LA-7121-H, Rev.

History

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Thirty-Five Years at Pajarito Canyon Site

University of California

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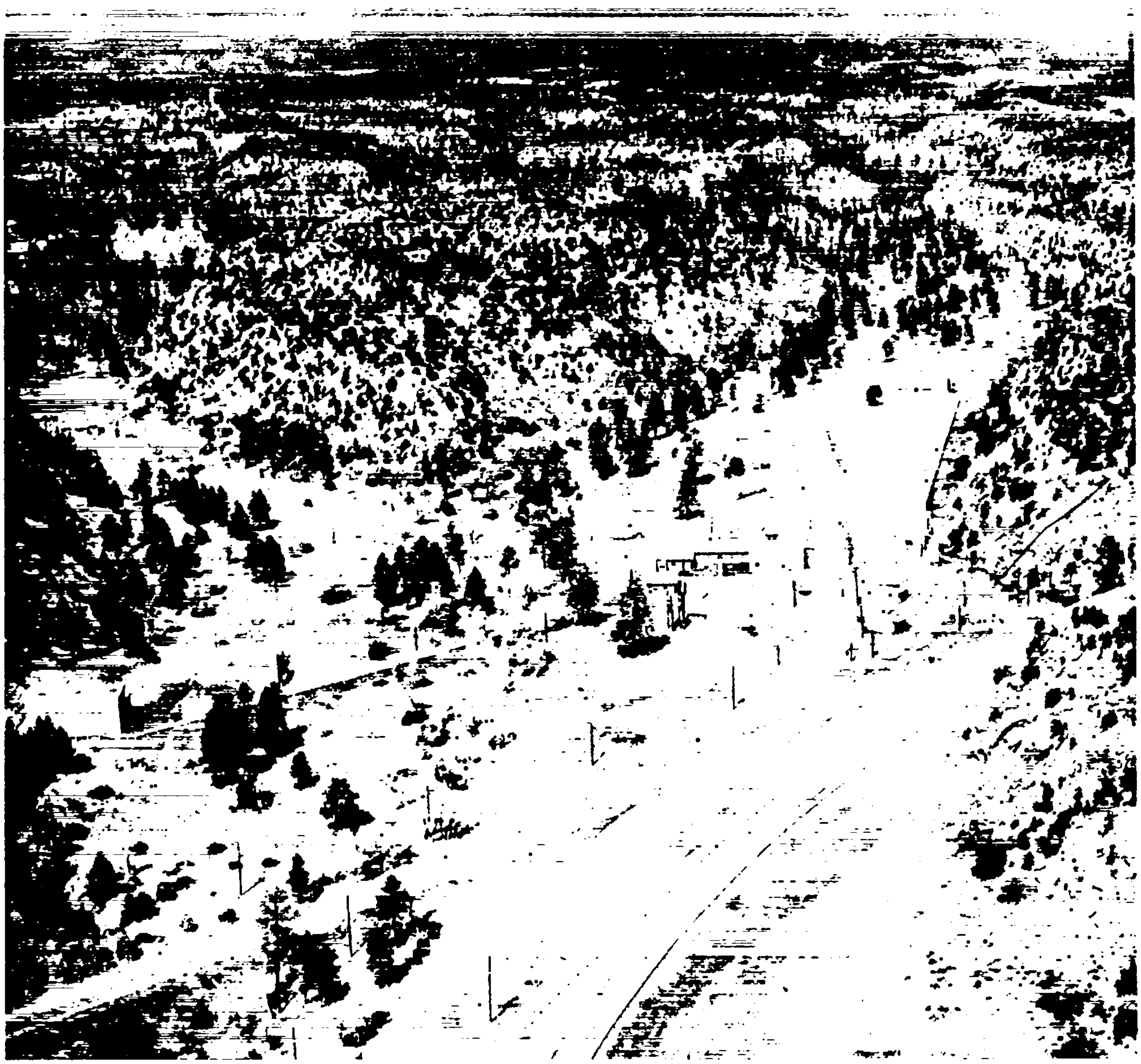
Hugh C. Paxton



Pajarito Site, March 1969. Main building with control room is at center; outlying buildings containing critical assemblies are Kiva 1 at right rear, Kiva 2 at left rear, and Kiva 3 in left foreground.

FOREWORD

A history without the names of outstanding participants—Columbus, Cortez, Drake—would lose color, yet too many names would destroy the effect. The proper balance in this account is elusive because of the team effort required in the critical experiments that play a central role. The senior member of a team could not act alone and so should not be singled out for credit, which seems to leave the choice between all names and none. I have selected the latter course at the sacrifice of color, but have moderated it some by naming those who appear in illustrations, the authors in an extensive list of unclassified publications (Appendix A), and the administrators of the Groups that have been at Pajarito Canyon (Appendix B).

Of the many who have helped reconstruct this history, several names stand out. Raemer Schreiber supplied the personal touch that I missed during the years before 1949; in particular he wrote Appendix C on critical-assembly guidelines. Roderick Spence of the Geosciences Division and Keith Davidson of the Materials Technology Group provided records and recollections of the Rover Program. And Walter Bramlett and Pres Martinez of the Los Alamos National Laboratory Records Center have unearthed much of the remaining information needed to correct my hazy recollections.

Hugh C. Paxton

THIRTY-FIVE YEARS AT PAJARITO CANYON SITE

PROLOGUE

In her *House at Otowi Bridge*, Peggy Pond Church tells of two years in Pajarito Canyon at her father's dude ranch, The Pajarito Club.[1] The location, where the Canyon broadens just below a fork, is the Pajarito Canyon Site of the present account. The Club was abandoned in 1916 when its water supply, a spring that fed a small stream, dried up — reminiscent of the much earlier history of the Canyon's Indian ruins.[2] A log cabin that actually predates the Club is still standing, and a nearly obscured sawdust pile shows that there had been a sawmill at some time.

The first use of the Pajarito Canyon by The Los Alamos Laboratory, as it was originally named, was by the Radioactivity Group in mid-1943.[3] The choice of this outlying Site for a field station was to avoid the radiation background arising from other Laboratory activities. A year or so later, this Group moved to the East Gate Laboratory that was set up specifically for spontaneous fission measurements.

In late 1944, the Site was adapted as a proving ground for the so-called "magnetic method" of diagnosing implosions. Three earth-covered bunkers are the only remaining evidence of that activity, which was abandoned before the end of 1945.

Finally, work with critical assemblies was moved from the Omega Laboratory to the Pajarito Site in April 1946.[4] Although this followed the fatal radiation injury of Harry Daghlian, urgently required critical assemblies were still manipulated by hand until Louis Slotin suffered the same fate about a year later. In each case, a component of the assembly slipped into a more reactive position, producing a superprompt-critical pulse of radiation. This second accident outlawed hand operation, thus increasing the urgency of need for a facility for remotely controlled critical assemblies. Because of its remoteness and existing rudimentary buildings, Pajarito Canyon remained the favored location for this new facility, which was rushed to completion in 1947. This brings us to the beginning of the thirty-five years during which activities at the Pajarito Canyon Site have evolved systematically.

BEFORE ROVER

In the course of numerous changes of activities and groups at the Pajarito Canyon Site, the thread of continuity has been the remote-control Critical Experiments Facility. Originally, this Facility consisted of a critical-assembly laboratory known as "Kiva" (the ceremonial chamber), located one-quarter mile from a control room in an existing shack. An exclusion area provided radiation protection by keeping people beyond this distance whenever the remotely controlled critical assemblies were operated. Guidelines directed toward the safety of operations are described in Appendix C. Except as required directly for critical experiments, the operating Group M-2 was housed in Gamma Building near the Los Alamos townsite.

Kiva operations began in April 1947 as subcritical measurements for weapon safety guidance. Accidental criticality had to be avoided during the handling, storage, and transportation of weapon components, and during the assembly and manipulation of weapons. The experimental guidance was necessary to avoid impractical restrictions.

In early brute-force weapons, yield was limited by criticality-safety restrictions, and each high-yield capsule was tested to be certain that those restrictions were satisfied. As weapon design became more subtle, the need for capsule tests decreased, but guidance for the storage of complete weapons became more important, especially for shipboard storage in severely limited space.

Fig. 1.
Site of The Pajarito Club, about 1914. From the collection of Peggy Pond Church, courtesy of the Los Alamos County Historical Museum.

Fig. 2.
The still-standing log cabin of early days. Known now as "Dwight's cabin," after Dwight Young who batched there in the 1960s and greeted us in mornings with the fragrance of fresh bread.

Fig. 3.
The original Kiva from an Indian cave in the nearby wall of Pajarito Canyon.

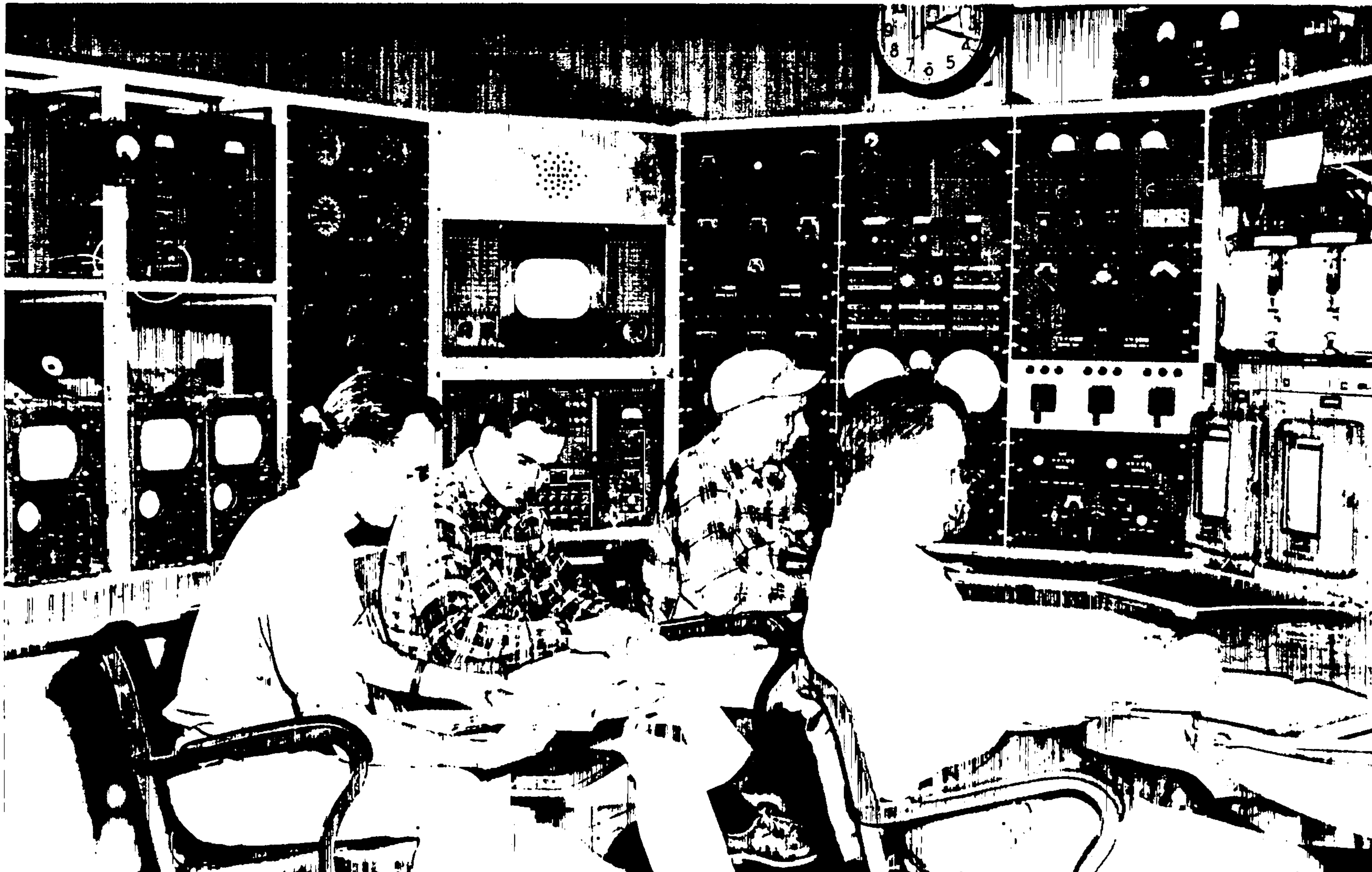


Fig. 4.
The original Kiva control room in a previously existing shack. From left to right, Vernal Josephson, Roger Paine, Lester Woodward, and Hugh Karr. Josephson was Alternate W-2 Group Leader. Commander Paine and Colonel Woodward were military personnel who contributed invaluably to our critical experiments.

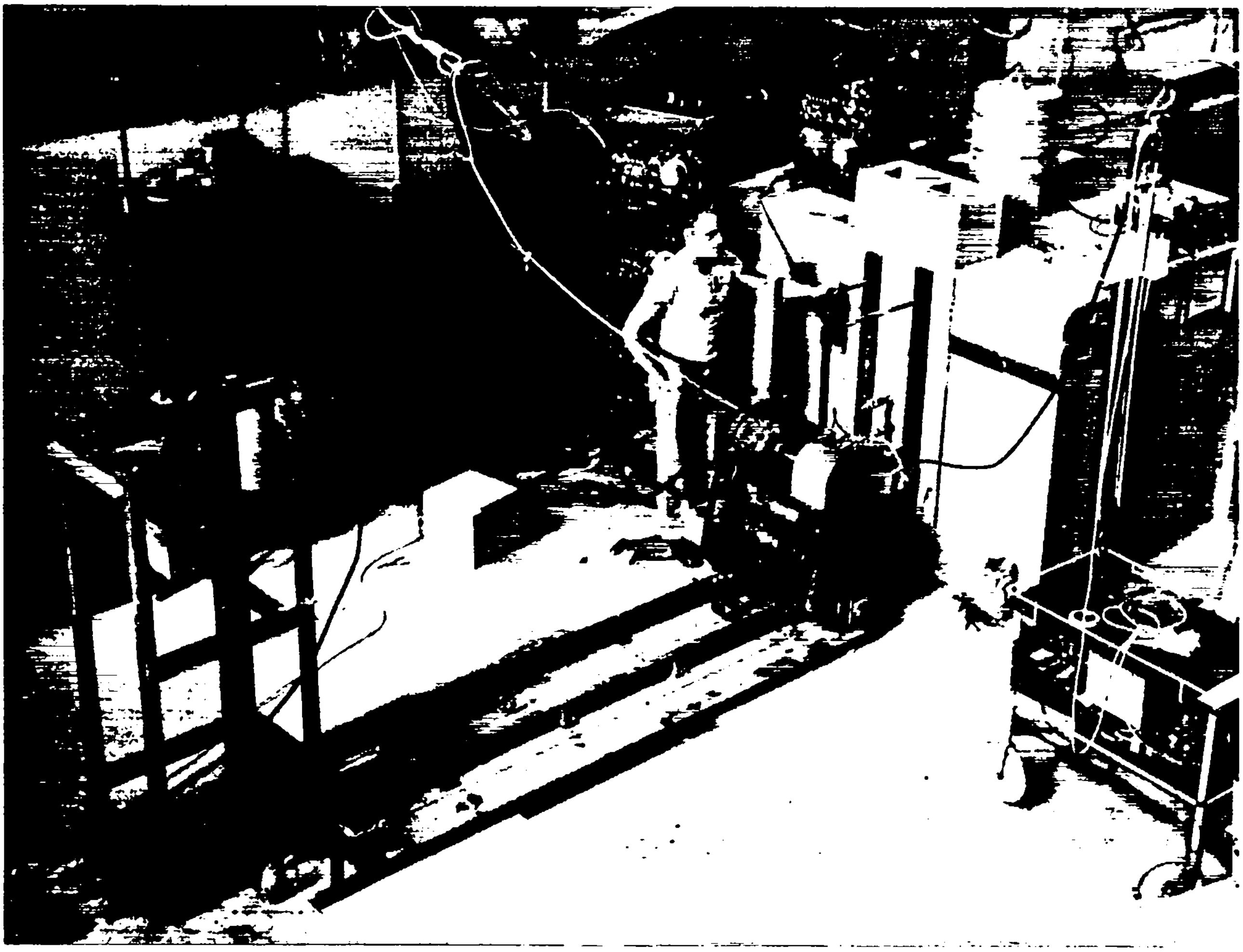


Fig. 5.
A concrete vault with remote closure for early weapon-capsule storage tests in Kiva 1. The entire stockpile was called upon for these measurements. The participant is Raemer Schreiber, then M-2 Group Leader. Stringent security was maintained during these experiments, including a special contingent of Military guards, machine gun emplacements on the walls of Pajarito Canyon, and a requirement that all operating personnel wear distinctive jackets while moving between buildings. Operations were conducted around the clock to minimize the total time the stockpile was exposed.

Fig. 6.
Dirty jobs were part of the game—an adult version of mud pies being mixed and tamped into parts of a bomb mockup. Identifiable of these old Group M-2 members are William Wenner who holds the bucket, Gustave Linenberger in the center foreground, and James Roberts standing above.

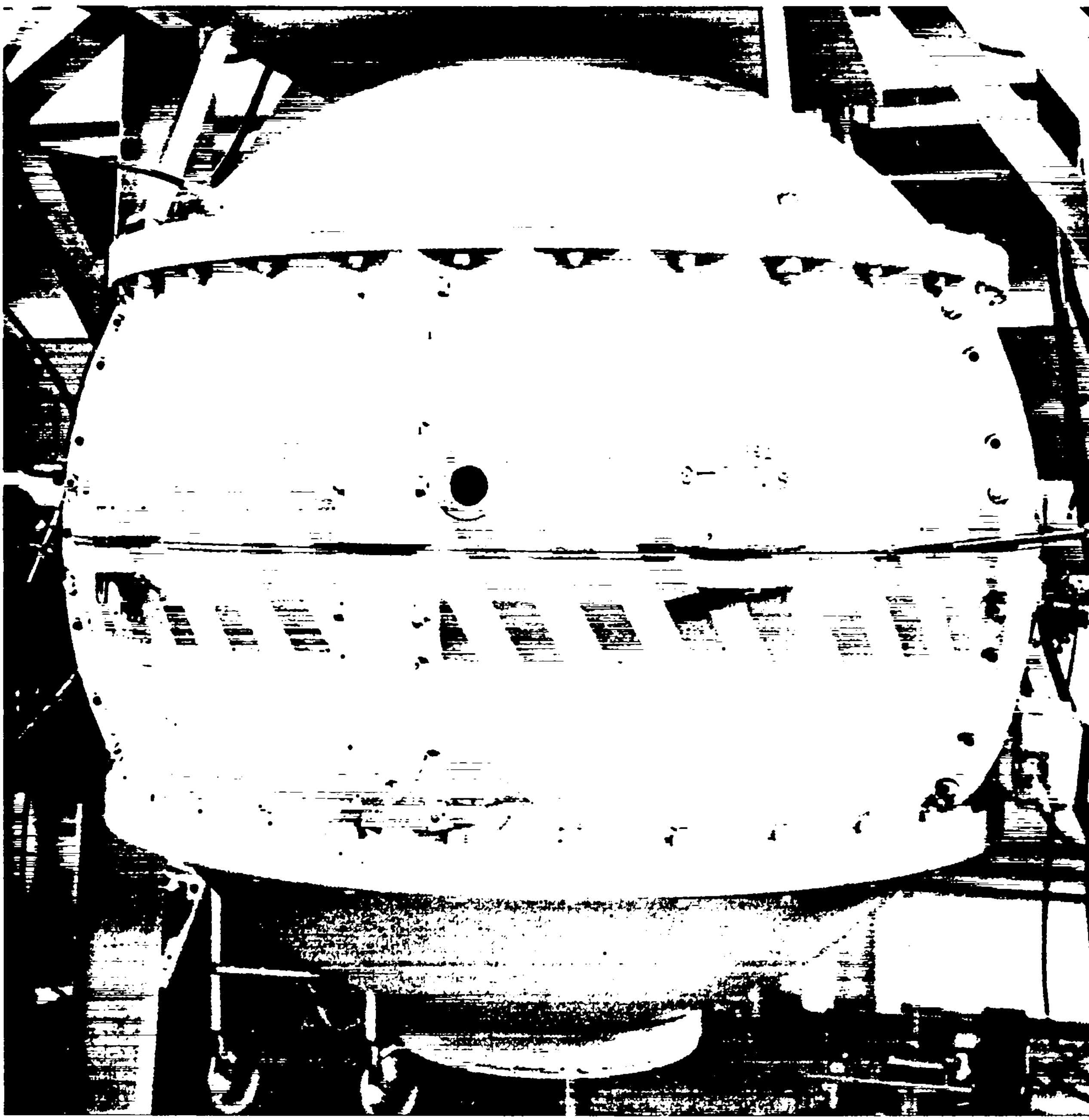


Fig. 7.
A Kiva 1 implosion weapon mockup in which capsules are replaceable. Measurements in this bomb mockup established subcritical limits for more advanced designs than the Nagasaki weapon.

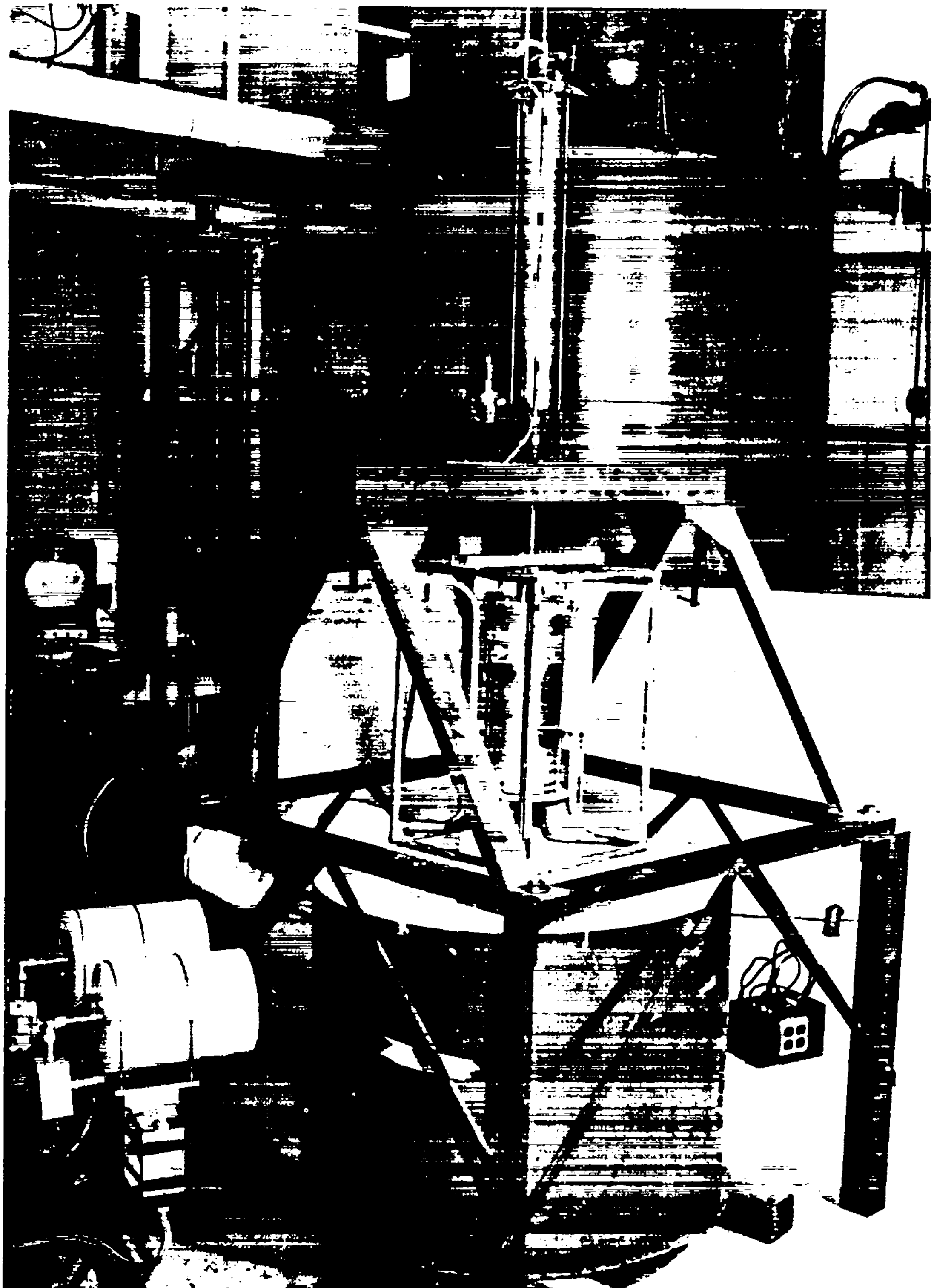


Fig. 8.
Weapon capsule in carrying case about to be lowered into water tank to measure the effect of flooding.

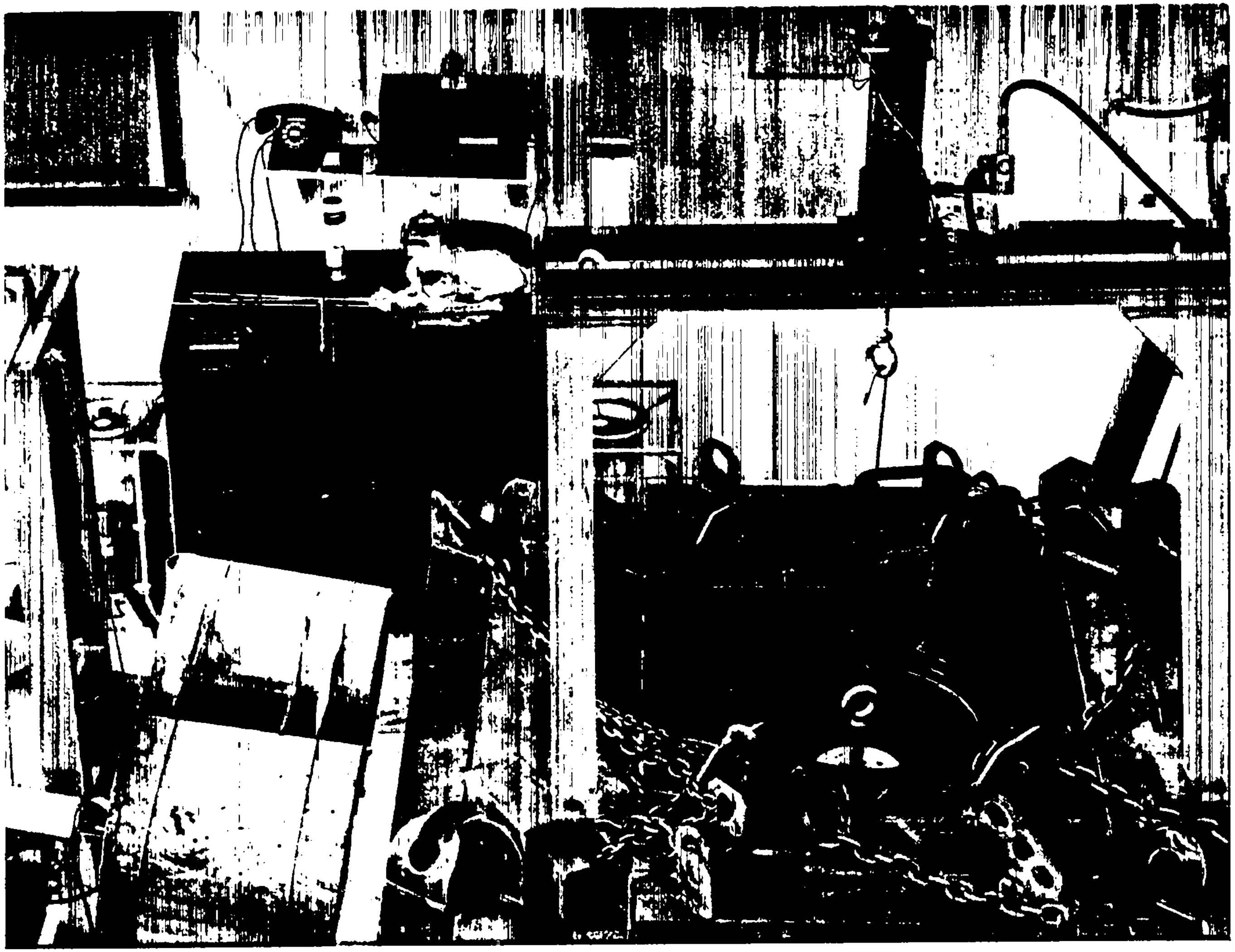


Fig. 9.
Artillery weapon in steel simulating the breech of a Naval gun. Safety was established by lowering the weapon remotely.

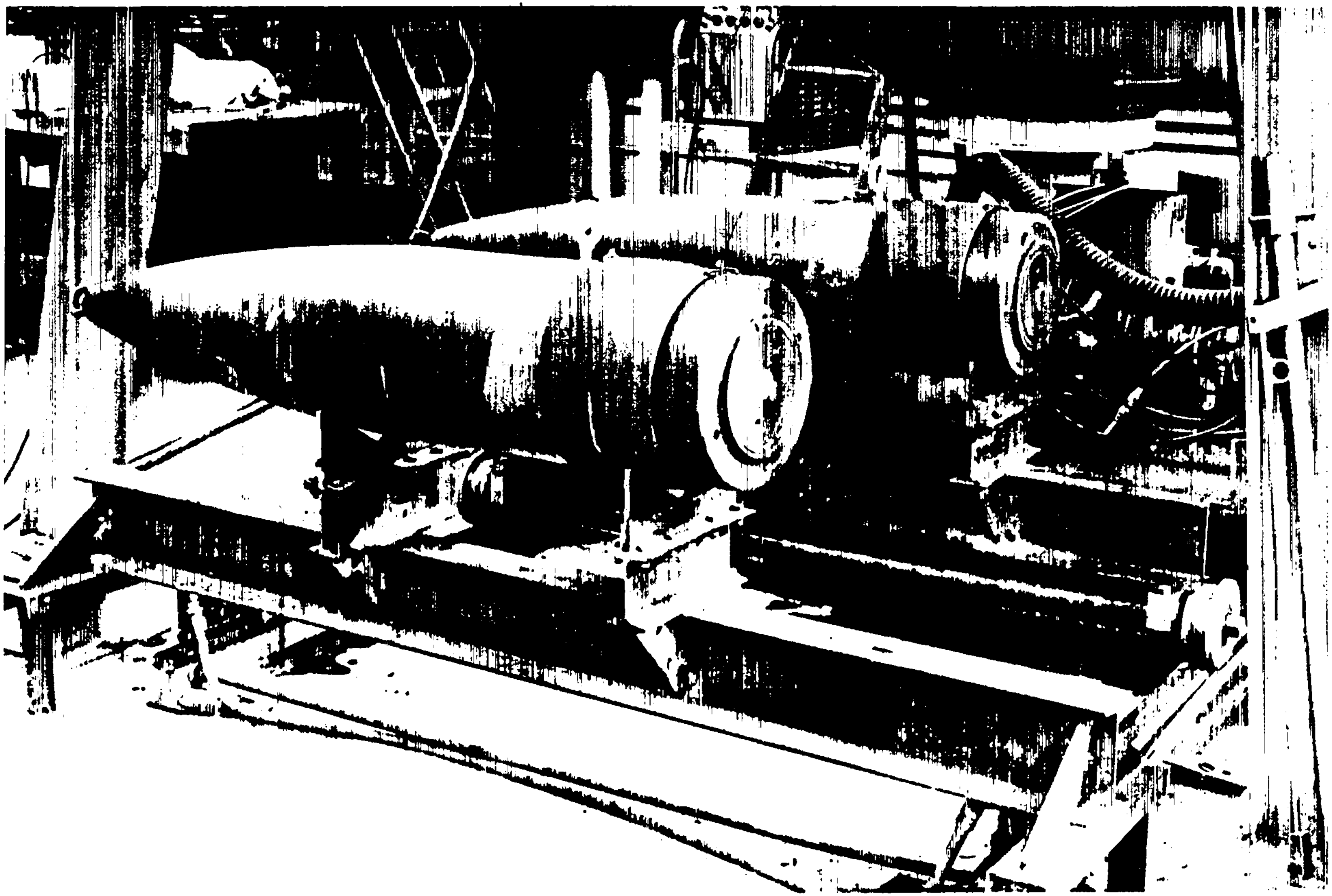


Fig. 10.
Setup for measuring the interaction between artillery shells. Results helped to establish rules for safe storage.

Eighteen months after the Kiva became operational, criticality of the Topsy assembly (she just growed) was reported by the Group, redesignated W-2. The matter-of-fact report of Topsy operation gives no hint of its real significance. This metal assembly of enriched uranium in thick natural uranium provided the first basic information about fast-neutron fission chains in a readily computable system. Superprompt-critical pulses that had occurred were too fleeting for neutronic experiments, and earlier critical mockups of a mercury-cooled fast reactor at Omega Site were too complex for reliable calculation. Thus Topsy was the first of a series of assemblies to provide fast-neutron data for checking the powerful computational techiques that relied upon high-speed machines being developed at the time.

These techniques, used for both weapon and fast-reactor design, required experimental confirmation because of uncertainties in the many input cross sections. In addition to observed critical specifications, data for this purpose included descriptions of neutron energy spectra, effective cross sections of various materials within the assembly, the time behavior of prompt-neutron chains (on a scale of microseconds), and delayed-neutron characteristics (on a scale of seconds). Prompt neutrons from fission lead to the runaway reaction in a nuclear explosion; the minute fraction of delayed neutrons makes reactor control possible.

These neutronic measurements to assist weapon designers increased in importance as designs became sophisticated. They gradually supplanted direct tests on components and assembled weapons, but even today such tests have not been eliminated.

As a natural result of work with critical systems, we became a source of advice on nuclear criticality safety. This covered chemical processing, fabrication, storage, and transportation of enriched uranium and plutonium. It focused on operations at Los Alamos and certain other AEC installations, but invited generalization. An outcome was the promotion of criticality safety as a discipline, and concomitant participation in the preparation of safety guides and standards—a continuing activity.

Another diversion from critical experiments was a study of fission outside critical assemblies. Experiments with a betatron borrowed for this purpose promised sufficiently useful weapon applications to justify splitting off this line of research. The new group, designated W-5, remained in old buildings at Pajarito from the time of its formation in May 1951 until the fall of 1954 when it moved from the Site and, as Group K-4, redirected its efforts toward controlled thermonuclear development. As W-5, its most important contribution was a practical external initiator of weapon explosions.

A second critical assembly for basic studies, Lady Godiva (she was unclad), began operation in August 1951. This essentially bare sphere of enriched uranium, simpler than the two-component Topsy, had not been planned earlier because of unknown sensitivity to outside influence, facetiously, even the effect of a fly alighting on the surface. This assembly was followed a year later by a plutonium core in Topsy.

The addition of Lady Godiva and a couple of new machines for safety tests stretched the capacity of the Kiva to its limit. There was even three-shift operation, although at some presumed sacrifice of continuity and alertness of experimenters. To improve both the efficiency and safety of critical experiments, a central laboratory and office building brought the entire Group to the Site, and a second remote-control laboratory, Kiva 2, shared the critical assemblies. After transfer to this Kiva, Lady Godiva, for example, began operation about February 1953.

Shortly thereafter, we ran the first reactor mockup at Pajarito. This simplified version of the LAPRE solution reactor being developed by newly formed K Division was suitable for checking design calculations. Another simplified mockup, a few months later, assisted the Argonne National Laboratory in its design of the proposed EBR II reactor. Studies of reactor mockups such as these remained brief and incidental to weapon-related activities until the advent of Rover.

In mid-1953 there was the handsomest payoff of remote control, the superprompt-critical operation of Lady Godiva. This delicate stepping into a previously forbidden region depended upon isolation from people. The typical result was a sharp, intense radiation pulse terminated by the thermal expansion of Lady Godiva.[5] Although intended simply to confirm predictions of superprompt-critical behavior, these pulses were immediately in demand as near-instantaneous sources of radiation for a variety of experiments ranging from biological to solid state. Because the pulses simulated the radiation from a test

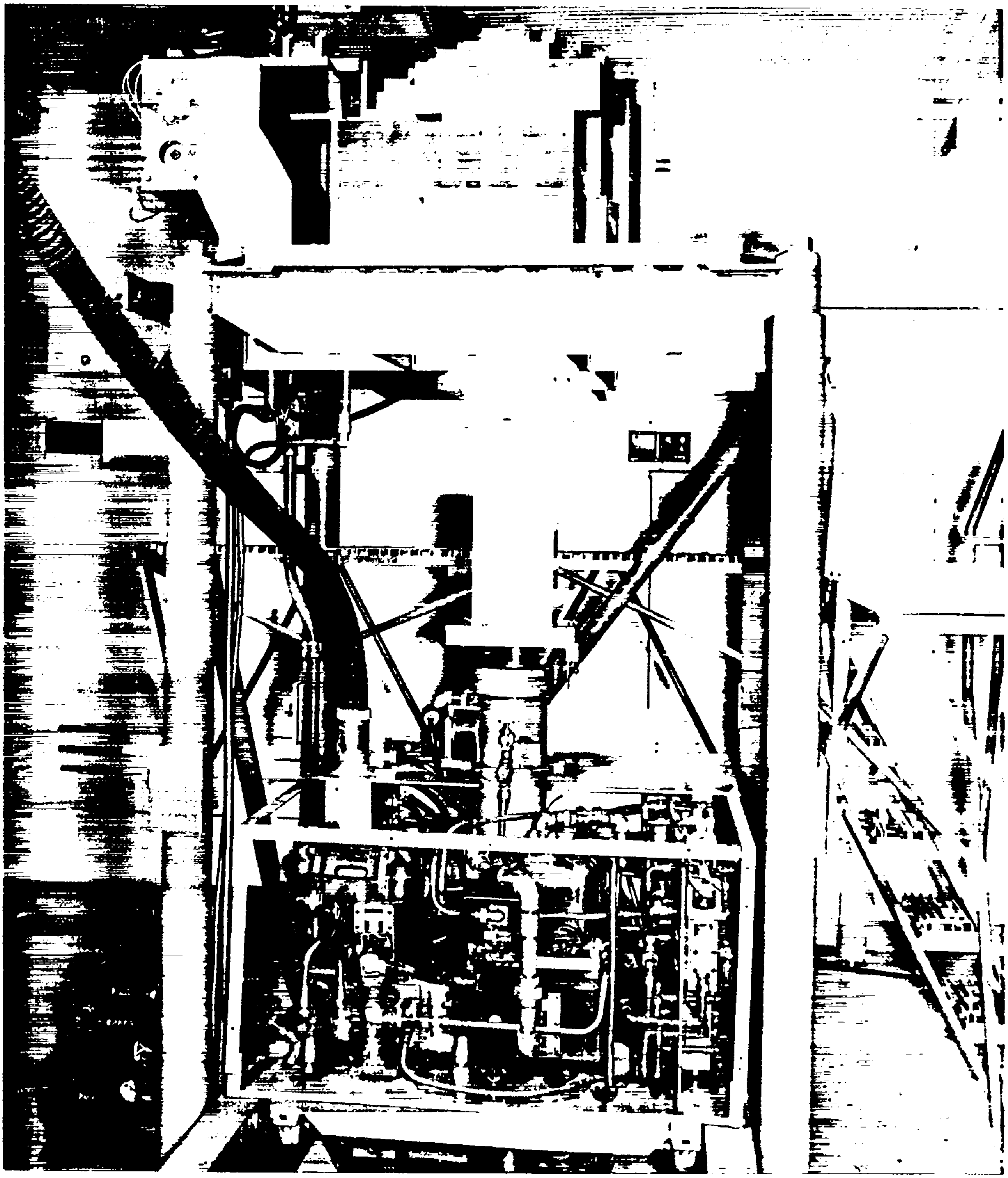


Fig. 11.
The Topsy critical assembly. The enriched uranium core embedded in part of the natural uranium reflector rises into a cavity in the main reflector body. Spherical or cylindrical cores were approximated by one-half-inch cubic blocks.

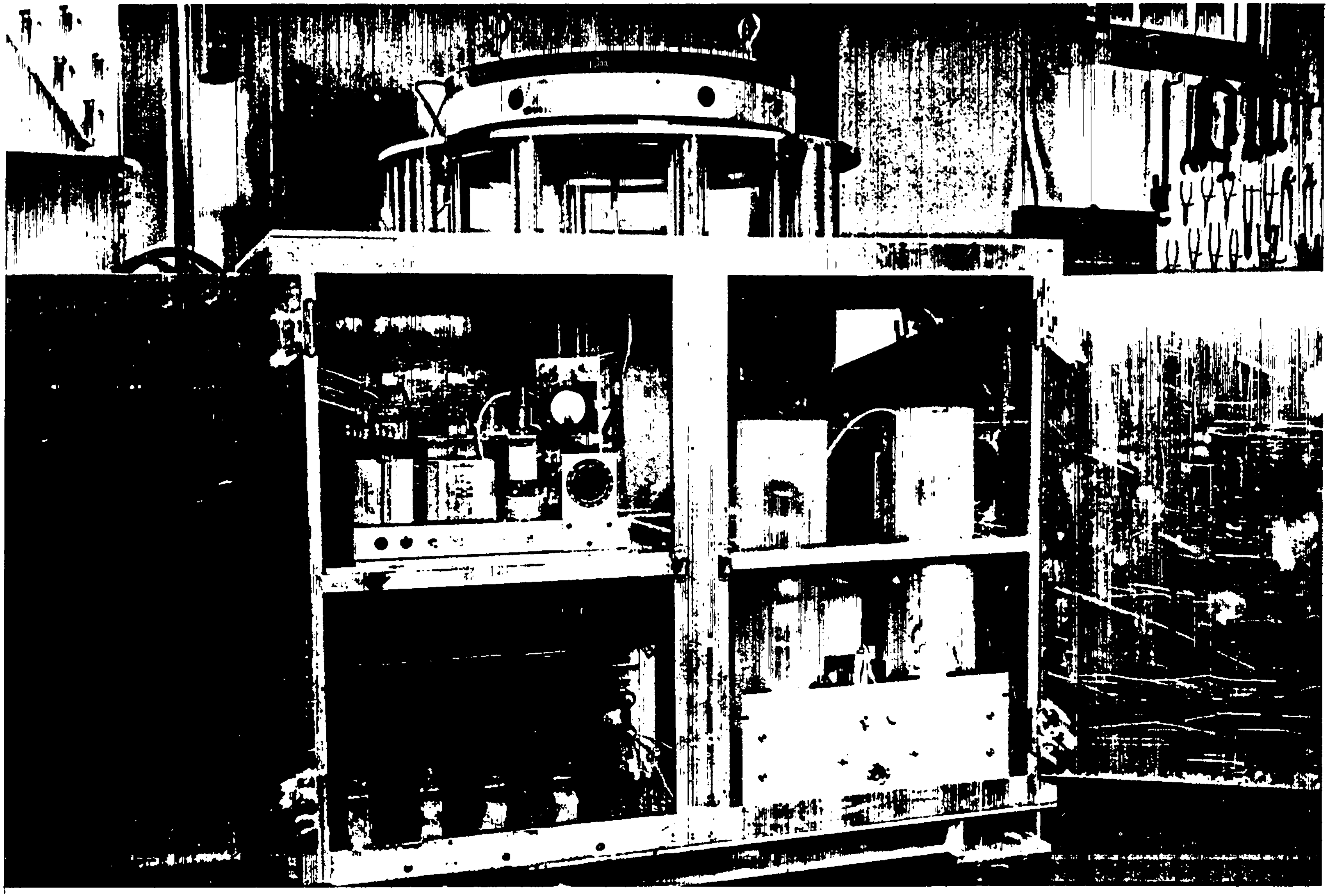


Fig. 12.
A compact successor to the General Electric Company betatron that started the activities of Group W-5.

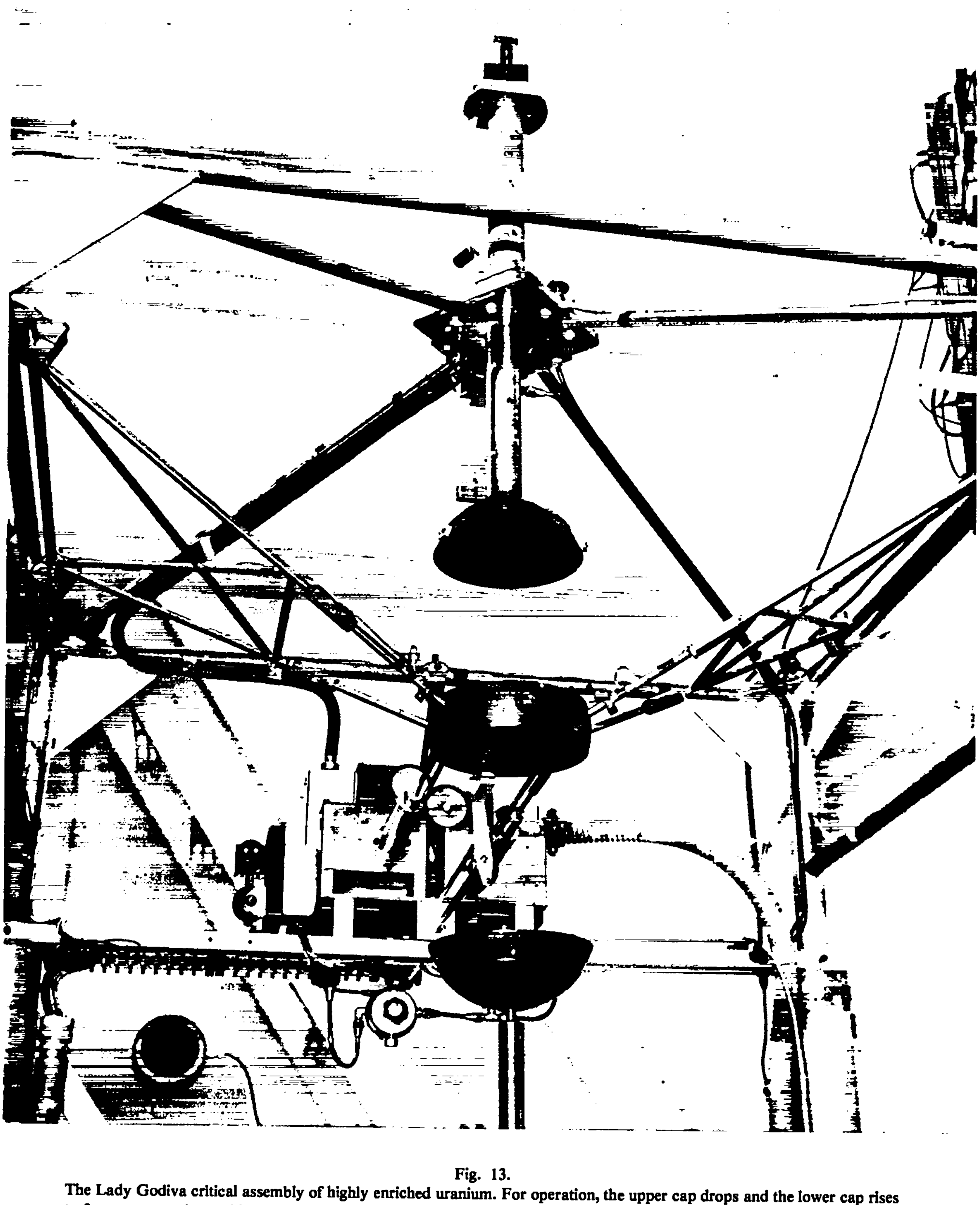


Fig. 13.
The Lady Godiva critical assembly of highly enriched uranium. For operation, the upper cap drops and the lower cap rises to form a near-sphere without reflector.

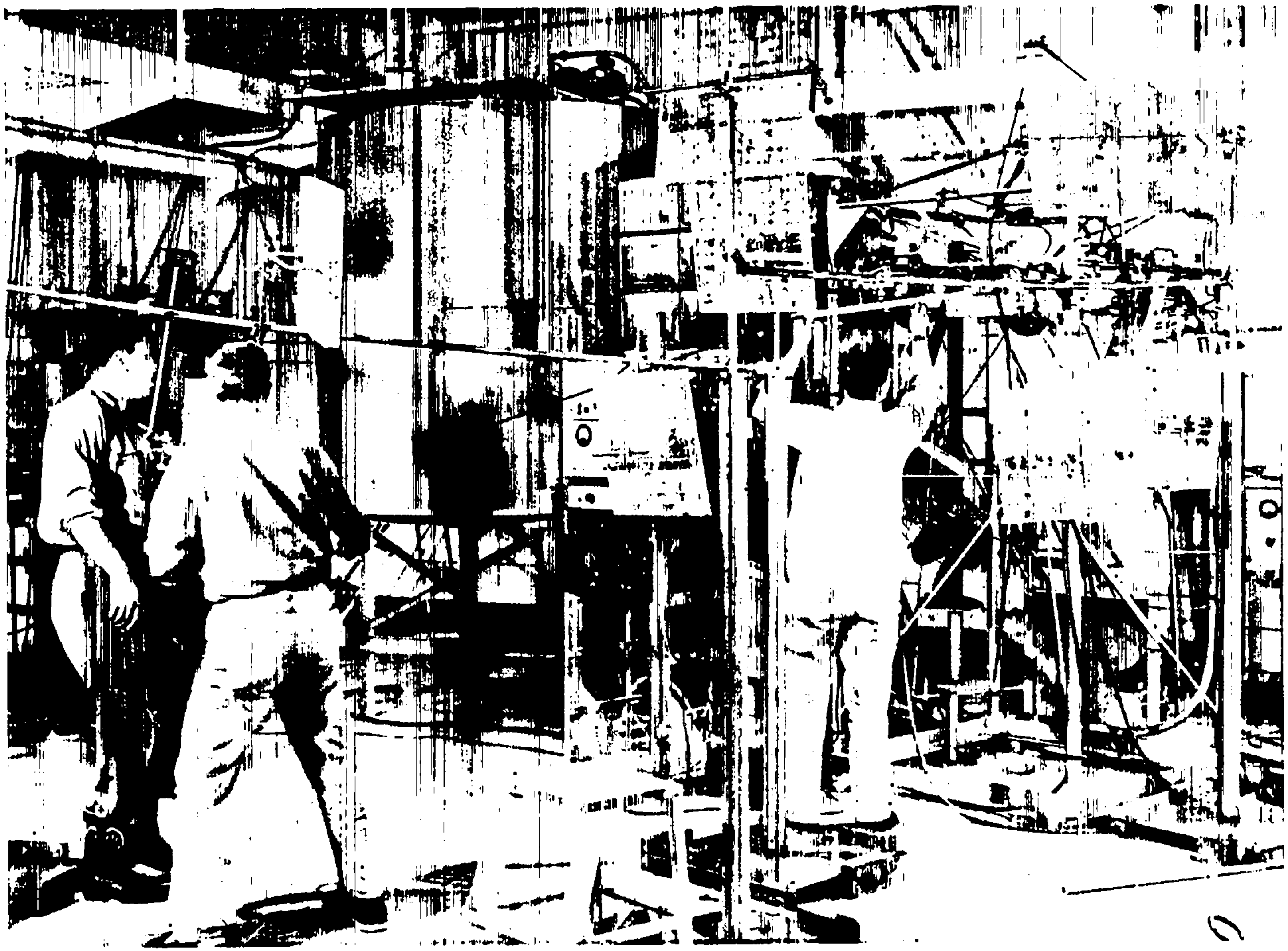


Fig. 14.
Mice disposed about Lady Godiva for prompt-burst irradiation. Dr. Payne Harris, then of Group H-5, is identifiable. Effects on other irradiated mammals, including burros and monkeys, when extrapolated to man, helped to establish both lethal doses and the greater immediately incapacitating doses.

device beyond blast-damage range, they were also used to proof-test instrumentation and controls that were supposed to withstand radiation from a nuclear explosion. Thus they provided an alternative to expensive field tests, and ultimately led to the family of fast-burst reactors that extended to the Sandia Laboratories, Oak Ridge National Laboratory, Lawrence Livermore Laboratory, White Sands Missile Range, and Aberdeen Proving Ground.

The total of about 1000 prompt bursts from Lady Godiva were not without incident, for twice the safe limit beyond prompt criticality was overstepped. The first time, damage was repairable, but in the second incident, uranium parts were too badly warped and corroded for further use. The assembly was replaced by Godiva II, designed specifically for burst production. In addition to the Lady Godiva accidents, remote control has served its purpose in six instances where prompt criticality was attained unintentionally.[6]

In the pre-Rover period, late 1954, another critical assembly for basic studies came into operation. This unreflected sphere of delta-phase plutonium, called Jezebel, is still in operation. Because it is unique and simple, it is classed as a bench-mark assembly, one of the standards for checking fast-neutron calculations.

THE ROVER PERIOD

The Rover nuclear-propulsion program that came to Los Alamos in the spring of 1955 added a new dimension to Pajarito critical experiments. N Division, newly formed to take on this work, had headquarters at the Site until more suitable housing could be built. We became part of this Division, were renamed Group N-2, and shared the excitment of developing rocket reactors.

Throughout the next seventeen years, the neutronics of Rover reactors dominated our attention, although weapon-related work was not neglected. First there were parametric surveys to provide general guidance for the designers. In these, geometric imperfections were tolerated for the sake of flexibility. Then, when overall dimensions became fixed, details of core, controls, and internal structures were established in a mockup with good geometry. Finally, the reactor destined for testing in Nevada was checked at Pajarito and adjusted if found to depart from specifications. With a few exceptions, this progression was followed for each new Rover reactor.

A computational capability at Pajarito, which had been required for interpreting and supplementing critical experiments, was expanded for the Rover program. It encompassed the conversion of room-temperature critical data to high-temperature operating conditions, the detailed evaluation of radiation heating, and the calculation of shielding required in an operable rocket.

The additional demands on Group N-2 included assisting in the preparation for field tests and work on a competitor to the favored graphite-moderated reactor. This competitor, Dumbo, was to take advantage of the excellent high-temperature properties of tungsten, and, to keep weight down, required a cooled hydrogenous moderator. Following several years of intensive design effort requiring continual neutronic experiments, this concept was abandoned in the fall of 1959.

Another concept was a gas-core reactor with external moderator cooled by a spiral of incoming gaseous propellant. Although too "far out" for immediate development, this type of reactor was simulated by a series of assemblies with large cavities surrounded by thick heavy water or beryllium. Neutronic studies of these assemblies immediately followed the Dumbo program.

In addition to its part in these activities, Group N-2 helped to prepare for reactor tests in Nevada; for example, it provided the initial neutronic instrumentation and prepared the accident analyses required for safety documentation. Further, it assisted in performance of the tests by providing neutronic and reactor-safety specialists. As a result of the extensive—and intensive—program, the Group grew in size and required a third Kiva that was completed in 1960. At that time, local work with Nevada test reactors

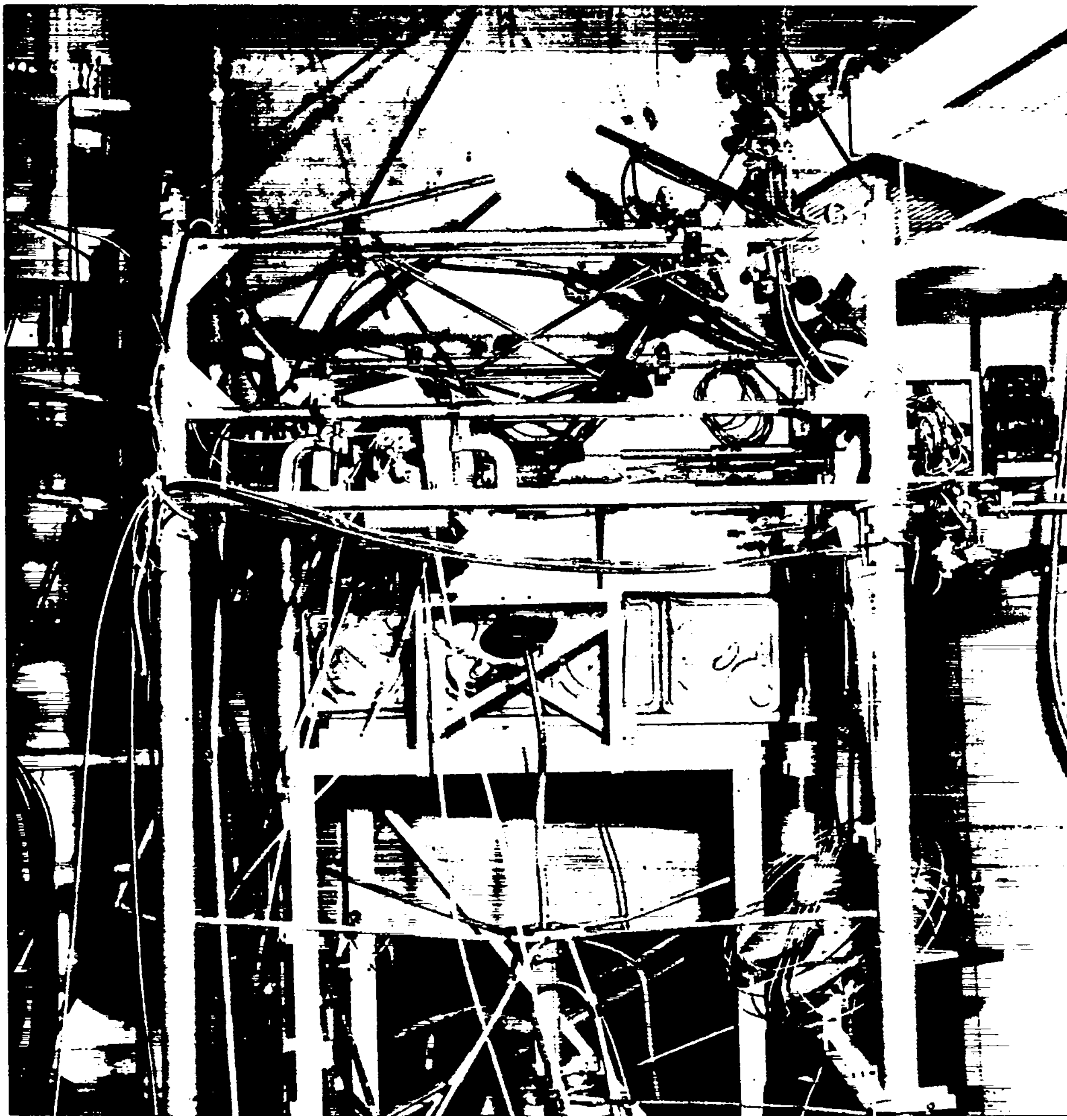


Fig. 15.
Lady Godiva after the accident that led to retirement.

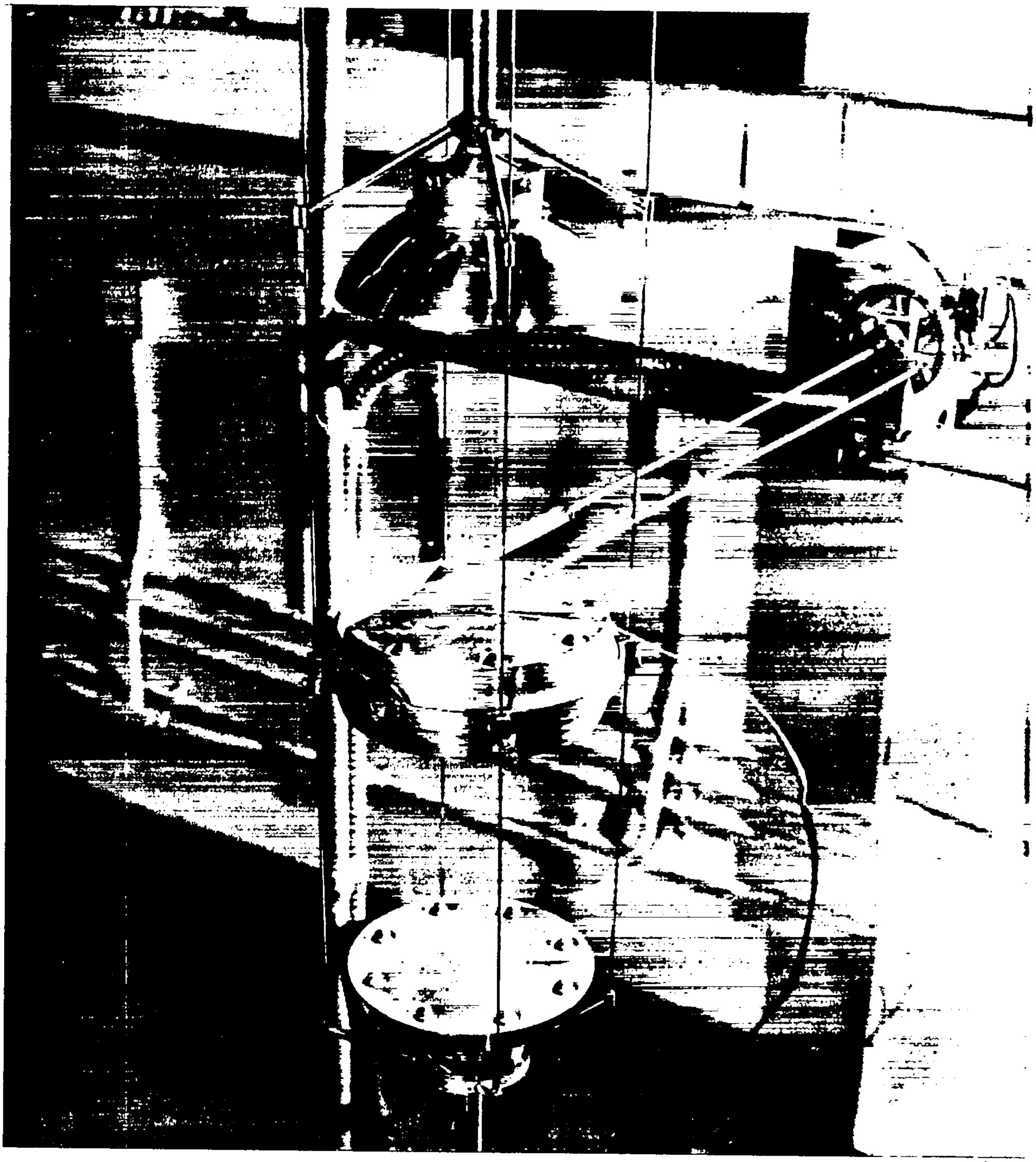


Fig. 16.
The Jezebel assembly of unreflected plutonium. For operation, the upper cap drops and the lower cap rises to form a near-sphere.

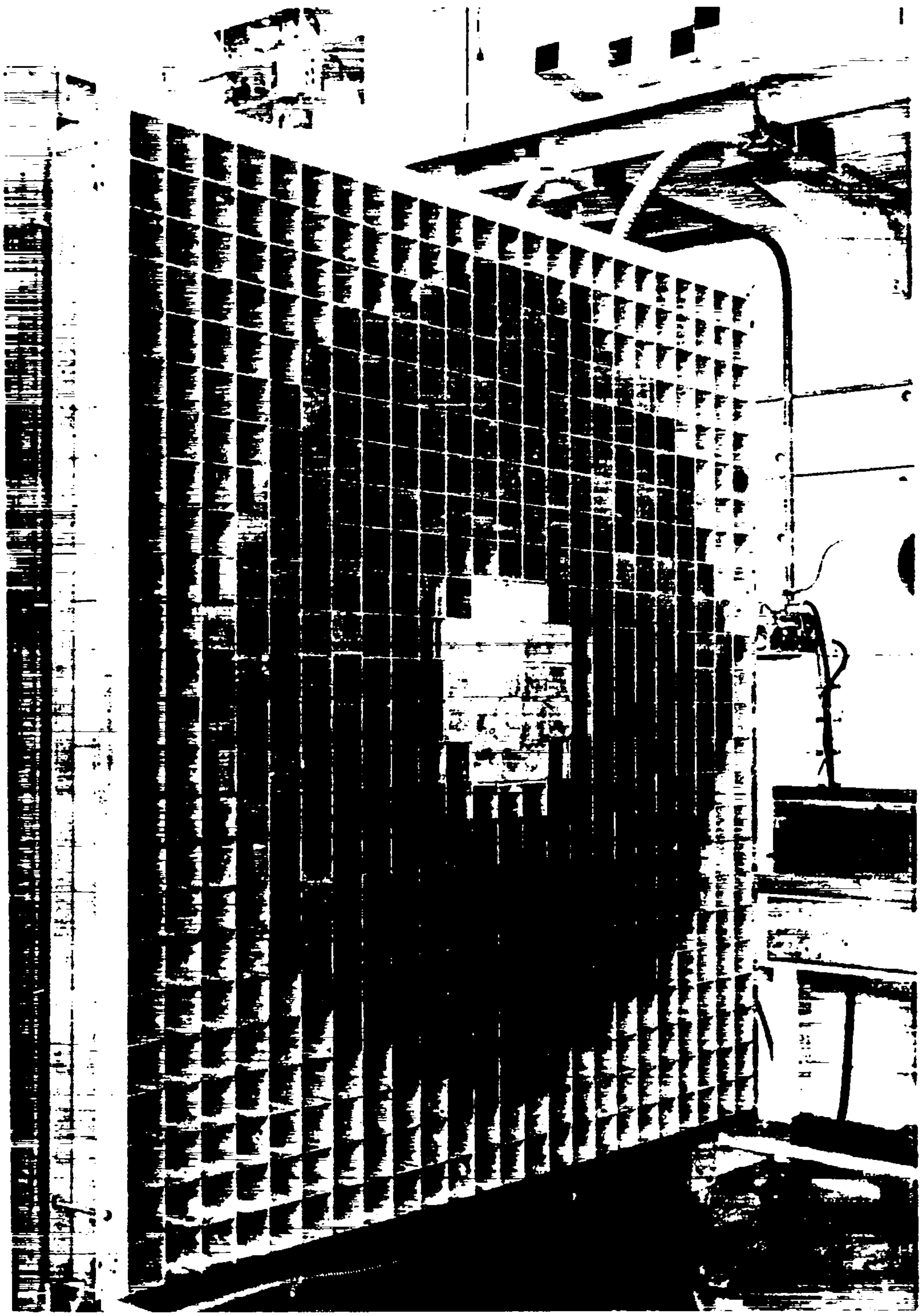


Fig. 17.
The Honeycomb assembly machine for Rover parametric surveys. The fixed portion shown contains part of a crude mockup of the first Rover reactor.

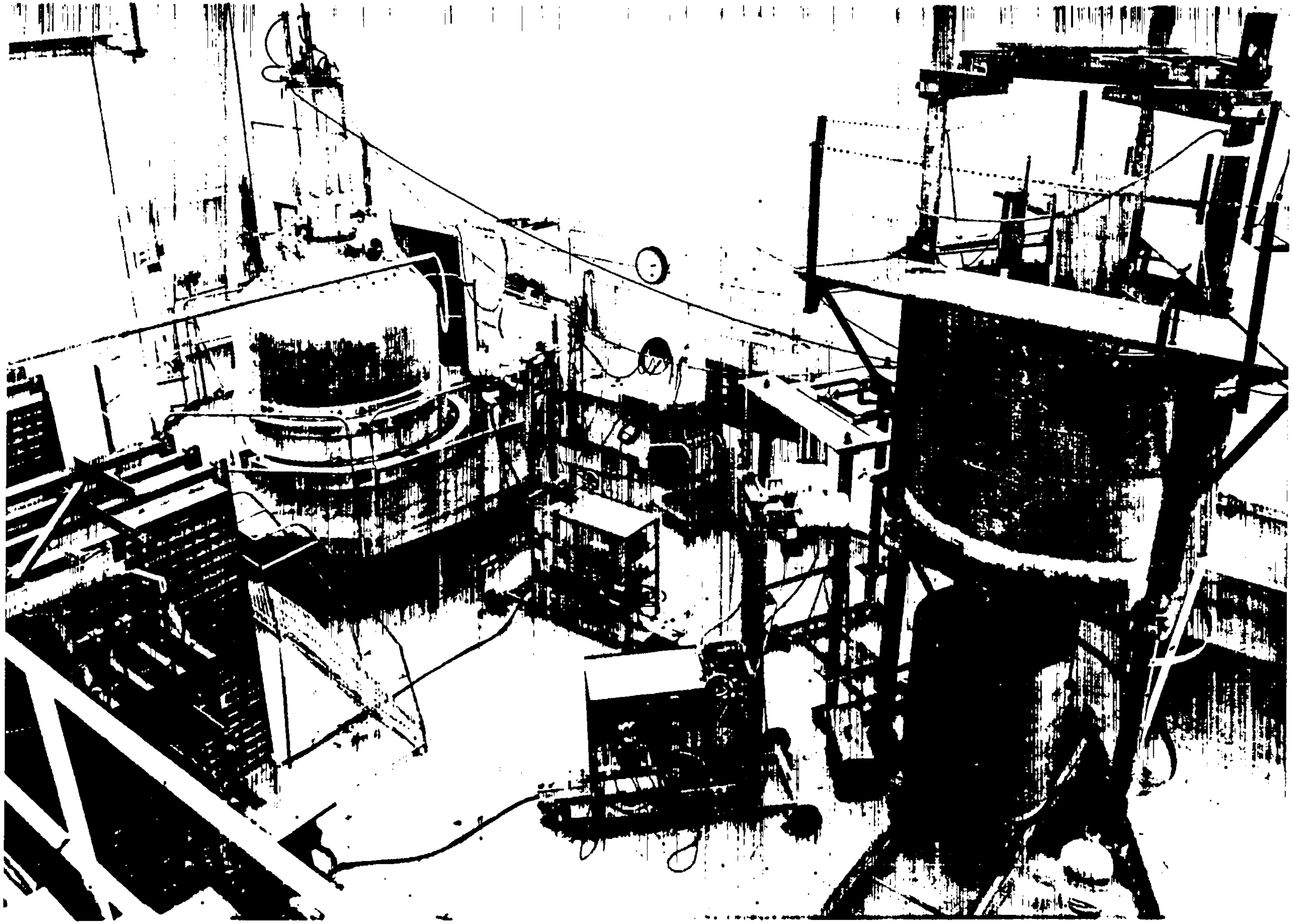


Fig. 18.
Kiwi-A, the first reactor for testing at Nevada, in Kiva 1. A zero-power mockup of the same reactor appears at the right, and part of Honeycomb with a crude mockup is at the far left.

Fig. 19.
The "Pajarito Club" of January 1956—personnel associated with the Critical Experiments Facility. 1. Cleo Byers, 2. G. A. Linenberger, 3. E. Plassmann, 4. D. Mascarenas, 5. L. Engle, 6. T. Wimett, 7. M. Taylor, 8. A. Usner, 9. R. White, 10. M. Fogelsong, 11. J. Grundl, 12. T. Thomas, 13. F. Korbitz, 14. D. Young, 15. H. Paxton, 16. P. Koontz, 17. G. Jarvis, 18. A. Spooner, 19. K. Dunahugh, 20. H. Duhamel, 21. R. Keepin, 22. C. Mascarenas, 23. D. Wood, 24. C. Hoogterp, 25. J. Orndoff, 26. R. Wagner, 27. M. Diaz, 28. G. Hansen, 29. G. Graves, 30. D. Barton, 31. H. Lacey.

was transferred from Kiva 1 to Kiva 3. For these reactors, the design group, N-3, managed assembly, disassembly, and packaging for shipment, leaving neutronic checkouts for N-2. Zero-power mockups remained in Kiva 1, and non-Rover assemblies were concentrated in Kiva 2.

Here we should update critical assemblies directed toward weapons, and, in principle, toward fast reactors. The Flattop machine in Kiva 2, a replacement for Topsy, had spherical components instead of a core and reflector made up of blocks. It first operated with a highly enriched uranium core in 1958, and with a ^{233}U core two years later (as for Topsy, a plutonium core also was available). Shortly afterward, a bare ^{233}U assembly was set up on Jezebel, rounding out the triumvirate of fissile metal assemblies, unreflected and in thick uranium.

As contrasted with enriched uranium and nickel-coated plutonium, ^{233}U components were awkward to handle because of intense gamma radiation arising from ^{232}U impurity. As a result, Jezebel components of this material were retired after a cursory, but adequate survey. The smaller Flattop core is somewhat easier to handle without significant exposure, so it has been retained.

At this stage, the monumental Rover test series was under way at Nevada, having started with Kiwi-A high-temperature operation in mid-1959. Thereafter, there were twelve other operational tests through 1968, identified in Appendix D. The role of Group N-2 in preparation for each of these tests and neutronic analysis afterward was both arduous and rewarding, an experience certainly shared with the other Rover participants.

These Nevada tests, on which our attention focused, are summarized in Appendix D and discussed further in the following paragraphs. In the first series, called Kiwi-A, an axial D_2O island conserved enriched uranium and made possible "proof-of-principle" tests at a power of about 100 MW. The fuel elements, graphite loaded with uranium carbide, were distributed in a graphite matrix. Although contributing to early testing, both island and gaseous-hydrogen coolant were inappropriate for a flyable system. Severe erosion in the first test was reduced in the next two by niobium liners in the hydrogen flow channels.

In the pair of Kiwi-B1 reactors that followed, elimination of the D_2O island led to a more realistic power—about 900 MW in the second test. Of course, this was at the expense of greater enriched-uranium content. Fuel rods were still distributed in a graphite matrix. Gaseous hydrogen in the first test was replaced by liquid hydrogen in the second, a further step toward a flyable system. Liquid hydrogen remained the coolant-propellant in all succeeding tests.

As observers, we were fascinated by the technology used to produce fuel elements of the ultimate form. The 132-cm-long hexagonal rods, 1.9 cm across, each contained 19 precisely located flow channels—a production feat. These elements were packed together as cores of the Kiwi-B4 series and succeeding reactors (the last Nevada reactor was an exception). A niobium coating on element surfaces controlled corrosion, but a more serious problem was encountered in the first test. Vibration led to the fracturing of fuel elements and ejection of pieces. The cure, a different design of core constraint, was confirmed by satisfactory behavior during the next two tests of this series. Restart capability and 10-minute operation at about 1000 MW were demonstrated.

Puzzling behavior of the first Kiwi-B4 reactor was encountered during its checkout at Pajarito Site. Contrary to results with mockups, the system was too reactive to be completely assembled as designed. For proper operation, it was necessary to replace some fuel by inert material and to introduce neutron "poison." Ultimately, the extra reactivity was traced to hydrolysis of the uranium carbide distributed as particles throughout the graphite fuel matrix. The source was moisture in the air. Starting later in the Kiwi-B4 series, hydrolysis was eliminated by distributing the uranium carbide as small beads with a protective coating.

The final reactor of this class, with a special arrangement to increase reactivity very rapidly, was purposely destroyed to simulate a reactivity accident. This served to check the required accident analyses, thereby increasing confidence in yield calculations.

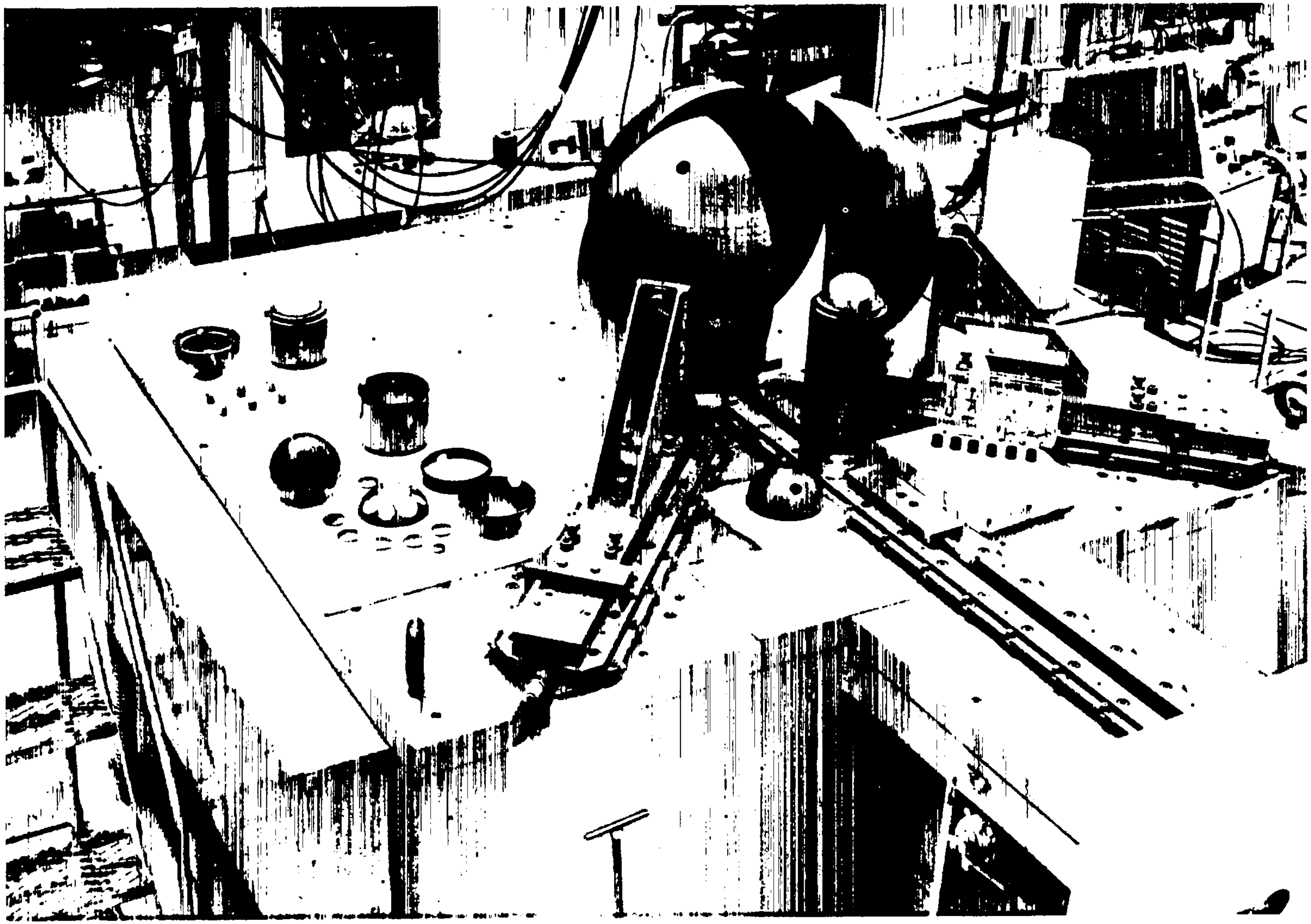


Fig. 20.
The Flattop critical assembly machine. The plutonium core is shown retracted from the natural-uranium reflector; enriched-uranium and ^{233}U cores with adapters are laid out at left.

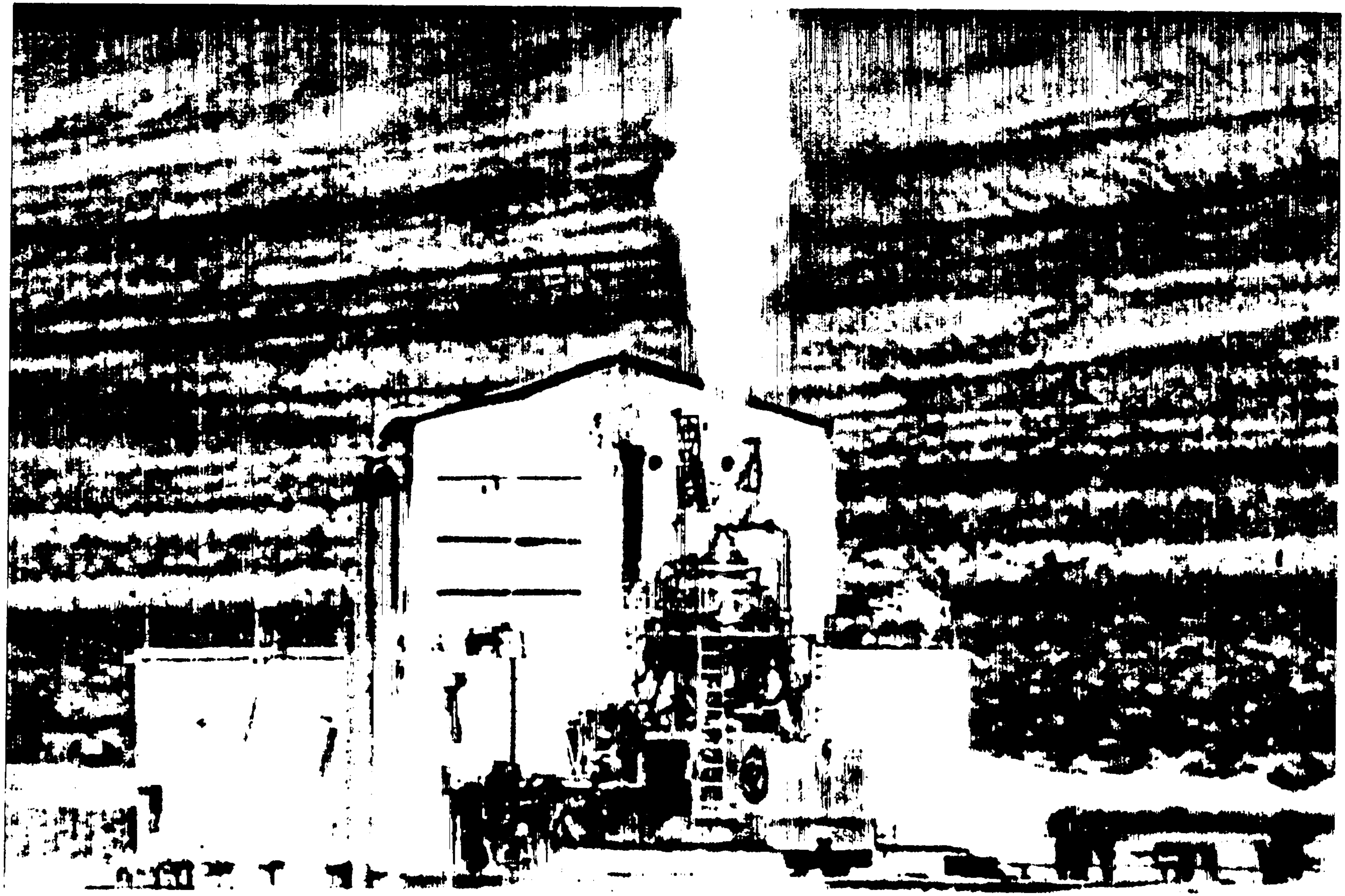


Fig. 21.
Kiwi-A operating test at Nevada. Kiwi nonflying reactors are named after the earth-bound New Zealand bird.

Fig. 22.
William Martin of Group CMB-6 holding a Rover fuel element of the ultimate form. Nineteen flow channels are positioned precisely. Dies for extruding elements appear on the right.

Fig. 23.
Extrusion of 19-hole Rover fuel elements. Conducting the operation are, left to right, Donald Schell, Belarmino Abeyta, and Keith Davidson, all of Group CMB-6. After extrusion, the elements were baked, graphitized, and coated with niobium that converted to carbide in the reactor.

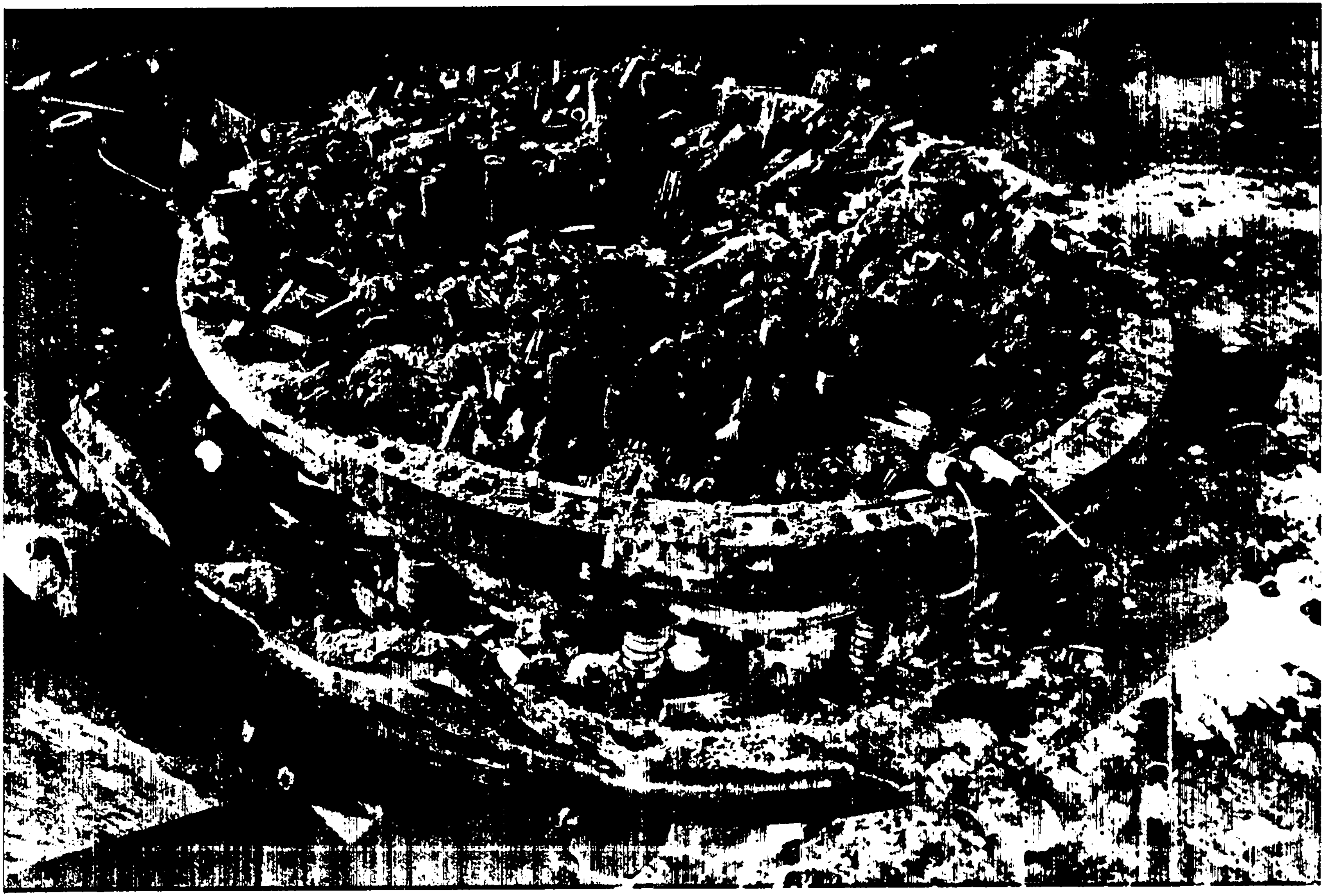


Fig. 24.
Remnant of Kiwi-TNT on test stand after the planned destructive excursion.

Before going to Nevada, this reactor was involved in a unique series of experiments at Pajarito Site. It and the similar PARKA reactor, positioned close together, were operated simultaneously in order to measure their interaction. This information was desired for estimating the effect of clustering several reactors to power a single high-thrust rocket.

Refinements for flyable systems were introduced in the Nevada tests of the next two reactors, designated Phoebus 1. These reactors were of Kiwi-B4 size and general design. Improved fuel led to increased power density and duration of operation. More specifically, the second test demonstrated 30-minute operating time at about 1500 MW, and a propellant exhaust temperature of 2500 K.

The final test of a potentially flyable reactor, Phoebus-2, was directed toward increased power and thrust. To attain this goal, the core size was increased (it contained 4000 fuel elements!); otherwise, the design was generally like that of Phoebus-1. In Nevada, power greater than 4000 MW was attained.

The final two LASL reactors operated at Nevada, Pewee and Nuclear Fuel Furnace, were designed specifically for relatively inexpensive testing of improved fuel elements. Again, they were inappropriate for flyable systems. Although Pewee contained just 400 elements, one-quarter the number in Phoebus-1, test of a second version was canceled in 1971 because of funding restrictions. The power density attained in Pewee-1, 5 MW per liter of fuel, was the greatest observed. It was still possible to test the much smaller Nuclear Fuel Furnace the next year (only 49 elements with water moderation), but the entire program was canceled eighteen months later.

Loss of the Rover program was a traumatic experience, but, unlike most of N Division, a greatly attenuated Critical Experiments Group was allowed to survive. P Division (the Physics Division) provided a place for us under the designation P-5 (in February 1973). The Group dropped to 17 persons from a peak of 41 in 1968-1969. A legacy from Rover was PARKA, essentially a Phoebus 1 reactor set up as a critical assembly. Another new assembly was Big Ten, a cylindrical uranium-metal system with a core averaging 10% ^{235}U. Big Ten is a step from our very small metal assemblies toward fast-neutron power reactors. It was designed for easily interpreted measurements of internal neutron spectra and effective cross sections.

In December 1960, two members of our Group became the nucleus of Group A-1, formed to handle safeguards technology. A portion of this group that had remained at Pajarito Site was split off in September 1970 and named A-2. It was redesignated Q-2 in February 1977, but retained the functions of its title, Detection, Surveillance, Verification, and Recovery.

AFTER ROVER

During two years in P Division, our Group became increasingly involved with projects for the National Aeronautics and Space Administration (NASA). The major project, active until August 1979, was directed toward a plasma-core power reactor to be operated at very high temperature. In that reactor concept, a helically flowing buffer gas protected the containing vessel from the hot gaseous core. Beryllium reflector components and control drums left over from the Rover Program were essential parts of a progressive series of mockups of this reactor. In the earlier versions of this so-called Plasma Cavity Assembly, the gas cores were simulated by thin foils of enriched uranium, either distributed within a large cavity or lining it. In later versions, distributed Rover fuel elements were used instead of foil, then some of these elements were replaced by gaseous UF_6. Although planned, a complete UF_6 core was not attained.

Another NASA project was a study of gaseous lasers for transmitting power. This was related to the reactor development as a possible means of extracting power through radiation from the plasma core. A noteworthy result of this project was one of the first demonstrations of a laser pumped by uranium fission products.

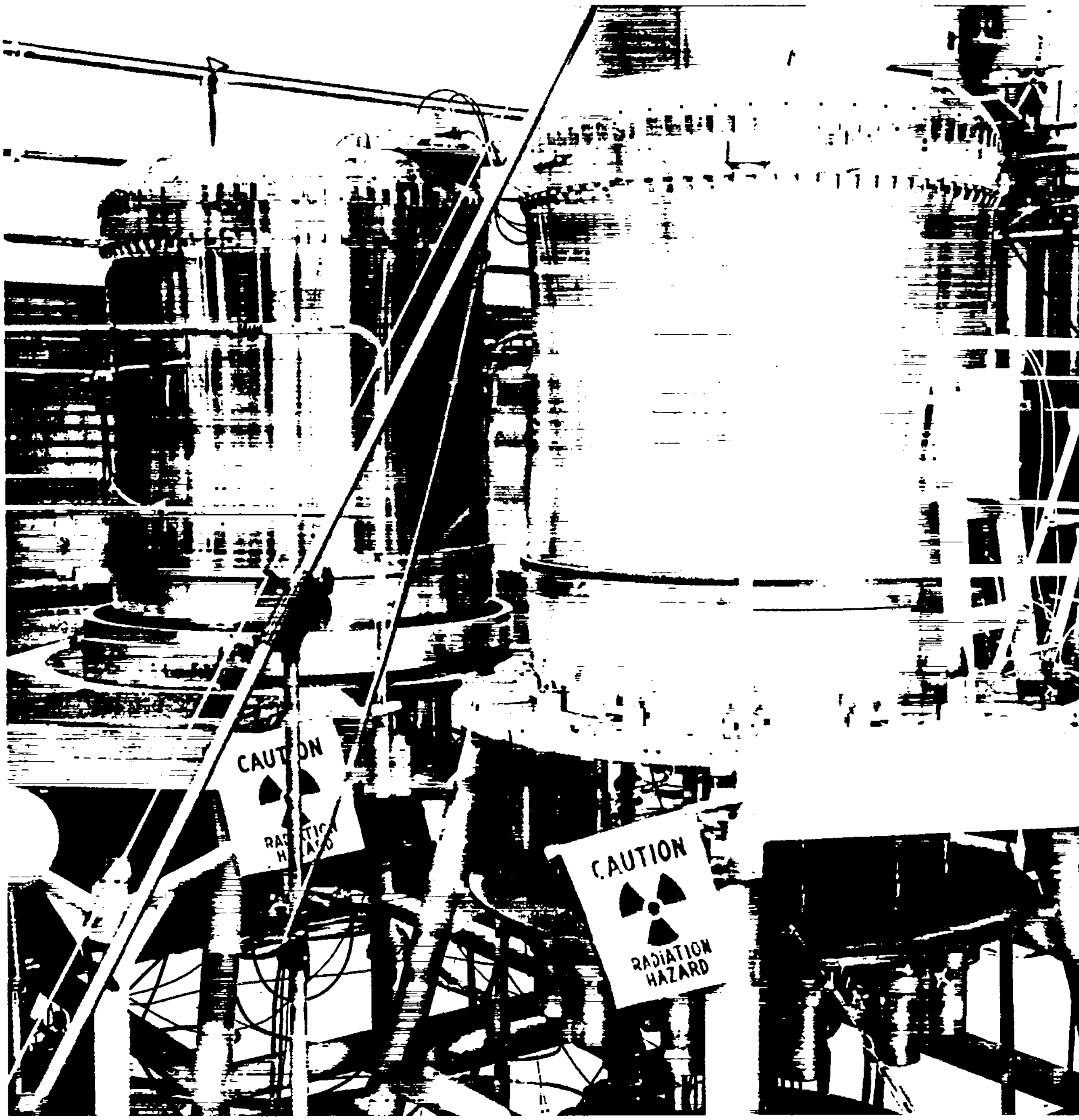


Fig. 25.
The Kiwi-TNT and PARKA reactors in Kiva 3 for measurement of interaction at various separating distances.

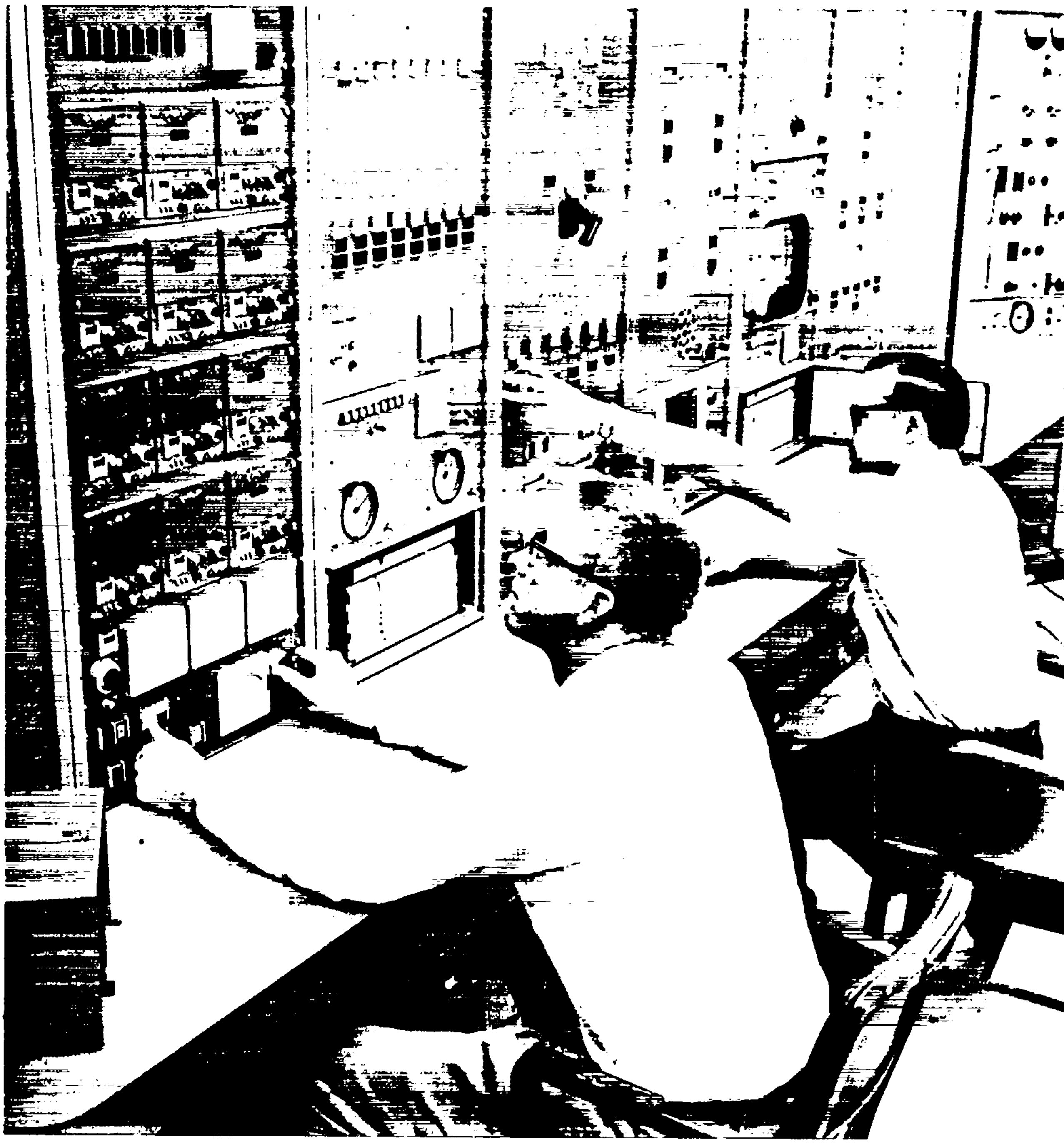


Fig. 26.
Herbert Helmick and Robert Seale operating Kiwi-TNT and PARKA simultaneously. Helmick became Group Leader of Q-8, and Seale is a long-standing consultant from the University of Arizona.

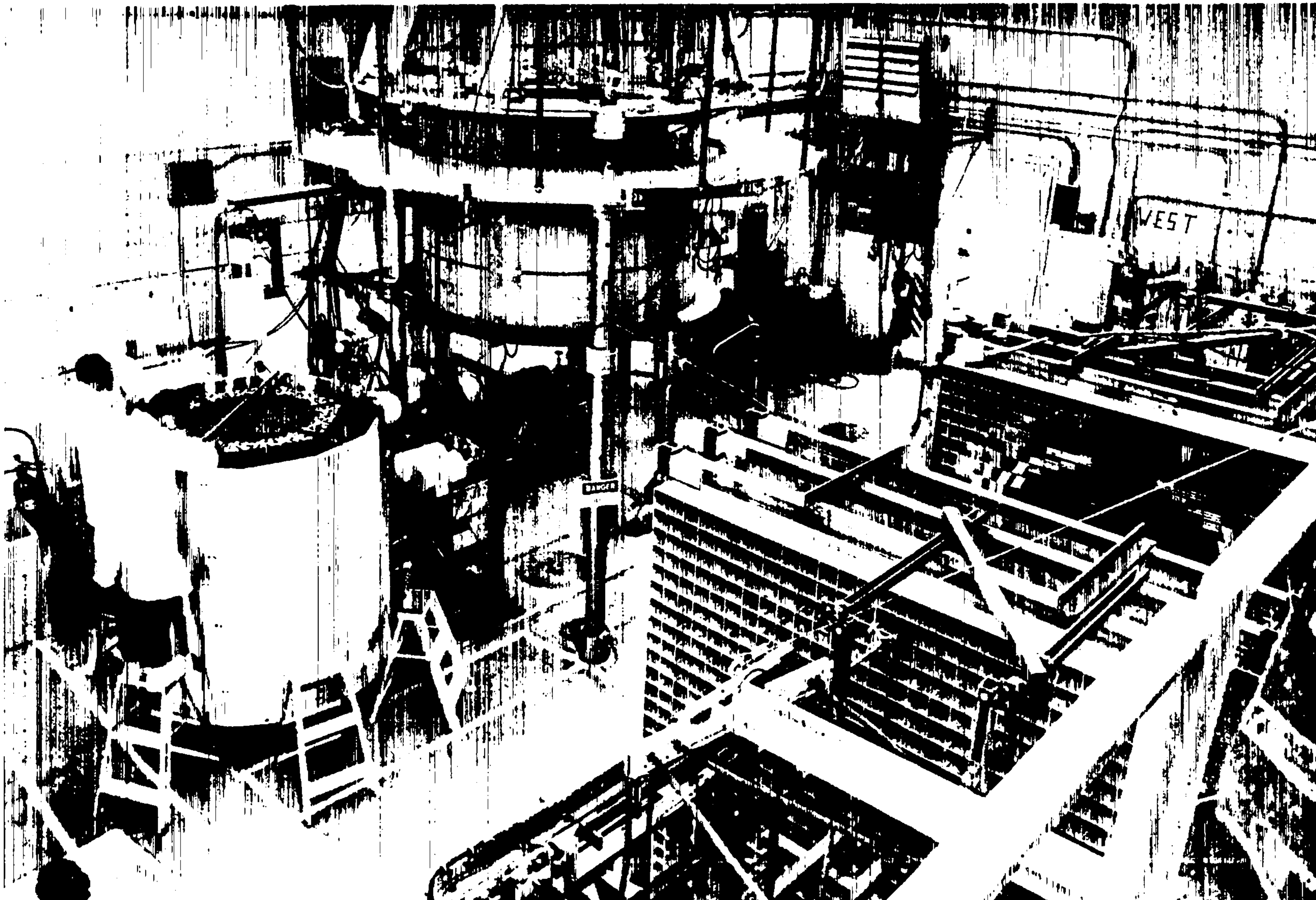


Fig. 27.
The core, with 4000 fuel elements, being assembled in a mockup of the Phoebus-2 reactor. A much cruder simulation of the same reactor is in the Honeycomb machine at the right.

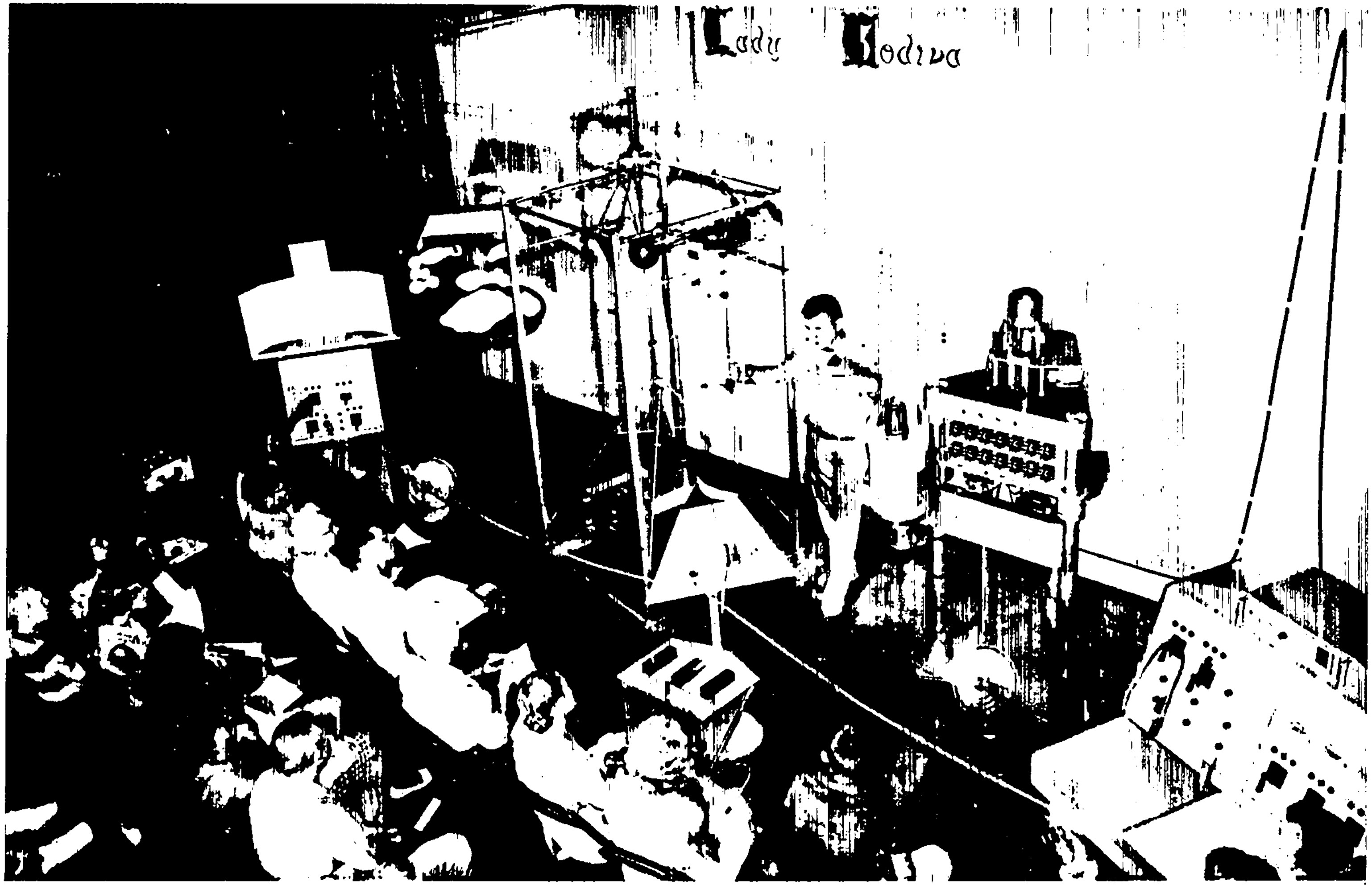


Fig. 28.
James Grundl demonstrating a model of Lady Godiva during Family Days of 1965. The chart in the background represents a superprompt-critical burst in which a power of ten billion watts is attained very briefly.

Fig. 29.
Seeing the Lady Godiva replica off to the Smithsonian Institution. James Grundl, master of ceremonies and instigator, has his back to the camera. Others, left to right, are Thomas Wimett, Roger White, Robert Wagner, Robert Keepin, David Barton, Lewis Osborn, Arthur Usner, Manuel Diaz, and Donald Peterson.

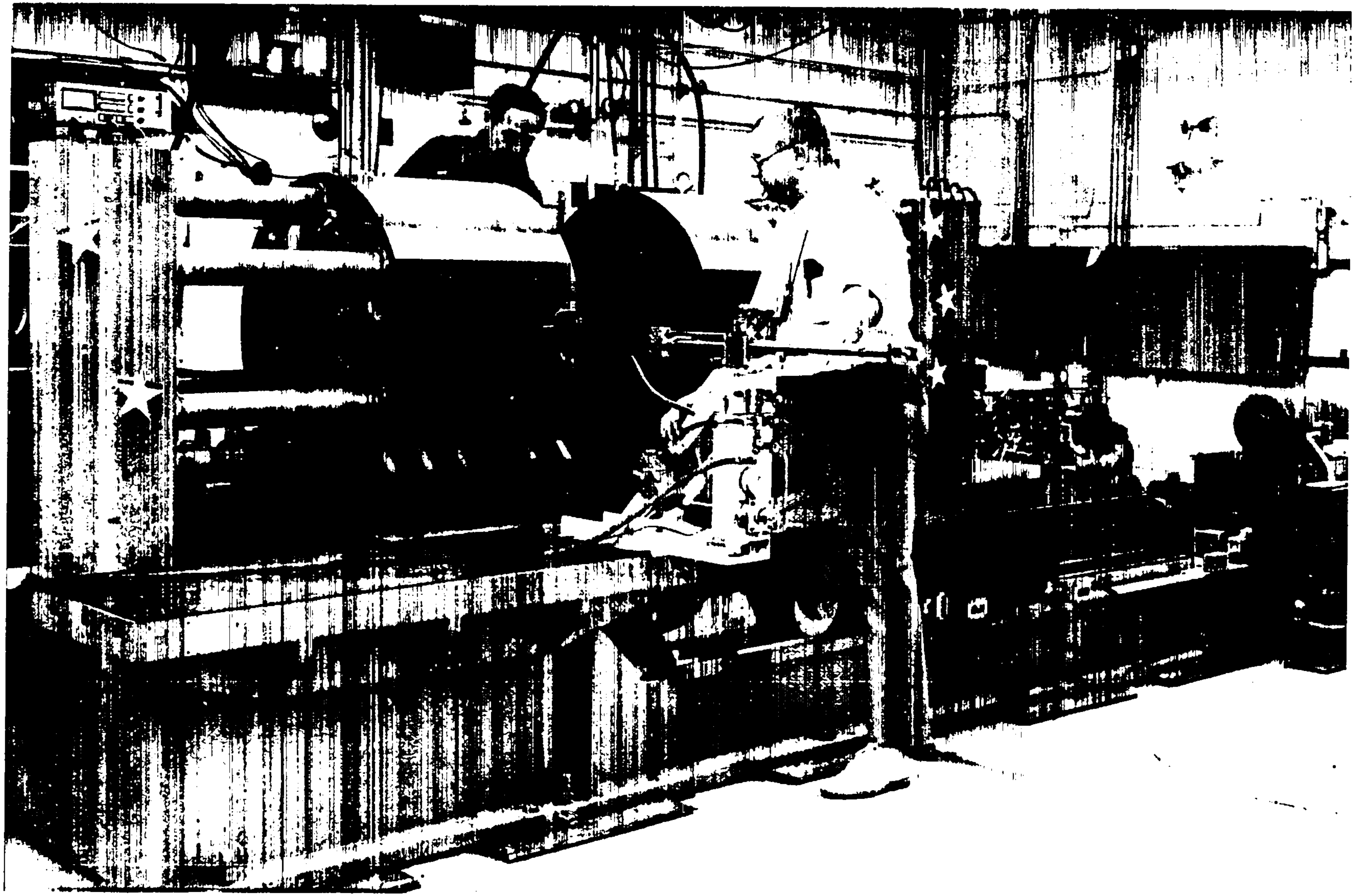


Fig. 30.
Big Ten, the all-uranium-metal assembly with core averaging 10% ^{235}U. Behind is Gordon Hansen of Group Q-14, and in foreground is Jerry Koelling who left to join Group WX-8.

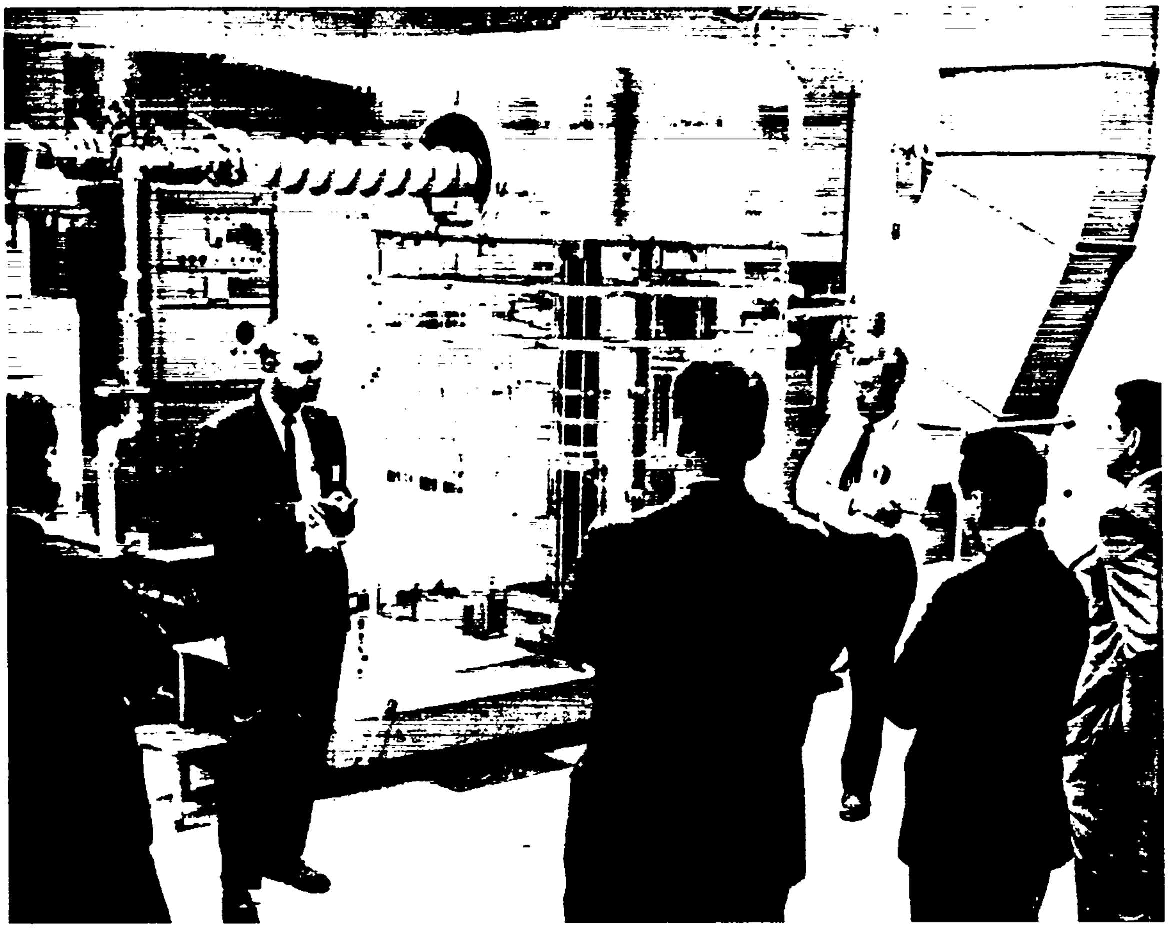


Fig. 31.
Robert Keepin showing the Pajarito Cockcroft-Walton to visitors escorted by Henry Motz, then P-Division Leader. At present, the accelerator is operated by Group Q-14, and Keepin is the Program Manager for Safeguards Affairs.

Fig. 32.
Carl Henry, when Q-2 Group Leader, and Gary Worth of that Group evaluating a radiation monitor for detecting fissile materials at plant exit points.

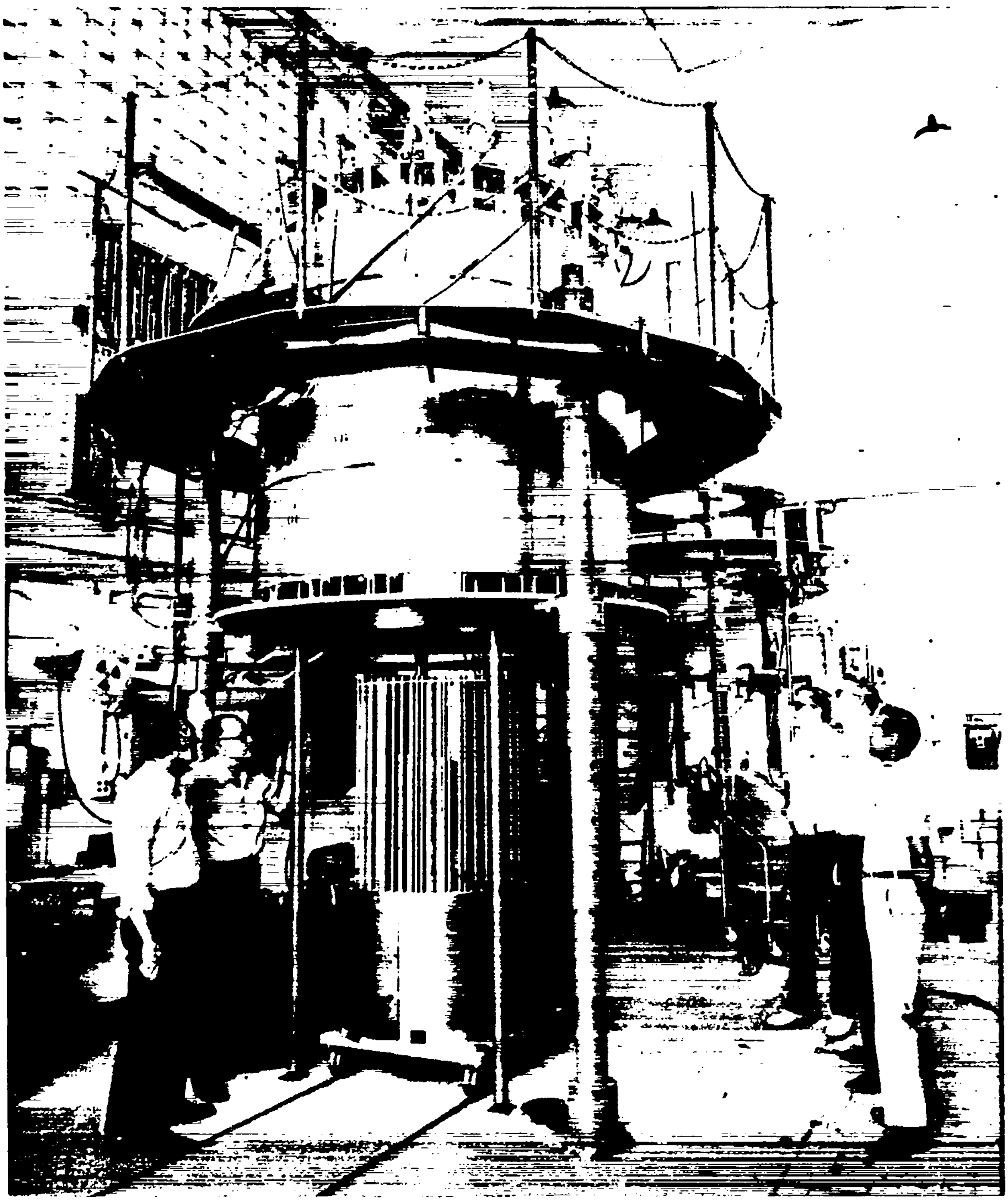


Fig. 33.
The Plasma Cavity Assembly with gas core simulated by Rover fuel. The thick beryllium reflector consists of Rover reactor components. Shown left to right are William Bernard, George Jarvis, Carl Schwenk of NASA, Herbert Helmick, and Gordon Hansen.

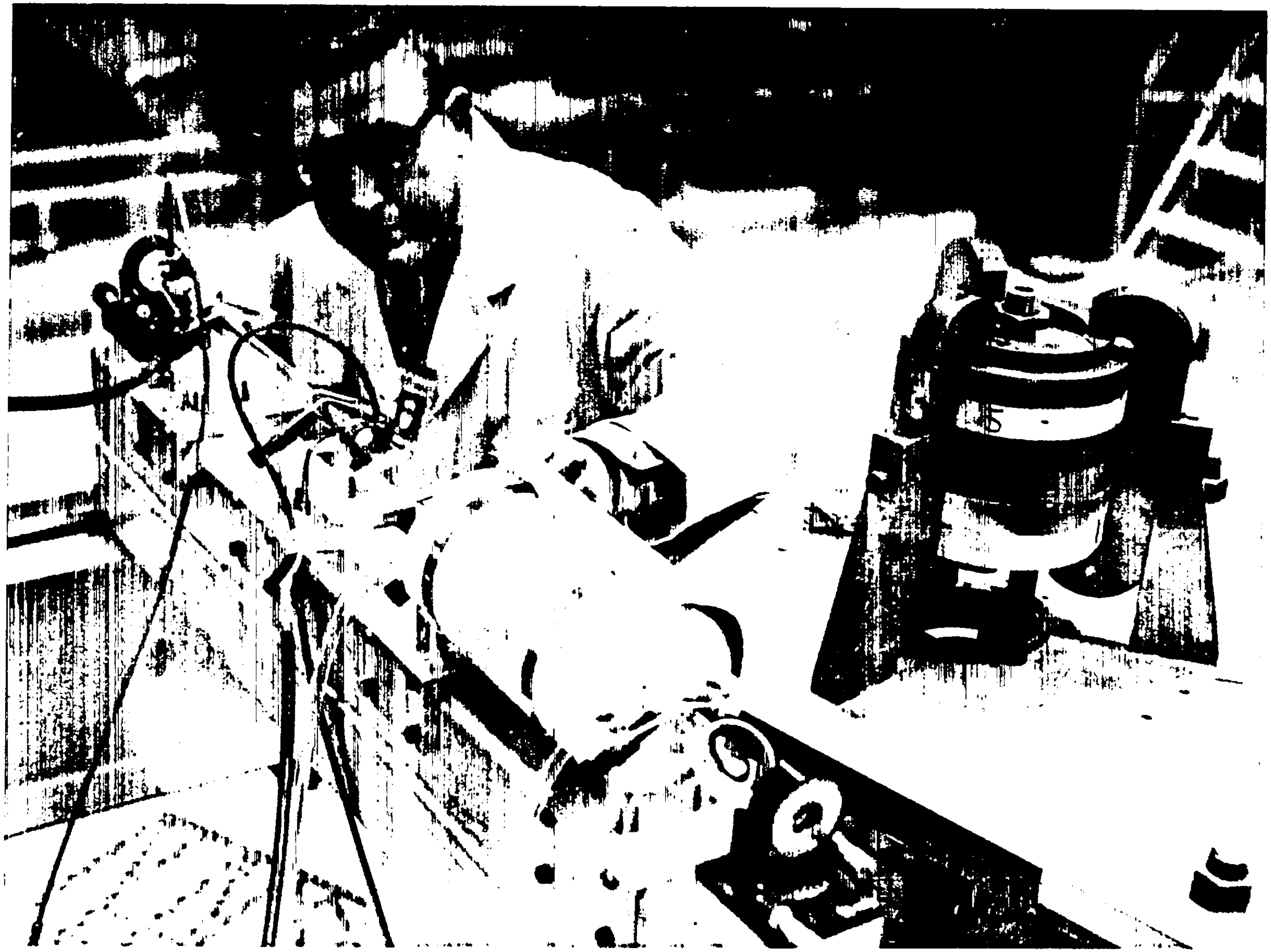


Fig. 34.
Fission-pumped laser with Godiva IV as a source. Herbert Helmick is checking the setup.

Since February 1977, the NASA projects have been managed by Group Q-8, a further subdivision of the Critical Experiments Group that remained at Pajarito Site until December 1977. Another NASA interest being investigated by this Group is the nature of radiation from a uranium plasma. The plasma is simulated by rapid compression of UF_6 in the barrel of a Naval "cannon."

Following our period in P Division, we became A-5 and then R-5 (in the Reactor Division) for roughly a year each. During this period, fast-reactor safety studies funded by the Nuclear Regulatory Commission were added to our responsibilities. These fell into two categories: the calculation of yields from various reactor accidents, and the development and evaluation of techniques for measuring fuel behavior in a destructive environment such as Argonne National Laboratory's TREAT reactor. The calculational program extended the computational techniques that had been used for Rover accident analyses, and it was transferred to Group Q-7 in February 1977. The development and evaluation made use of the PARKA assembly, another remnant of Rover, and incorporated weapon-test technology, relying upon continuing efforts by Group J-12 and the research section of the P-Division Office. Upon its formation, Group Q-8 (Reactor Safety Experiments) took over and expanded the portion of this project dealing with the generalized development of diagnostic instrumentation for reactor safety studies, whether or not in a reactor. The portion directed specifically toward a proposed Safety Test facility remained in the Critical Experiments Group.

In recent years, educational activities of our Group have grown. Largely, but not exclusively, for Los Alamos personnel, training sessions in criticality safety are conducted at Pajarito. Although conceived as a limited series, the sessions are in such demand that they are being repeated seemingly without end. Also, we have cooperated in several short courses on Nuclear Criticality Safety presented by the University of New Mexico. Both in connection with these courses and separately, our staff and facilities have been made available to augment the laboratory experience of Nuclear Engineering students. As encouraged by Los Alamos administration, we expect cooperation with the University of New Mexico to continue along these lines.

Activities of the Critical Experiments Group were expected to diversify further as we shifted in February 1977 from a Division with emphasis on reactor safety and technology to the Energy (Q) Division with its broader interests. But, as Q-14, the Group dropped to a new low of 11 members by 1980. This followed transfer of criticality safety activities to H Division under the designation H-DOT (now Group H-6). By part-time use of former Group members, some on loan from other groups and some as consultants, it was possible to add to the range of critical experiments on an attenuated scale.

Noteworthy accomplishments during this period included:

- construction of a series of plutonium assemblies with large ^{242}Pu content;
- mockup of a nuclear power supply in the Honeycomb assembly machine for space application;
- use of Godiva IV as an adjunct of the Phermex accelerator to establish feasibility of increased diagnostic capability;
- operation of the SKUA metal burst assembly; and
- setup of a low-enrichment uranium solution assembly, SHEBA, largely for standardizing accident instrumentation.

Throughout the thirty-five year history recounted here, there has been no dearth of projects for the Critical Experiments Group, and there is no sign that the end is near. Thus, there should be further accomplishments to report at the end of this fourth decade.

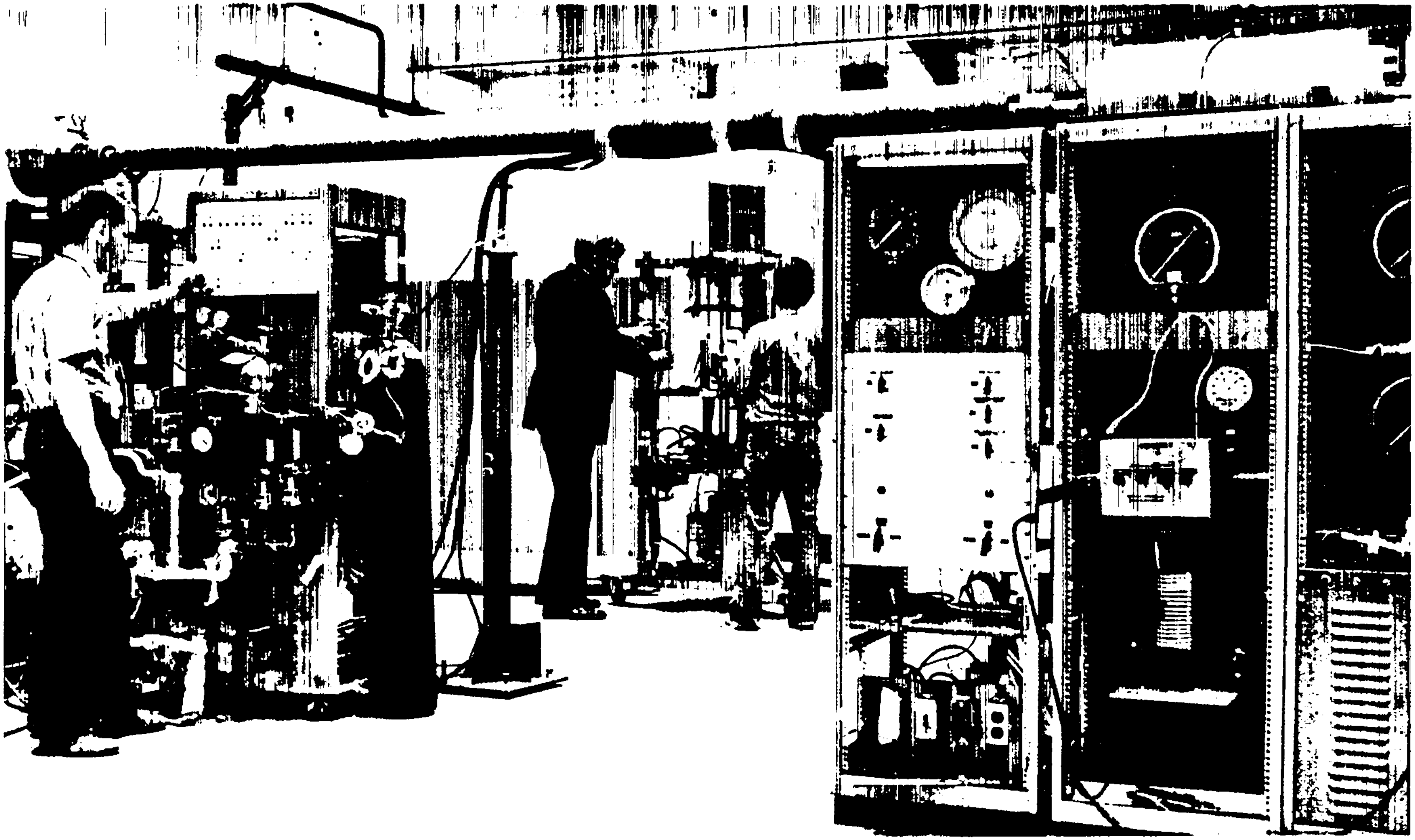


Fig. 35.
A Naval "cannon" adapted as a chamber for compressing UF_6 gas to 450 atmospheres and a temperature of 1250 K. The purpose is to examine radiation from the hot gas. In the foreground is Charles Mansfield of Group Q-8. With Godiva, which is used as a neutron source, are (left) Herbert Helmick, then Q-8 Group Leader, and Raymond Pederson, then Health Physics Surveyor.

Fig. 36.
Raemer Schreiber, then LASL Deputy Director, right, presenting a safety award to the Critical Experiments Group. Hugh Paxton is accepting a plaque recognizing 1,500,000 manhours (25 years) without a disabling injury.

Fig. 37.
University of New Mexico students assembling about Flattop in Kiva 2. David Smith (left) and Cleo Byers are in the foreground, and Thomas McLaughlin is at the right rear.

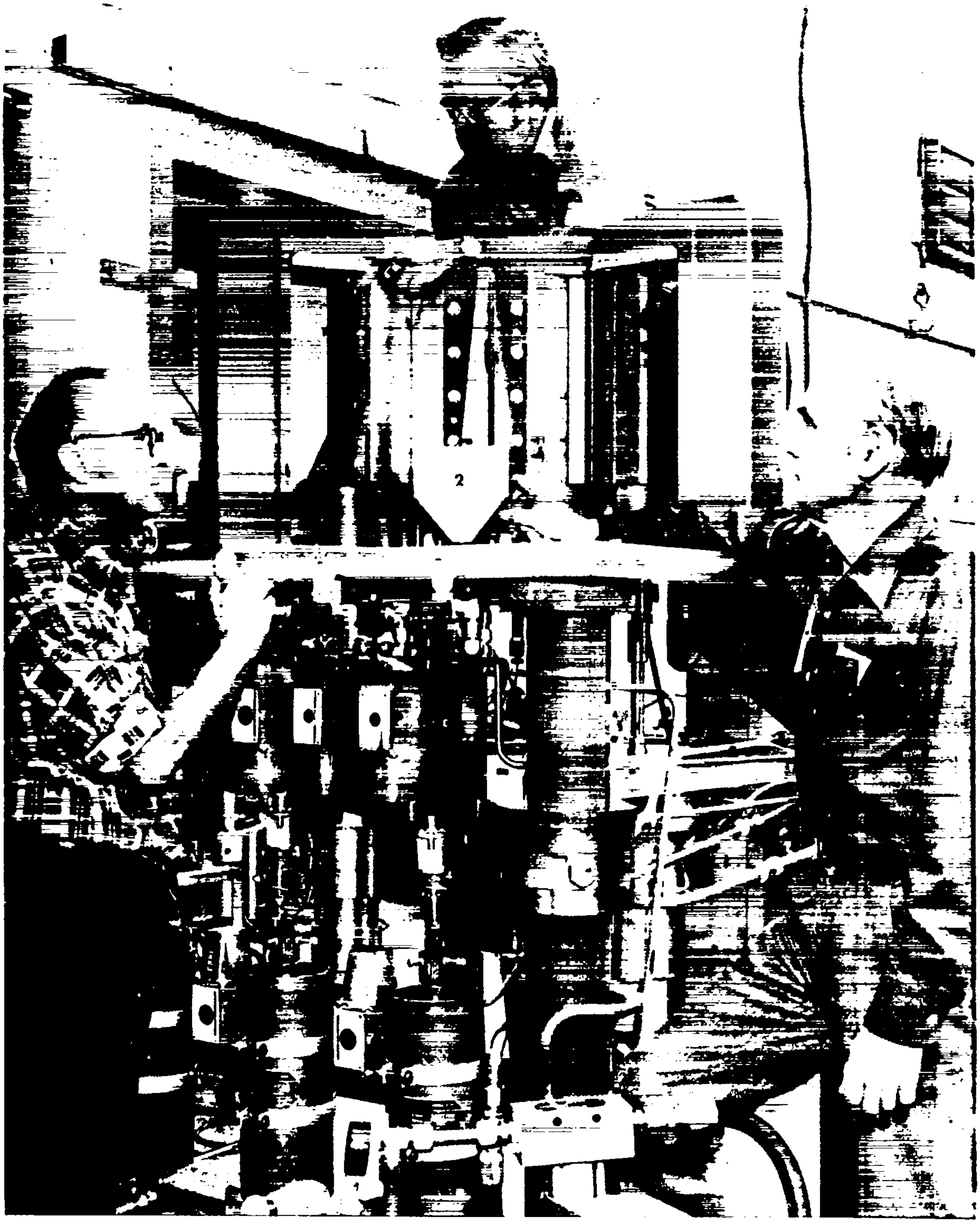


Fig. 38.
SKUA, a descendent of Godiva for producing high-fluence pulses of low-energy neutrons. Expected applications include investigation of the influence of its intense radiation fields on air chemistry, and improved excitation of fission-pumped lasers. At the left is Calvin Davis of the Shops Department, above and to the right are Edward Ferdinand and Thomas Wimett of Group Q-14.

Fig. 39.
System for circulating argon buffer gas and uranium hexafluoride in the Plasma Cavity Assembly (core shown at right rear). Grouped, from left to right, are David Barton, Frank Hohl of NASA, Roger White, Bennie Pena, Herbert Helmick, Bonnie Wilson, Raymond Martin, Edward Ferdinand, William Bernard, and Jerry Jaminet, John Kendall, and Norman Winters of United Technologies Research Center, and George Jarvis.

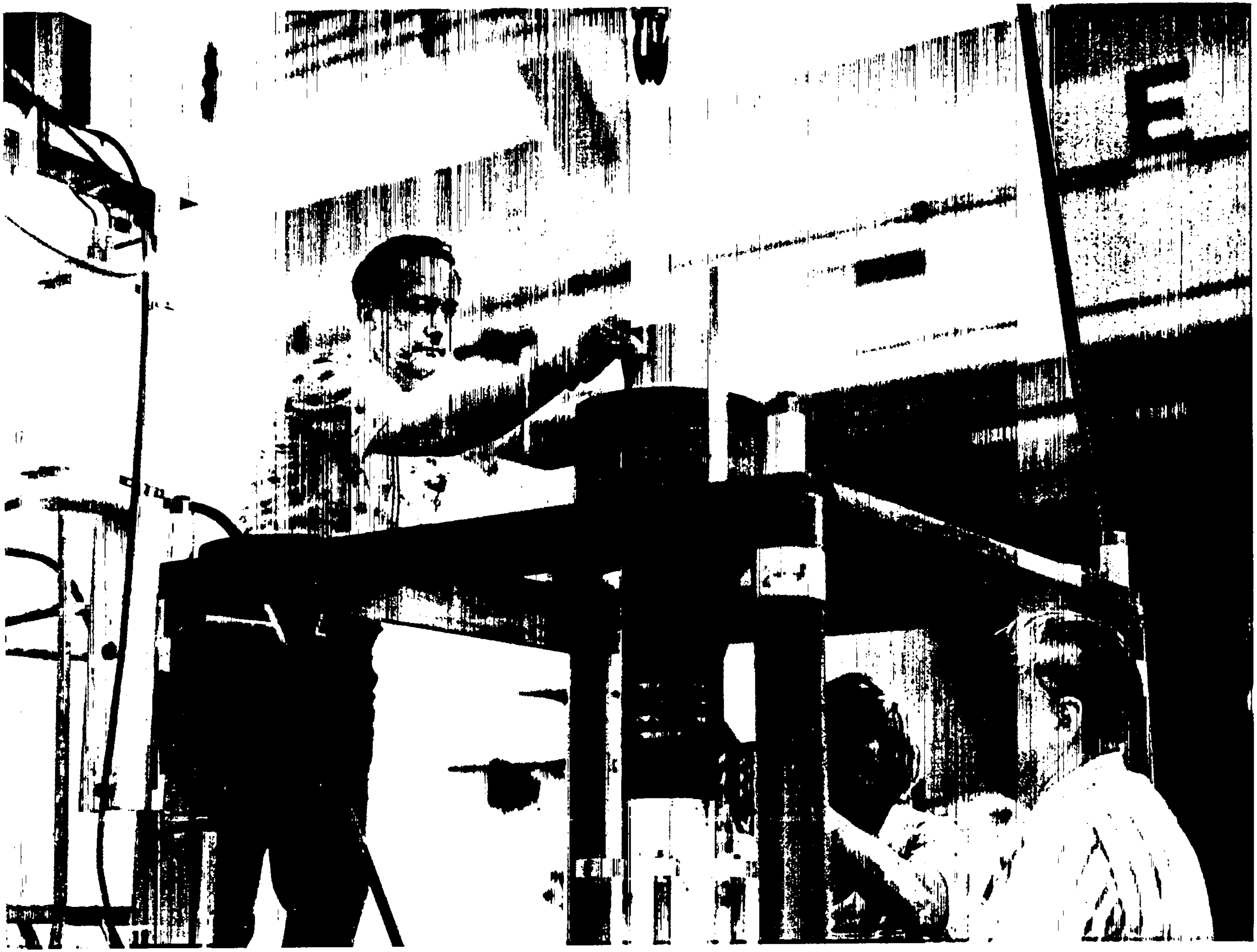


Fig. 40.
Plutonium-242 assembly with Richard Malenfant above, Eugene Plassmann at rear, and William Brown.

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APPENDIX B

TECHNICAL GROUPS AT PAJARITO CANYON SITE

TITLE OR FUNCTION: CRITICAL ASSEMBLIES (EXPERIMENTAL NEUTRONICS, CRITICAL EXPERIMENTS AND DIAGNOSTICS).

Designation and Dates: M-2 at Site about April 1946 through July 1948, W-2 through March 1955, N-2 through January 1973, P-5 through December 1974, A-5 through November 1975, R-5 through January 1977, Q-14 to date.
Group Leader: L. Slotin through May 1946, R. E. Schreiber from September 1946 through October 1947, J. H. Roberts (acting) through August 1948, V. Josephson (acting) through December 1948, H. C. Paxton through March 1975, G. E. Hansen through September 1977, W. L. Talbert through August 1979, R. E. Malenfant to date.
Alternate Group Leader: V. Josephson, August 1948 and January 1949 through April 1951, J. D. Orndoff through June 1973, W. G. Davey from January 1975 through March 1975, H. H. Helmick through January 1977, J. D. Orndoff through June 1977, R. E. Malenfant from September 1977 through August 1979.
Associate Group Leader: J. H. Roberts from September 1946 through October 1947, V. Josephson (acting) through July 1948, G. E. Hansen from November 1961 through June 1973, W. L. Talbert from July 1977 through September 1977, G. E. Hansen to date.
Assistant Group Leader: G. A. Graves from April 1967 through October 1972, H. H. Helmick from May 1973 through February 1975, R. H. White from February 1977 through June 1977, E. A. Plassmann to date.

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FUNCTION: EXTERNAL INITIATOR DEVELOPMENT.

Designation and Dates: W-5 from May 1951 through August 1954, when it left the Site as K-4.
Group Leader: V. Josephson.
Alternate Group Leader: J. Wieneke.

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TITLE OR FUNCTION: DETECTION AND VERIFICATION (NUCLEAR SAFEGUARDS RESEARCH).

Designation and Dates: N-6 from December 1966 through August 1970 when it split. The part remaining at the Site was A-2 through November 1975, R-2 through January 1977, Q-2 to date.
Group Leader: G. R. Keepin through August 1970, W. H. Chambers through January 1977, C. N. Henry through June 1980, E. J. Dowdy to date.
Alternate Group Leader: C. N. Henry from July 1971 through January 1977, E. J. Dowdy through June 1979, C. H. Reed to date.
Assistant Group Leader: J. T. Caldwell from September 1979 to date.
Assistant Group Leader: N. Nicholson from September 1979 to date.

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TITLE: THERMAL HYDRAULICS (REACTOR SAFETY EXPERIMENTS).

Designation and Dates: Q-8 from February 1977 through September 1979 when it left the Site.
Group Leader: H. H. Helmick through September 1979, W. L. Kirchner to date.

APPENDIX C

GUIDELINES FOR CRITICAL ASSEMBLY WORK

After the fatal accidents in 1945 and 1946, direct manual manipulation of fissile materials that could lead to a planned or accidental critical (self-sustaining or runaway) nuclear configuration was banned. At the same time, it was recognized that criticality experiments would be necessary if the overall program was to continue. The guidelines adopted by the Laboratory therefore emphasized personnel safety as a first priority, with the safeguarding of the fissile material and versatility and reproducibility of experiments as important objectives. No experiment was to be conducted without a detailed set of operating procedures that had been reviewed and approved by Laboratory management.

A variety of options were available within the guidelines. For example, a very early choice had to be made between "hot cell" type of manipulation and true remote control that used large (quarter-mile) separation rather than heavy walls for protection of the operators. Similarly, a choice had to be made between complex robots duplicating human dexterity and adaptability and more conventional machines limited to much simpler motions. In either case, the ability to reverse operations and provide "fail-safe" assembly procedures was a requirement.

After much consideration, it was decided that remote operations and conventional machines should be used and that gravity provided the most reliable "fail-safe" mechanism.

Operating procedures for each class of experiment were prepared and reviewed in detail before the approval of the experiment. One individual was designated to monitor the safety of the experiment, but any member of the crew could stop the experiment in case of a safety question.

The effectiveness of the design and operating philosophy described above can be judged by the fact that critical assembly operations have not caused any fatality or disabling injury due to nuclear radiation in the 30 years since this program was started.

APPENDIX D

HIGH-TEMPERATURE ROVER REACTOR TESTS AT NEVADA

In the Kiwi-A series, moderation by an axial D_2O island conserved enriched uranium in the graphite-uranium core, making possible high-temperature tests at 70 to 100 MW. All the following were tested with gaseous-hydrogen coolant.

Kiwi-A, with plate-type elements supported in graphite annuli, tested July 1, 1959, coolant bypass overheated fuel, pronounced erosion of plates.

Kiwi-A′, with short rod-type elements in packed graphite modules, four niobium-lined flow channels in each element, tested July 8, 1960, some modules broken, liner blistered in places.

Kiwi-A3, similar to above, tested October 19, 1960, liner blistering reduced.

The D_2O island was eliminated in Kiwi-B1 reactors, leading to increased operating power. Full-length rod-type elements, each containing seven lined flow channels, were in packed full-length graphite modules. Tests took place as follows.

Kiwi-B1A, tested December 7, 1961, gaseous hydrogen coolant limited power to 300 MW.

Kiwi-B1B, tested September 1, 1962, liquid hydrogen introduced as coolant, 900 MW, some hot spots.

The Kiwi-B4 series had cores consisting of packed full-length hexagonal fuel elements with niobium coating. Each element contained 19 flow channels. In the following, the power remained at about 1000 MW in tests with liquid hydrogen.

Kiwi-B4A, tested November 30, 1962, evidence of vibration, fuel fragments ejected.

Kiwi-B4D, redesigned core constraint, tested May 13, 1964, hydrogen fire attenuated the full-power run, no vibration or fuel failure.

Kiwi-B4E, similar to above but with "beaded" fuel, tested August 28, 1964, rerun September 11, 1000 MW for 10.5 min, local corrosion of graphite pieces, fuel in good condition.

Kiwi-TNT, special controls for rapid introduction of reactivity for destructive test of January 13, 1965, destruction violent, yield 3.1×10^{20} fissions.

The two Phoebus-1 reactors were similar in design to Kiwi-B4E, but with fuel improvements directed toward increased power density, longer operating duration, and restart capability. The coolant was liquid hydrogen.

Phoebus-1A, tested June 25, 1965, 1000 MW for 10 min, liquid hydrogen exhausted, overheating led to core damage.

Phoebus-1B, tested June 26, 1968, 1500 MW for 30 min, attained 1500 K, groups of elements bonded by deposited pyrocarbon.

The Phoebus-2 reactor was similar in design to Phoebus-1 but with two and one-half times as many elements in the core (4000 elements). It was intended for operation at 5000 MW (with liquid hydrogen).

Phoebus-2A, tested June 26, 1968, ~4000 MW for 32 min, limited by larger temperature loss of reactivity than predicted (Phoebus-2B canceled).

In the Pewee reactor core, moderation by zirconium hydride reduced the required number of fuel elements to one-quarter of those in Phoebus-1, leading to less expensive fuel testing.

Pewee-1, tested November 21, 1968, rerun December 4 (3 cycles), 514 MW, 2500 K for 40 min, terminated by flashes in exhaust, damage to graphite fillers outside core (Pewee-2 canceled).

Finally, in the Nuclear Furnace, the cost of fuel testing was reduced even further by distributing 49 elements in a water moderator. This was at the expense of nonuniform power density across each element.

NF-1, operated June 29 and July 12, 21, and 27, 1972, a total of 108 min at 54 MW (~2450 K).

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