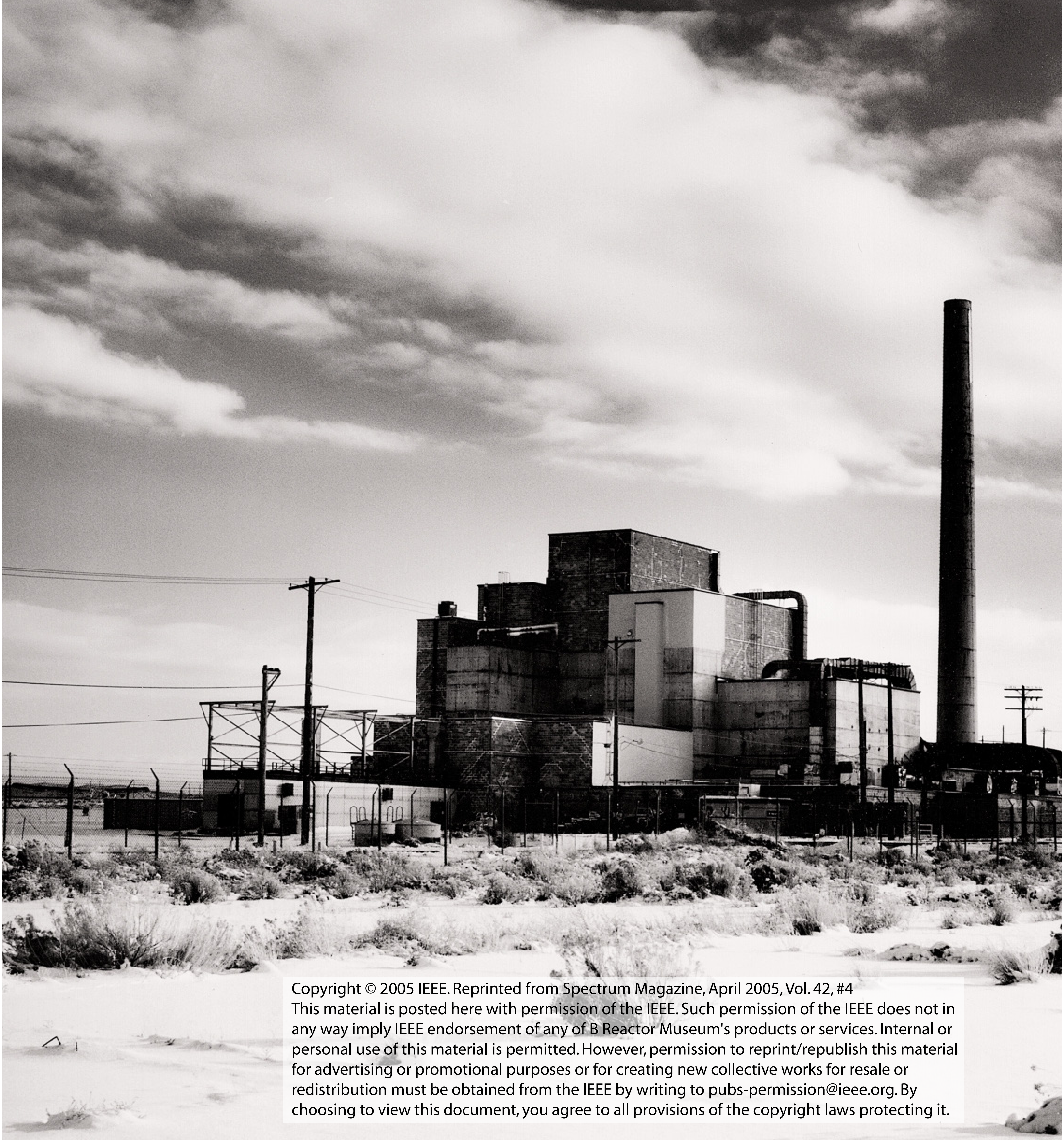


THE ATOMIC FORTRESS

FORTRESS OF SOLITUDE: Built in less than a year during World War II, B Reactor was once surrounded by a vast and sprawling industrial compound. Today, only the main reactor building and an exhaust stack remain.

ON A DESOLATE STRETCH OF HIGH DESERT in the northwestern United States, a fortresslike building stands alone, windowless, its massive concrete walls seemingly guarding a secret. But its secret was revealed long ago. What took place here affected the world like no other technology before it.

Building 105-B, better known as B Reactor, was the world's first full-scale nuclear reactor. It produced not electric power but plutonium, an invaluable atomic-bomb ingredient when the reactor first went into operation at the height of World War II. It was B Reactor that produced the plutonium used in the first man-made nuclear explosion, the Trinity test in the desert north of Alamogordo, N.M., on 16 July 1945. It also produced the plutonium used in the bomb detonated over Nagasaki, Japan, on 9 August 1945.

The reactor is part of the Hanford Site, a 1500-square-kilometer plutonium-production complex in the state of Washington. It was established by the Manhattan Project, the U.S. government's secret program that produced the world's first nuclear weapons during World War II.

B Reactor was one of three reactors built during the war, and one of nine eventually constructed at Hanford. They all sit along a 50-kilometer-long crook of the Columbia River. Together, they produced 67.4 metric tons of plutonium, or nearly two-thirds of the total created by the United States before the country ended production in the mid-1990s.

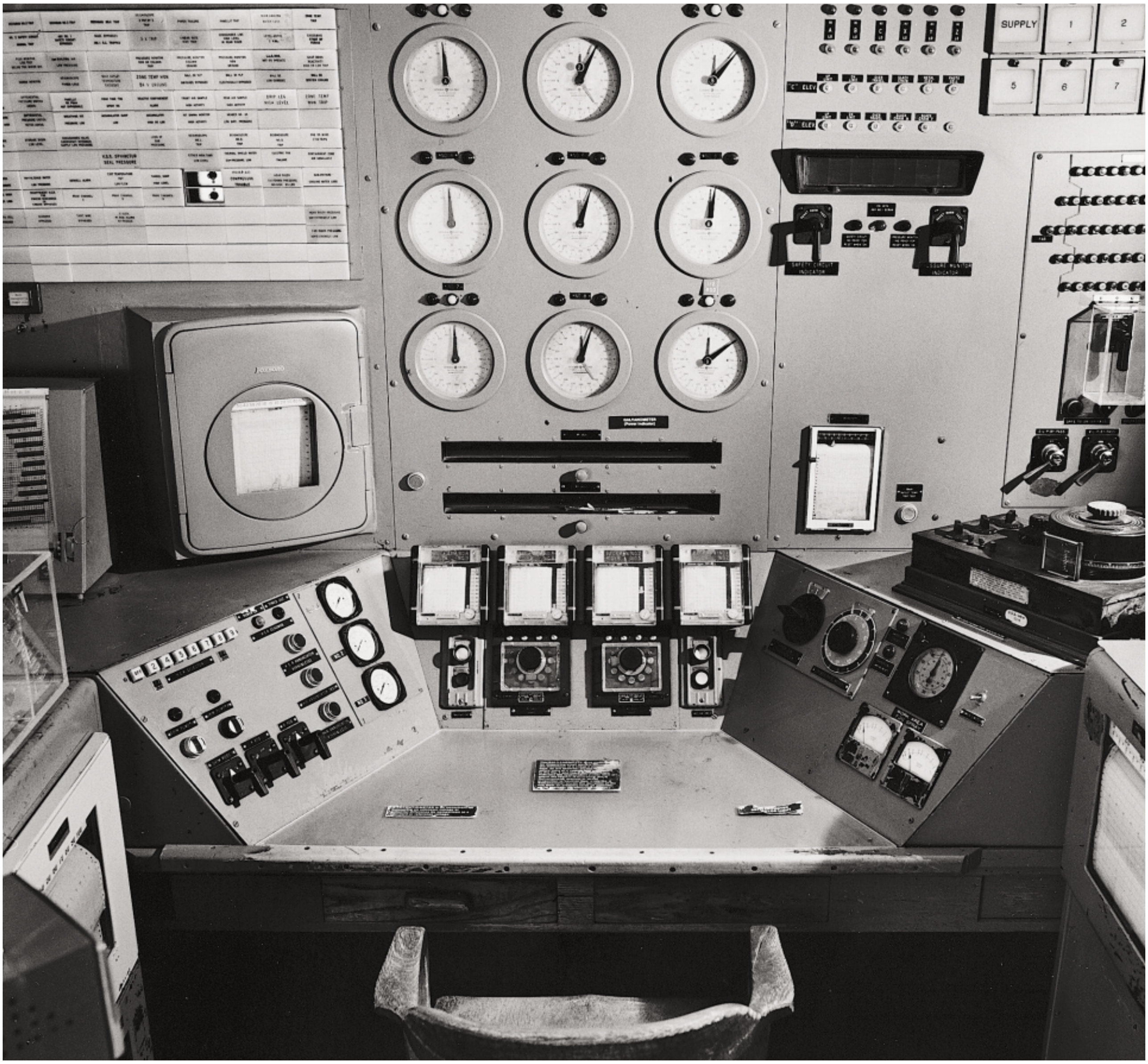
Despite its enormous historical significance, however, the reactor—permanently shut down since February 1968—now faces an uncertain future.

The world's first plutonium-making reactor is an Atomic Age landmark—and it faces an uncertain future

By Erico Guizzo

PHOTOGRAPHS BY WALTER WHITMAN

THAT TIME FORGOT


SUPPLY
1
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70
80
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110

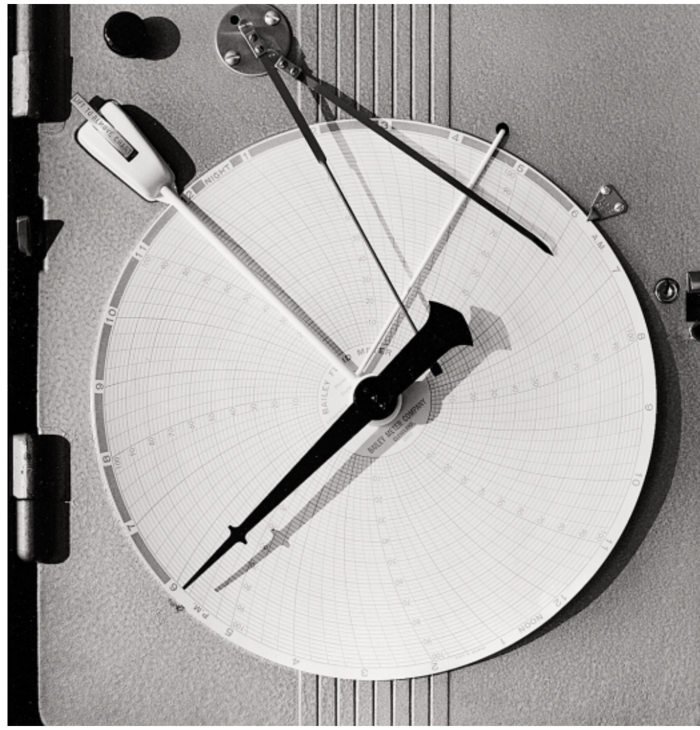
The U.S. Department of Energy has been laboring for years to clean up the radioactive and chemical contamination at Hanford. The site's several decades of operation resulted in the accumulation of about 500 million curies of radioactivity in the form of atomic wastes dumped into the soil and other nuclear products stored at aging facilities. (For comparison, the Hiroshima and Nagasaki bombs produced a total of less than 5 million curies of radioactivity.) Getting rid of all that mess is expected to cost some US $50 billion and last until 2035.

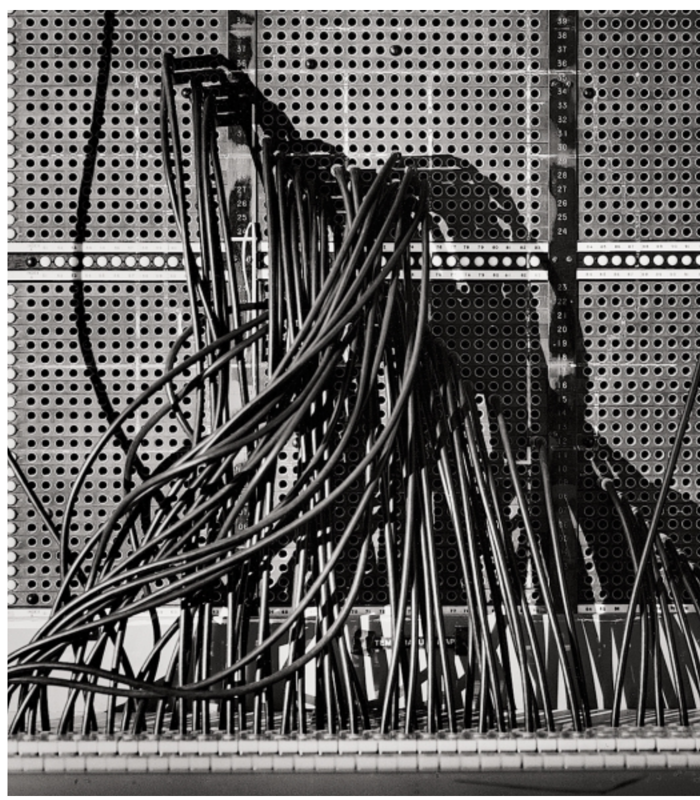
This year the DOE is starting yet another cleanup initiative at the site. The work, distributed over a long stretch of the Columbia River, includes cocooning four of Hanford's reactors, which basically means demolishing all the reactors' structures but their cores and then sealing and roofing them. The B unit is on the list.

Before sending the wreckers in, however, the DOE will wait for the outcome of a study that will assess the possibility of converting some of the Manhattan Project's historic sites into parks and museums. In arguing for the U.S. Senate version of the bill proposing the study, Senator Maria Cantwell (D.-Wash.) called B Reactor "a stunning feat of engineering" and exhorted her colleagues to "preserve the reactor for future generations, which must learn about the Manhattan Project and its impact on world history."

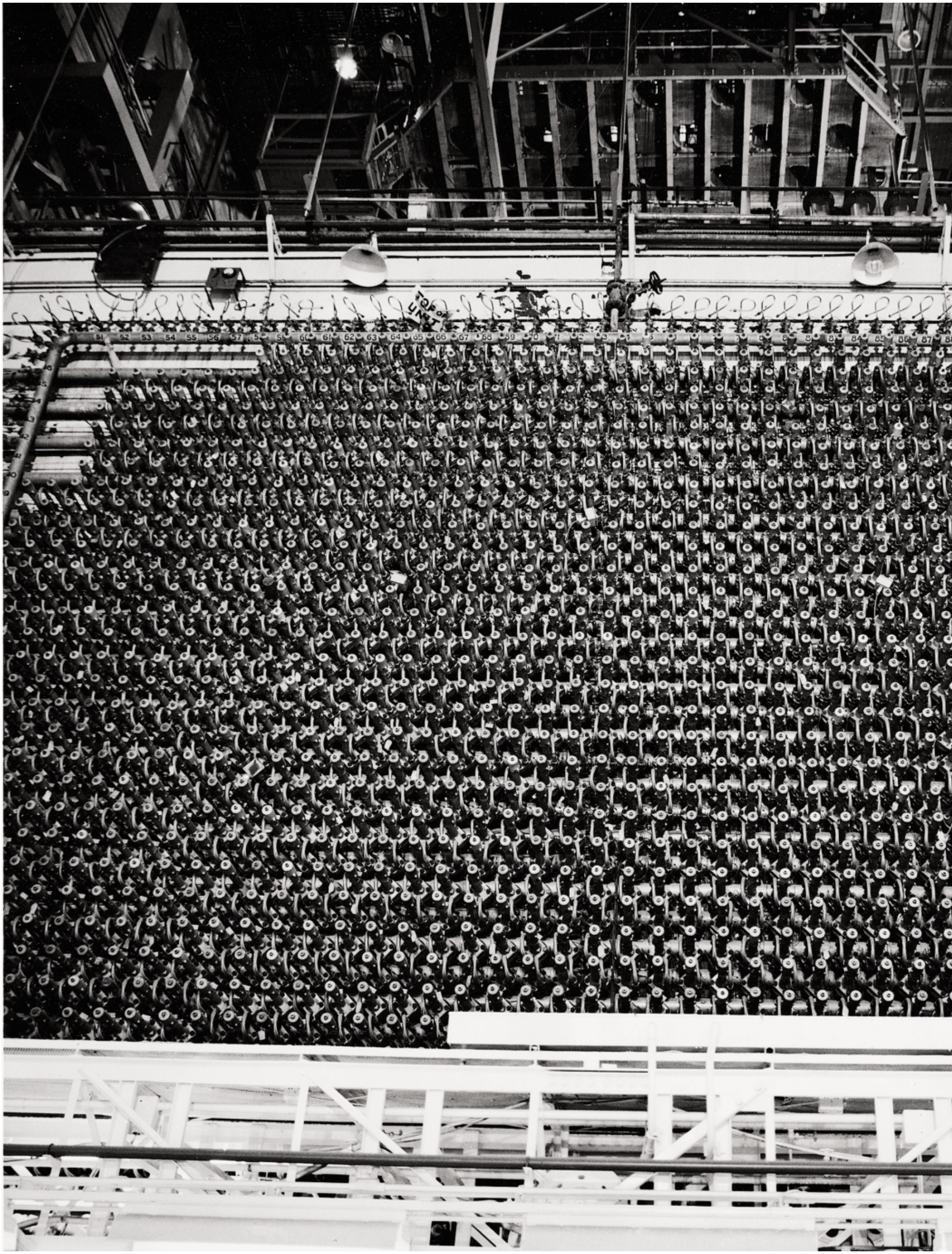
Although the cost of turning the facility into a museum has not been calculated, Bechtel Hanford, the main contractor at the site, estimates that a full decontamination of B Reactor, plus necessary structural repairs, could cost US $30 million. Several rooms have already been cleaned up, but hazards still exist, including lingering radiation, toxic chemicals, asbestos, heavy metals, and also some sneaky bats and snakes. For many years, occasional visitors were allowed into the decontaminated rooms, where no type of protection is required, though for security reasons access was significantly restricted after September 11, 2001.

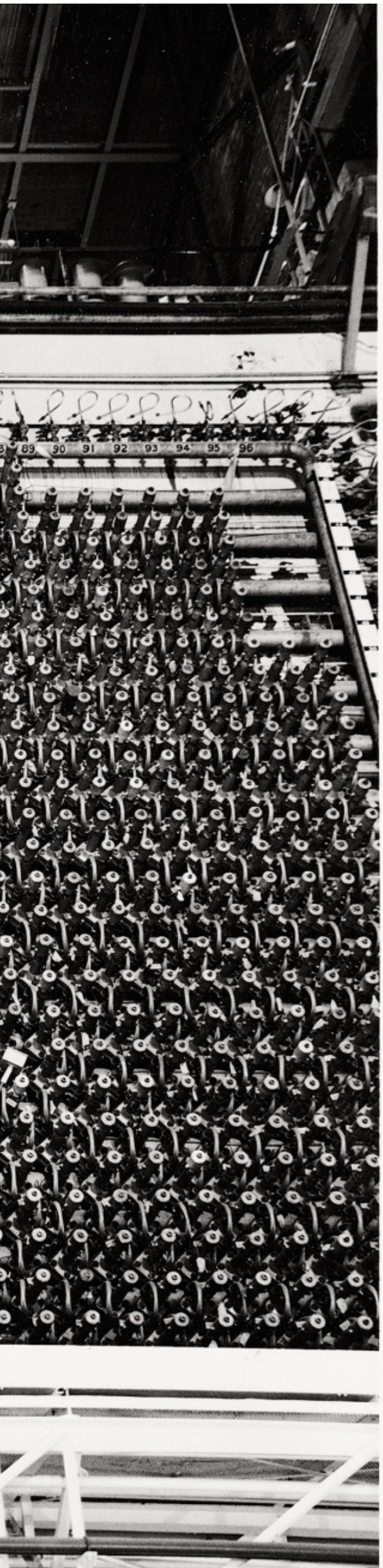
A LAYER OF MELTING SNOW blankets Hanford's rocky soil and its sparse sagebrush and cheatgrass covering. In the vicinity of B Reactor, the only signs of life on this winter day are a few maintenance workers driving by in pickup trucks and a lonely coyote wandering near the road. It's hard to picture the place as it was 60 years ago, when tens of thousands of workers toiled in scattered facilities all over Hanford, which almost overnight became the third most populous region in Washington State.





COMMANDING THE BEAST: An operator, sitting at the control room's main instrument console [opposite page, top], adjusted the reactor's power level by driving regulating rods into or out of the nuclear core. The rods' positions were shown on the nine white dials, and the power level was indicated on the two dark rectangles just below them. Other instruments in the control room included a gauge [opposite page, bottom left] that read the temperature of the core's radiation-blocking shield; a panel [opposite page, bottom right] with water pressure gauges, one for each of the 2004 aluminum tubes in the core; a 24-hour-readout recorder [this page, top] that monitored concentration levels of helium kept inside the core to prevent air from going in and reducing reactivity; and a telephone-switchboard-like panel [this page, bottom] used to measure water temperature in the core's 2004 tubes, each of which corresponded to one of the panel's plug holes.





As you step through B Reactor's main entrance, pale-green double doors are visible straight ahead, at the end of a short hallway. It's behind those doors that B Reactor's atomic heart resides. In a vast, high-ceilinged hangarlike room, the enormous core looms 12 meters tall, its somber façade covered by protruding metal nozzles.

The core consists of an inner structure, called the pile, enclosed by thick shielding layers of iron, steel, and Masonite. The pile is a 2000-ton cubical block of pure graphite that 2004 aluminum tubes traverse horizontally. Workers manually filled those tubes with tens of thousands of aluminum-clad uranium cylinders called slugs, each about the size of a large sausage. When enough slugs were in place, they would form a "critical mass," which would initiate the uranium's transformation into plutonium.

Two nuclear reactions took place simultaneously. In one, nuclei of uranium-235, one of the isotopes present in the slugs' natural uranium, started to fission and emit neutrons. These fast neutrons, slowed down by the surrounding graphite, would then hit and split other uranium-235 nuclei in nearby tubes, thereby generating more neutrons, which in turn would split other nuclei, and so on. This fission chain reaction deluged the pile with neutrons. In the other reaction, another isotope in the slugs, uranium-238, would absorb some of the fast neutrons and transmute into plutonium.

The fission reaction released enormous quantities of energy. The reactor, originally rated at a thermal power level of 250 megawatts, would simply have melted down if it weren't for a torrent of Columbia River water directed through its tubes. Located nearby, a water plant large enough to serve a city of 300 000 people pumped 114 000 liters of cooling water through the reactor's seething core every minute. The effluent water would stay in a retention basin for 3 or 4 hours and then flow back into the Columbia River.

Operators adjusted the reactor's power level from a control room separated from the core by a 1-meter-thick concrete wall. From there, they could regulate the chain reaction

FACE TO FACE: B Reactor's massive nuclear core [left] could house 200 tons of uranium. Its three-story-tall front face is covered by 2004 metal nozzles, each connected to an aluminum tube running horizontally through the core. Workers used a white metal scaffold along the core's front face to insert uranium slugs into the tubes at all levels. Nozzles [below] had cylindrical caps to close them and numbered tags to indicate their location. The thin, curling tube around each nozzle—called a pigtail—fed water to the tubes to cool down the core.

HELLO, OPERATOR? The huge volume of cooling water coursing through the core created a deafening roar. Microphones [top] connected to loudspeakers were hung around the core to facilitate communication. Water flow through specific tubes could be controlled through a manual system of valves [bottom]. Uranium slugs removed from the core were put into special railroad cask cars that ran on tracks [opposite page] connecting the reactor to a chemical-separation plant a few kilometers south, where plutonium—the reactor's end product—was extracted from the slugs.

by inserting or retracting one or more of nine motor-driven neutron-absorbing horizontal control rods, which were interspersed perpendicularly among the uranium-filled tubes. In addition, 29 vertical safety rods, suspended by electromagnets, would drop into the core to shut it down immediately if something went awry.

At the control room, operators also kept an eye on a number of gauges and recorders that let them monitor such parameters as the temperature of the pile's shielding and the water pressure of the core's tubes. To see it all today is to drop in on another era—one of dials and knobs instead of liquid-crystal displays and keyboards.

B REACTOR'S BASIC DESIGN WAS DERIVED from the experimental pile built by nuclear physicist Enrico Fermi's team in a squash court at the University of Chicago, where the group demonstrated the first controlled self-sustaining nuclear chain reaction. Fermi himself came to Hanford—where his code name was Eugene Farmer—and supervised the loading of the uranium slugs into B Reactor's tubes, a process that took several days.

Finally, at 10:48 p.m. on 26 September 1944—less than two years after Fermi's demonstration—the reactor entered operation, progressively advancing toward higher power levels. All seemed well, but after a few hours, the chain reaction mysteriously began to die out.

It turned out that an unexpected fission byproduct, xenon, was absorbing neutrons and thus spoiling the reaction. The solution was simple: override the xenon effect by inserting more slugs into the pile to increase its reactivity. Fortunately, there were several extra channels in the graphite that could readily house additional slugs.

The exact reason those extra channels were there is still a matter of debate. The original design created by Eugene Wigner, a physicist and engineer who had worked with Fermi at Chicago, called for 1500 parallel channels arranged circularly (a cross section of the graphite block would show holes uniformly distributed in a circular pattern). But Crawford Greenewalt, an engineer for E.I. Du Pont de Nemours and Co., the company in charge of the reactor's construction, decided to add 504 extra channels to the block (changing its cross section to a somewhat square pattern of holes).

Greenewalt hadn't anticipated the xenon effect but had feared that corrosion would make it necessary to reinforce the slugs' aluminum cladding at some point. If that happened, he had figured, the pile would need more slugs to compensate for its decreased reactivity. Whatever the reason for their inclusion, the extra channels proved instrumental and gave Greenewalt his place in atomic history. He would later become president of Du Pont.

Slugs remained inside the pile for several weeks. After that period, only one in every 4000 atoms of uranium-238 would have been transmuted into plutonium, but it was nevertheless time to refill the tubes with fresh slugs. Workers would open a tube's front nozzle and insert new slugs through it, pushing the old, highly radioactive slugs out the rear of the tube. These would fall into a water-filled storage pool in the rear of the reactor, where they were left to cool off for a while.

Railroad cask cars would then transport the slugs to a plutonium-separation plant a few kilometers south. There, workers operated remotely controlled machines

that dissolved the slugs in nitric acid and performed a series of chemical processes on the solution. Tons of uranium slugs would yield only tens of grams of plutonium.

During World War II, B Reactor operated around-the-clock for nine months. Its processed output, usually in the form of a concentrated plutonium nitrate paste, was packed into metal cans and driven in U.S. Army ambulances from Hanford to the top-secret laboratory in what is now Los Alamos, N.M. There the team led by the laboratory's director, J. Robert Oppenheimer, designed and built the first atomic bombs.

The Nagasaki bomb carried 6 kilograms of plutonium and exploded with a yield equivalent to that of 20 000 tons of TNT, causing 70 000 deaths by the end of 1945. (The Hiroshima bomb, which exploded with a yield of roughly 15 000 tons of TNT, used highly enriched uranium-235, produced at another Manhattan Project industrial complex, in Oak Ridge, Tenn.)

B Reactor was fundamental to a project that altered world history forever. For as long as it stands, it will help us remember the technological watershed that marked the Atomic Age's transition from laboratory experimentation to industrial-scale operation and all the profound political and moral consequences it brought with it. ■

TO PROBE FURTHER

For extended, more detailed photo captions, see http://www.spectrum.ieee.org.

For more on B Reactor's technology, see http://www.hanford.gov/doe/history/docs/rl-97-1047/.

For more on Hanford's contamination, see *On the Home Front: The Cold War Legacy of the Hanford Nuclear Site*, by Michele S. Gerber (University of Nebraska Press, 1992).