

Chicago Pile-1 (CP-1) was the world's first **nuclear reactor** to achieve **criticality**. Its construction was part of the **Manhattan Project**, the Allied effort to create **atomic bombs** during **World War II**. It was built by the Manhattan Project's **Metallurgical Laboratory** at the **University of Chicago**, under the west viewing stands of the original **Stagg Field**. The first man-made self-sustaining **nuclear chain reaction** was initiated in CP-1 on 2 December 1942, under the supervision of **Enrico Fermi**, who described the apparatus as "a crude pile of black bricks and wooden timbers".^[4]

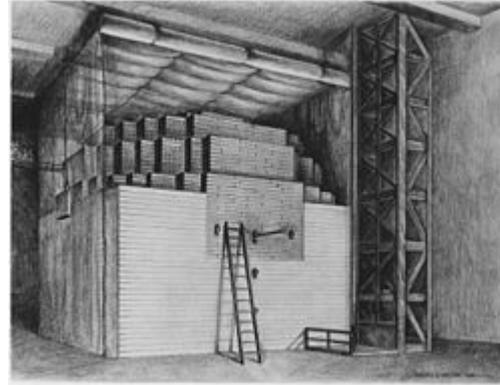
The reactor was assembled in November 1942, by a team that included Fermi, **Leo Szilard**, discoverer of the chain reaction, and **Herbert L. Anderson**, **Walter Zinn**, **Martin D. Whitaker**, and **George Weil**. It contained 45,000 **graphite** blocks weighing 400 short tons (360 t) used as a **neutron moderator**, and was fueled by 6 short tons (5.4 t) of uranium metal and 50 short tons (45 t) of uranium oxide. In the pile, some of the free neutrons produced by the natural decay of uranium were absorbed by other uranium atoms, causing **nuclear fission** of those atoms, and the release of additional free neutrons. Unlike most subsequent nuclear reactors, it had no radiation shield or cooling system as it only operated at very low power. The shape of the pile was intended to be roughly spherical, but as work

Site of the First Self Sustaining Nuclear Reaction

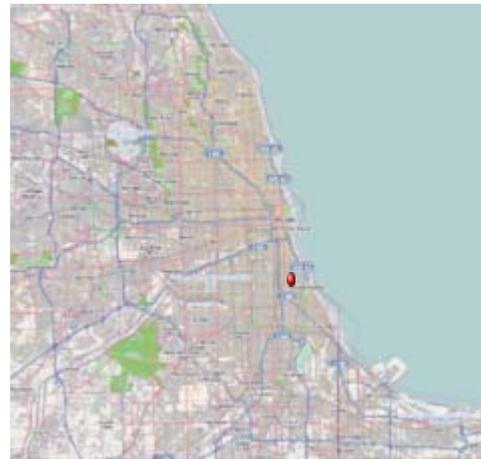
U.S. National Register of Historic Places

U.S. National Historic Landmark

Chicago Landmark



Drawing of the reactor



Location	Chicago, Cook County, Illinois, USA
Coordinates	41°47′32″N 87°36′3″W﻿ / ﻿41.79222°N 87.60139°W﻿ / 41.79222; -87.60139
Built	1942 ^[2]
NRHP Reference #	66000314 ^[1]

Significant dates

Added to NRHP	15 October 1966 (66000314) ^[1]
Designated NHL	18 February 1965 ^[2]
Designated CL	27 October 1971 ^[3]

proceeded Fermi calculated that critical mass could be achieved without finishing the entire pile as planned.

In 1943, CP-1 was moved to [Red Gate Woods](#), and reconfigured to become Chicago Pile-2 (CP-2). There, it was operated until 1954, when it was dismantled and buried. The stands at Stagg Field were demolished in August 1957, but the site is now a [National Historic Landmark](#) and a [Chicago Landmark](#).

Chicago Pile-1 (CP-1)

Reactor concept	Research reactor
Designed and build by	Metallurgical Laboratory
Operational	1942 to 1943
Status	Dismantled
Main parameters of the reactor core	
Fuel (fissile material)	Natural uranium
Fuel state	Solid (pellets)
Neutron energy spectrum	Information missing
Primary control method	Control rods
Primary moderator	Nuclear graphite (bricks)
Primary coolant	None
Reactor usage	
Primary use	Experimental
Remarks	The Chicago Pile-1 (CP-1) is the world's first nuclear reactor .

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Origins

The idea of [chemical chain reactions](#) was first put forth in 1913 by the German chemist [Max Bodenstein](#) for a situation in which two molecules react to form not just the molecules of the final reaction products, but also some unstable molecules which can further react with the parent molecules to cause more molecules to react.^[5] The concept of a [nuclear chain reaction](#) was first hypothesized by the Hungarian scientist [Leo Szilard](#) on 12 September 1933.^[6] Szilard realized that if a nuclear reaction produced [neutrons](#) or [dineutrons](#), which then caused further nuclear reactions, the process might be self-perpetuating. Szilard proposed using mixtures of lighter known isotopes which produced neutrons in copious amounts, although he did entertain the possibility of using uranium as a fuel.^[7] He filed a patent for his idea of a simple nuclear reactor the following year.^[8] The discovery of [nuclear fission](#) by German chemists [Otto Hahn](#) and [Fritz Strassmann](#) in 1938,^{[9][10]} followed by its theoretical explanation (and naming) by [Lise Meitner](#) and [Otto Frisch](#),^{[11][12]} opened up the possibility of creating a nuclear chain reaction with uranium or [indium](#), but initial experiments were unsuccessful.^{[13][14][15][16]}

In order for a chain reaction to occur, additional neutrons had to be emitted from fissioning uranium atoms. At [Columbia University](#) in New York, [Enrico Fermi](#), [John Dunning](#), [Herbert L. Anderson](#), [Eugene T. Booth](#), [G. Norris Glasoe](#), and [Francis G. Slack](#) conducted the first nuclear fission experiment in the United States on 25 January 1939.^{[17][18]} Subsequent work confirmed that fast neutrons were indeed produced by fission.^{[19][20]} Szilard obtained permission from the head of the Physics Department at Columbia, [George B. Pegram](#), to use a laboratory for three months, and persuaded [Walter Zinn](#) to become his collaborator.^[21] They conducted a simple experiment on the seventh floor of [Pupin Hall](#) at Columbia, using a radium-beryllium source to bombard uranium with neutrons. They discovered significant neutron multiplication in natural uranium, proving that a chain reaction might be possible.^[22]

As a neutron moderator, Szilard suggested Fermi use [carbon](#) in the form of [graphite](#). Szilard felt he would need about 50 tonnes (49 long tons; 55 short tons) of graphite and 5 tonnes (4.9 long tons; 5.5 short tons) of uranium. As a back-up plan, he also considered where to find a few tons of [heavy water](#); [deuterium](#) would not absorb neutrons like ordinary hydrogen, and was a better moderator than carbon, but was difficult and expensive to produce.^[23] Fermi and Szilard still believed that

enormous quantities of uranium would be required for an [atomic bomb](#), and therefore concentrated on producing a controlled chain reaction.^[24] Fermi determined that a fissioning uranium atom produced 1.73 neutrons on average. It was enough, but a careful design was called for to minimize losses.^{[25][26]}

Fermi and Szilard met with representatives of [National Carbon Company](#), who manufactured the graphite, and Szilard made another important discovery. By quizzing them about impurities in their graphite, he found that it contained [boron](#), a neutron absorber. He then had graphite manufacturers produce boron-free graphite.^[27] Had he not done so, they might have concluded, as the Germans did, that graphite was unsuitable for use as a neutron moderator.^[28]

Government support

Szilard drafted a confidential letter to the President, [Franklin D. Roosevelt](#), explaining the possibility of nuclear weapons, warning of a [German nuclear weapon project](#), and encouraging the development of a program that could result in their creation. With the help of [Eugene Wigner](#) and [Edward Teller](#), he approached his old friend and collaborator [Albert Einstein](#) in August 1939, and convinced him to sign the letter, lending his fame to the proposal.^[29] The [Einstein–Szilard letter](#) resulted in the establishment of research into nuclear fission by the U.S. government.^[30] An [Advisory Committee on Uranium](#) was formed under [Lyman J. Briggs](#), a scientist and the director of the [National Bureau of Standards](#). Its first meeting on 21 October 1939, was attended by Szilard, Teller and Wigner, who persuaded the Army and Navy to provide \$6,000 for Szilard to purchase supplies for experiments—in particular, more graphite.^[31]



Pupin Hall at [Columbia University](#)

In April 1941, the [National Defense Research Committee](#) (NDRC), created a special project headed by physicist, [Arthur Compton](#), a Nobel-Prize-winning professor at the [University of Chicago](#), to report on the uranium program. Compton's report, submitted in May 1941, foresaw the prospects of developing [radiological weapons](#), [nuclear propulsion](#) for ships, and [nuclear weapons](#) using [uranium-235](#) or the recently discovered [plutonium](#).^[32] In October he wrote another report on the practicality of an atomic bomb. For this report, he worked with Fermi on calculations of the [critical mass](#) of uranium-235. He also discussed the prospects for [uranium enrichment](#) with [Harold](#)

[Urey](#).^[33]

[Niels Bohr](#) and [John Wheeler](#) had theorized that heavy isotopes with odd [atomic numbers](#) were [fissile](#). If so, then [plutonium-239](#) was likely to be.^[34] In May 1941, [Emilio Segrè](#) and [Glenn Seaborg](#) at the [University of California](#) produced 28 μg of plutonium in the 60-inch [cyclotron](#) there, and found that it had 1.7 times the [thermal neutron capture cross section](#) of uranium-235. At the time only such minute quantities of plutonium-239 had been produced, in cyclotrons, and it was not possible to produce a sufficiently large quantity that way.^[35] Compton discussed with Wigner how plutonium might be produced in a [nuclear reactor](#), and with [Robert Serber](#) about how the plutonium produced in a reactor might be separated from uranium. His report, submitted in November, stated that a bomb was feasible.^[33]

The final draft of Compton's November 1941 report made no mention of using plutonium, but after discussing the latest research with [Ernest Lawrence](#), Compton became convinced that a plutonium bomb was also feasible. In December, Compton was placed in charge of the plutonium project.^[36] Its objectives were to produce reactors to convert uranium to plutonium, to find ways to chemically separate the plutonium from the uranium, and to design and build an atomic bomb.^[37]^[34] It fell to Compton to decide which of the different types of reactor designs that the scientists should pursue, even though a successful reactor had not yet been built.^[38] He proposed a schedule to achieve a controlled nuclear chain reaction by January 1943, and to have an atomic bomb by January 1945.^[37]

Development

In a nuclear reactor, [criticality](#) is achieved when the rate of neutron production is equal to the rate of neutron losses, including both neutron absorption and neutron leakage. Thus, in the simplest case of a bare, homogeneous, steady state nuclear reactor, the neutron leakage and neutron absorption must be equal to neutron production in order to reach criticality. The critical radius of an unreflected, homogeneous, spherical reactor was calculated to be:^[39]

$$R_{crit} = \frac{\pi M}{\sqrt{k - 1}}$$



On the fourth anniversary of the team's success, 2 December 1946, members of the CP-1 team gathered at the University of Chicago. Back row, from left: [Norman Hilberry](#), [Samuel Allison](#), Thomas Brill, Robert Nobles, Warren Nyer, and Marvin Wilkening. Middle row: [Harold Agnew](#), William Sturm, [Harold Lichtenberger](#), [Leona Woods](#)

where M is the migration area and k is the medium [neutron multiplication factor](#). The first generation of the reaction will produce k neutrons, the second will produce k^2 , the third k^3 and so on. In order for a [self-sustaining nuclear chain reaction](#) to occur, k must be greater than 1. For a practical reactor configuration, it needs to be at least 3 or 4 percent more.^{[39][40]}

and [Leo Szilard](#). Front row: [Enrico Fermi](#), [Walter Zinn](#), [Albert Wattenberg](#) and [Herbert L. Anderson](#).

Fermi christened his apparatus a "pile". Emilio Segrè later recalled that:

“ I thought for a while that this term was used to refer to a source of nuclear energy in analogy with [Volta](#)'s use of the Italian term *pila* to denote his own great invention of a source of electrical energy. I was disillusioned by Fermi himself, who told me that he simply used the common English word *pile* as synonymous with *heap*. To my surprise, Fermi never seemed to have thought of the relationship between his *pile* and [Volta](#)'s.^[41]

”

Another grant, this time of \$40,000, was obtained from the S-1 Uranium Committee to purchase more materials, and in August 1941 Fermi began to plan for a new test. The pile he proposed to build was 8 feet (2.4 m) long, 8 feet (2.4 m) wide and 11 feet (3.4 m) high.^[42] This was too large to fit in the Pupin Physics Laboratories. Fermi recalled that:

“ We went to Dean Pegram, who was then the man who could carry out magic around the University, and we explained to him that we needed a big room. He scouted around the campus and we went with him to dark corridors and under various heating pipes and so on, to visit possible sites for this experiment and eventually a big room was discovered in Schermerhorn Hall.^[43]

”

The pile was built in September 1941 from 4-by-4-by-12-inch (10 by 10 by 30 cm) graphite blocks and [tinplate](#) iron cans of uranium oxide. The cans were 8-by-8-by-8-inch (20 by 20 by 20 cm) cubes. When filled with uranium oxide, each weighed about 60 pounds (27 kg). There were 288 cans in all, and each was surrounded by graphite blocks so the whole would form a lattice structure. The uranium oxide was



One of at least 29 experimental piles that were constructed in 1942 under the West Stands of Stagg Field. Each tested elements incorporated into the final design.

heated to remove moisture, and packed into the cans while still hot on a shaking table. The cans were then soldered shut. For a workforce, Pegram secured the services of Columbia's [football](#) team. It was the custom at the time for football players to perform odd jobs around the university. They were able to manipulate the heavy cans with ease. The final result was a disappointing k of 0.87.^{[40][44]}

Compton felt that having teams at Columbia University, [Princeton University](#), the University of Chicago and the University of California was creating too much duplication and not enough collaboration, and he resolved to concentrate the work in one location. Nobody wanted to move, and everybody argued in favor of their own location. In January 1942, soon after the United States entered World War II, Compton decided on his own location, the University of Chicago, where he knew he had the unstinting support of university administration.^[45] Other factors in the decision were that scientists, technicians and facilities were more readily available in the [Midwest](#), where war work had not yet taken them away, and Chicago's central location.^[45] In contrast, Columbia University was engaged in uranium enrichment efforts under Harold Urey and John Dunning, and was hesitant to add a third secret project.^[46]

Before leaving for Chicago, Fermi's team made one last attempt to build a working pile at Columbia. Since the cans had absorbed neutrons, they were dispensed with. Instead, the uranium oxide, heated to 480 °F (249 °C) to dry it out, was pressed into cylindrical holes 3 inches (7.6 cm) long and 3 inches (7.6 cm) in diameter drilled into the graphite. The entire pile was then canned by soldering sheet metal around it, and the contents heated above the boiling point of water to remove moisture. The result was a k of 0.918.^[47]

Choice of site

In Chicago, [Samuel K. Allison](#) had found a suitable space 60 feet (18 m) long, 30 feet (9.1 m) wide and 26 feet (7.9 m) high, sunk slightly below ground level, in a space under the stands at [Stagg Field](#) originally built as a [rackets](#) court.^{[48][49]} Stagg Field had been largely unused since the University of Chicago had given up playing American football in 1939,^{[39][50]} but the rackets courts under West Stands were still used for playing [squash](#) and [handball](#). [Leona Woods](#) and [Anthony L. Turkevich](#)

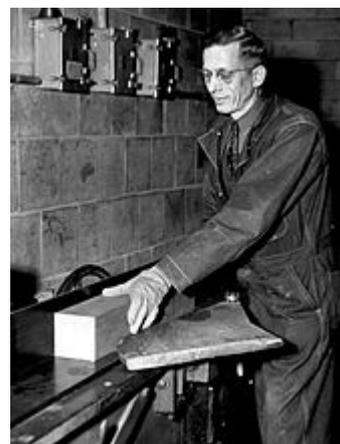
played squash there in 1940. Being intended for strenuous exercise, the area was unheated. The nearby North Stands had a pair of ice skating rinks on the ground floor, which although unrefrigerated, seldom melted in winter.^[51] Allison used the rackets court area to construct a 7-foot (2.1 m) experimental pile before Fermi's group arrived in 1942.^[48]

The [United States Army Corps of Engineers](#) assumed control of the nuclear weapons program in June 1942, and Compton's [Metallurgical Laboratory](#) became part of what came to be called the [Manhattan Project](#).^[52]

[Brigadier General Leslie R. Groves, Jr.](#) became director of the Manhattan Project on 23 September 1942.^[53] He visited the Metallurgical Laboratory for the first time on 5 October.^[54] Between 15 September and 15 November 1942, groups under Herbert Anderson and Walter Zinn constructed 16 experimental piles under the Stagg Field stands.^[55]

Fermi designed a new pile, which would be spherical to maximize *k*, which was predicted to be around 1.04, thereby achieving criticality.^[56] Leona Woods completed her doctoral thesis and then was detailed to build [boron trifluoride neutron detectors](#). She also helped Anderson locate the large number of 4-by-6-inch (10 by 15 cm) timbers required at lumber yards in [Chicago's south side](#).^[57] Shipments of high-purity graphite arrived, mainly from National Carbon, and high-purity [uranium dioxide](#) from [Mallinckrodt](#) in St Louis, which was now producing 30 short tons (27 t) a month.^[58] Metallic uranium also began arriving in larger quantities, the product of newly developed techniques.^[59]

On 25 June, the Army and the [Office of Scientific Research and Development](#) (OSRD) had selected a site in the [Argonne Forest](#) near Chicago for a plutonium pilot plant. This became known as Site A. 1,025 acres (415 ha) were leased from [Cook County](#) in August,^{[60][61]} but by September it was apparent that the proposed facilities would be too extensive for the site, and it was decided to build the pilot plant elsewhere.^[62] The subcritical piles posed little danger, but Groves felt that it would be prudent to locate a critical pile—a fully functional nuclear reactor—at a more remote site. A building at Argonne to house Fermi's experimental pile was commenced, with its completion scheduled for 20 October. Due to industrial disputes, construction fell behind schedule, and it became clear the materials for Fermi's new pile would be on hand before the new structure was completed. In early November, Fermi came to Compton with a proposal to build the experimental



Augustus Knuth cuts a wooden block for the timber frame

pile under the stands at Stagg Field.^[63]



CP-1 under construction: 4th layer

The safety of building an operational reactor running at criticality in a populated area was a significant issue. However, the physics of the system suggested that the pile could be safely shut down even in the event of a **runaway reaction**. When a fuel atom undergoes fission, it releases neutrons that strike other fuel atoms and leads to the chain reaction.^[63] The time between absorbing the neutron and undergoing fission is measured in nanoseconds, often using a convenient unit for this purpose, the *shake*.^[64] Szilard had noted that this reaction leaves behind **fission products** that may also release neutrons, but do so over much longer periods, from microseconds to as long as minutes. In a slow reaction like the one in a pile where the fission products build up, these neutrons account for about three percent of the total flux.^{[63][65][66]}

Fermi argued that by using these *delayed neutrons*, and by carefully controlling the reaction rates as the power is ramped up, a pile can reach criticality at fission rates slightly below that of a chain reaction relying solely on the *prompt neutrons* from the fission reactions. Since the rate of release of these neutrons depends on fission events taking place some time earlier, there is a delay between any power spikes and the later criticality event. This time gives the operators leeway; if a spike in the prompt neutron flux is seen, they have several minutes before this causes a runaway reaction. If a neutron absorber, or *neutron poison*, is injected at any time during this period, the reactor will shut down. Compton felt this delay was enough to provide a critical margin of safety,^{[63][65]} and allowed Fermi to build Chicago Pile-1 at Stagg Field. There was a fear of a catastrophic **nuclear meltdown** blanketing one of the United States' major urban areas in radioactive fission products.^{[67][65]}

Compton later explained that:

“ As a responsible officer of the University of Chicago, according to every rule of organizational protocol, I should have taken the matter to my superior. But this would have been unfair. **President Hutchins** was in no position to make an independent judgment of the hazards involved. Based on considerations of the University's welfare, the only answer he could have given would have ”

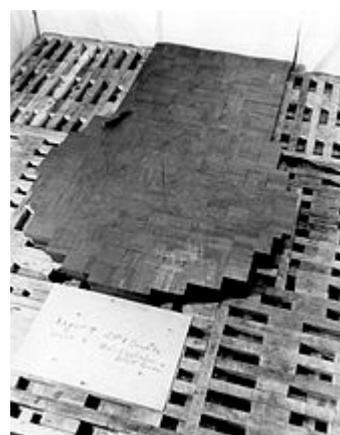
been—no. And this answer would have been wrong.^[67]

Compton informed Groves of his decision at the 14 November meeting of the S-1 Executive Committee.^[65] Although Groves "had serious misgivings about the wisdom of Compton's suggestion", he did not interfere.^[68] **James Bryant Conant**, the chairman of the NDRC, was reported to have turned white. But because of the urgency and their confidence in Fermi's calculations, no one objected.^[69]

Construction

Chicago Pile 1 was encased within a balloon so that the air inside could be replaced by **carbon dioxide**.

Anderson had a dark gray balloon manufactured by **Goodyear Tire and Rubber Company**. A 25-foot (7.6 m) cube-shaped balloon was somewhat unusual, but the Manhattan Project's AAA priority rating ensured prompt delivery with no questions asked.^{[55][70]} A **block and tackle** was used to haul it into place, with the top secured to the ceiling and three sides to the walls. The remaining side, the one facing the balcony from which Fermi directed the operation, was furled like an awning.



CP-1 under construction: 7th layer

A circle was drawn on the floor, and the stacking of graphite blocks began on the morning of 16 November 1942.^[71] The first layer placed was made up entirely of graphite blocks, with no uranium. Layers without uranium were alternated with two layers containing uranium, so the uranium was enclosed in graphite.^[71] Unlike later reactors, it had no radiation shielding or cooling system, as it was only intended to be operated at very low power.^[72]

The work was carried out in twelve-hour shifts, with a day shift under Zinn and a night shift under Anderson.^[73] For a work force they hired thirty high school dropouts that were eager to earn a bit of money before being drafted into the Army.^[74] They machined 45,000 graphite blocks enclosing 19,000 pieces of uranium metal and uranium oxide.^[75] The graphite arrived from the manufacturers in 4.25-by-4.25-inch (10.8 by 10.8 cm) bars of various lengths. They were cut into standard lengths of 16.5 inches (42 cm), each weighing 19 pounds (8.6 kg). A lathe was used to drill 3.25-inch (8.3 cm) holes in the blocks for the control rods and the uranium. A hydraulic press was used to shape the uranium oxide into "pseudospheres", cylinders with rounded ends. Drill bits had to be sharpened after

each 60 holes, which worked out to be about once an hour.^[71] Graphite dust soon filled the air and made the floor slippery.^[67]

Another group, under Volney C. Wilson,^[73] was responsible for instrumentation. They also fabricated the **control rods**, which were **cadmium** sheets nailed to flat wooden strips, cadmium being a potent neutron absorber, and the **scram** line, a **Manila rope** that when cut would drop a control rod into the pile and stop the reaction.^[74] Richard Fox, who made the control-rod mechanism for the pile, remarked that the manual speed control that the operator had over the rods was simply a **variable resistor**, controlling an **electric motor** that would **spool** the "clothesline" wire over a pulley that also had two lead weights attached to ensure it would "fail-safe" and return to its zero position when released.^[76]



CP-1 under construction: 10th layer

About two layers were laid per shift.^[71] Woods' boron trifluoride neutron counter was inserted at the 15th layer. Thereafter, readings were taken at the end of each shift.^[77] Fermi divided the square of the radius of the pile by the intensity of the radioactivity to obtain a metric that counted down to one as the pile approached criticality. At the 15th layer, it was 390; at the 19th it was 320; at the 25th it was 270 and by the 36th it was only 149. The original design was for a spherical pile, but as work proceeded, it became clear that this would not be necessary. The graphite was now more pure than hitherto, and 6 short tons (5.4 t) of very pure metallic uranium began to arrive from the **Ames Project** at **Iowa State University**,^[78] where a team under **Frank Spedding** had developed **a new process** to produce uranium metal. **Westinghouse Lamp Plant** supplied 3 short tons (2.7 t), which it produced in a rush with a makeshift process.^{[79][80]}

The 2.25-inch (5.7 cm) metallic uranium cylinders, known as "Spedding's eggs", were dropped in the holes in the graphite in lieu of the uranium oxide pseudospheres. The process of filling the balloon with carbon dioxide would not be necessary, and twenty layers could be dispensed with. According to Fermi's new calculations, the countdown would reach 1 between the 56th and 57th layers. The resulting pile was therefore flatter on the top than on the bottom.^[71] Anderson called a halt after the 57th layer was placed.^[81] When completed, the wooden frame supported an elliptical-shaped structure, 20 feet (6.1 m) high, 6 feet (1.8 m) wide at the ends and 25 feet (7.6 m) across the middle.^[74] It contained 6 short tons (5.4 t) of uranium metal, 50 short tons (45 t) of uranium oxide and 400 short tons (360 t) of

graphite, at an estimated cost of \$2.7 million.^[82]

First nuclear chain reaction

The next day, 2 December 1942, everybody assembled for the experiment. There were 49 scientists present.^[83]

Although most of the S-1 Executive Committee was in Chicago, only [Crawford Greenewalt](#) was present, at Compton's invitation.^[84] Other dignitaries present included Szilard, Wigner and Spedding.^[83] Fermi, Compton, Anderson and Zinn gathered around the controls on the balcony, which was originally intended as a viewing platform.^[85] Samuel Allison stood ready with a bucket of concentrated cadmium nitride, which he was to throw over the pile in the event of an emergency.

The start up began at 09:54. Walter Zinn removed the zip, the emergency control rod, and secured it. Norman Hilberry stood ready with an axe to cut the scram line, which would allow the zip to fall under the influence of gravity. While Leona Woods called out the count from the boron trifluoride detector in a loud voice, [George Weil](#), the only one on the floor, withdrew all but one of the control rods. At 10:37 Fermi ordered Weil to remove all but 13 feet (4.0 m) of the last control rod. Weil withdrew it 6 inches (15 cm) at a time, with measurements being taken at each step.^{[85][86]}

The process was abruptly halted by the automatic control rod reinserting itself, due to its trip level being set too low.^[87] At 11:25, Fermi ordered the control rods reinserted. He then announced that it was lunch time.^[85]

The experiment resumed at 14:00.^[85] Weil worked the final control rod while Fermi carefully monitored the neutron activity. Fermi announced that the pile had [gone critical](#) (reached a self-sustaining reaction) at 15:25. Fermi switched the scale on the recorder to accommodate the rapidly increasing electrical current from the beryllium trifluoride detectors. He wanted to test the control circuits but after 28 minutes, the alarm bells went off to notify everyone that the [neutron flux](#) had passed the preset safety level, and he ordered Zinn to release the zip. The reaction rapidly halted.^{[88][86]} The pile had run for about 4.5 minutes at about 0.5 watts.^[89] Wigner opened a bottle of [Chianti](#), which they drank from paper cups.^[90]

Compton notified Conant by telephone. The conversation was in an impromptu code:



The [Chianti](#) bottle purchased by [Eugene Wigner](#) to help celebrate the first self-sustaining, controlled chain reaction. It was signed by the participants.

“ **Compton: The Italian navigator [has landed in the New World](#).**
Conant: How were the natives?
Compton: Very friendly.^[91] ”

Later operation

On 12 December 1942 CP-1's power output was increased to 200 W, enough to power a light bulb; but lacking shielding of any kind, it was a radiation hazard for everyone in the vicinity. Thereafter, testing was continued, but at 0.5 W.^[92]

Operation was terminated on 28 February 1943,^[93] and the pile was dismantled and moved to Site A in the Argonne Forest, now known as Red Gate Woods.^{[94][95]}

There the original materials were used to build Chicago Pile-2 (CP-2). Instead of being spherical, the new reactor was built in a cube-like shape, about 25 feet (7.6 m) tall with a base approximately 30 feet (9.1 m) square. It was surrounded by concrete walls 5 feet (1.5 m) thick that acted as a [radiation shield](#), with overhead protection from 6 inches (15 cm) of lead and 50 inches (130 cm) of wood. More uranium was used, so it contained 52 short tons (47 t) of uranium and 472 short tons (428 t) of graphite. No cooling system was provided as it only ran at a few kilowatts. CP-2 became operational in March 1943, with a *k* of 1.055.^{[96][97][98]}

During the war Zinn allowed CP-2 to be run around the clock, and its design made it easy to conduct experiments.^[99] CP-2 was joined by [Chicago Pile-3](#), the first heavy water reactor, which went critical on 15 May 1944.^{[97][98]}



Commemorative boulder at Site A

The reactors were used to undertake research related to weapons, such as investigations of the properties of [tritium](#). Wartime experiments included measuring the neutron absorption cross-section of elements and compounds. Albert Wattenberg recalled that about 10 elements were studied each month, and 75 over the course of a year.^[100] An accident involving

radium and beryllium powder caused a dangerous drop in his [white blood cell](#) count that lasted for three years. As the dangers of things such as inhaling uranium oxide became more apparent, experiments were conducted on the effects of radioactive substances on laboratory test animals.^[61]

The Red Gate Woods later became the original site of [Argonne National Laboratory](#), which replaced the Metallurgical Laboratory on 1 July 1946, with Zinn

as its first director.^[101] CP-2 and CP-3 operated for ten years before they outlived their usefulness, and Zinn ordered them shut down on 15 May 1954.^[61] Their remaining usable fuel was transferred to [Chicago Pile-5](#) at the Argonne National Laboratory's new site in [DuPage County](#), and the CP-2 and CP-3 reactors were dismantled in 1955 and 1956. High-level nuclear waste such as fuel and heavy water were shipped to [Oak Ridge, Tennessee](#), for disposal. The rest was encased in concrete and buried in a 40-foot-deep (12 m) trench in what is now known as the [Site A/Plot M Disposal Site](#). It is marked by a commemorative boulder.^[61]

By the 1970s there was increased public concern about the levels of radioactivity at the site, which was used by the local residents for recreational purposes. Surveys conducted in the 1980s found [strontium-90](#) in the soil at Plot M, trace amounts of tritium in nearby wells, and plutonium, technetium, cesium, and uranium in the area. In 1994, the [United States Department of Energy](#) and the Argonne National Laboratory yielded to public pressure and earmarked \$24.7 million and \$3.4 million respectively to rehabilitate the site. As part of the clean up, 500 cubic yards (380 m³) of radioactive waste was removed and sent to the [Hanford Site](#) for disposal. By 2002, the [Illinois Department of Public Health](#) had determined that the remaining materials posed no danger to public health.^[61]



[Leo Szilard](#) (right) and [Norman Hilberry](#) under the plaque commemorating [Chicago Pile-1](#) on the West Stands of Old Stagg Field. While the stands were later demolished, the plaque is now located at [the site memorial](#).

Significance and commemoration

A commemorative plaque was unveiled at Stagg Field on 2 December 1952, the occasion of the tenth anniversary of CP-1 going critical.^[102] It read:

“ On December 2, 1942 man achieved here the first self-sustaining chain reaction and thereby initiated the controlled release of nuclear energy.^[103] ”

The plaque was saved when the West Stands were demolished in August 1957.^[104] The site of CP-1 was designated as a [National Historic Landmark](#) on 18 February 1965.^[2] When the [National Register of Historic Places](#) was created in 1966, it was

immediately added to that as well.^[1] The site was also named a [Chicago Landmark](#) on 27 October 1971.^[3]

Today the site of the old Stagg Field is occupied by the University's [Regenstein Library](#), which was opened in 1970, and the [Joe and Rika Mansueto Library](#), which was opened in 2011.^[105] A [Henry Moore](#) sculpture, *Nuclear Energy*, stands in a small quadrangle just outside the Regenstein Library.^[2] It was dedicated on 2 December 1967, to commemorate the 25th anniversary of CP-1 going critical. The commemorative plaques from 1952, 1965 and 1967 are nearby.^[103] A graphite block from CP-1 can be seen at the [Bradbury Science Museum](#) in [Los Alamos, New Mexico](#); another is on display at the [Museum of Science and Industry](#) in Chicago.^[106]

Notes

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- ↑ ^a ^b ^c ^d "Site of the First Self-Sustaining Nuclear Reaction" . *National Historic Landmark Summary Listing*. National Park Service. Retrieved 26 July 2013.
- ↑ ^a ^b "Site of the First Self-Sustaining Controlled Nuclear Chain Reaction" . *City of Chicago*. Retrieved 26 July 2013.
- ↑ Fermi 1982, p. 24.
- ↑ ^Ölander, Arne. "The Nobel Prize in Chemistry 1956 – Award Ceremony Speech" . The Nobel Foundation. Retrieved 23 September 2015.
- ↑ Rhodes 1986, pp. 13, 28.
- ↑ Wellerstein, Alex (16 May 2014). "Szilard's chain reaction: visionary or crank?" . *Restricted Data*. Retrieved 23 September 2015.
- ↑ Szilard, Leo. "Improvements in or relating to the transmutation of chemical elements, British patent number: GB630726 (filed: 28 June 1934; published: 30 March 1936)" . Retrieved 23 September 2015.
- ↑ Rhodes 1986, pp. 251–254.
- ↑ Hahn, O.; Strassmann, F. (1939). "Über den Nachweis und das Verhalten der bei der Bestrahlung des Urans mittels Neutronen entstehenden Erdalkalimetalle (*On the detection and characteristics of the alkaline earth metals formed by irradiation of uranium with neutrons*)". *Die Naturwissenschaften* **27**: 11.

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- [Photos of CP-1](#) The University of Chicago Library Archive. Includes photos and sketches of CP-1.
- [Video Showing the Met Lab, Fermi, and an active experiment using CP-1](#)
- [The First Pile](#) 11 page story about CP-1
- ["First-Hand Recollections of the First Self-Sustaining Chain Reaction"](#) . [Department of Energy](#). Retrieved 23 September 2015. Video of two of the last surviving CP-1 pioneers, [Harold Agnew](#) and Warren Nyer.
- [Audio files of Fermi recounting the success of the reactor on the 10th anniversary in 1952](#)