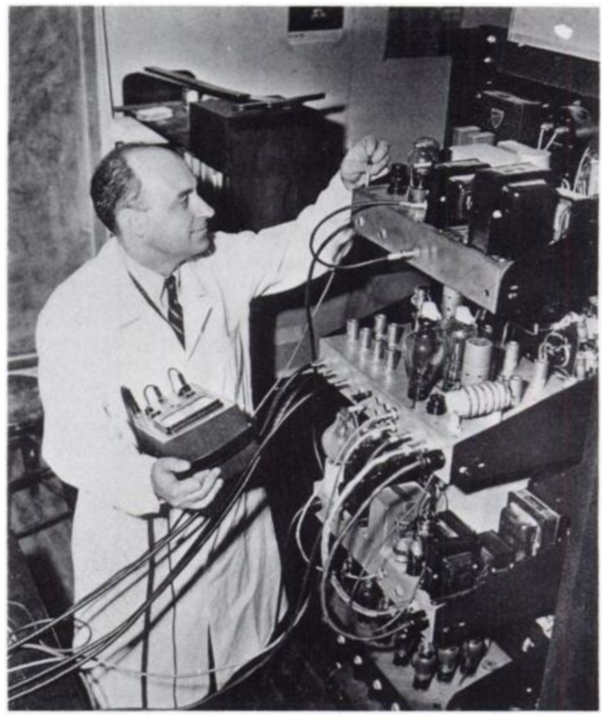
Editor's Note: *The Society's Nuclear Pioneer Citation for 1977 goes not to an individual but to a distinguished group of individuals: those who took part in the epochal "Chicago Pile" experiment of Dec. 2, 1942, which produced the first successful atomic pile chain reaction. The 42 members of the Chicago Pile group are listed on page 591. One of those named, Harold M. Agnew, now Director of the Los Alamos Scientific Laboratory, is the Nuclear Pioneer Lecturer for the 24th Annual Meeting.*

The guiding force behind the Chicago Pile experiment was Enrico Fermi, recipient of the Nuclear Pioneer Citation of 1963. In the article which follows, Laura Fermi recreates the excitement and mystery that surrounded the work of her husband's research team in the early 1940s in Chicago.

The First Atomic Pile: Recollections and Reconstructions

by Laura Fermi



Enrico Fermi at work, ca. 1942.

As far as I can remember at the distance of almost 35 years, the first guests to arrive at our party on that beastly cold December night were the Zinns, Wally and Jean. As they shook the snow off their coats, stamping their feet on the floor, Wally turned to Enrico and said: "Congratulations!" I was surprised; for Enrico had given me no hint that anything unusual or commendable had happened that day.

Those were the times of great secrecy for atomic scientists. Like the Zinns, we had moved earlier that year from a suburb of New York to Chicago, after some mysterious "they" (mysterious to me, at least) had decreed that all the secret work being done at Columbia should be moved to the Metallurgical Laboratory in Chicago. This fictitious name for the atomic project was chosen with an eye on plausibility: it sounded right on the campus of a university; but there were no metallurgists on the premises. This was the only secret I knew. Of what went on inside the Met Lab I had no inkling.

Perhaps not all husbands adhered as strictly as Enrico to the rules of secrecy when talking to their wives. He couldn't have been more tight-lipped. Once I related some gossip to him: "People say that you scientists at the Met Lab are seeking a cure for cancer. . . ." "Are we?" he asked with his usual imperturbable expression. "So you are not," I countered. "Aren't we?" he asked again, and his expression did not change.

There was no point in trying to extract information from Enrico, and very seldom did I try. I did not mind: secrecy was giving me the first vacation from physics since my wedding day. Yet, on that distant December evening I felt provoked and angered. Many more guests arrived, all friends from the Met Lab, since we were discouraged from social intercourse with the faculty of the University or the population at large. The powers that be were afraid of loose talk. Among our guests I remember the Graves, Dizzy bubbling with vitality, and Al, who a few years later made early history in nuclear medicine when he was involved in a nuclear accident in Los Alamos, New Mexico; the Agnews, Harold and Beverly, the youngest couple in our crowd, still beset by their first housekeeping problems—how to carve a leg of lamb and how to prevent boiling eggs from exploding and splashing on the ceiling; and Herbert Anderson, who at Columbia had been Enrico's graduate student and his mentor in American idiom—my own English had indirectly benefited from Herbert's teachings.

As the guests came and complained about the inclemency of the weather, the word "congratulations" was repeated many times, and as many times my inquiries went unheeded. To me, this refusal of any answer, in my own home, after the pains I had taken to ready the party, seemed a personal affront. I went up to Leona Woods (now Mrs. Willard Libby), a tall girl with black hair, a degree in physics, and the reputation of working harder than any man. Although younger than me, she was my friend and usually she treated me kindly. Indeed, it looked for a moment as if she were willing to give me satisfaction. Bending her head to the level of my ear, she whispered: "He has sunk a Japanese admiral and his ship." That was that; I could elicit no further comments, and for almost three years I was left to my doubts; had Leona made a fool of me, or had Enrico perhaps discovered rays so powerful that from Chicago they could affect boats in the Pacific?

At long last, at the end of the war I got the full explanation. We were then living at Los Alamos, the most secret site of the Manhattan District, where the atomic bomb was built. One day Enrico brought me a mimeographed book saying: "Read it; it may interest you." It was a copy of the "Smyth Report," the scientific history of the uranium project [Henry D. Smyth: *Atomic Energy for Military Uses* (1945)], which was being circulated among top Los Alamos scientists for their comments. Thus I learned that on the day of our party, Dec. 2, 1942, Enrico had lead the experiment in which the first atomic pile was operated and the first self-sustaining chain reaction was achieved. Leona had considered the achievement of a chain reaction equal in importance to the sinking of a Japanese admiral. But the atomic bomb was not then yet in the making, and the amount of energy released by the pile was of no practical use.

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Planning and constructing the pile was, for Enrico, the resumption of investigations he had begun in Rome, Italy. In 1934, with a group of collaborators (including Emilio Segrè, the Nobel Prize discoverer of the antiproton), he had produced artificial radioactivity in many elements, by bombarding them with neutrons. Artificial radioactivity was a new art, practiced for the first time a few months earlier by the Joliot-Curies in Paris. They had used alpha particles as nuclear projectiles, but Enrico thought that neutrons (discovered as recently as 1932) might be more effective because they have no charge—and so they turned out to be, causing most elements to become radioactive. When in their systematic bombardment of elements, from the lightest to the heaviest, they reached uranium, the Roman investigators obtained puzzling

SOME MEMBERS of the Chicago Pile group, pictured on the steps of Eckhart Hall, University of Chicago, Dec. 2, 1946. Back row (left to right): N. Hilberry, Samuel Allison, Thomas Brill, Robert Nobles, Warren Nyer, and Marvin Wilkening. Middle row (left to right): Harold Agnew, William Sturm, Harold Lichtenberger, Leona Woods Libby, and Leo Szilard. Front row (left to right): Enrico Fermi, Walter Zinn, Albert Wattenberg, and Herbert Anderson. [Photo, courtesy Argonne National Laboratory.]

results: the products of disintegration were none of the elements close to uranium on the periodic table, and on theoretical considerations they were led to think that they might have created an element that did not exist on earth, element 93. In reality, they had produced fission of uranium without recognizing it.

It took four more years of steady research by another team, Otto Hahn, Lise Meitner, and Fritz Strassmann, in Berlin before the riddle of element 93 was solved. In late fall of 1939 Hahn and Strassmann, in the absence of Meitner, who had been obliged to flee Nazi Germany, came to the startling conclusion that under neutron bombardment uranium behaves differently from any other element and splits into two almost equal parts. To this phenomenon Lise Meitner gave the name "fission."

Meanwhile, in Rome, Enrico, feeling incompetent to isolate and identify the hypothetical element 93, gave up the quest—techniques for handling the minimal quantities of radioactive substances produced were as yet almost nonexistent. He resumed neutron bombardment on other elements. In the fall of that same 1934, he and his collaborators discovered slow neutrons and their effectiveness in producing artificial radioactivity.

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News of the discovery of fission was brought to the United States by Niels Bohr, in mid-January, 1939. We, the Fermis, had arrived in New York two weeks before, refugees from Fascist Italy. In fact, on our way to this country, we had stopped in Stockholm to let Enrico pick up his Nobel Prize; and there one day we ran into Lise Meitner, a tense little woman with the almost scared look common to many refugees. There was no talk of fission: clearly she had not yet heard from Hahn and Strassmann.

It was natural that when he learned of fission from Bohr, Enrico take up the study of this phenomenon. For a while he told me what he was doing, how he had ascertained that during fission neutrons were emitted, opening the theoretical possibility of a chain reaction and the release of atomic energy on a large scale. In case of war, I was told in that politically uneasy spring of 1939, atomic energy might be used to propel warships: explosions were never mentioned in my presence. Soon a self-imposed secrecy fell on the work of atomic scientists, and my vacation from physics began. It was from here that I had to pick up the story from the Smyth Report.

The concept of a lattice pile of uranium and graphite was due primarily to the Hungarian Leo Szilard, a constant generator of ideas, and an experimental physicist "without hands" who would go to great pains to avoid using his hands. And so, when graphite and uranium began arriving at Columbia on a $6,000 government grant, it was Herbert Anderson and Enrico who set themselves to pile up the heavy materials, helped later on by the baseball team of the University. Throughout the years of research on the pile, scarcity of materials hampered the work. Huge amounts of graphite were needed, and of a purity never conceived before; of metallic uranium only a few grams were available in this country, and many of its properties had not yet been determined.

Slowly, painstakingly, the Columbia physicists studied the properties of uranium and graphite and the behavior of neutrons. Once enough material had arrived, they began building "small piles" that would not react but would yield much information about a large pile. Their results were so encouraging, that on Dec. 6, 1941, the government decided to make an "all-out effort" to produce atomic energy. The next day it was Pearl Harbor, and the decision became irreversible.

In the reorganization that followed, Arthur H. Compton of the University of Chicago became the director of all work on the pile: when the United States entered the war, Enrico, like the rest of our family, became an enemy alien. He could not be entrusted with the whole project, but he remained in charge of construction of the pile. Anderson moved at once to Chicago, where he began building small piles. Wally Zinn lingered in New York to wind up some experiments, and Enrico shuttled between the two cities. Soon all Columbia researchers, their materials, and their equipment were settled in Chicago.

The slow arrival of uranium and graphite kept on delaying work. But at last, by the end of October 1942, there was enough uranium and graphite of the required purity, and the final assembly of the pile began, in a large court under the West Stands of Stagg Field, the University stadium. The pile was assembled inside a "square balloon," a huge cube of rubberized cloth, one side of which could be left open. If necessary, a vacuum could be drawn from the balloon; the vacuum would decrease loss of neutrons to the air trapped in the porous graphite and improve the performance of the pile.

When Anderson went to place an order for the balloon, the people at the Goodyear Company were skeptical; they did not think that a square balloon would fly. Because of secrecy, Anderson could offer no explanations; but it was wartime and the order was accepted. In the end, the balloon proved unnecessary either for flying or for drawing a vacuum.

By the morning of Dec. 2, 1942, the pile was ready. Some 20 persons gathered under the West Stands, each given to his own reflections; but unfortunately not many of the thoughts were recorded. The most tense in the room must have been the "suicide squad," three young men perched on top of the pile, ready to extinguish it with a cadmium solution, should some-

LIST OF THOSE PRESENT AT THE "CHICAGO PILE" EXPERIMENT, DEC. 2, 1942.

H. M. Agnew	A. C. Graves†	G. Monk, Jr.	W. J. Sturm
S. K. Allison†	C. H. Greenewalt	H. W. Newson	L. Szilard†
H. L. Anderson	N. Hilberry	R. G. Nobles	A. Wattenberg
H. M. Barton	D. L. Hill	W. E. Nyer	R. J. Watts
T. Brill	W. H. Hinch	W. P. Overbeck	G. L. Weil
R. F. Christy	W. R. Kanne	H. J. Parsons	E. P. Wigner
A. H. Compton†	P. G. Koontz	L. Sayvetz	M. Wilkening
E. Fermi†	H. E. Kubitschek	G. S. Pawlicki	V. C. Wilson
R. J. Fox	(Mrs.) L. Woods Libby	L. Seren	W. H. Zinn
S. A. Fox	H. V. Lichtenberger	L. A. Slotin†	
D. K. Froman	G. Miller	F. H. Spedding	†Deceased.

thing go wrong. George Weil stood alone on the floor, for his was the task of manning the manual control rod that would regulate operations. All others took their places on the gallery around the pile, next to the Geiger counters and other instruments. Anderson was sleepy and grouchy: he had been up all night to put the finishing touches to the pile, and he could have been the first man to release atomic energy; but he had promised that he would not, and now the show was all Enrico's, who had slept well and soundly. By contrast, Zinn was unconcerned. He had been some kind of general contractor for the pile, placed orders for materials, supervised all phases of construction, and spurred on workers with his biting exclamations; he must have felt the relief of a job successfully completed. In her overalls and short hair, Leona Woods, the only woman in the room, was indistinguishable from the men.

Enrico began the experiment, explaining what he was to do in his calm, even voice, devoid of any excitement. He ordered Weil to pull out the control rod a little at a time, small step by small step, and at each step he read the instruments to interpret the behavior of the pile, checked it against his previous predictions, and calculated how the pile would behave at the next step. Each time the rod was pulled out a little, the Geiger counters clicked a little faster, the pens moved a little higher on the graphs, and tension mounted in the room.

At noon he broke the spell, saying "Let's go to lunch." He sensed that a respite was badly needed. The experiment was resumed in the afternoon at the same slow pace; but eventually the pile chain-reacted: for 28 minutes it released atomic energy, so quietly and smoothly that it decried the earlier anxieties. Then Weil pushed back the rod, and the pile was shut off. The Geiger counters stopped clicking and the pens came to a halt on the graphs. In the hush that followed, Eugene Wigner produced a bottle of Chianti wine which he had bought with great foresight before the war conditions drove all Chianti off the market. Everybody present drank a silent toast from paper cups; then they signed the empty bottle, thus providing the only record of the attendance.

Al Wattenberg picked up the bottle as a souvenir, and when, 10 years later, he found himself unable to attend the celebrations for the anniversary of the pile, he shipped the bottle from Cambridge, Massachusetts, to Chicago. He insured it for 1,000 pre-inflation dollars, a fact that brought the bottle into the headlines. An importer, grateful for the free advertisement, sent us and a few other scientists' families each a case of Chianti wine.

I pieced the story of Dec. 2, 1942, in many more details that I can relate here, from the same friends who in the evening of the same day refused to enlighten me: once secrecy was lifted, they were more than willing to talk. Each stressed what had impressed him mostly, but all agreed on one point: Enrico had been the calmest, the least tense of those attending the experiment. I may have been oversensitive, but it seemed to me that his friends hinted some reproach for his imperturbability during an experiment of that kind, conducted in a densely populated area. So I took up the question of risk with Enrico himself. He answered that he and his collaborators had taken accurate measurements and made all possible theoretical calculations. According to theory, an explosion was impossible and the release of lethal amounts of radioactivity almost as improbable. Yet they were dealing with the unknown and could not exclude completely that some unforeseen phenomenon might intervene to disturb the experiment. Hence the extreme precautions: the suicide squad with the cadmium solution; the automatic control rods; the gradual, circumspect extraction of the manual rod; and the verification, each time the rod was pulled out a bit, that the experimental results matched calculations.

This is how "The Italian Navigator reached the New World," in the code words used by Arthur H. Compton to inform James Conant at the other end of a long-distance telephone line. He found the natives very friendly.