Processes and Experiences at the Hanford Site
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Introduction

The Hanford site was revealed as a major nuclear site on August 9, 1945 when the atom bomb was dropped on Nagasaki, Japan. Before the announcement in 1945, one of the largest industrial/construction sites in the world had existed in wartime secrecy.

The Manhattan Project chose the Hanford site for plutonium production in January 1943. Construction of two large nuclear reactors and two reprocessing plants began shortly thereafter. The graphite-moderated reactors began operation in 1944. The first plutonium was separated in T Plant in 1945. The plutonium produced at Hanford was used for the first weapon demonstration in Alamogordo, New Mexico in July 1945.

Nuclear materials production continued at Hanford through 1989.

The area chosen for the site encompassed about 700 square miles on both sides of the Columbia River. In 1942, three horticultural communities were located along the Columbia River. White Bluffs and Hanford were two small horticultural communities located near the center of the site and on the west bank of the Columbia River. Hanford gave the site its name. This region west of the Columbia River was known as Hanford before the government began nuclear activities. The town of Richland was near the confluence of the Yakima River and the Columbia River. Richland and Hanford each had a population of about 500. White Bluffs was somewhat smaller. Several other very small communities were located throughout the site on both sides of the river. These communities had survived the depression and had entered into a period of relative prosperity due to the beginning of World War II activities.

Site residents were removed and Richland eventually became the bedroom community for the site.

The site had a history going back about 100 years. George McClellan, of Civil War history, passed through the area as an army surveyor in the 1850s. Ben Snipes, a cattle baron, started running his herds in Eastern Washington between the Canadian border and the Oregon border in the 1850s. The population slowly started to increase in the late 1800s when railroad lines were run through Eastern Washington. Irrigated agriculture began about 1890 in the Yakima valley and about the same time on the Hanford site.

Indigenous populations are assumed to have lived along the river since the last ice age. Glacial ice did not cover the site, but the site was covered by hundreds of feet of water at various times due to the cataclysmic Missoula floods.

Site Selection

The Hanford site satisfied several selection criteria and especially the three principal ones: 1) abundant water for reactor cooling, 2) abundant electrical power to support a large industrial site, and 3) relative isolation for security and safety.

Hanford also had the advantage of relatively low rainfall and a moderate climate. Construction was possible year around with little impact from the weather.

The site selection was made very soon after the decision to place Colonel Leslie Groves in charge of the Manhattan Project. Before his selection, the project had been mostly research and development. He immediately created an emphasis of design/construction and operations. This change was accomplished by hiring major corporations such as duPont, which was placed in charge of Hanford site work.

Nuclear Background

Groves had purchased the site that became Oak Ridge (Tennessee) in September 1942. That site would seek to enrich uranium as weapons material. Seaborg and Wahl had discovered plutonium in February 1941. By July 1941, plutonium was demonstrated superior to uranium as a fissile material. Enrico Fermi had been working with graphite and uranium to create a nuclear chain reaction. In December 1942, Fermi's reactor went critical. In January 1943, the Hanford site was acquired as the location to build reactors and produce plutonium.

Reactors

Nine production reactors were built at Hanford. Three started during World War II. B Reactor started operation in September 1944, which was less than 18 months from the start of design and construction. B Reactor was the world's first full scale reactor.

Three more were added through 1952. The KE and KW Reactors started operation in 1955. N Reactor started in 1963. The production reactors at Hanford were graphite-moderated with horizontal fuel tubes. The fuel used in the production reactors was aluminum-clad uranium metal until N Reactor was started in the early 1960s. The fuel used in N Reactor was zircaloy-clad uranium metal. Fuel was fabricated on site from uranium billets prepared off site.

N Reactor also provided steam for electricity production.

As the first production reactors, all the details associated with operation such as shielding workers from radiation had to be included in the reactor designs. Methods for handling the fuel before and after irradiation were developed. Irradiated fuel was discharged frequently because a relatively large amount of fuel is handled to support plutonium production as contrasted with electrical production.

The fuel was discharged into water basins. The water basins supplied shielding and were convenient for loading casks for shipping to the reprocessing plants. Remote methods and tools were developed for handling the fuel.

Fuel Reprocessing

Hanford used three reprocessing methods. Bismuth phosphate was the initial method. This method consisted of batch precipitation from dissolved fuel using multiple steps. T Plant and B Plant used this method. The plutonium was recovered, purified, and shipped off site. The separated uranium was not purified. The uranium was treated as a waste and transferred to underground storage tanks.

The second method used was the Redox process. This process used methyl isobutyl ketone (hexone) as the solvent in a continuous process. A significant improvement over the Bismuth phosphate process, the Redox process comprehensively recovered the uranium and plutonium.

Due to drawbacks of the Redox process, the AEC sites adopted the Purex process by the mid 1950s. The Hanford Purex plant began operation in early 1956. The Purex process uses continuous solvent extraction to recover and purify uranium and plutonium. The solvent is 30% tri-butyl phosphate in an organic diluent. The Purex process is the standard process that is used throughout the world for reprocessing nuclear fuel.

Uranium Recycling

Uranium recovered from spent fuel reprocessing was recycled for other uses including U^{235} enrichment.

The uranium discharged to the underground storage tanks by the bismuth phosphate process was recovered from the tank waste beginning in 1952. The recovery and purification were accomplished by tri-butyl phosphate solvent extraction.

Waste Management

Opponents' primary objection to the use of nuclear power is the lack of an acceptable waste disposal method. Waste management has always been a significant part (cost) for the fuel cycle. High-level waste is stored in underground tanks at Hanford. With the bismuth phosphate process, the volume of waste per ton of uranium was very large because several batch processes were needed and uranium was not recovered.

The Redox process recovered uranium and the amount of high-level waste per ton of uranium processed was significantly reduced.

The Purex process had high-level waste volumes much less than the previous processes. The Hanford Purex plant was significantly optimized over its operating life to reduce waste volumes and the volume of environmental effluents.

Fission Product Recovery

Various radioisotopes were produced and recovered for selected purposes from the earliest days of the site activities. Tritium, transuranic elements, and other isotopes were produced for defense, medical, and research purposes.

In 1967, fission product recovery took an enormous step change in scale when B Plant was converted to recover cesium and strontium from the high level tank waste. The purpose was to remove Cs^{137} and Sr^{90} from the tank waste to reduce the heat load on the high level waste storage tanks. After the spent fuel is out of the reactor for more than one year, virtually all of the radioactive heat is from cesium and strontium isotopes. After removal of the heat sources, the waste was concentrated to reduce the amount of space needed for waste storage.

The total amount of Cs^{137} and Sr^{90} recovered was well over 100 million curies. The recovered cesium and strontium were purified and double encapsulated for storage in water basins.

Fast Flux Test Facility

The Hanford site also had reactor testing facilities such as the PRTR (Plutonium Recycle Test Reactor). The fuel for this small reactor was plutonium to test the concept of completing the fuel cycle.

The next step was the exploration of the “breeder” reactor concept with the Fast Flux Test Facility, generally known as FFTF. FFTF operated during the 1980s. This reactor used sodium cooling and plutonium fuel. Plutonium-based fuels were successfully tested over a broad range of conditions.

Hanford Today

The size of the Hanford site has shrunk from 700 square miles to less than 600 square miles. Approximately one-half of the site became a national monument in 2000. Part of the national monument is managed by the Washington State Department of Fish and Wildlife. The other part of the monument is managed by the U.S. Fish and Wildlife Service. Most of the rest of the site is undergoing cleanup to remove or stabilize waste sites and to consolidate low level and nonradioactive waste into approved waste sites.

The Department of Energy runs its activities on the site through three major programs: 1) tank waste disposal, 2) site cleanup and waste disposal, and 3) the national laboratory.

In 1965, Hanford activities were diversified among several contractors. The research and development activities became the Pacific Northwest Laboratory. Today the lab is known as Pacific Northwest National Laboratory. Most of the laboratory work in 1965 supported Hanford-related activities including the development of the Fast Flux Test Facility. The laboratory is the largest single employer at the Hanford site. The laboratory activities are significantly diversified and support many programs that are unrelated to the Hanford site.

All of the major operating facilities were shut down by the end of the 1980s. B Plant and Purex were stabilized and deactivated. N Reactor and the other production reactors are going through a process that leads to a removal of all of the reactor facilities and buildings except the reactor core, which is cocooned. The exception is B Reactor, which was recently declared a National Historic Landmark. B Reactor may eventually become a museum as the world's first full-sized reactor.

The major activity on site today is the removal and disposal of waste from the underground storage tanks. The Waste Treatment Plant (WTP) is being built to receive the waste for vitrification. Construction started in about 2001. The various facilities that are part of the WTP complex are expected to start operating within the next decade. Based on the throughput capacity for the WTP, the plant will operate for over 30 years to process and vitrify all of the tank waste.

Other major activities located on the original Hanford site include the Energy Northwest power reactor, Areva's commercial nuclear fuel plant, and LIGO. LIGO is the Laser Interferometer Gravitational-Wave Observatory, which is operated by Caltech and MIT. A duplicate facility is located in Livingston, Louisiana. The purpose of the LIGO is to detect gravity waves.

Hanford Tomorrow

Accurately predicting the future of the Hanford site has not been possible in the last 70 years and will not be possible in the future. There are expectations. Most of the site is expected to be returned to pristine conditions in 50 to 60 years. A portion of the site, particularly the area around the tank farms, will be committed to nuclear waste storage or waste sites. These locations will need to be under administrative control indefinitely for up to 500 years.

Archeological evidence shows the western United States has undergone dramatic climatic changes in the last few thousand years. Prior to historic times, the Columbia River basin has seen some of the most dramatic and cataclysmic floods and geologic events that have been studied. The floods were the result of ice sheet formation and lake formation behind massive ice dams in what is now Montana and British Columbia. New ice sheet formation is not imminent. Fortunately, the recently active volcanoes in the Northwest are not close to the Hanford site.

The forces at work to determine the Hanford site future are similar to those in the battles that are fought daily over drilling versus not drilling for oil and using nuclear energy versus not. The Hanford site has been committed to the pristine versus the industrial as evidenced by the national monument designation. The irony is that if the Hanford site had not been committed to industrial production by the Manhattan Project, the site would be fully developed as a vibrant agricultural and industrial area much as all of the surrounding area is.

The Hanford nuclear activities actually created a false view of what the site was before and what it would have been. The only part of the Columbia River that is not backwater behind a major hydroelectric dam is the so called Hanford Reach along the Hanford site. As another example, a natural gas well existed on the site in the 1930s. Future drilling in a national monument will not be likely. The large elk herd on the site originated from a few stragglers that found the site during a bad winter in the early 1970s. However, elk are not natural to the site or even Eastern Washington. Elk were introduced into Eastern Washington near Yakima in 1913. No elk had lived in Eastern Washington for hundreds of years before that. Removal of the elk herd will not occur even though the herd would not exist if not for the nuclear reservation.

Since part of the site was designated a national monument, the uses for the site are going to be severely limited unless a national emergency occurs. Thus, the Hanford nuclear reservation has created a different paradigm for 600 square miles. The fate of the site is now controlled out of Washington, D.C., by the Washington State congressional delegation, and those intervener and special interest groups that have the ear of those in government.

Insights/Lessons Provided by Hanford

Hanford provided some of the most extraordinary examples of industrial deployment in human history. The initial reactors and reprocessing plants was constructed and started up in less than 18 months. This feat was accomplished even though no similarly-sized nuclear reactors or reprocessing plants had ever operated. The large projects that produced larger reactors and more complex reprocessing plants in the 1950s resulted in operating plants within 5 years.

Today large projects within the government purview require a decade or more to complete even while deploying existing technology. Over such timeframes, government priorities change and political will can be lost. The costs associated with such projects is very large when the inevitable projects changes and overhead costs are applied to the extended project period. Many projects controlled by the Department of Energy during the last several decades were not completed or produced “white elephants” that were not operated or did not operate as intended. The lesson that must be learned is that projects must be needed and must proceed with urgency. Shorter project schedules are more effective (even for complex projects).

Practically, operating plants are optimized after startup. All of the major facilities at Hanford went through significant improvements after startup. Many of the improvements and changes were driven by needs and requirements that occurred after startup. That introduces a philosophy that says that some flexibility needs to be built into the design of nuclear facilities. My experience with newer and ongoing projects is that an effort is made by the projects to provide a perfect facility design with few or no options for making modifications or changes after startup. Not allowing for post project modifications is a perfect way to build an inoperable or ineffective facility.

The amount of laboratory testing, equipment development, and pilot scale testing prior to the deployment of production facilities in the 1940s and 1950s was enormous. Multiple sites and laboratories developed the data and design information needed to support design, construction, and operation. The Hanford site alone had significant facilities for both radioactive and non-radioactive testing through the 1970s. Capabilities from test tube-scale chemistry to full scale equipment testing were available. Processes were demonstrated before deployment. Startups were generally successful and predictable. Laboratory and pilot scale work continued after facility startup to support optimization and modification efforts and new initiatives. Computer modeling is currently in vogue throughout industry. However, for deployment of more complex chemical processes and equipment, thorough development and testing at the appropriate scale worked at Hanford and will still be needed for future deployment of nuclear and chemical facilities.