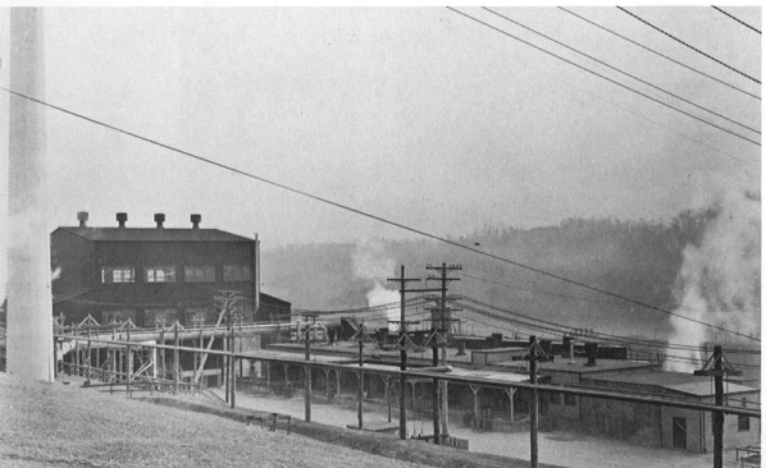


The originally planned facilities for Clinton Laboratories were completed by the summer of 1944, and there is little construction evident by this aerial photograph.



FOOTNOTES TO HISTORY

Above are the instruments and controls for the remotely-operated chemical processing system used to separate and purify the plutonium. The Clinton Pile building and pilot plant are seen below in this photograph taken December 20, 1943—the day the first fuel slugs from the pile were sent to the pilot plant for processing.



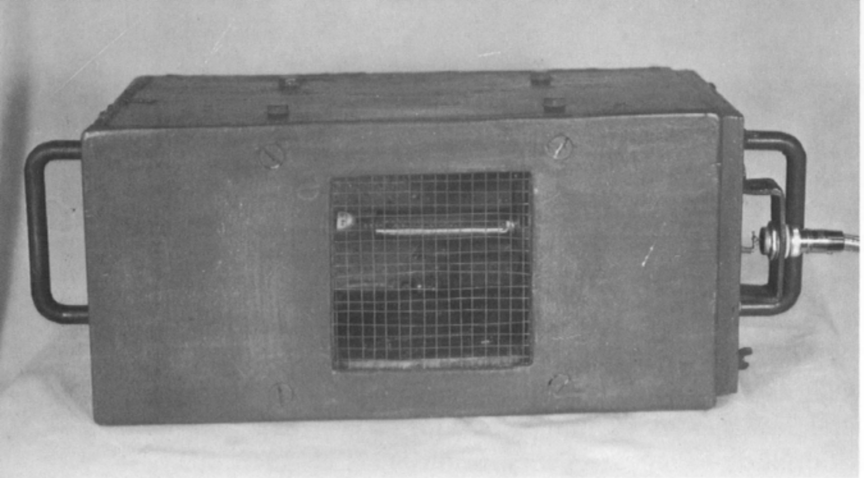
One of the first construction subcontracts to be let for Clinton Laboratories was to Layne Central Company of Memphis in February of 1943 for drilling a well at the X-10 site for drinking water. When the well was completed, the water was unfit for drinking. Consequently, it was necessary to continue hauling drinking water by tank truck from Clinton about 20 miles away until the river water pumping and purification systems were put into operation in July, 1943.

Construction of the initial facilities at Clinton Laboratories cost $12 million, with an additional million for "emergency additions" in 1946 to provide space for the growing staff and for the newly initiated training school activities. The du Pont construction division issued 6,800 purchase orders for the materials to construct the facilities.

At first, it was difficult to keep workers on the payroll for the construction activities. During summer of 1943, much of the construction was rescheduled because the available work force was capable of performing only three-fourths of the work originally scheduled. Twenty-three buses were contracted by du Pont to haul workers to the X-10 site as a means of overcoming part of the problem. Although the city of Oak Ridge was under construction, very few houses were ready by the summer of 1943, and du Pont set up barracks for laborers in the Scarboro School about seven miles east of the X-10 site.

The summer of 1943 was unusually rainy. With hardly any paved roads in the entire area and with extensive grading in progress at the site, mud was a serious and almost continuous problem. Rainfall during July amounted to 9.3 inches—more than twice the normal amount.

Code words for project materials were a standard part of wartime security. Some made useful abbreviations, like "25" for uranium-235 and "49" for plutonium-239, and are still in occasional use. "Tuballoy" for uranium was a British import, but "Myrnalloy" for thorium was the inspiration of an American genius. With 23, 25, 28 and 49 being code names for U-233, U-235, U-238 and Pu-239, respectively, it was a remarkable coincidence that the three power line crossings on the Bethel Valley Road near the Laboratory had clearance signs (for protection of mobile cranes) showing 23, 28 and 49 feet. The posted speed limit was 25. Some code words make reading old documents especially difficult. "Safety," applied to pile design, meant "certainty of achieving criticality," and "sensitivity" meant "radiation."



Above, a 1943 model Geiger-Mueller tube radiation detector. Although heavy and awkward, this instrument was an advance over those previously available. The plutonium purification equipment is pictured at the right below. Final steps of plutonium purification were performed in the chemistry building. Little shielding was required because the fission product separations at the pilot plant effectively removed most of the radioactivity with the exception of the plutonium.

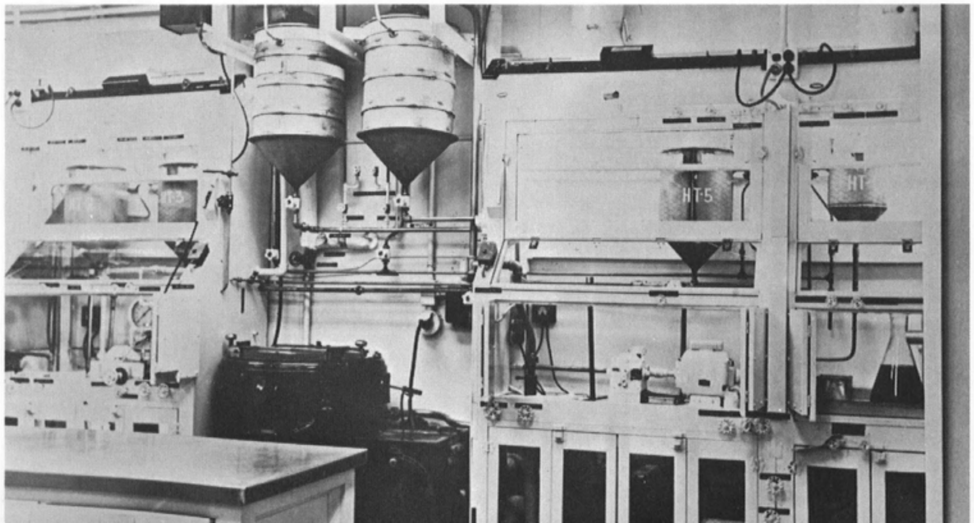
Two crews performed the loading of the Clinton Pile. In Crew No. 1 were I. Smith as supervisor and W. P. Rankin as accountant. On the elevator were F. Mask, R. Cullinan, R. K. Harris, W. H. Pennington, J. L. Frothingham, W. B. Reed, E. F. Curran, E. C. Stewart and R. M. Berry. The ground crew included R. Davenport, O. R. Volk, E. G. Bell, W. S. Andrus, J. C. Horton, J. W. Scott, R. S. Pressly and J. E. Hudgens. Crew No. 2 had H. L. Henry as supervisor and W. P. Rankin again as accountant. On the elevator were V. Morrell, W. Edwards, J. R. Leary, J. H. Gillette, W. N. Mobley, W. D. Hull, H. Blauer and J. M. Heard. The ground crew included K. Flanders, W. H. Jones, H. W. Huntley, W. J. Scraba, S. J. Rimshaw, H. G. Van Buren, E. A. Herre and P. J. Quinn.

FINAL ISOLATION OF PLUTONIUM

The final isolation of plutonium was to be done in ordinary chemical hoods in the chemistry building. The first batch came through before the blowers were connected to the hoods, but the chemists, no less devoted than their colleagues at the pile, performed the two peroxide precipitations with the hoods inoperative.

Work-area contamination with radioactive materials was a particular problem in the very early days because even those who were experienced in radioactivity had not enough experience with large quantities to anticipate all of the circumstances in which spillage or leakage could cause major contamination. Some scientists felt they were learning more about scrubbing floors than about the research for which they had been hired. This was further complicated by the scarcity of radiation detection instruments. In the beginning, also, many of the radiation instruments available in the work areas would not work satisfactorily because the designers had not yet overcome the circuit problems introduced by the almost constant high humidity of the site.

Individual reactions toward the dangers of radioactivity naturally varied widely, but a certain pattern is reflected in this (perhaps apocryphal) story. A young chemist was embarking with commendable caution on the sampling of a solution of radio-antimony. The physicist for whom he was doing the sampling said, "Don't worry about spilling it. We've got plenty."



1,248 FUEL CHANNELS

The reactor proper is a 24-foot cube of graphite blocks pierced by 1,248 diamond-shaped, parallel fuel channels on eight-inch centers. The graphite cube, called the moderator, lies within a shell of seven-foot-thick concrete shielding with air space on two sides.

The shield structure itself is 47 feet long, 38 feet wide and 32 feet high. Behind the shielding on the loading face and in front of the moderator is a three-foot inlet air gap. Behind the reactor is a six-foot air gap which separates the moderator and shield.

During the past 20 years, the Graphite Reactor has been visited by thousands of persons who received briefings from many Laboratory staff members like Robert Wesley (right) of the Public Information staff. This group is directly in front of the reactor, with the elevator shown about head high. Most of the 18,000 people who visited ORNL in 1962 had a look at the Graphite Reactor.

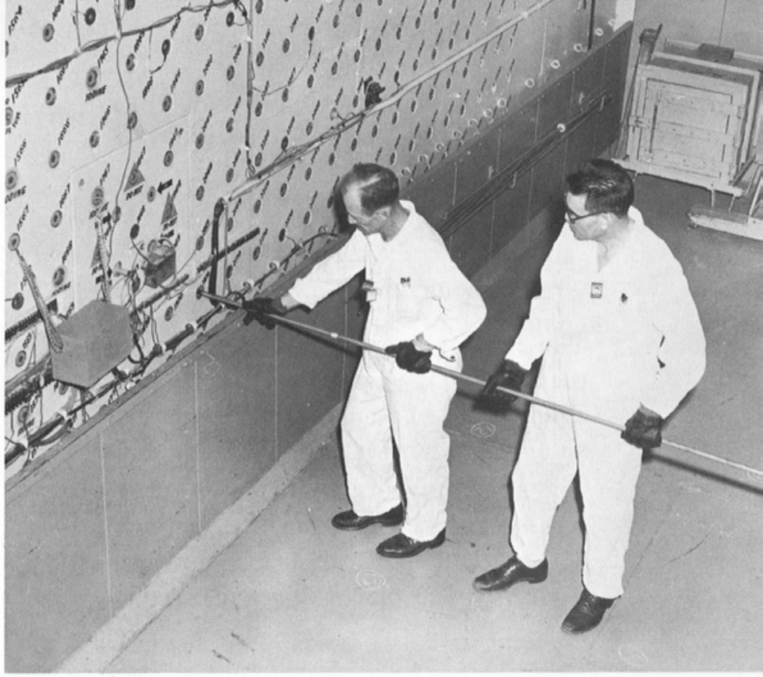
The fuel slugs, natural uranium contained in gas-tight, cyclindrical, aluminum jackets, are 4.1 inches long and about an inch in diameter. Loading may consist of any number of slugs from 24 to 54 per channel. The reactor, on shutdown, had 54 tons consisting of 43,200 slugs.

The reactor operated around the clock with weekly shutdowns of about 10 hours each. During that time, ruptured slugs were removed as well as those for radioiodine production. Maintenance work was performed, radioisotopes removed and target material inserted, instruments for investigations were assembled, and other associated services performed.

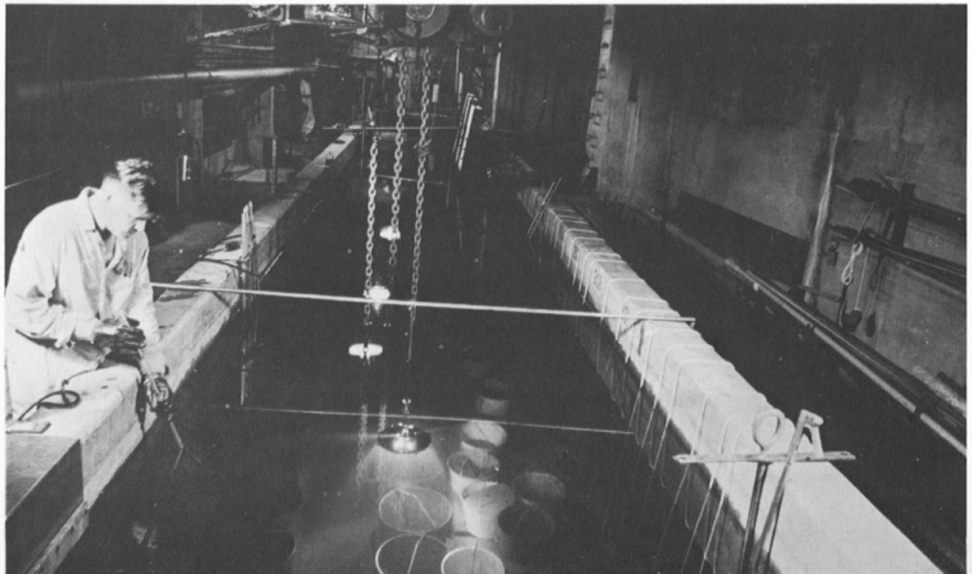
During fuel-loading, the shield plugs were removed from the channels on the loading face after the reactor was shut down. The slugs were loaded manually and positioned with long rods assembled to the desired length. Steel pipes, which penetrate the shield, span the inlet air gap and enter the graphite to permit passage of slugs into the reactor.

When slugs were removed, the rods were used to push them completely through the moderator and into the exit air gap where they fell on a neoprene slab and were then guided into a water canal 20 feet deep. The water serves as a shield and the slugs could be handled with long tongs to effect a safe transfer.

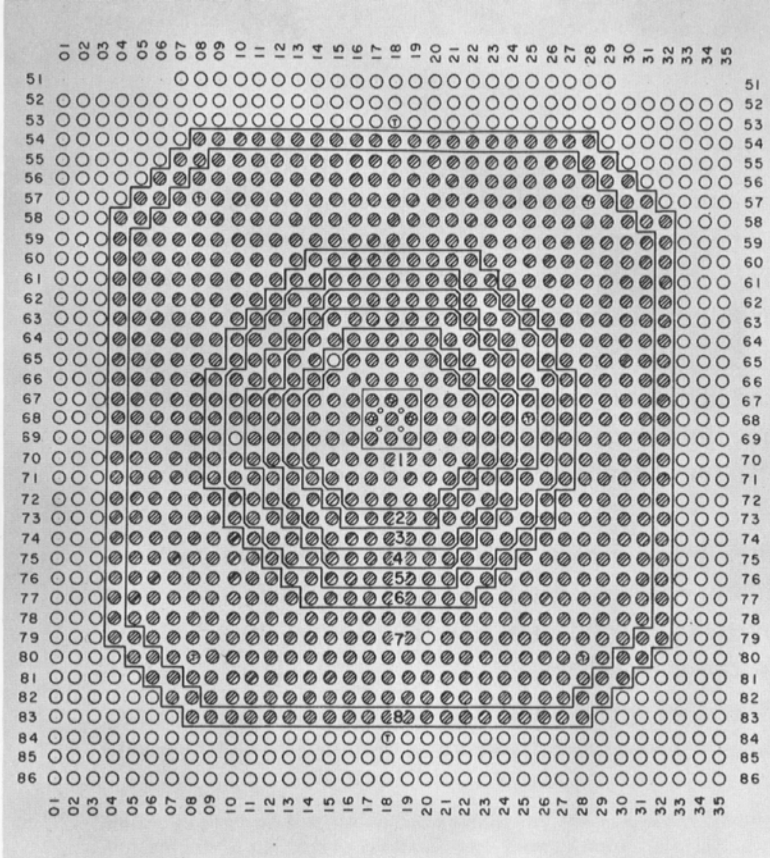
Slugs pushed into the canal included ruptured fuel, and those for separation of radioiodine and other fission products. The depletion rate was less than 1% a year, so discharging slugs for fuel renewal was not necessary.



Loading of the reactor (above) is done at the front face. The shield plug is removed, the fuel inserted and then positioned with a rod as shown by the technicians. Fuel being removed from the reactor is pushed through the reactor and falls into the storage canal (left below).



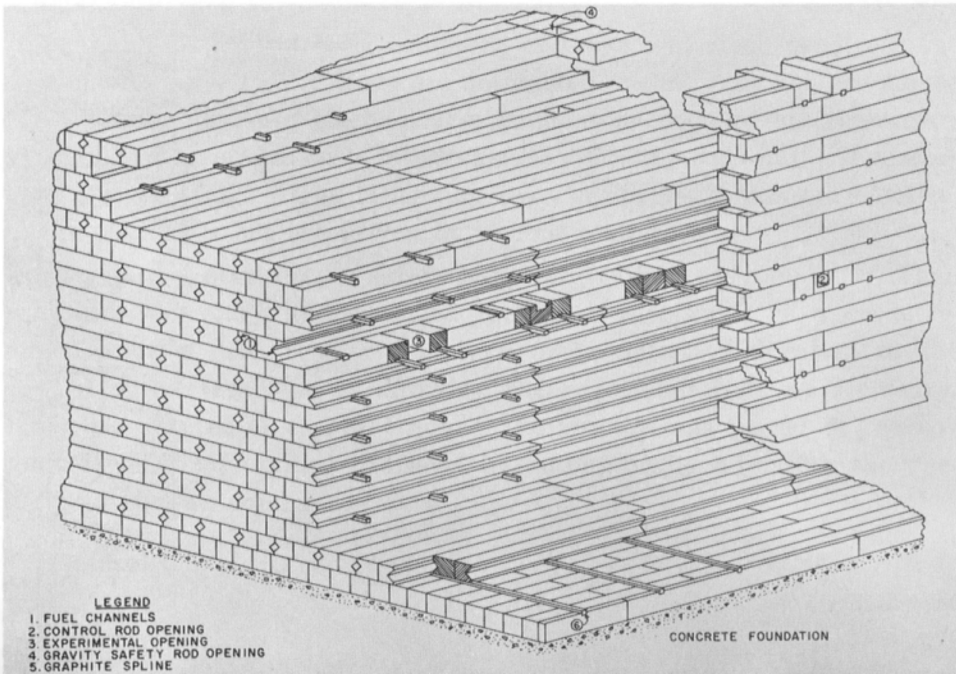
LOADING CAN VARY



OVER-DESIGN ADVANTAGEOUS

The fission which occurred in the reactor during operation produced energy resulting in heat, measured in kilowatts. The reactor was designed to operate at 1,000 kw, but eventually operated at the 3,500-4,000 kw level. The increased power level was a result of the reactor having been over-designed initially.

Following initial operation, the over-design was recognized and steps were initiated to take advantage of it. This included a change in loading pattern, better fuel cladding, some rerouting of cooling air and larger cooling fans. At the 4,000 kw level, the shielding was more than adequate, the lattice was not overloaded with fuel, and control was easy and dependable.



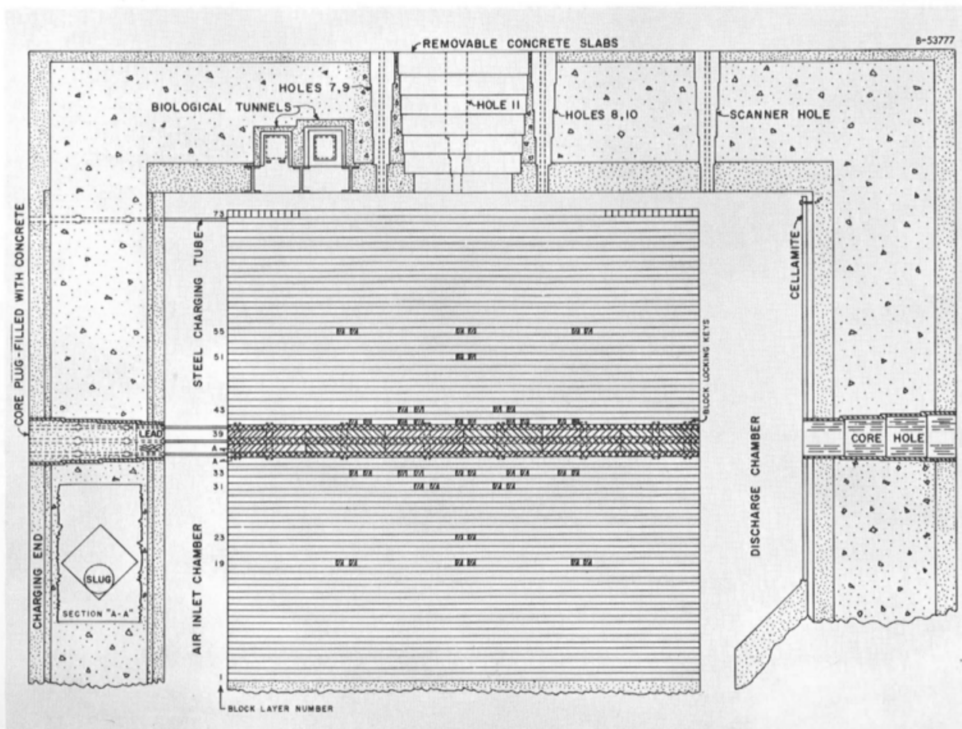
WEATHER DETERMINES POWER LEVEL

During operation, the maximum temperature of the slugs was 527°F and the moderator 392°F. The system was cooled by atmospheric air drawn through the reactor by two huge fans at 100,000 cfm. Air was drawn through the reactor to minimize dangers from outward leakage of contaminated air.

The air went through the inlet filter where foreign particles were removed, entered the inlet air manifold under the floor level, rose in the inlet air gap, flowed through the fuel channels, passed into the exit air gap and out the air manifold.

It then entered the filter house where 99% of the radioactive particles (fission products, graphite, concrete, etc.) down to 1/100,000 of an inch in diameter were removed. The cooling air was then forced up a 200-foot stack and expelled into the atmosphere.

Since atmospheric air was used for cooling, the maximum operating power level was greater in the winter—about 4,100 kw compared to 3,400 kw in the summer.



NEUTRON ABSORBERS FOR INSTANTANEOUS SHUTDOWN

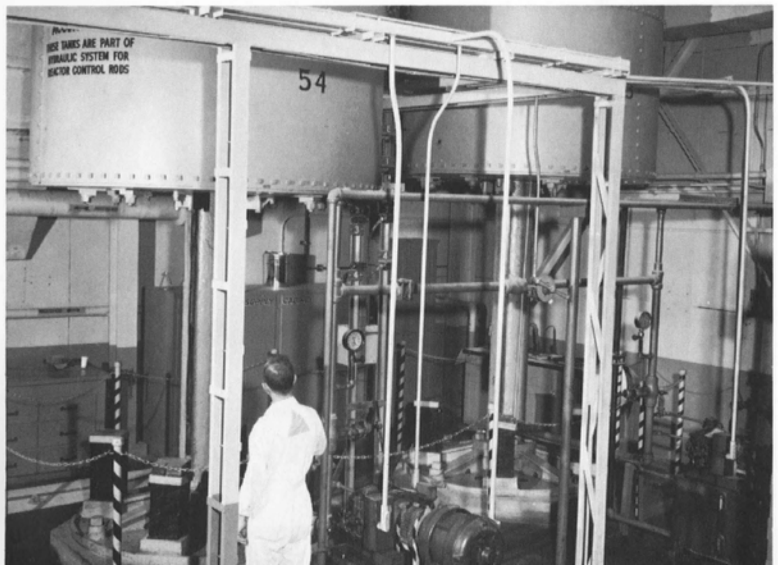
When a sufficient amount of uranium is in the reactor, the start of the chain reaction is spontaneous. A reactor, therefore, must have enough neutron absorbers in its safety and control system to ensure instantaneous shutdown.

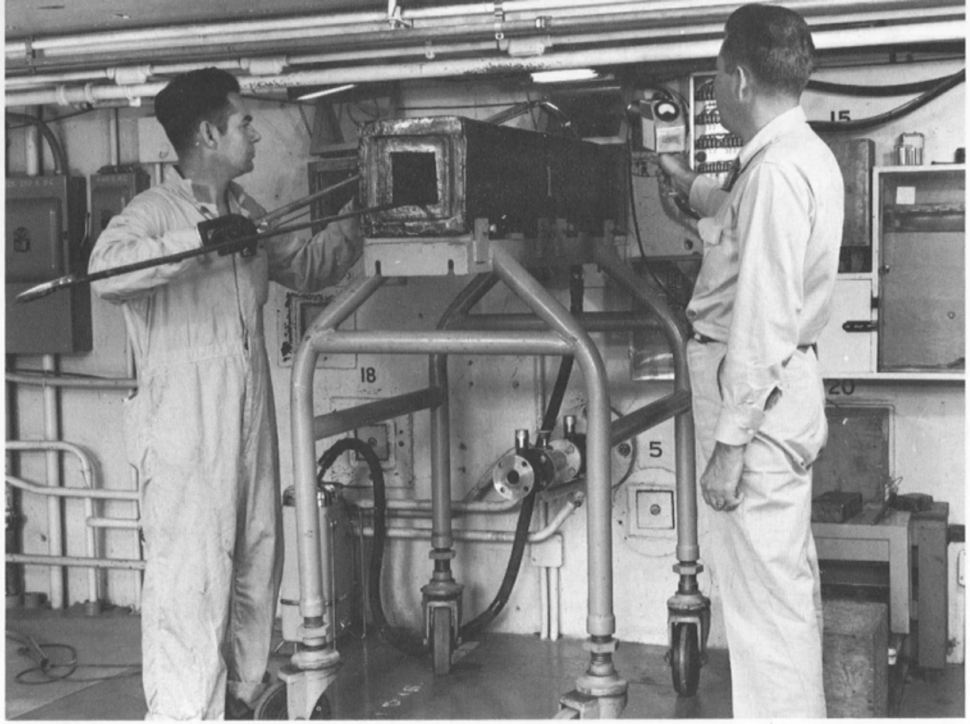
The safety system of the Graphite Reactor consists of seven control rods composed of materials which act as a neutron poisoner or absorber. Three rods of cadmium and steel, designed as "safety" rods, penetrate the core vertically. They are attached to steel cables wound on drums operated by electric motors through an electromagnetic clutch. If power to the clutch is lost, the drum is free to turn, allowing the rod to fall into the core by its own weight. When the safety rods enter the core, they absorb the neutrons and stop the chain reaction.

The other four control rods, composed of boron and steel, penetrate the core horizontally. Two of these are designated "shim" rods and are moved by hydraulic pistons. Mechanical accumulators provide an emergency hydraulic reservoir which is interlocked to drive the rods into the reactor upon a power failure. The remaining two "regulating" rods are identical to the shim rods but are driven by electric motors.

During reactor startup, the safety rods were withdrawn completely. Then one shim rod was withdrawn and the other withdrawn to a predetermined position. The reactor was then made critical and raised to the desired power level by withdrawing the regulating rods as necessary. When the desired level was reached, the reactor was placed in "servo" control which maintained the level by automatically adjusting the partially withdrawn shim rod.

Below is part of the hydraulic system for the reactor control rods of three vertical and four horizontal rods.





A lead shield, known as a "coffin", is used for the withdrawal of radioisotopes from the south face of the reactor (left photo). Below, a technician inserts piston rings for irradiation which helps determine wearability.

GRAPHITE OPENINGS PERMIT VARIETY OF RESEARCH WORK

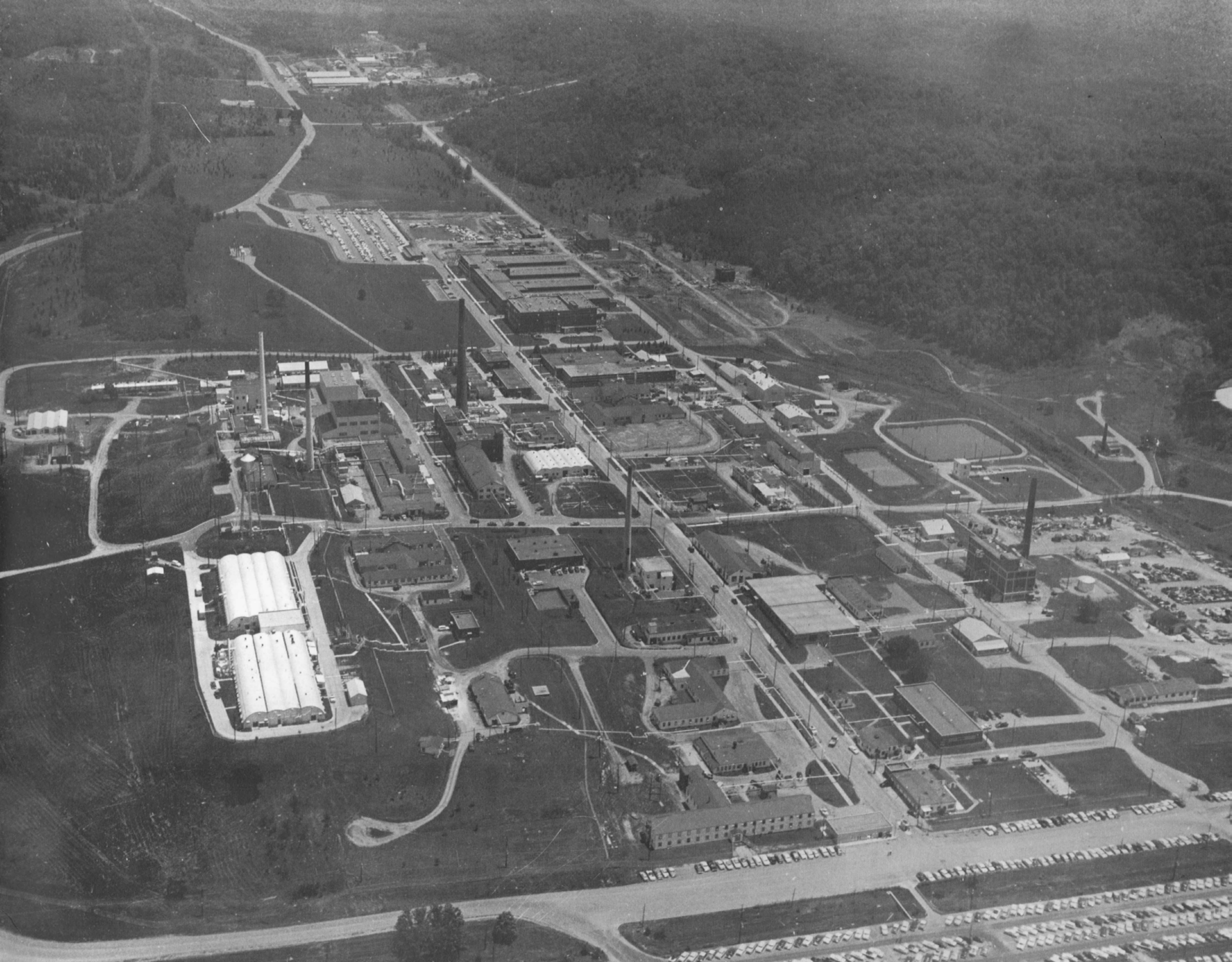
The Graphite Reactor served as a good research tool because of the openings left in the moderator by omission of strings of the graphite building blocks. These avenues provided exposure chambers and served as sources of collimated beams of neutrons for use outside the reactor. The facilities could handle more than 36 experiments and expose 1,000 target materials simultaneously.

Not only could isotopes be produced in the reactor, but items like piston rings and cylinder liners could be irradiated for wear tests. Also available are tunnels for irradiation of small animals and other biological specimens. These facilities have been used for irradiating soy beans, popcorn and peanut seeds for mutation studies.

At one time, the Graphite Reactor was a prime producer of radioisotopes. Elements in aluminum capsules were placed in graphite blocks (stringers) and inserted into the reactor on the south face. Following irradiation, the stringers were pulled into lead shields (coffins) to prevent exposure to personnel. The capsules were then shifted to carriers for transfer to the isotope processing area.

In this 1947 photograph of the Clinton Laboratories, the Training School building is visible downhill from the pilot plant. Under construction were the quonset huts, left center of the picture, which became the central machine shops. The Graphite Reactor building has taken on a new look with shiny siding.

By the summer of 1951 (above), Buildings 4500 and 4501 were nearing completion. The new Instrument Building, the Isotopes structures, the Cafeteria and the change house near the west end of Central Street were all completed. Also complete were the LITR and the Bulk Shielding Facility, while the Metal Recovery Plant was still under construction. By 1959 (opposite page), Oak Ridge National Laboratory took on a more permanent atmosphere with the addition of several large facilities. Completed were the ORR, the Solid States laboratory addition, the Fission Products Development Laboratory, the Instrumentation and Controls addition, the Central Research Shops, the Process Waste Water Treatment Plant, and the High Radiation Level hot cells west of Building 3019.



The Graphite Reactor (front cover), housed in the building shown above, was the world's oldest operating reactor for 20 years beginning in 1943. Originally known as the Clinton Pile, this reactor became the forerunner of one of the nation's largest nuclear energy research and development centers — Oak Ridge National Laboratory. ORNL, as it looks today, is shown on the back cover.

OAK RIDGE
NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U. S. ATOMIC ENERGY COMMISSION