Part 5
Making a Bomb
The Manhattan Engineering District

From the Einstein letter to the Manhattan Project

After reading Einstein's letter, President Roosevelt formed the U. S. Advisory Committee on Uranium, chaired by Lyman Briggs, head of the National Bureau of Standards. The committee immediately allocated Szilard and Fermi $6,000 ($100,000 in 2017 dollars) to buy uranium and graphite to continue their chain reaction experiments, but the money was not immediately forthcoming. Meanwhile researchers such as Ernest Lawrence were being financed by their universities and private donors. There followed a series of organizational changes that included the formation of the National Defense Research Council (NDRC), the National Academy of Sciences Review Committee and the Office of Scientific Research and Development (OSRD-S1).

Until Pearl Harbor, there was tepid enthusiasm for building a bomb, but that began to change at an OSRD-S1 meeting on December 6, 1941. After the U. S. was in the war, things moved ahead rapidly, with more funding and support. In late 1941, the estimated cost was $5,000,000 ($78,000,000 in 2017 dollars), but by May, 1942, the estimate had risen to $500,000,000 ($7,000,000,000).

By August of 1942, Roosevelt had put the army in charge of the project under the pseudonym, D. S. M., Development of Substitute Materials (The Manhattan Engineering District). By September, General Leslie Groves was in total control. It would still be four months before his previous project, the building of the Pentagon, was completed.

Separation at Oak Ridge

In September, 1942, one day after he took control of the Manhattan Project, General Groves visited Robertsville and Scarboro, Tennessee[1]; he was looking for a site for plants to produce U^{235}. The narrow valleys and steep ridges that were a hindrance to farmers, were ideal for General Groves. He could build a plant in one valley and a town in an adjacent one and if the plant exploded, the town would be spared; it was also far from the sea and the threat of enemy attack. By November, U. S. Marshalls were removing the residents and demolishing their homes. By Thanksgiving, Robertsville and Scarboro were gone and construction had begun on Groves's new secret city. Fences surrounded the entire 60,000 acres and work was started on the plants long before the town was complete. Armed guards patrolled the perimeter and everyone was checked as they entered or left through one of the few gates. The new industrial city had the homey name of The Clinton Engineering District. It would not become Oak Ridge until after the war.

[1] One of the first pioneers in the eastern Tennessee Valley between the Cumberland Plateau and the Blue Ridge Mountains was Collins Roberts who, in 1804, set up a rest stop on the coach road. The town of Robertsville grew and other surrounding towns followed, but the ridges were steep, the valleys narrow and the farms small. In addition, the towns of Scarboro, Wheat, and Elza were gathering places near the Clinch River with churches, a country store, but few houses. The area was isolated from worldly events until the early 20th century. All in all, there were about one thousand families in this corner of Tennessee.

Y-12 and the Calutron

Ernest Lawrence was the world expert in whirling charged particles around in magnetic fields. In the summer of 1941, Mark Oliphant convinced him to turn his 37-inch cyclotron into a mass spectrometer to sort and collect the different isotopes of uranium. This machine, now called a calutron for Cal University Cyclotron, first produced U^{235} five days before Pearl Harbor.

The first mass spectrometers operated in a vacuum and had very low production. The problem was that the charged particles repelled each other, thus dispersing the beam. This space-charge limitation was overcome when Lawrence realized that air molecules would resist the repulsion and create a less scattered beam. He made the adjustment and production went up dramatically. Eighteen micrograms[2] of U^{235} were collected in one nine-hour run in January of 1942, from a machine only a yard in diameter. Lawrence spent the year using the new 184-inch cyclotron to further research electromagnetic separation and build a prototype calutron. In June, before the model was complete or the details of the process worked out, the decision was made to put up a huge plant full of calutrons at Oak Ridge and ground was broken.

The electromagnets for the calutrons were enormous and used huge amounts of copper, which was in short supply due to the war, so it was decided to use silver instead. Colonel Kenneth Nichols, second in command of the Manhattan Project, calculated they would need 6,000 tons of silver and the only place to find that much was in the U. S. Depository in West Point, New York[3]. He met with the Under Secretary of the Treasury. “Young man, you may think of silver in tons, but the Treasury will always think of silver in troy ounces.” “How many Troy ounces is that?[4]” In the end, over thirteen-thousand tons of silver were used at Oak Ridge. It was returned to the treasury after the war.

Calutrons were the only method of separation that was producing results, so even though they were more costly, both to build and operate, they went into production in November, 1942. The first ones were delivered to the site in January, 1943 and in February, the land was cleared for the gigantic Y-12 calutron plant. The project proceeded so quickly, warehouses had to be thrown up to store the train-loads of equipment arriving weekly.

Unlike gaseous diffusion, electromagnetic separation significantly concentrates U^{235} in one operation. To enrich uranium to the eighty-five percent needed for a bomb, required two stages, and thus two types of calutrons, one feeding the other. One type, the alpha produced fifteen percent enriched uranium, while the beta produced weapons grade material. Numbers of each type were arranged in an oval configuration called a racetrack; ninety-six alpha units in one building and thirty-six beta units in another.

Early problems were severe and required the calutrons to be completely rebuilt but, despite the setback, all units were operating and producing bomb-making material by June, 1944. It was found that the highly-sophisticated isotope separators were best operated by young women who had just graduated from high school. They were trained like soldiers, to respond without thinking, and would carefully move the controls to adjust the calutrons for optimal production. If college-educated male physicists did the job, they would be experimentally tweaking and constantly wondering how they could make the process more efficient. A production race was held which the Ph.D.'s lost. By the winter of 1944-45, with the "calutron girls" at the controls, all the units were humming along at peak efficiency.

[2] One microgram is one millionth of a gram.

[3] The silver was backing for the silver certificates printed by the Treasury.

[4] One ton equals 29,167 troy ounces. The 13,300 tons of silver used equals 430,000,000 troy ounces.

K-25 and Gaseous Diffusion

Separation of isotopes by gaseous diffusion is very difficult. Oxford's Franz Simon built a plant in Liverpool designed to produce 1 kilogram of U^{235} per day but it never did so; the problem was the holes.

Gaseous diffusion is based on the law that gases of different weights scatter at different rates, but with uranium, this difference is very small. The process relies on the size of the extremely-tiny holes in a nickel membrane separating the enriched product from the feed stock. Not only did the holes need to be very tiny, they also could not plug up. Until the scientists could find the correct hole size, the diffusers would remain incomplete. Even though the process was not workable, Groves started construction of an enormous building to house a gaseous diffusion plant. On January, 16, 1944, with the enrichment of uranium at still less than fifty percent, they could not wait for improvement and Groves gave the green light to the latest nickel barrier.

Thousands of diffusion cells were required, each the size of a Volkswagen and each with several pumps and motors. The building that housed all this equipment, K-25, was the largest ever constructed. The fifty-percent-enriched product would then be fed into the beta calutrons at Y-12 for the final concentration to bomb-grade. The old town site of Wheat completely disappeared under the roof of K-25.

Another secret city was necessary to house the workers needed to build K-25. Named Happy Valley, it was started in the summer of 1943 and included a school, churches, a bakery, eight cafeterias, three recreation halls; it housed 15,000 people. After the plant was completed in 1944, the entire town was demolished. As at Y-12, construction of the building started before the final design of the equipment was complete.

Like the calutrons, the gas diffusion units were complicated machines. They operated in a partial vacuum so all the piping had to be air tight. With such tiny holes, cleanliness was critical and the workers wore white, lint-free gloves. By April, 1944, enough pipes and wires had been installed in the first section so that testing could begin.

The uranium hexafluoride gas, which was used as the feed stock, was produced on site and required a large warehouse for storage. A pump house and a bank of cooling towers near the river was dedicated to the K-25 plant. There were also testing laboratories, an instrument repair facility, buildings of changing rooms and a fire station. There were separate eating areas and bathrooms for white and black workers.

At start-up, the enrichment by gaseous diffusion was only 1.1 percent per stage, but due to the enriched feed stock provided by S-50, a thermal diffusion plant built in 1944, by June it was seven. By March, 1945, enriched uranium from K-25 was flowing to the calutrons at Y-12. All the highly enriched uranium used in the bomb dropped on Hiroshima was produced at S-50, K-25 and Y-12.

The precious grams of U^{235} were stored in a concrete bunker near a white farmhouse on the edge of the Clinton Engineering reservation. Cattle grazed nearby and a tall silo housed a machine gun nest to guard the treasure.

Hanford and Plutonium

After Wigner's ceremonial bottle of chianti had been finished, and the paper cups thrown away, Fermi got back to work on CP-1. The first nuclear reactor produced only one half watt of power, but by the end of the week, it was chugging along at 200 watts. As there was no shielding or cooling, the power was soon reduced.

CP-1 was dismantled and moved to Red Gate Woods along Route 66, twenty miles southwest of Chicago in what became the Argonne National Laboratory. The reactor now had concrete shielding and ran at a few kilowatts year-round; a heavy water moderated reactor, CP-3, started operation in 1944. These were small research reactors, but Groves needed a larger pile to learn how to produce plutonium. A graphite-moderated, air-cooled natural uranium reactor designated X-10, was built at Oak Ridge. The forerunner of the huge reactors that would provide the plutonium for atomic bombs, X-10 was a thousand times more powerful than the Chicago piles and was used to research production and train operators.

Those at the highest levels feared the German bomb so greatly that they chose to take one of the largest gambles in modern history, to pursue both the enrichment of uranium and the production of plutonium simultaneously. Tens of thousands of workers were hired, and construction begun on plants at both Oak Ridge and Hanford, Washington, before it was known if their processes would work. The Manhattan Project had the highest priority in the nation and the strictest security, but no one was sure it would produce a bomb.

In December, 1942, thirty-four-year-old Colonel Franklin Mathias visited an isolated site along a bend in the Columbia River in central Washington. Because of the unknown dangers of the new atomic reactors and their by-products, he was looking for a site far from population centers. The land was desert, with no roads or railroads and no one lived there, well almost no one. He decided this was the place for the plutonium plant.

In the spring of 1943, with a full crop of fruit growing on the trees, the farmers in the small towns of Hanford and White Bluffs were given thirty days to leave[5] and a new town of 50,000 sprouted in their place, with houses, stores and gas stations, school teachers, police and firemen, churches, bars and, most likely, brothels. Among the families there were births and deaths, parties, arguments and infidelity, joy, drunkenness, and sorrow, but the construction work went on, three shifts a day.

The Army took over the nearby town of Richland and it became a closed community; only those working on the project could live there. Like Oak Ridge, there were fences, gates, armed guards, mail censors, and plain clothes FBI agents. In 1957 the federal government returned jurisdiction of Richland to the residents.

Isolation and the constant wind, sand and dust were the curse of Hanford. Unusually-high “termination winds” drove many to quit. DuPont, the company that built the town, provided good food, high pay and a recreation hall with big-name bands as an incentive to retain a workforce; journeymen with families were especially prized.

In the summer of 1943, construction started on three huge nuclear reactors, their only purpose to produce plutonium[6]. First completed, was B reactor, a fifty-foot-tall pile of graphite honeycombed with uranium-filled tubes. Every minute thirty thousand gallons of cooling water was instantly heated from 50° to 190° F.; the heat produced was dissipated into the Columbia River. Whereas the first Chicago pile operated at two hundred watts, Hanford's B reactor ran at two hundred and fifty million.

Once operational, uranium slugs encased in aluminum filled each of the two thousand tubes. After six weeks of intense neutron bombardment, they were pushed out the other end by a new charge, and fell into a pool of water. A series of isolated concrete pits, known as canyons, with walls from three to seven feet thick processed the two-hundred-ton loads of radioactive material. Periscopes, remotely-controlled cranes and isolated pumps and centrifuges were necessary as the cans contained not only uranium and now, plutonium, but a myriad of very radioactive fission by-products, to which no one expecting a long life could be exposed.

Maintenance or repair of the machinery was impossible. Once the spent fuel had been dissolved, precipitated and centrifuged over and over, pipes carried the plutonium-bearing liquid to another building. At this point, it was 100,000 times less radioactive and could be handled without the extraordinary precautions of the canyons. The dissolving, precipitating and centrifuging continued until the plant produced its end-product, plutonium nitrate paste.

In February, 1945, the bomb-making scientists were desperate for plutonium, so Colonel Mathias personally carried the first shipment from Hanford to Portland and on to Los Angeles by train. The Army officer who would take it to Albuquerque and hence to Los Alamos, New Mexico met him at Union Station. The officer had no idea what he was transporting and stated he would sleep in an upper berth on the train.

Mathias then calmly explained that the shipment was very valuable, “Well, it cost about three-hundred-million dollars to make it.” The officer quickly decided to get a compartment with a locking door. By April, bomb making material left every five days, transported in an Army ambulance accompanied by armed guards.

It had taken less than fifty years to go from the toil of the Curies, the wood and wire of Rutherford and the tabletop experiments of Fermi and Hahn and Strassman, to nuclear reactors, gaseous diffusion plants and calutrons, but by 1945, America was ready to build an atomic bomb. Now it was up to the scientists at Los Alamos to do so.

[5] The compensation for losing their homes was not paid until years later.

[6] As they produced no steam or electricity, power for the project had go come from nearby Grand Coulee Dam.