Nukes – Early History

By John Benson

May 2025

1. Introduction

First of all, your author found a very interesting book about Nuclear Energy that is referenced here.[1] I've included a link to the Amazon site for this book in Reference 1 below. If any readers are former employees in this industry like your author, or are otherwise Nuclear Geeks, I believe that you would enjoy this book.

This paper will be about a tragic historical event that quickly bootstrapped the nuclear industry into existence, and remarkable early power reactors with a long list of firsts that were, and are a preview of future reactors.

2. WWII - The First Fission and Power Reactor

There were many breakthroughs in the 1930s that led to Nuclear Fission, but the first demonstration of fission was in 1938 in France and Germany.

In 1938, Irene Joliot-Curie and Pavle Savic, a Serbian scientist working in France, found lanthanum in the products of uranium that had been subjected to neutron bombardment. They recognized it had properties similar to lanthanum, but did not conclusively identify it as such. However, working with Frederic Joliot-Curie, they made one of the first determinations of the neutron mass.[1 2]

Late that year, Otto Hahn, a radiochemist, and Fritz Strassmann, a chemist, working at the Kaiser Wilhelm Institute in Berlin, used slow neutrons to irradiate uranium.

They showed that the minute amounts of new, lighter elements in the targets were barium, lanthanum, and other elements. These elements were about half the mass of uranium, thus demonstrating that atomic fission had occurred. They submitted a paper on their work to the journal Naturwissenschaften (The Science of Nature) on December 21, 1938; it was published on January 6, 1939.

The year 1939 continued to be a seminal one, as teams in France, Germany, and the United States were all able to demonstrate the emission of neutrons during the fission process and to conduct further work aimed at proving the possibility that a chain reaction could be sustained. Key work was accomplished by four groups in the three countries, including a team in France one in Germany and:

Two teams at Columbia University, one involving Walter Zinn, a Canadian, and the Hungarian Leo Szilard, and the other involving Enrico Fermi, with Walter Zinn. his associates Herbert L. Anderson, an American, and H. B. Hanstein (origins unknown). On January 25, 1939, the Anderson team conducted the first nuclear fission experiment in the United States. The Zinn/Szilard experiment began a few weeks later, on February 27, 1939. Their aim was to determine if the number of neutrons emitted during fission was sufficient to sustain a chain reaction.

---

[1] Gail H. Markus, Nuclear First: Milestones on the Road to Nuclear Power Development, © 2010 American Nuclear Society, https://www.amazon.com/Nuclear-Firsts-Milestones-Power-Development/dp/0894485768

[2] Irène Joliot-Curie was the daughter of Pierre and Marie Curie, the married couple that made many pivotal discoveries about radioactive elements, and the wife of Frederic Joliot-Curie.

The experiments successively demonstrated the net production of neutrons, and the scientists concluded that there was a possibility that the neutrons could produce a self-sustaining chain reaction leading to a very large release of energy.

The short story is that there were two applications for a fission chain reaction. One was a nuclear reactor, and the other was an atomic bomb. Since 1939 was at the beginning of World War II (WW-II), the latter was much more important. Also, note that one of the teams working on this development was in Nazi Germany. The latter fact made the Allied Teams realize that the race to develop the ultimate weapon was on. Note the French team moved to the UK when Hitler invaded France.

The Manhattan Project is an epic story that has been told many times, but you would like to read good and thorough renditions of it, go through the first link below. The second link is also a story of this project, is officially sanctioned and has additional resources.

https://en.wikipedia.org/wiki/Manhattan_Project

https://www.energy.gov/lm/manhattan-project-historical-resources

2.1. The First Nuclear Reactor

Shortly after 2 p.m. on December 2, 1942, in an abandoned squash court under the stands of Stagg Field Stadium at the University of Chicago in Chicago, Illinois, the ability to design and construct a self-sustained fission chain reaction was demonstrated. This demonstration opened up the possibility of developing reactor systems for practical applications, including the generation of electric power.[1]

2.1.1. The Rest of the Story

By the beginning of the 1940s, scientific research had demonstrated the existence of fission, as well as of the generation of excess neutrons in the fission reaction. These findings had opened up the tantalizing possibility that a chain reaction could be created and that, under the proper circumstances, it could be controlled. An outstanding team was assembled, including the renowned Italian physicist Enrico Fermi (Nobel Prize in Physics, 1938), who was then a refugee from Fascist Italy.

Other members of the team included scientists who were well known at the time and those whose research subsequently made their names well recognized, including Arthur Holly Compton (Nobel Prize in Physics, 1927), Hungarian-born Eugene Wigner (Nobel Prize in Physics, 1963), Glenn T. Seaborg (Nobel Prize in Chemistry, 1951), Hungarian-born Leo Szilard, Canadian-born Walter Zinn, Harold M. Agnew, George L. Weil, and many others.

*The work began at Columbia University, but, after the bombing of Pearl Harbor by the Japanese and the entry of the United States into World War II, was transferred to the Metallurgical Laboratory (or Met Lab) of the Manhattan Project at the University of Chicago. There, a "pile;' dubbed Chicago Pile No. 1 (CP-1) was constructed under the unused bleachers of a squash court in Stagg Field at the university. (The word **pile** was used to describe these early assemblies; the word reactor had not yet been applied.) The choice of location was somewhat driven by external events. The original plan to conduct the experiment in a forest reserve at Argonne, Illinois (Argonne National Laboratory had not yet been created), had been stymied by a labor strike.*

The pile used uranium oxide and uranium metal as the fuel and graphite blocks as the moderator. Detailed calculations were made to determine the quantities and placement of the uranium and graphite. For example, Fermi wanted to build the pile in as spherical a shape as possible to minimize the surface-to-volume ratio and, therefore, the leakage of neutrons. Holes were drilled in the graphite to hold the cylindrical uranium pellets. Ultimately, the pile grew to 20 feet in height, and was 6 feet by 25 feet on its sides. It consisted of 45,000 graphite blocks with 19,000 holes drilled into them for the uranium pellets.

The reaction became self-sustaining and operated for 28 minutes before Fermi ordered the cadmium-coated control rod to be inserted, stopping the reaction.

CP-1 did not produce any power, nor was designed to. But another reactor about a year later (November 4, 1943) did produce a tiny amount of power (a third of a watt) using a toy generator, but this was mainly an afterthought. This reactor's (X-10) primary purpose was to demonstrate the breeding of plutonium (see below).

There are two major isotopes of Uranium, U-238 and U-235. The former is much more abundant in natural uranium (99.3% U-238 and 0.7% U-235). Although natural uranium can be used for a reactor, it must use a very effective moderator. A moderator reduces the speed of fast-neutrons emitted by each nuclear reaction to slow- (thermal) neutrons suitable to initiate other reactions (and thus a chain reaction).

For instance, the CANDU Reactor (Canadian Deuterium Uranium) uses natural uranium for fuel and "Heavy Water (D_2O rather than H_2O (water), where "D" is deuterium, the second isotope of hydrogen) as a moderator and heat-transfer fluid. US Reactors use enriched uranium (to 3% to 5% U-235) for fuel and H_2O for the moderator and heat-transfer fluid.

Nuclear bombs and warheads use 90% enriched (90% U-235) uranium in a subcritical geometry that is compressed into a critical geometry by conventional explosives to initiate a nuclear explosion.

Back to plutonium. Plutonium is created by placing U-338 in a high-neutron-flux. The most effective way of doing this is to place it in a nuclear reactor. Thus, both the US and CANDU reactors "breed" plutonium from the U-238 that is the major constituent-uranium in the fuel. This can then be chemically reprocessed from the fuel and used for enrichment en-lieu of U-235 for either fuel or weapons. Plutonium is easier to manufacture and separate than U-235.

Of the two nuclear weapons the US dropped on Japan in WW-II, one used U-235 and the other used plutonium, and each was a completely different design (U-235: "Little Boy", and plutonium: "Fat Man")[3].

2.2. Prototype for Modern Nuclear Reactors

Although the reactor featured in this subsection was built on solid-ground, it was designed to test the most promising mobility application, which will be explored in the next subsection. No points for guessing what the mobility application is, because this reactor was named *Submarine Thermal Reactor (STR).* The reactor was a scaled-down, albeit otherwise typical pressurized light water reactor (PWR), and thus used H_2O for moderating the neutrons and transferring heat (cooling).

[3] https://en.wikipedia.org/wiki/Atomic_bombings_of_Hiroshima_and_Nagasaki

At 11:17 p.m. on March 30, 1953, the first reactor designed and built to produce power began operation. It was called the Submarine Thermal Reactor (STR) Mark I, and was a land-based facility designed to test the concept of using a reactor for submarine propulsion. It produced mechanical power rather than electrical power. It was also the first pressurized water reactor to operate.

In the early 1950s, the primary applications envisioned for the nascent nuclear technology continued to be military ones. The value of providing nuclear propulsive power to submarines in order to allow them to travel at high speeds for long distances and to remain submerged for long periods without surfacing resulted in the initiation of a program to develop a reactor suitable for the conditions a submarine required.

The Navy turned to pressurized water reactor technology to achieve its objectives. Because this was a new concept, the Navy decided to build a land-based version first. The government's Bettis Atomic Power Laboratory in Pennsylvania, operated by Westinghouse Corporation, developed the design. It was initially designated Submarine Thermal Reactor Mark I, but was renamed S1W (standing for Submarine Model 1 - Westinghouse). The reactor used an enriched uranium-zirconium alloy as the fuel. It started operation on March 30, 1953, and generated 15,000 hp.

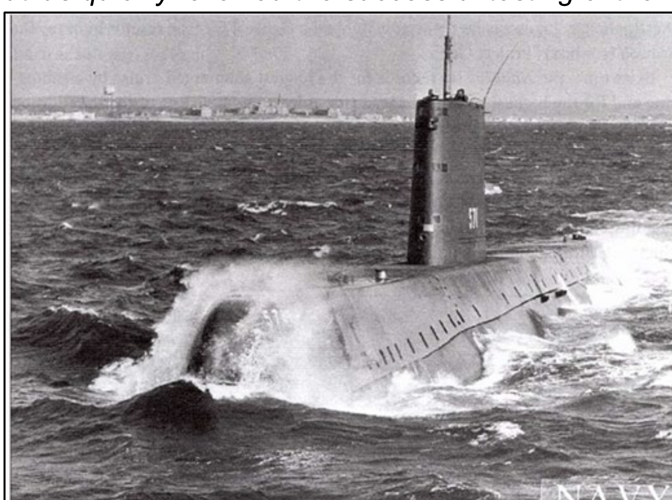
The above description of this reactor is typical of later generations of PWRs, including the manufacturer[4]. However, note that S1W did not generate power, only rotational torque. However, electricity production would only require adding an AC generator.

2.3. Mobility Applications

It was clear from the beginning that the primary mobility application for nuclear reactors would be military submarines. The big weaknesses of these weapons before nuclear power were (1) they were battery powered when submerged, and thus needed to surface to recharge frequently, and (2) they used mostly diesel power to recharge and for surface propulsion which requires air and frequent refueling. With nuclear power, these issues suddenly went away. The first nuclear submarine had a legendary name:

On January 17, 1955, the USS Nautilus put to sea for the first time under nuclear power, thus becoming the first submarine-indeed, the first vehicle of any sort-to be propelled by nuclear power. The launch of the Nautilus quickly followed the successful testing of the S1W reactor in 1953.

In fact, the submarine was under construction even prior to the initiation of testing of the S 1 W. Nautilus's keel was laid at the Electric Boat Division of General Dynamics in Groton, Connecticut, on June 14, 1952. President Harry S. Truman officiated. The Nautilus was launched on January 21, 1954, and commissioned on September 30, 1954. The vessel embarked on its first cruise on January 17, 1955.



USS *Nautilus* under way. (USN official photo #199068; courtesy of United States Navy.)

[4] https://westinghousenuclear.com/

The Nautilus was powered by an S2W reactor. This reactor was similar to the prototype S1W reactor, previously discussed, with minor design changes. It is reported that Admiral Rickover called the reactor "Project Wizard;' with the W standing for Westinghouse. Likewise, he reportedly dubbed a General Electric reactor built for the Seawolf (below) "Project Genie:'

At the time the Nautilus was built, the U.S. Navy was also experimenting with the use of sodium-cooled reactors to power submarines. In parallel with the Submarine Thermal Reactor program (described above) for pressurized-water-cooled reactors, a sodium-cooled Submarine Intermediate Reactor (SIR) was built at the Knolls Atomic Power Laboratory near West Milton, New York. The land-based SIR, also known as S1G (for submarine-prototype 1-General Electric), went critical on March 20, 1955. This design was tested in the USS Seawolf (SSN-575), the U.S. Navy's second nuclear-powered submarine.

The Seawolf (sometimes written as Sea Wolf) was launched on July 21, 1955, but due to problems with the reactor, did not begin its sea trials until January 1957. The submarine operated successfully for about two years with this reactor, but ultimately, the concept was dropped in favor of the pressurized water design. In December 1958, the reactor was replaced with a pressurized water reactor, and no further Navy vessels were built using sodium-cooled reactors.

Author's comment: For my first two jobs after college my employers were Rockwell Atomics International (1975-1977) and GE Nuclear (1977-1980). In each of these jobs I worked with some of the professionals that worked on the Seawolf program. It should be noted that Rockwell Atomics International and GE Nuclear were early pioneers in liquid metal nuclear reactors and test facilities. Although GE pivoted to Boiling Water Reactors (BWRs), as described below. Rockwell continued to develop the liquid metal concept via the reactor described in the next paragraph (albeit with unfortunate results).

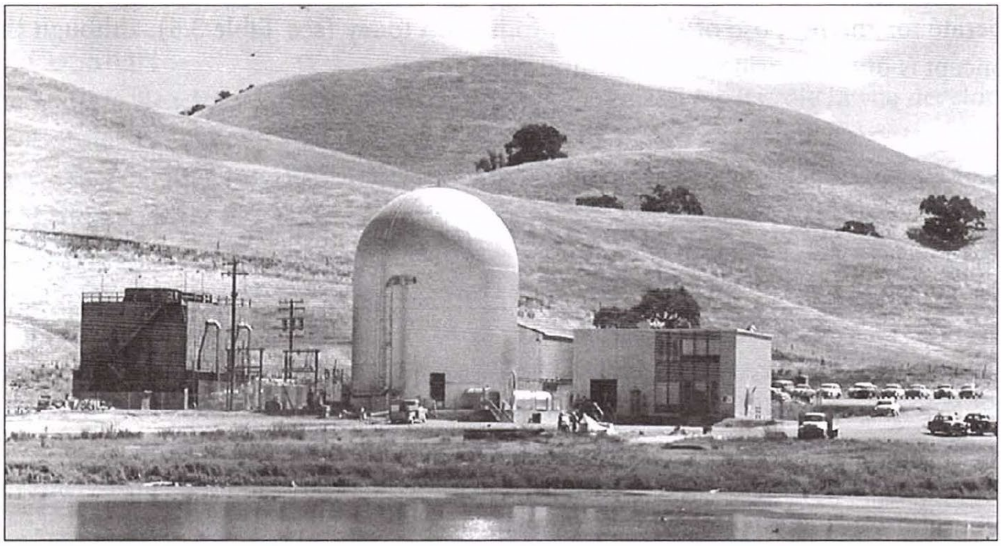
On July 12, 1957, the Sodium Reactor Experiment (SRE) at Santa Susana, California, became the first nuclear power plant in the United States to provide electricity to the public on a sustained basis. It was also the first liquid-metal-cooled reactor to provide electricity to the grid. The SRE was also the first power-producing reactor in the United States to experience a core meltdown accident.

Rockwell Atomics International's (RAI) Santa Susana Facility was in the hills between the San Fernando Valley (where RAI's main facility was), and Simi Valley (where I lived when I worked for RAI). It also hosted a Rocketdyne test facility where Rocketdyne was testing the Space Shuttle Main Engine at the time I worked for RAI. Rockwell – Rocketdyne was a sister-company to RAI and its headquarters were a few blocks away from RAI's HQ in Canoga Park, California.

2.4. The First Nuclear Power Reactor

Regarding my time with GE Nuclear, I spent about half the time at Vallecitos Nuclear Center (VNC) as a faculties engineer. VNC's primary reactor when I worked there was the GE Test Reactor (GETR, pronounced Jeeter). GETR mainly produced medical and industrial radio-isotopes. VNC also had a couple of older decommissioned reactors and one of them was Vallecitos Boiling Water Reactor (VBWR)

On October 19, 1957, the Vallecitos Boiling Water Reactor (VBWR) was connected to the grid and became the first privately funded nuclear power reactor to supply electricity to the transmission grid. It was also the holder of Power Reactor License No. 1-the very first operating license issued by the US Atomic Energy Commission for a power reactor.



Vallecitos Boiling Water Reactor (VBWR), Pleasanton, California. (Used with permission of GE Hitachi Nuclear Energy.)

VNC (including VBWR) is just over the hill (Pigeon-Hole Pass) from Livermore, where I lived then (late 1970s) and live now. VBWR is currently in the process of being demolished as I'm writing this. The reactor vessel has been removed from its containment and shipped for final disposal (see the text below). VNC will be completely decommissioned and taken back to grass.

NorthStar Group Services has announced that it has closed on an agreement to acquire ownership of the Vallecitos Nuclear Center from GE Vernova and GE Hitachi Nuclear Energy (GEH) for NorthStar's nuclear decontamination, decommissioning, and environmental site restoration.[5]

GEH and NorthStar announced in May 2023 their intention to transfer ownership of the 1,600-acre Vallecitos site, located about 40 miles east of San Francisco in Sunol, Calif. The Nuclear Regulatory Commission approved the transfer in April 2024.

The center was home to the Vallecitos Boiling Water Reactor (VBWR), which operated from 1957 until 1963 and was the first commercially owned nuclear plant to supply power to the general public. Several other test reactors, laboratories, and hot cell facilities are located on the site, and from 1965 through 1975 Vallecitos was used to conduct research work for the Atomic Energy Commission's Nuclear Energy Program and the civilian nuclear power industry.

[5] Nuclear Newswire, "Northstar closes on Vallecitos D&D Agreement," March 18, 2025, https://www.ans.org/news/2025-03-18/article-6858/northstar-closes-on-vallecitos-dd-agreement/

The deal: The deal structure, through which NorthStar becomes the NRC-licensed owner of the research reactor complex, is modeled on NorthStar's 2018 acquisition of the former Vermont Yankee nuclear power plant in Vermont. According to NorthStar, the decommissioning of Vermont Yankee is currently ahead of schedule for on-budget completion by 2026.

Since the deal was first announced in 2023, NorthStar has been active on the Vallecitos site continuing work begun by GEH, which included partial decommissioning work on the VBWR as well as on the site's GE Test Reactor and the ESADA Vallecitos Experimental Superheat Reactor.

In November 2023, NorthStar completed the removal of the VBWR reactor vessel from the center and shipped it for disposal to the facility operated by NorthStar affiliate Waste Control Specialists in Andrews County, Texas. As with its other ongoing nuclear decommissioning projects, NorthStar will dispose of additional low-level radioactive waste from the Vallecitos decommissioning at the WCS facility.

NorthStar has agreed to restore the Vallecitos Nuclear Center to conditions suitable for productive reuse for other commercial or industrial purposes.

2.5. The First Utility-Operated Nuclear Power Reactor

Although VBWR was privately owned and operated, and it first generated power in October 1957, there is another reactor that first generated power in December 1957, but has stronger credentials: Shippingport Atomic Power Station in Pennsylvania:

- VBWR was only 5 Mwe, and Shippingport was 60 Mwe, much closer to "utility-scale."
- Although Shippingport started out as a Naval project to build a reactor to power a carrier, the original project was cancelled, and later converted to a civilian power station operated by Duquesne Light Company, who also built the balance-of-plant part of the power plant (Stone and Webster, Dravo Corp. and Burns and Roe built the main reactor and generator).
- At the time the plant was completed (in 12 months), President Dwight D. Eisenhower participated in the opening ceremony, showing that, at the time, the plant was seen as a great development.
- VBWR was shut down after operating for 6-years. Shippingport operated for 25 years.
- Shippingport has been widely celebrated as being the reactor that launched the U.S. nuclear power industry.

2.6. The First Boiling Water Reactor

Arguably, the first nuclear power reactor in the U.S. was Vallecitos Boiling Water Reactor (VBWR), at Vallecitos Nuclear Center where I worked early in my career (well after VBWR was retired). See section 2.4 above.

Even while the Vallecitos operation was still in its early stages, General Electric contracted with Commonwealth Edison Company in Chicago to build the first large-scale, privately financed, utility-owned and -operated nuclear power plant. At the time, the U.S. Atomic Energy Commission was conducting a Power Reactor Demonstration Program (PRDP) to provide some support to early power reactor projects.[6]

[6] Gail H. Markus, Nuclear First…, See reference 1 for additional details.

A proposal was initially submitted for support from this program, but it was withdrawn before awards were made. GE and Commonwealth decided that, if nuclear power were to succeed in the United States, it had to operate as a private enterprise without government support. As a result, Dresden 1 was funded by Commonwealth Edison Company and a group of associated utilities, and by GE. It was the first plant to be built without any government involvement or financial support, making it the first truly private power plant. The project was a turnkey, fixed-price project.

The plant was located in Morris, Illinois, about 50 miles southwest of Chicago. Construction began in 1956. Dresden went critical in October 1959. It was connected to the grid on April 15, 1960, and reached full-power commercial operation on July 4, 1960. The initial net electrical output was 180 MWe, but in 1961, the power rating was increased to 210 MWe.

The reactor was shut down in 1978. Two other units, Dresden 2 and 3, were built on the site in 1970 and still operate today. Dresden 1 was designated an ANS Nuclear Historic Landmark in October 1991.