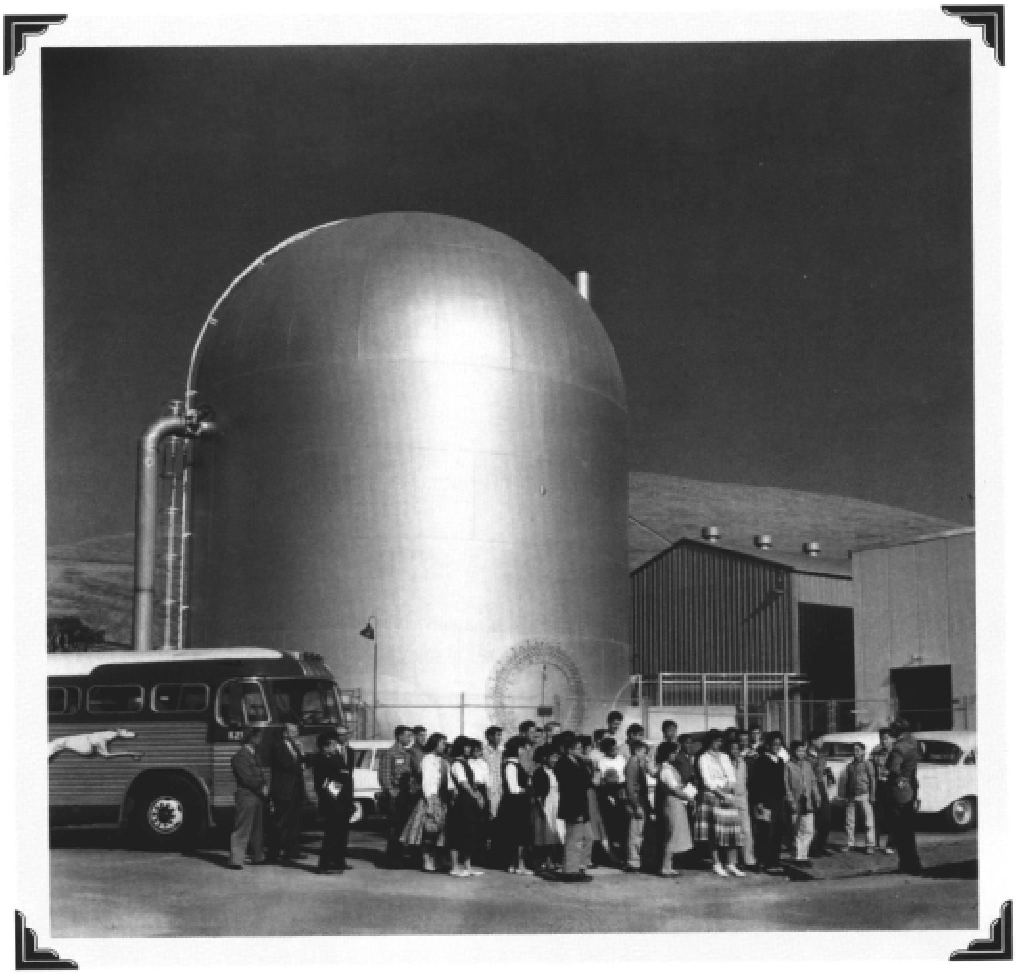
A N I N T E R N A T I O N A L M E C H A N I C A L E N G I N E E R I N G L A N D M A R K

the

VALLECITOS BOILING WATER REACTOR



Vallecitos Nuclear Center, Pleasanton, California

The American Society of Mechanical Engineers

Mt. Diablo Section **October 7, 1987**

Text of the plaque installed at the site:

INTERNATIONAL HISTORIC MECHANICAL ENGINEERING LANDMARK

VALLECITOS BOILING WATER REACTOR

PLEASANTON, CALIFORNIA

1957

THIS FACILITY WAS THE FIRST PRIVATELY OWNED AND OPERATED NUCLEAR POWER PLANT TO DELIVER SIGNIFICANT QUANTITIES OF ELECTRICITY TO A PUBLIC UTILITY GRID. DURING THE PERIOD OCTOBER 1957 TO DECEMBER 1963, IT DELIVERED APPROXIMATELY 40.000 MEGAWATTHOURS OF ELECTRICITY WHILE SERVING AS A VALUABLE TRAINING AND TEST FACILITY.

THE PLANT WAS A COLLABORATIVE EFFORT OF THE GENERAL ELECTRIC COMPANY AND PACIFIC GAS AND ELECTRIC COMPANY WITH BECHTEL SERVING AS ENGINEERING CONTRACTOR.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

1987

Historical Significance

The Vallecitos Boiling Water Reactor (VBWR), located near Pleasanton, California, was the first privately funded and constructed nuclear power plant to supply power in megawatt amounts to an electric utility grid. The reactor was issued Power Reactor License No. 1 by the U.S. Atomic Energy Commission. The plant had a capacity of 5,000 kilowatts. This was small compared to most other non-nuclear power plants, but tests conducted over the six-year life of this developmental plant helped pave the way for the large nuclear plants that followed.

The plant's construction was approved by General Electric Company's management in 1955, begun in 1956 and completed in 1957. The reactor went critical (that is, it achieved a controlled, self-sustaining reaction) on August 3,1957. It was connected with the utility grid on October 19, 1957.

From the time of its first operation until it was shut down on December 9, 1963, the VBWR helped to develop and test boiling water reactor fuel, core components, controls and systems. During its lifetime, it generated 391,000 megawatthours of thermal power and 40,400 megawatthours of electricity. It reached a maximum power level of 40 megawatts (thermal).

The plant was a valuable training facility for engineers, physicists, supervisors and operators. The VBWR represents a landmark in the development of practical nuclear power, and for this reason, it has been designated an International Historical Mechanical Engineering Landmark by the American Society of Mechanical Engineers.

Technical Background

From the time nuclear fission was discovered in 1939, scientists knew that fission (the splitting of atoms) released far more energy than common chemical reactions such as coal burning. Yet early nuclear reactors were built solely to produce plutonium (mainly for weapons) instead of useful heat or electricity.

To get useful heat from fission, nuclear engineers had to find ways to make uranium fuel stable at high temperatures. They also had to choose a suitable fluid to transfer the heat produced. They naturally considered the option of extracting heat from the fissioning fuel by boiling water, but this posed some tough problems.

Nuclear reactions are very sensitive to small changes in the geometry of the fuel and the moderator (the material that controls the speed of the neutrons) as well as to changes in temperature. Unless the water at the fuel's surface could be made to boil smoothly, vapor bubbles might form and collapse, which would cause geometric changes that could, at best, make the reactor hard to control. At worst, they could make it unsafe.

The concept of a boiling coolant had several enthusiastic supporters. Among them was Samuel Untermyer, who would play a key role in designing and building Vallecitos. He and other experts performed experiments to test this concept. The experiments included the BORAX test series which led to the construction of the Experimental Boiling Water Reactor at Argonne National Laboratory in Illinois. The soundness of using boiling water to cool reactors was demonstrated.

Interior of turbine-generator building.

In the early 1950s, Commonwealth Edison Company, in cooperation with Nuclear Power Group, Inc., signed a contract with General Electric Company and Bechtel Corporation to design and build the Dresden Nuclear Power Station, a generating plant with a capacity of 180 megawatts (electric), to be built in Illinois. After this contract was signed, G. E. began to design and build the Vallecitos Boiling Water Reactor (VBWR) to serve as a pilot plant for the Dresden project.

The Vallecitos reactor was designed with a high degree of operating flexibility for testing of various aspects of boiling water reactor operation, nuclear stability, alternative control systems, instrumentation, heat transfer, etc.

The VBWR plan was approved by General Electric's management in late 1955, and construction began in June 1956. Pacific Gas and Electric Company (PG&E) installed and operated the turbine-generator. The reactor first went critical on August 3, 1957. Early on October 21, the plant's licensed power of five megawatts flowed into the PG&E system.

It was possible to build this plant in such a short time in part because it was relatively small, but mostly because of the close cooperation of all concerned. The plant's cost was well below the original estimate. The VBWR and the whole Vallecitos Atomic Laboratory were built entirely with private funds—the first such facility to be privately financed.

Description of the Landmark

The VBWR is located at General Electric's Vallecitos Nuclear Center (formerly known as the Vallecitos Atomic Laboratory) near Pleasanton, California. The center included chemistry, metallurgy and physics laboratories, and a machine shop and other needed support facilities. The center also had a hot laboratory, which is a lab with heavy shielding walls and remotely operable tools for handling very radioactive materials. The reactor, pressure vessel, laboratories and much other equipment are still there as of 1987, but the fuel, turbine-generator, instrumentation and some other components have been removed.

The reactor is inside a pressure vessel with an inside diameter of seven feet, made from ASTM A212 Grade B steel and completely lined with Type 304L stainless steel. The vessel wall is 3-3/8 inches thick. The pressure vessel contains the reactor, coolant and control rods.

Nozzles were provided for control rod drive shafts, instrumentation and other piping, and four 12-inch nozzles in the vessel head allowed partial refueling without removing the head. The design safety valve setting was 1,215 pounds per square inch (psi), for a nominal operating pressure of 1,000 psi.

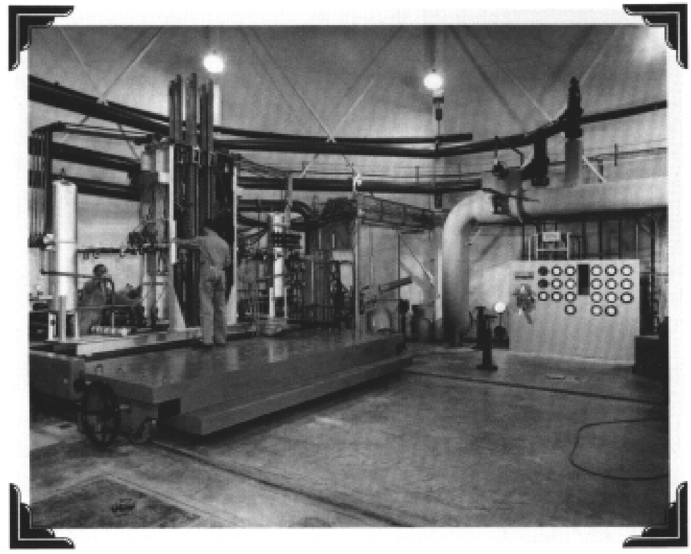
The first core was made up of 3-inch-square plate-type assemblies. Each plate had an active area of enriched uranium oxide dispersed in stainless steel 2-1/2 inches wide by 36 inches long by 0.015 inch thick, placed in a "picture frame" of pure stainless steel 0.015 inch thick. These were then placed between, and bonded to, 0.005-inch-thick sheets of stainless steel to make a completely clad fuel plate of 0.025 inch total thickness. These fuel plates were trimmed to 2.95 inches wide and 37 inches long, then spot-welded into slots in stainless steel side plates to make the fuel assemblies.

For flexibility in loading the reactor's core, these elements were made with varying amounts of uranium oxide, ranging from about 180 to 270 grams of U-235 (the fissionable form of uranium) per element. The original core loading had 101 of these plate-type elements.

The fuel elements and core plugs (used to prevent coolant flow through unfueled core positions) were supported by a stainless steel lower grid hung by four long bolts attached to the upper part of the pressure vessel. The upper, positioning grid was hinged so it would be easier to replace the fuel elements.

Seven control rods—long rods of neutron-absorbing material which are inserted into the reactor—controlled the rate of the reaction. These rods were made of 1/4-inch-thick boron-carbide plates encased in stainless steel. The active absorbing area of each rod was 12 inches wide by 3-1/2 feet long, except for the six-inch-wide center rod. Each rod was attached to a long shaft extending through a seal in the pressure vessel head to its control rod drive mechanism mounted on the missile shield above the reactor.

Each control rod was activated by a double-acting air cylinder with a piston attached to a corresponding control rod shaft. While



Reactor building showing control rod drives.

the reactor was operating, constant air pressure applied to the bottom of each piston drove the corresponding control rod up until its motion was limited when a stop attached to it met a corresponding motor-driven stop above it. Because the motor's force was strong enough to override the air cylinder's force, the position of control rods was determined by setting the upper stop to the desired position using the drive motor.

To rapidly shut down or "scram" the reactor, air pressure was removed on the bottom sides of all seven air cylinders and higher pressure was applied to their tops, driving all control rod shafts down and inserting control rods into the reactor core at a rate limited by air pressure and the inertia of the rods and drive shafts. After all control rods were fully inserted, the control rod motors automatically drove all of the upper stops down until they touched their mating stops on the control rod drive shafts. In this way, the operator was forced to begin restart procedures with the rods fully inserted in the core, ensuring safety.

The reactor in its pressure vessel is housed in a gas-tight enclosure: a 48-foot-diameter steel cylinder with hemispherical ends, 100 feet tall. About two-thirds of the enclosure is above grade. A four-foot-thick concrete floor at the grade level separates the reactor vessel, steam generator, pumps and piping from the upper service area. All pipes penetrating the enclosure have automatic quick-closing valves inside the enclosure wall, and manual valves outside.

The ventilation system had a capacity of 10,000 cubic feet per minute. Ventilation air, off-gases (such as oxygen, nitrogen and hydrogen) from the reactor system and steam from the dual-cycle generator were vented into the 75-foot-high stack next to the enclosure.

The enclosure also has a 20-ton polar crane covering the entire working area. Access to the enclosure is through either of two airlocks with three-by-five-foot doors.

The reactor is below the enclosure operating floor. Above the reactor at floor level is a 19-inch-thick steel radiation and missile shield weighing 80 tons and split into three parts, each rolling on rails. The control rod drive mechanisms are mounted on the center section of the shield. For refueling through the 12-inch head ports, only the outer shield sections were rolled back. The entire shield could be rolled back to remove the pressure vessel head.

The turbine-generator and its auxiliaries were in a two-story sheet-metal building next to the reactor enclosure. The turbine-generator was on the upper floor, with a condenser, condensate pumps and feedwater pump below. The turbine was a standard General Electric Type T-2 SE-A1 marine unit, slightly modified to accept saturated steam.

Interestingly, this turbine had already had two former lives. It started out aboard an American-built tanker that was leased to the Russians at the end of World War II. This ship, the Donbass III, was wrecked in a storm and some of its crew lost their lives. But the stern half floated and was salvaged, and PG&E bought it. PG&E beached the half-ship permanently in Eureka and adapted the still-intact turbine to produce power for local distribution. Later the turbine was adapted again for use in the Vallecitos plant.

A shielded room enclosed water treatment equipment such as demineralizers, filters, deoxygenizers and so on. The oxygen concentration in the condensate was reduced in a de-aerating hotwell before the condensate was sent to the water-treatment equipment.

A closed-circuit TV camera in the reactor enclosure made it possible to watch the control rod drive mechanisms, a panel of gauges and other above-floor components of the system while the reactor was operating. All other reactor control instruments were in a control room in a two-story office and control building next to the enclosure and the turbine building.

These instruments were concentrated on a five-section panel, with positions for a reactor operator and a turbine-generator operator. The panel in front of the reactor operator had a neutron-level indicator and recorder, indicating lamps for isolation valves, a viewing screen for the TV camera in the enclosure and controls and digital position indicators for each control rod. The control rods could be individually moved up or down by motor at six or 12 inches per minute, or they could all be inserted simultaneously at 40 inches per minute by motor or scrammed by air as described above.

The turbine-generator control instrumentation was nearly identical to that for a conventional fossil-fueled plant of similar size.

The pressure vessel from above, showing reactor control rods being inserted.

Operating Experience

Fuel loading of the VBWR began on July 30, 1957, with six-plate, 180-gram fuel elements. Criticality was reached just after midnight on August 3 when the loading had reached about 15 kilograms of U-235.

The next six weeks were spent calibrating control rods, trying different loading patterns and measuring temperature coefficients of reactivity and void coefficients. These tests were done before installing the vessel head.

The loading configuration selected for the initial operation at power was a 101-element core with about 22 kilograms of uranium. The excess reactivity for this core when cold and "clean" (unirradiated) was estimated at about 7-½ percent—about 2-½ percent less than the 10 percent total worth of the seven control rods. Tests had indicated a negative temperature coefficient of reactivity at temperatures above 100°F, and a strong negative void coefficient of reactivity under all operating conditions. In other words, there was no danger of runaway from a temperature excursion or partial loss of water from a fuel element if boiling did not occur smoothly.

After these low-temperature experiments, the vessel head was installed and preparations were made for power operation. The reactor was started on October 17. Power and pressure were gradually increased, and on the night of October 19 the generator was connected to the PG&E system. Two and a half hours later, the plant delivered its licensed power to the system.

Three weeks of testing and adjustments followed, after which the plant was ready for routine operation. The first Dresden-prototype fuel segment was inserted for irradiation on November 12, 1957. The Vallecitos Boiling Water Reactor had begun its six-year life as a test and training facility.

As a facility for irradiation testing of boiling water reactor fuel and structural materials, the VBWR was unique because its radiation environment (water at 550°F and 1,000 pounds per square inch) was identical to that in larger boiling water power reactors. Also, its operating schedule could be adjusted to the needs of engineers doing irradiation tests—something that couldn't be done at a utility power plant dedicated entirely to producing electricity.

During its lifetime, many changes were made to its structure and operating procedures. License amendments increased the power levels at which it was permitted to operate.

Radiation experiments that were carried out included the following:

- Dresden prototype element irradiations.
- Fuel elements irradiated for post-irradiation heat transfer analyses based on microscopic examination.
- Metal specimens irradiated to determine the effects of fast neutron radiation on fracture and tensile properties.
- Fuel specimens irradiated to study the fission gas release phenomenon.
- First known nuclear production of superheated steam in the Superheat Advanced Demonstration Experiment (SADE).
- Irradiations to study neutron reactions (transmutations).

When the VBWR was shut down for the last time on December 9, 1963, it had generated 391,000 megawatthours of thermal energy. Its generator had been connnected to PG&E for 16,614 hours and had delivered 40,400 net megawatthours of electricity to PG&E's customers.

Notably, the National Safety Council gave the plant an award for operating without a single lost-time accident. About 230 people received nuclear training and the Atomic Energy Commission issued more than 100 operator's licenses to operate the reactor. And finally, more than 30,000 visitors had viewed the plant.

The plant provided reliable performance data on boiling water reactor characteristics and operation, and it did much to demonstrate the safety of nuclear power.

References

The material above was obtained mainly from the following sources:

1. *Boiling Water Reactors* by A. W. Kramer (Addison-Wesley Publishing Co., 1958).
2. Report VAL-60, *Vallecitos Boiling Water Reactor* by L. Kornblith, Jr., S. Untermyer, L. Welsh and W. H. Nutting (General Electric Co. APED, 1958).
3. *Vallecitos Boiling Water Reactor: Operating History and Personnel Summary* by Pacific Gas and Electric Company.
4. Personal communications with, and reminiscences of, early VBWR personnel including J. C. Carroll, Earl Strain and the author of this brochure, Dr. M. B. Reynolds.

The ASME History and Heritage Program

The History and Heritage Landmark Program of the American Society of Mechanical Engineers (ASME) began in 1971. To carry out the landmarks program, ASME has a national History and Heritage Committee including mechanical engineers, historians of technology and the curator of mechanical engineering from the Smithsonian Institution. The committee performs a public service by examining, noting and acknowledging mechanical engineering achievements of particular significance.

The Vallecitos Boiling Water Reactor is the 24th International Historic Mechanical Engineering Landmark to be designated. Since the ASME program began, 121 landmarks, three heritage sites and one heritage collection have been recognized. Each reflects its influence on society, either in its immediate locale, nationwide or throughout the world.

An ASME landmark represents a step in the evolution of mechanical engineering. Site designations note an event or development of clear historical importance to mechanical engineers. Collections mark the contributions of a number of objects with special significance to the historical development of mechanical engineering.

The History and Heritage Landmark Program illuminates our technological heritage and encourages preservation of the physical remains of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers. And it helps establish persistent reminders of where we have been and where we are going along the divergent paths of discovery.

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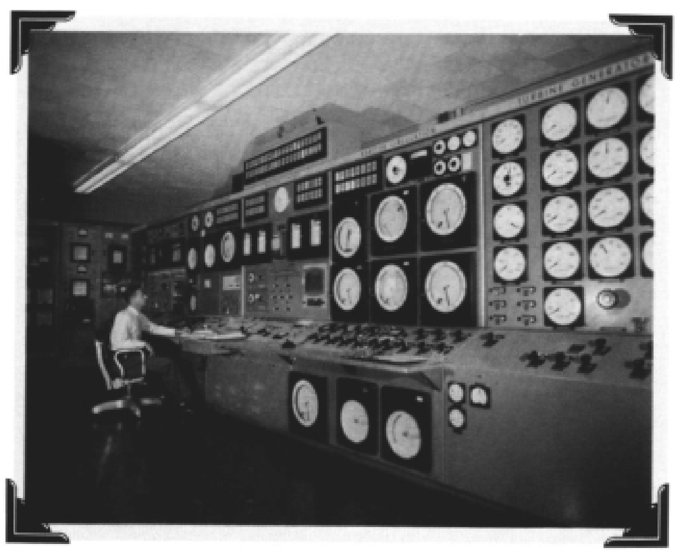

Reactor control panel.