EASTMAN KODAK & THE MANHATTAN PROJECT

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Today I'll do my best to take us back almost sixty years. It was in February of 1943 that I began working for the Manhattan Project. "Manhattan Project" was the code name that the War Department gave to the project of developing and producing an Atomic Bomb. Secrecy about all phases of the atomic bomb project was kept at the highest possible level. For example, the word "Uranium" was never used. The word that was substituted for Uranium was "Tuballoy." That word meant something only to those persons who had a real need to know what it meant. Plant operators, mechanics and many supervisors saw the word in Operating Procedures and heard the word used in conversations and verbal instructions without having the slightest idea of what it really meant. All that was a long time ago, so today we will use the word Uranium, and I hope I don't stutter using it.

The Manhattan Project had three major sites. They were:

1. **"The Clinton Engineer Works" at Oak Ridge, Tennessee, where all work on producing Uranium-235 was done. The number associated with Uranium is the "atomic weight" of that particular atom.**

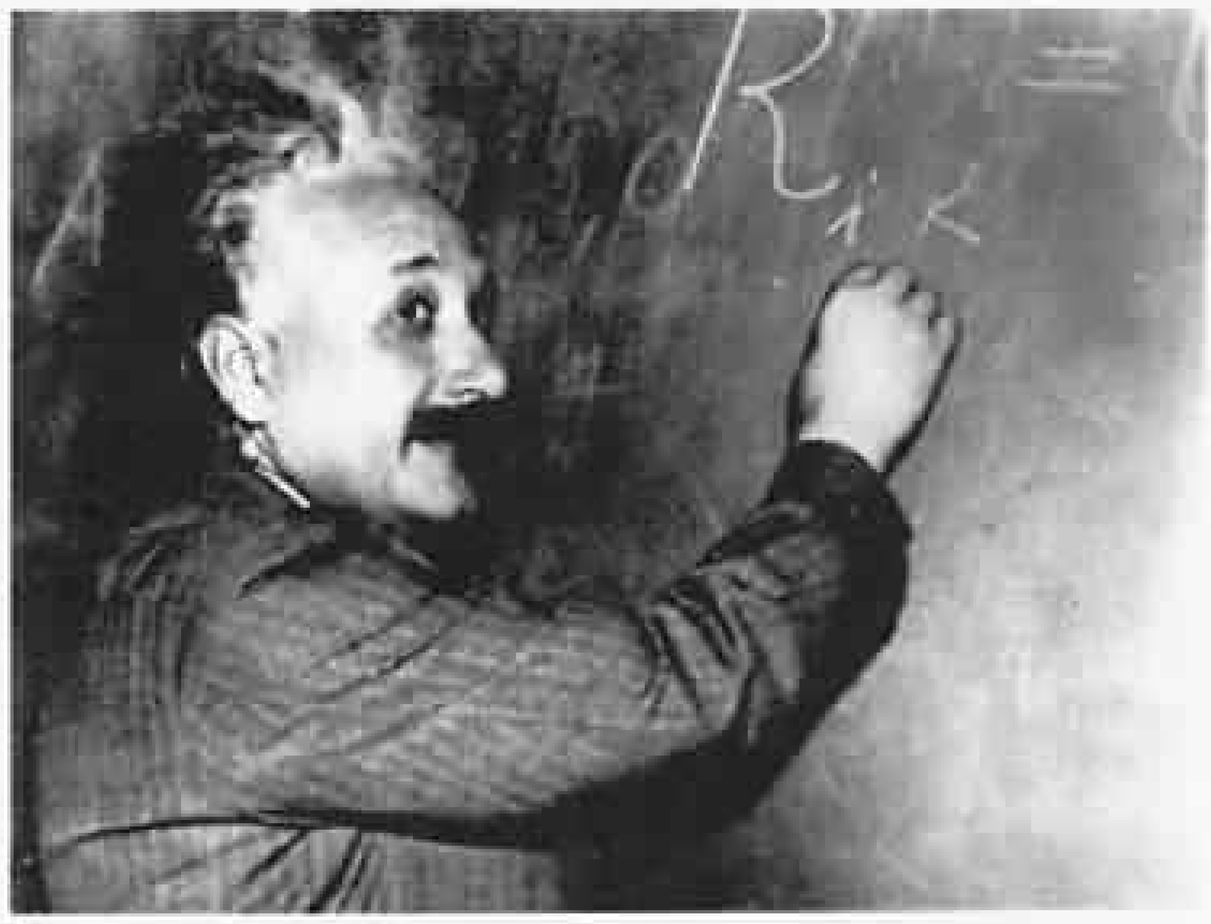
2. **"The Hanford Engineer Works" at Hanford, Washington, where all work on the production of Plutonium, was done.**

3. **"The Los Alamos Laboratories" in New Mexico, where all the work on the design and fabrication of the Atomic Bomb took place.**

Today's presentation will start with a short review of the events that culminated in getting the possibility of producing an Atomic Bomb to the attention of the President of the United States.

THE DISCOVERIES OF ATOMIC STRUCTURE AND FISSION

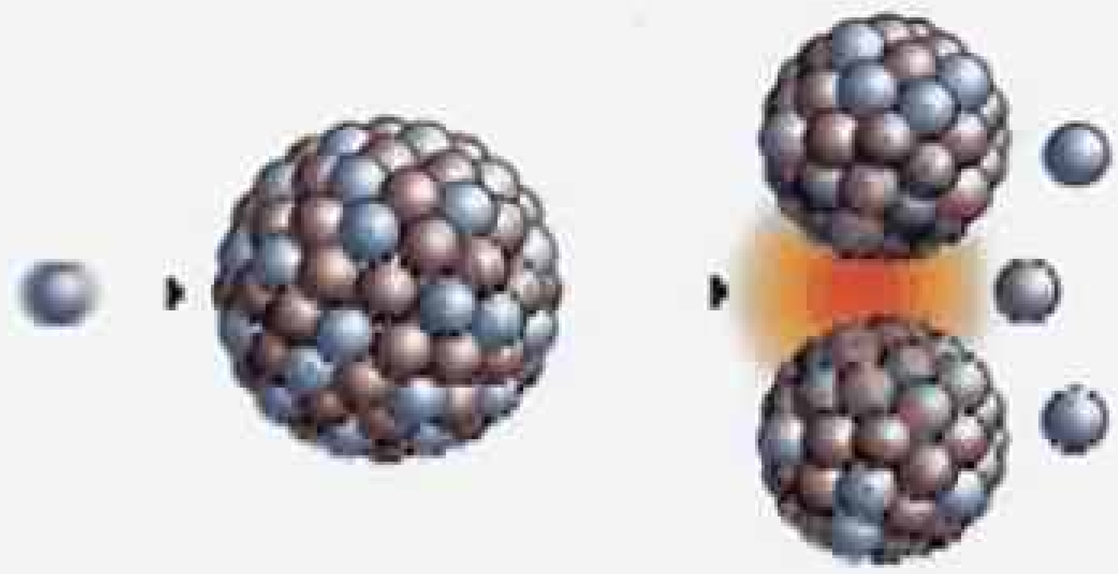
The story of the Atomic Bomb started in 1905 when Albert Einstein, a German physicist-mathematician, developed the "theory of relativity." Without any experimental facts, and I mean absolutely none, Einstein reached the conclusion that energy can be converted into mass and mass can be converted into energy. Einstein concluded that the amount of energy, E, equivalent to a mass, m, was given by the equation: $E = mc^2$ where c is the velocity of light (186,000 miles per second). At the time that Einstein published his theory in 1905, it attracted little attention. To most physicists the theory appeared to be a lot of mathematical fiction and of no practical use.

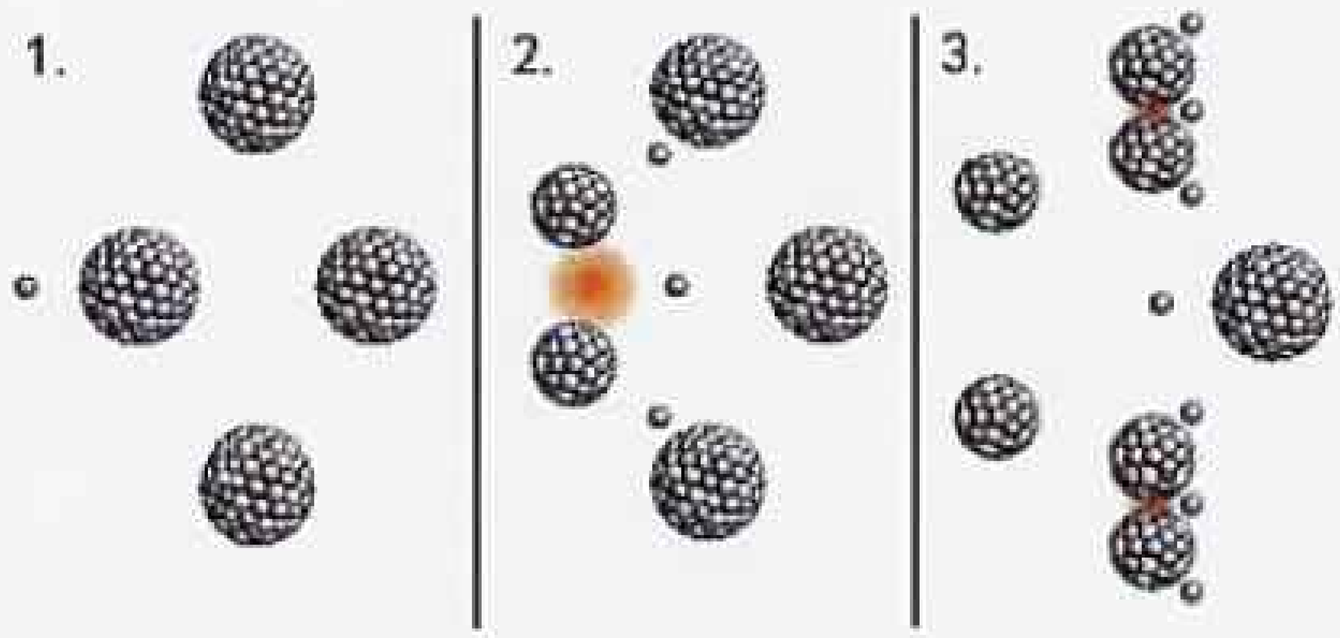


In 1911, physicist Ernest Rutherford made a discovery that led to the theory that the energy in matter was largely stored in the nucleous of atoms, and by the late 1930s evidence that Einstein's theory was real began to appear. Leading physicists in the free-world recognized the possible importance of this knowledge to war efforts in the future. Largely because of the novelty of the work, however, these physicists were unable to get the attention of our countries leaders or to get support for additional work to bring their theory to actual practice.

In January 1939, Professor Niels Bohr, who had escaped from Germany to Denmark, visited the United States. Here he talked with Professor Albert Einstein, who had also fled Germany and was living and teaching in Princeton, New Jersey.

During the visit they discussed an interesting phenomenon. At the time it was known that all matter was made up of atoms, which in turn were made up of electrons, protons, and neutrons. What Dr.Bohr had observed was that when Uranium was bombarded with neutrons some of the Uranium atoms were split into two particles. Dr. Bohr named this process "fission." Further work showed that fission of Uranium occurs only with U-235 and not with the much more common U-238.





Uranium ore contains only about 0.7% U-235. We should also note that when Uranium-238 adds a neutron to its nucleous, Uranium-239, or neptunium, is formed. Neptunium transforms almost completely into Plutonium in about two days. During fission if more neutrons are formed, than are used up or lost, a "chain reaction" can occur. In a chain reaction the number of neutrons generated and the number of U-235 atoms split can increase at an extremely rapid rate.

By the year 1939, or just before the start of WWII, nuclear physicists had all of the theoretical information needed to produce atomic bombs.

THE FORMATION OF THE MANATTAN DISTRICT

Now lets review how the Manhattan Project came about, and the effect that it had on the development of the atomic bomb.

In the fall of 1939 two physicists, Szilard and Wigner, conferred with Albert Einstein about how to gain the governments interest in fission. A short time later, the three of them *discussed the possibility of producing an atomic bomb with businessman Alexander Sachs of New York. Mr. Sachs was a highly thought of financier and a friend and economic adviser of President Roosevelt. By chance Mr. Sachs had an amateurs interest in atomic physics and he had read everything on the subject that he could find in the literature.

In the picture Mr. Sachs is shown on the left, along with General Groves.

The group told Mr. Sachs that Einstein's "Theory of Relativity" showed that the conversion of only one kilogram of mass to energy would produce over 25 billion kilowatts of electrical power. This is more energy than could be developed in one year by the entire electric-power industry in the United States. Let's think about that for a moment. Something that weighs only 2.2 pounds can develop more energy than all of the power plants in the United States can generate in a whole year. Furthermore, they told Mr. Sachs that they believed that the energy from a chain reaction could be released in a bomb, and that Germany was already working on the project at their Kaiser Wilhem Institute. Such a bomb would have an explosive force many times that of TNT.

Then, on October 11, 1939, with the support of a letter written by the two physicists, and signed personally by Dr. Einstein, Mr. Sachs went to President Roosevelt and reviewed with him what he had learned. The President proceeded to immediately set up and fund a committee known as "The Advisory Committee on Uranium." From a security standpoint that wasn't a very smart name, and the committee was soon renamed to the "S-1 Executive Committee."

About two years later, in May, 1942, not long after Pearl Harbor (December , 1941), the S-1 Committee met to discuss in detail the status of the processes for producing materials that could be used to make an atomic bomb. The committee consisted of the following people:

J. Robert Oppenheimer
Harold C. Urey, Nobel Prize laureate
Ernest O. Lawrence, Nobel Prize laureate (developer of the Cyclotron)
James B. Conant, Head of the S-1 Committee
Lyman J. Briggs, Director of the National Bureau of Standards
Eger V. Murphree, Standard Oil Company
Arthur Holly Compton, Nobel Prize laureate
Robert L. Thornton
Kenneth D. Nichols, Colonel US Army

As you can see this is a list of distinguished people.

An all-day discussion followed, but nothing was settled. The committee did agree that "we were probably well behind the Germans," and that even a small delay in our work could be disastrous. Then they selected the three processes that appeared to have the best chance of success.

The most promising processes were—(not in any order of preference):

1. **<u>Gas Diffusion Process for Producing U-235</u>—In this process Uranium Fluoride gas is passed through a long series of metal sheets, each of which contains millions of very small and very uniform holes. Since U-235 ions are slightly smaller than the heavier and larger U-238 ions they pass through the tiny holes in the metal barriers more readily and become concentrated.**

2. **<u>Plutonium</u>—You will recall that earlier we saw that when U-238 absorbs a neutron, U-239, which is Neptunium, is formed. Neptunium degrades over a period of several days to Plutonium. Unlike U-235, Plutonium can be separated chemically from other forms of Uranium. The hope was that the chemical separation would be easier to do than to concentrate the rare U-235 by physical means. Unfortunately the Plutonium is contaminated with a small amount of an isotope, and we will discuss this disadvantage when we talk about the design of atomic bombs.**

3. **<u>The Electromagnetic or Cyclotron Separation Process</u>—This process is the most difficult to describe in a simple way. Rather than giving you a scientific explanation, we will just use a simple analogy.**

   Let's assume that we have two balls and that one ball is slightly heavier than the other. Now we will attach the balls to identical rubber cords and swing the balls around our head at equal revolutions. I think that we can agree that the heavy ball will circle slightly farther out than will the light ball. Likewise, in a constant magnetic field the heaviest particle (U-238) will circle slightly farther out than the lighter particle (U-235). Therefore, with proper positioning of the collector vessels the lighter U-235 atoms can be separated from the heavier U-238 atoms.

<u>At the end of that long days meeting the S-1 Committee then made one of the boldest decisions of the entire war.</u> All three processes were still in the laboratory stage of development. None of them offered the certainty of success. They could not determine the best process to commercialize. Then they agreed that all three processes should be built simultaneously on a commercial scale. They were confident that the first country to have an atomic bomb would quickly win the war, and that we shouldn't take the time that would be needed for normal development work to be done.

When their recommendation was sent to the White House, President Roosevelt quickly reviewed the committee's recommendation, and in one corner marked: "OK, FDR."

With that the "Manhattan District" was formed, and was given the job of producing an atomic bomb. Brigadier General L. R. Groves of the Corps of Engineers was placed in charge of the entire project. Dr. Oppenheimer was selected to lead the Los Alamos Laboratories at Los Alamos, New Mexico. That Laboratory was responsible for the design and fabrication of the Atomic Bomb.

ASSIGNMENT OF PROCESSES TO COMPANIES

It was obvious that the operation of the three projects that had been selected would require more technical personnel than any one company could provide. So each of the projects was assigned to a major American company. They were:

1. **Union Carbide Co.—the Gas Diffusion Process.**
2. **Kodak's Tennessee Eastman Co.—the Electromagnetic or Cyclotron Process.**
3. **DuPont Co.—the Plutonium Process.**

Today we will concentrate on the Y-12 Electromagnetic, or Cyclotron, Separation Process. The Tennessee Eastman Co. used that process to produce the U-235 for the bomb dropped on Hiroshima. Y-12 was the only facility that produced any bomb grade Uranium-235 during the war. Also, by producing a substantial amount of bomb grade material by over a year before anyone else produced bomb grade material, we enabled the physicists at Los Alamos to get a jump-start on designing the Uranium-235 and Plutonium bombs. The two bombs required entirely different designs. We will discuss the design of the bombs later.

EASTMAN KODAK COMPANY INVOLVEMENT WITH THE MANHATTAN PROJECT

Now lets review how Kodak got involved with the Manhattan Project. When Eastman Kodak was first asked by the government to participate in a new war effort, they requested to be excused. However, when the government came back to Kodak a short time later and pleaded for their help, Kodak management ultimately agreed to take on the new government project in Tennessee.

Kodak's plan was to give the overall responsibility for the new plant to its "chemical arm," the Tennessee Eastman Co. located in Kingsport, Tennessee. Technical and supervisory personnel would be assembled from both Rochester and Kingsport.

A review of Tennessee Eastmans anticipated employee requirements shows:

1. The Tennessee Eastman Plant at Kingsport had:	3,500 employees
2. A Gov. Sponsored RDX Explosives Plant to be Operated by Tenn. Eastman was under construction in Kingsport, TN, and was estimated to require	4,500 employees
3. The new Manhattan Project was est. to require:	9,000 employees (13,000used) 17,000 total employees

Using these figures the total number of Tennessee Eastman employees was projected to grow from 3,500 to over 17,000 employees. It doesn't take a mathematician to recognize that Tennessee Eastman's technical and supervisory personnel would be stretched to more than thin.

MY ASSOCIATION WITH THE MANHATTAN PROJECT

This brings us to the time when I became involved with the Manhattan Project. In February, 1943 I received a simple telegram that only said: "Please come to 161 Devonshire Street, sixth floor, in Boston." The telegram was signed by a person that I had never heard of, and the telegram gave no company name. At that time I was only a few months away from receiving a doctorate in chemical engineering from MIT. I was teaching a seniors class in Chemical Engineering for Dr. W. K. Lewis. I had accepted a job with the Eastman Kodak Company and planned to go to Rochester, NY after getting my degree. I had been married for about one year, and my wife was working in MIT's Radiation Laboratory where radar was being developed.

I went to the Devonshire St. address, which is just across the Charles River from MIT. When the elevator doors opened at the sixth floor, I was greeted by two soldiers with rifles on their shoulders, standing stiffly at the door in front of me. My first reaction was that this was a "sure fire" way to draft someone. When I showed the guards the telegram, however, it's originator came out to greet me. He introduced himself as W. R. Burton and said that he was an Eastman Kodak employee. Most of you remember Mr. Burton as "Waddie." As you know he worked here in Longview as Supt. of Engineering for Texas Eastman for a number of years.

Mr. Burton said that we needed to obtain security clearance for me before we could discuss the new job I was being assigned to by Kodak. We needed to get the security clearance quickly, since he was scheduled to return to Rochester that evening. On the way to the security office, Waddie told me that instead of going to work at Rochester, I would be working in a secret, government, war time effort in Tennessee that could bring WWII to an end. The Stone & Webster Engineering & Construction Co., located in Boston, was the primary contractor for the engineering and construction of the facility that Tennessee Eastman would operate.

Mr. Burton said that Kodak, because of their already heavy commitment to the war effort, had no one to move to Boston to be responsible for following and approving the design and construction of the chemical plants that Kodak would be operating at the Tennessee

project. Mr. Burton said that since I was already located in Boston, Kodak was assigning me that responsibility.

All this is supposed to explain why a student, still working on his doctorate, who had never been inside a chemical plant, would be given the responsibility for the design, construction and eventually the operation, of chemical plants that were needed to produce a product which could end World War II. At the time it didn't make sense, at least to me.

MY SECURITY CLEARANCE

When we got to the Army Intelligence Office, a sergeant started to obtain the information needed to obtain clearance for me to work on the Manhattan Project. He looked at my name and said, "Your name is German isn't it?" That seemed obvious, so I said yes. Then he asked, "What is your wife's maiden name?" When I said Kreighbaum, he turned to Waddie and said, "You bring me two Germans and want clearance this afternoon. Don't you know who we are at war with?" I'm not sure how he did it, but the clearance came through, and I started to work that afternoon. At the time I didn't know what my salary would be, or even if I'd have one. Things were going so fast that I didn't think to ask.

A personal problem that security at the Manhattan District caused me was the restrictions that it imposed on conversations with my wife. She couldn't talk about her work at the MIT Radiation Laboratory and now I couldn't talk about my work either. If you think that's easy to cope with, just try it for a week or two.

MY ASSIGNMENT AT THE MANHATTAN PROJECT

After receiving security clearance on that first day, Mr. Burton told me that the goal of the Project was to produce an atomic bomb. Eastman Kodak's assignment in that effort was to physically separate pure Uranium-235 from Uranium 238 by means of Cyclotrons. The Uranium-235 would be used to produce an atomic bomb.

Just a few weeks earlier, I'd been in a "bull session" with a group of MIT physicists, who reviewed how they thought pure Uranium-235 could be separated from natural uranium. Of the list of five or six methods discussed, cyclotrons for electromagnetic separation were mentioned as being only a laboratory curiosity, perhaps useful for analytical purposes. Now I was hearing that winning the war could depend on designing, building and operating a commercial plant using this laboratory analysis technique.

The electromagnetic process did have one big advantage for being selected that the MIT physicists hadn't considered—flexibility. Each separate Cyclotron unit was independent of

would always be open whenever I needed his advice or just wanted to discuss something with him.

Working two jobs was a busy time. I worked at Stone & Webster during the day and some nights and weekends. On the other nights and weekends, with my wife's assistance, I did the laboratory work needed to complete my doctoral thesis. While I was doing the experimental work, she recorded data, learned how to analyze samples, and in general was my "flunky." One evening Professor Gilliland stopped by. He was the very best chemical engineer that I have ever known, and under whom I chose to do my thesis for the Standard Oil Co. of New Jersey. After watching our operation for awhile he smiled and said: "To which of you am I supposed to give the doctorate." I thought later that I should have asked him if he had two.

URANIUM ORE SUPPLY

It was obvious that the Manhattan Project would need an ample supply of Uranium and the US Government didn't have any. The Army gave both Colonel Nichols, the top Army officer at Oak Ridge, and the Stone & Webster Engineering & Construction Co. the joint responsibility of securing that adequate amount of Uranium ore. Each of them took a separate means of obtaining the supply of Uranium.

I had heard some of the following as "scuttle but" in Oak Ridge when I was curious about the foreign labels on some of the Uranium Oxide drums we received. Belgium's "Union Miniere du Haut-Katanga" was the world's largest producer of uranium ore. It's president, Edgar Sengier, somehow knew that the United States Government was looking for uranium. He slipped word to the State Department that he had just shipped a large supply of the ore out of the Belgian Congo in order to keep it out of German hands. In the company's New York office, Sengier met with Colonel Nichols and they negotiated for the total amount. When Sengier, an alien, told Colonel Nichols that he would sell the uranium ore only for military use, Colonel Nichols was concerned about what to say. Sengier went on to add that he didn't need to know how it would be used. All that he wanted was Nichols assurance as an Army officer that the ore would be used for military purposes. Then the purchase of the 1,200 tons of ore in a hidden in a warehouse on Staten Island and all of the uranium ore stockpiled above ground in the Congo was completed.

Within weeks of the call from the government, Stone & Webster had contracted for Canada's supply of uranium ore. Uranium was mined at Great Bear Lake, beyond the Arctic Circle in Northern Canada, and S&W arranged to take the full output of that major source of supply. Since the lake is navigable only in midsummer, the mines usually operated for only a few months in the year. Stone & Webster quickly arranged for miners, food and supplies to be rushed to the last boat leaving that year for the trip up the MacKenzie River. That action assured that the mines would be able to work at peak capacity during the winter of 1942-1943.

other units, and units could be built in groups. The controls would be separate for each unit. Therefore, if a cyclotron unit developed problems or required maintenance, only that cyclotron would be affected, and the others would continue running. Grouping cyclotrons into tracks, shaped like an oval "racetrack," enabled the huge, expensive magnets to be used in economical arrangements for a number of cyclotrons.

During that first day I was introduced to the key Stone & Webster individuals that would be responsible for Manhattan Project work at Oak Ridge. Mr. Agust C. (Gus) Klein, a Stone & Webster Executive Vice President, was in charge of all work for the design and construction of both the city of Oak Ridge and the Y-12 plant that Tenn. Eastman would operate. Y-12 was the coordinates of the Tennessee Eastman plant site on an Army map that was classified.

Late in the afternoon a meeting was held to review a decision on the equipment to be used in one area of the chemical plants. I soon realized that I didn't know enough to participate effectively in the discussion. Early the next morning I went to see Mr. Klein. I told him that I was concerned that either I wasn't the Schrader that they were looking for, or I thought that some one had made a big mistake. I was just a student, I had never been in a chemical plant, and now I was being given the responsibility for work that could end the war.

Mr. Klein smiled and said that as long as both of us realized that, we would get along just fine. He assured me that I was Kodak's choice for the job. He said that because Stone & Webster's reputation was also on the line, he had reviewed my background in detail with both Kodak and MIT. He knew that I had won the Indiana State Geometry Championship in High School under difficult conditions, that I had obtained both a Bachelors and Masters degree with Honors in four years at Purdue, and that MIT had given me a full scholarship because of that record. Kodak had told him that I had been awarded the Eastman Kodak Fellowship, and that during a summer job with them I had used differential equation math to solve a problem in their film base department that was saving them a lot of money. A consultant that they had hired a year before to solve the problem had given them a formula that didn't work, but mine was working fine. He said that MIT also told him that I was the only graduate student to ever take 32 and 34 semester hours of classes in consecutive semesters during any year there and get top grades.

Mr. Klein went on to say that he would provide whatever help I might need in other disciplines, such as civil, electrical and mechanical engineering. He also said that his door

Uranium ore, called pitchblende, has a composition of U_3O_8. It is actually a mixture of UO_2 and UO_3. Mallinckrodt Chemical Works in St. Louis partially purified all of the ore by a newly developed, ether extraction process. They shipped the uranium as the four-valent uranium oxide, (UO_2), to us at the Y-12 chemical plant.

We were never close to being in short supply of crude Uranium.

PROJECT SECURITY AT STONE & WEBSTER, BOSTON

Now lets talk briefly about security at Stone & Webster in Boston.

Stone & Webster's work for the Clinton Engineer Works was done in buildings completely away from their regular facilities in Boston, and by a completely separate engineering organization. At its peak, this Stone & Webster group employed over 800 engineers, draftsmen and clerks, who worked in utmost secrecy, under constant guard, for three years, on thirteen floors, in four separate buildings. Each floor had armed guards on duty 24 hours a day and burglar alarms were installed on all doors and windows. Everyone had two wastebaskets—the one painted red was for classified material. Only American citizens were permitted to work on the project, and then only after being cleared by the War Department's intelligence services. Visitors had to fill out a slip and then tear off a stub from the slip. By doing so, they unsuspectingly left fingerprints on the specially sensitized paper of the stub.

MANHATTAN PROJECT—THE OAK RIDGE AREA

In this photograph the location of the Clinton Engineer Works, or the Oak Ridge Project, is shown by the black dot on the map.

Earlier Stone & Webster and the Corps of Engineers had selected the 95 square mile tract of land near Knoxville, Tenn. The land was located about 18 miles northwest of Knoxville and eight miles south of the small town of Clinton.

The tract answered all of the requirements for the location of atomic energy plants: it was an isolated area with plenty of TVA electrical power, it had an abundant water supply from the Clinch River on its southern border. It had almost no population, it had good access by road and train, and it had a mild climate that permitted outdoor work the year round. It was beautiful countryside. To the east were the Great Smoky Mountains and to the west were the peaks of the Cumberland Mountains.

The 95 square mile area was originally named "The Clinton Engineer Works." The name "Oak Ridge" replaced the name "Clinton Engineer Works" in the summer of 1943 when permanent housing started to be built. The commercial, or downtown, portion of the town was located in a valley with rolling hills to the north. The town site was purposely located at Elza Gate on the extreme east side of the 95 square mile tract. This was done so that access to the city was close to both the edge of the site and to a good highway going to Knoxville. Locating the city adjacent to the edge of the property was done largely for security reasons.

CODE NAMES FOR MANHATTAN DISTRICTS PLANTS AT OAK RIDGE, TN

Plant sites at Oak Ridge were assigned code names which actually were coordinates on a classified Army map. The code names for the major facilities at Oak Ridge were:

Y-12	Eastman Kodak's "Cyclotron" Plant
K-25	Union Carbide's "Gas Diffusion" Plant
X-10	DuPont's "Pilot Plant Reactor" for the Hanford, WA site
S-50	Fercleve's "Thermal Diffusion" Plant

"Y-12" Area

Kodak's plant was located in an area about six miles southwest of the town of Oak Ridge. The code name for Kodaks plant was "Y-12." It used the Cyclotron Process to produce "bomb grade" U-235. It was the only plant that produced bomb grade U-235 during WWII.

"K-25" Area

Union Carbide's "gas diffusion" plant was located in the far western part of the Clinton Engineer Works project and had the code name "K-25." While it was probably the least expensive process for the production of U-235 for the long haul, during WWII it did not produce any bomb grade product.

"X-10" Area

"X-10" was the code name for a Pilot Plant Reactor built at Oak Ridge for the Plutonium Plant at Hanford, WA. This facility was under the direction of Du Pont. The X-10 Pile was designed with Helium cooling. The pile was still under construction when Du Pont suddenly decided to use water-cooling at the commercial scale piles at Hanford. Thus, X-10 was not a pilot plant at all. It did produce small amounts of Plutonium which the Los Alamos physicists could use for experimental purposes.

"S-50" Area"

A thermal diffusion pilot unit had been built by the Naval Research Laboratory. It was decided to build a commercial plant a short distance from Carbide's K-25 Area in order to utilize 1000 psig steam being produced in the Carbide powerhouse. The plant was built by Ferguson Construction Co. and operated by it's subsidiary, Fercleve.

Later thousands more prefabricated houses were added. They were shipped to Oak Ridge in prefabricated sections, complete with walls, floors, room partitions, interior wiring and plumbing. Even furniture was placed in the sections before shipment. The system of final assembly was so efficient that workers were soon turning the houses over for occupancy at the rate of 30 to 40 a day. This picture is a view of the typical furniture that was shipped to Oak Ridge as a part of the Cemesto board homes.

In addition to homes, work was proceeding on the construction of shopping facilities, a hospital, schools, churches, motion picture theatres, restaurants, barber shops and athletic fields. Roane Anderson Co. was contracted to operate and maintain the town site facilities. This included supplying coal, mostly dusty slack, to the bins at each house.

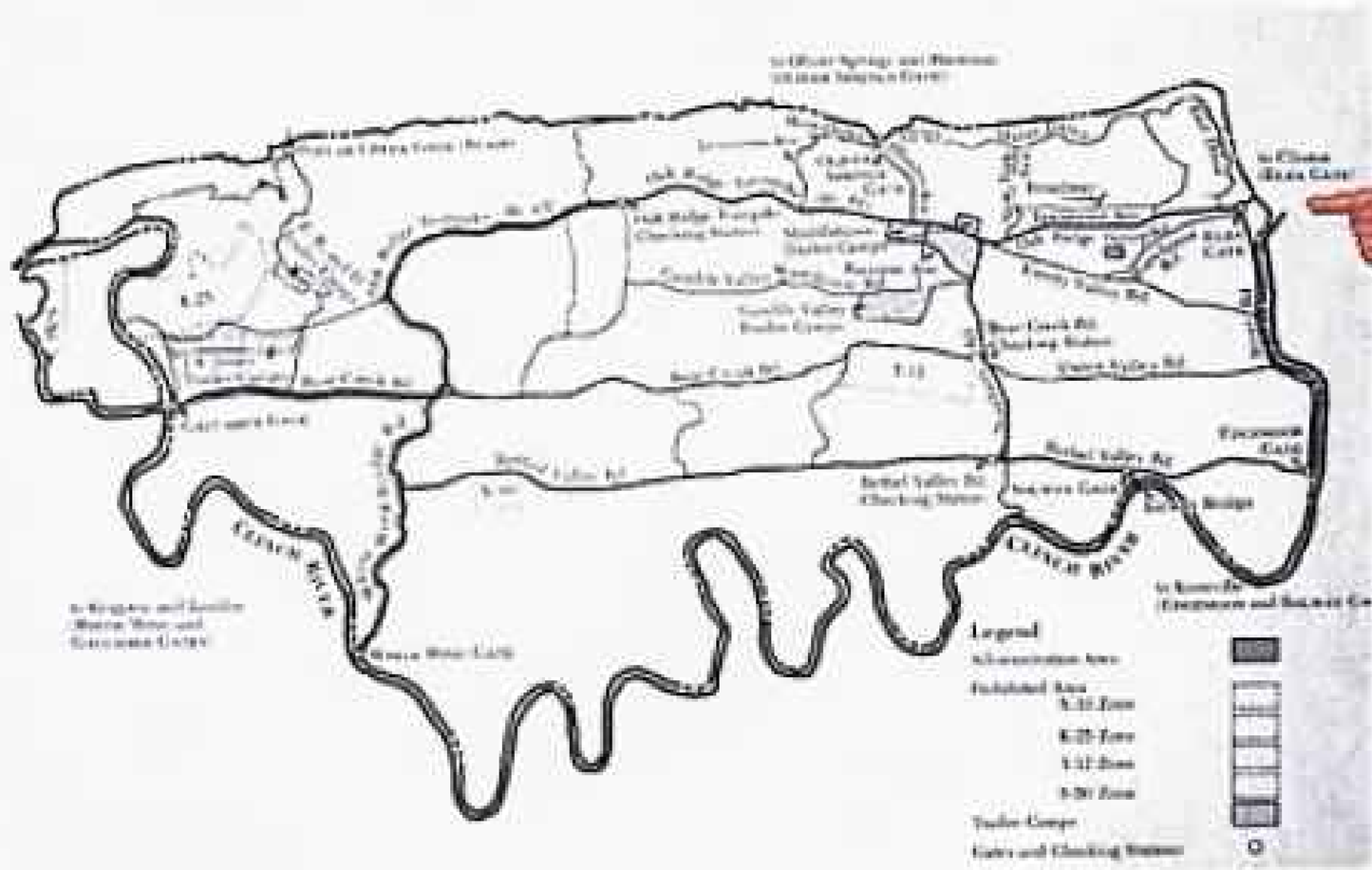
Some of the rules that the Army used in assigning, or rather not assigning, homes included no housing for the following:

1. Those with salaries less than $60 per week.
2. Those with positions less than Foremen (those on hourly pay roll).
3. Those who lived within 40 miles of Oak Ridge.
4. Single employees could use dormitories only.

The plants start up was attempted about one year after Y-12 went into operation. The thermal diffusion plant was only capable of producing a low enrichment of U-235, and many problems with the process were encountered. It was not an effective project.

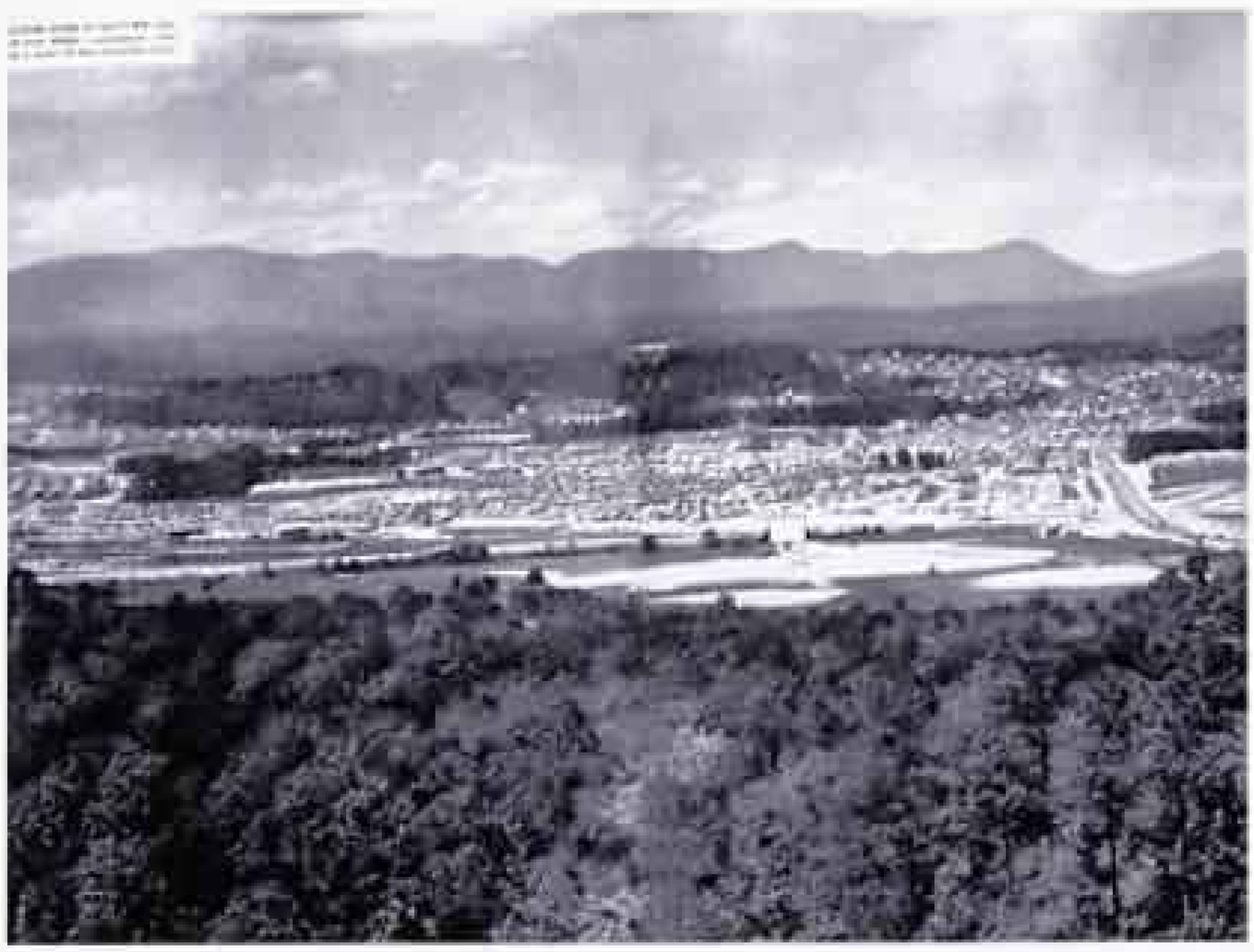
"Elza Gate"

Elza gate is located on the eastern edge of the Oak Ridge Area.



As you can see from the map to the left, the Clinton Engineer Works area of ninety five square miles was large enough that the town site and each of the plants could be separated from each other by a number of miles and by high ridges in the terrain.

THE TOWN OF OAK RIDGE, TENNESSEE



A view of the City of Oak Ridge is shown in the distance. At the time I first came to Oak Ridge in early 1943 there was one dormitory and a cafeteria in the town site. Land was being cleared and graded for construction of city roads and town facilities. A dirt road led about 5 or 6 miles to the Y-12 plant site, which was being enclosed by a 10 foot high chain link fence. Construction, mostly underground, was just getting underway.

The town itself was a narrow strip less than one mile wide and six miles long. The town is shown in the lower-right portion of the picture, and the housing is at the top and left. The town was located in a valley that had a 500 foot high ridge to its north. The area between the valley and the ridge was crisscrossed by smaller ridges.

Along the top of the major ridge was a road called "Outer Drive." In the valley below was the "Oak Ridge Turnpike" which ran parallel to Outer Drive. Between Oak Ridge Turnpike and Outer Drive were numerous connecting roads. On these connecting roads, and branches from them, the main housing was built. The city of Oak Ridge was not divided into a monotonous grid, with right-angled streets, but was designed to take advantage of the contours of the hills. The streets followed the natural curves of the terrain, without ever becoming too steep. The picture (right) shows a typical street in the housing area. Despite almost constant changes in requirements, the outcome proved to be one of the most skillful jobs of town planning ever seen.

A network of wooden sidewalks was built throughout the residential area. These wooden walks went by the shortest route through the woods to the town center where groceries and other supplies could be purchased. One hundred sixty three miles of wooden sidewalks were installed. Cars, tires and gasoline were scarce, so the sidewalks were well used.

The original townsite was designed for three thousand homes, and several apartment buildings and dormitories. All housing used prefabricated construction that utilized Cemesto-board. Cemesto-board is composed of a ¼-inch thick cement board laminated on each side of a one-inch thick center layer of compacted asbestos. This type of construction was substantial and used only readily available raw materials. There were a number of types of housing at Oak Ridge:

1. Buildings with four, one bedroom apartments. We were fortunate to be assigned space in one of the first four apartments that were built.
2. "A" House. A one story, one bedroom home.
3. "B" House. A one story, two bedroom home.
4. "C" House. A one story, three bedroom home.
5. "D" House. A one story, three bedroom home with more space.
6. Temporary dwellings, shown on the right.
7. Dormitories.
8. Trailer Camp.
9. Hutments.

Children were well schooled in Oak Ridge up to High School. All Oak Ridge teachers were required to have a Bachelor's Degree. High School students in Oak Ridge were bused to schools in Knoxville. Don Scoggins wife, Linda, Oak Ridge. Maybe Don can pick her out if she was in this classroom. Linda's father, Rick Rickmeyer, worked in the Y-12 Engineering Department. Our families were good friends, and we often played bridge together.

A "multi denominational church," known as the "Chapel on the Hill," provided worship services for the community until individual churches could be built after the war. This photograph shows parishioners at a worship service.

This is a photograph of the first shopping center in downtown Oak Ridge.

The Oak Ridge Health Association supplemented the Military medical staff with doctors and dentists from Knoxville. They all worked in the Army Hospital. The Medical Fee charged Oak Ridge patients was $2.00 a month for singles and $4.00 a month for families.

"A" House

"D" House

Temporary Dwelling

Trailer Camp

Dormitories

Hutments

Surfacing of the roads had a very low priority, and during rainy weather roads became a sloppy mess. The sticky layer of clay mud was often over six inches deep, and ruts were deeper than that. There wasn't much that could be done about the mud in rainy weather, except grade out the ruts whenever the rain stopped. In dry weather a big cloud of dust followed each vehicle. Roane Anderson combated the 351 miles of dusty roads with 25 sprinkler trucks that ran continuously from 8 AM to 7 PM each day that had no rain.

During rainy weather we had to wear calf high galoshes at the Y-12 plant site since the mud that had been churned up in the construction areas was deeper than rubbers. I remember a mishap that occurred during a downpour. A group of us were that were leaving the Chemical Area for lunch, included a Navy Ensign who was on loan to us to help with engineering construction. Suddenly he dropped down with only his outstretched arms supporting him from his armpits in the mud. He had stepped into a hole that had been drilled for a power pole. It had filled with mud in the rain. I believe that after we got over the shock, the only one not laughing was Ensign Johnny Russell. After his release from Oak Ridge, Johnny was reassigned to Los Alamos. He worked there until he passed away a few years ago.

In May of 1945 Oak Ridge and had a peak population of a little over 75,000 people, and a peak employment of about 83,000. There were 4,900 civilian guards, 740 military policemen and 400 civilian policemen. I've heard that about one-third of the guards and policemen were FBI employees.

Everyone living or working in Oak Ridge wore a pictured pass with a specific exterior gate entrance and a manufacturing area identification. Elza gate, located at the East edge of the town, had by far the most use.

Passage through any gate, either going in or out, required each vehicle to stop. All doors, the hood and the trunk were opened, and all passengers were required to exit the vehicle. The guards inspected all areas, including using a mirror with a long handle to view the under side of the vehicle. All luggage and packages were opened and thoroughly inspected.

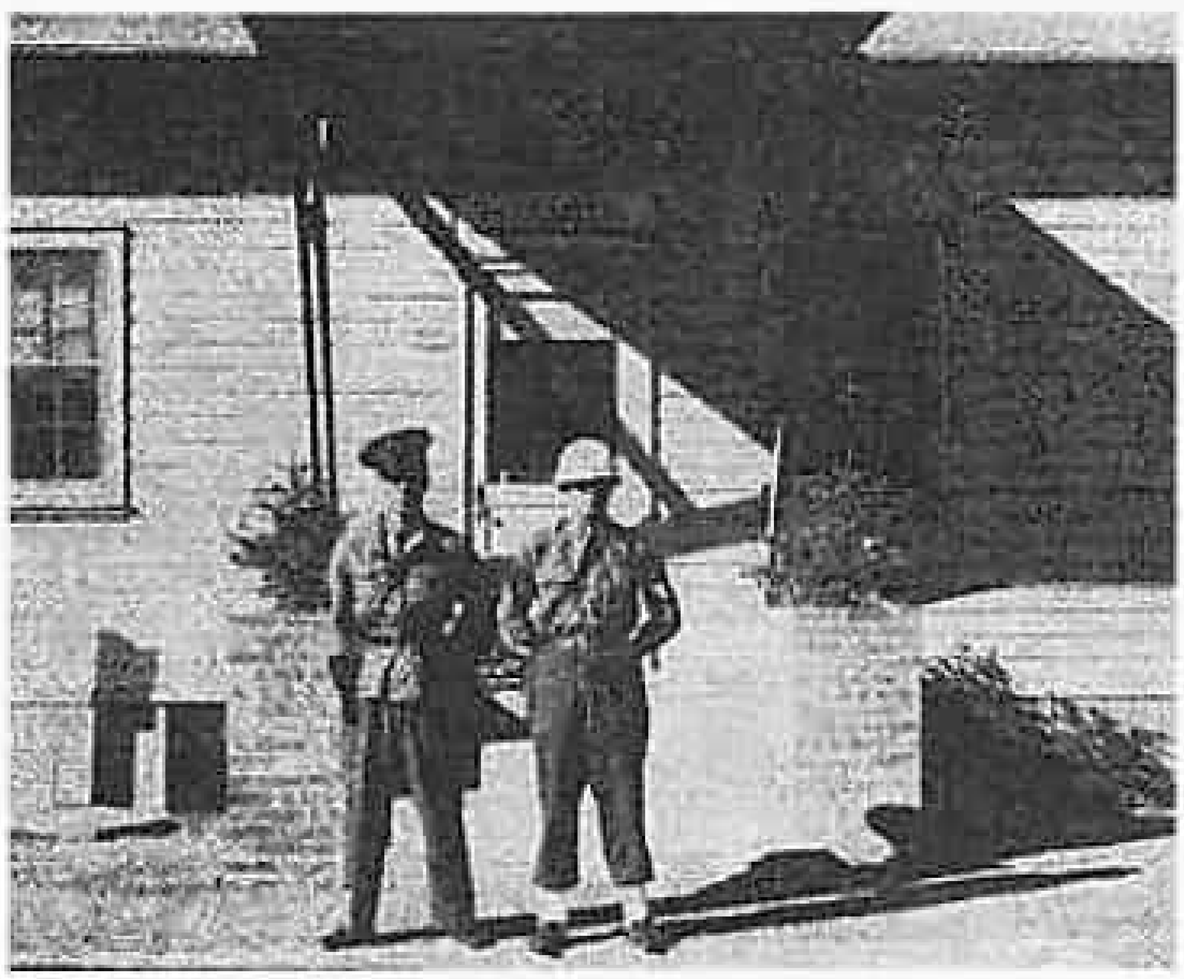
Almost overnight Oak Ridge became the fifth largest city in Tennessee by population, and the second largest consumer of TVA electrical power.

Because it was a closed Military Reservation, the hospital at Oak Ridge could not have obstetric facilities. Obstetricians from Knoxville treated patients in a "so called" emergency room. My first son, Larry, was born in one of them on December 22, 1944. He gave us the requirement that we needed to move into a two bedroom B-House. It was located on Meadow Lane. The house had a nice view of the town site and of the Smoky Mountains in the background.

"D" House

Some of the people who moved to Oak Ridge were unhappy there—especially the wives. In fact a few families had to be returned to Kingsport or Rochester. Looking back I realize that they were all older couples who missed their more luxurious homes and social activities. My wife and I had never owned a home of any kind and looked upon the whole thing as a challenge, and perhaps realized that we were more fortunate than those fighting overseas. Fortunately there were a lot of other families like us.

SECOND SESSION



Today we will start with a discussion of "Security in the Manhattan Project." Early on, President Roosevelt decreed that all phases of the Manhattan Project should be "Top Secret," and that all security actions should reflect that fact. "Need to know" was the basis for what information would be available to each individual. It was strongly suggested that personnel from different areas at Oak Ridge (Y-12, K-25 and X-10 laboratories) should not mingle socially. Each individual wore a pass that clearly showed the entrance gate that the individual must use and the areas in Y-12 into which that person was allowed to enter.

During my first trip from Boston to Oak Ridge, I had an experience that illustrated how security was sometimes carried out. In 1943 no air travel existed between Boston and Knoxville, and travel was by train. When dinnertime came I went to the dining car and was seated at a two-place table. The dining car was filling up, so when a nice looking gentleman asked if he could join me in the other seat, I said that would be fine. After some pleasantries, he asked me what kind of work I did. I said that I was a chemical engineer. Then he asked where I lived, and I told him "in the Knoxville area." He then asked how long I'd lived there, and I said "not long." When he asked who I worked for I began to get uncomfortable, but said "Eastman Kodak." His reply was, "that's strange, I didn't know that Kodak had an installation near Knoxville." By that time I didn't want any more questions. I excused myself by saying that I wasn't feeling well, and went to my compartment. No dinner that night!

At the time I thought that my dinner partner was just a nosy traveler, but when I returned to Boston there was a large envelope in the center of my desk marked "Top Secret." Inside, typed on FBI stationery, was a word for word transcript of the conversation at dinner. At the bottom, in ink, was a note, which said, "You did fine. Just remember, there are eyes and ears everywhere."

In the end, the Manhattan Project, with the many companies and the thousands of workers, kept a secret, which has been described as the most important and best-kept secret in the history of the world. Personally, I do not know of a single person who knew the purpose of the Manhattan Project and did not have the right to know that.

A similar event happened about a year later. This time the gentleman pulled a small piece of metal out of his pocket and said: "This has thousands of small holes in it. Do you know what it is?" I knew that if it was real, he had to be talking about the "diffusion grid material" used at Carbide's K-25 Gas Diffusion Plant. This time I got irritated and told the fellow to put the metal sample back in his pocket, and that I wasn't interested in talking to him further. I got up and left another meal behind. He was either very stupid or was another security agent. I reported the incident to Army Intelligence, and didn't hear anything further about the incident.

THE ARMY'S ORGANIZATION AT Y-12

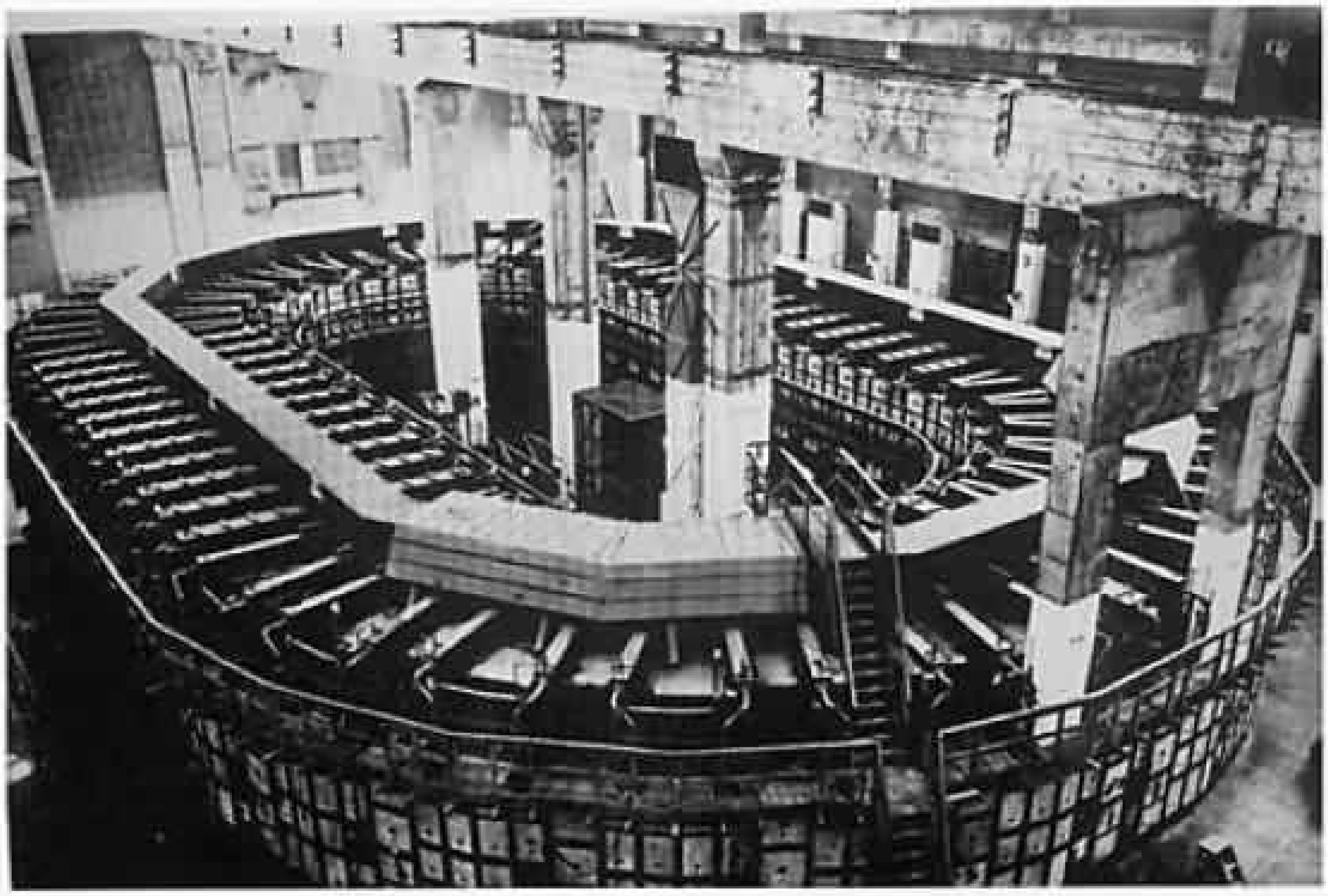
At Y-12 the Army had an unusual organizational set-up. Every member of Tennessee Eastman's supervision had an Army counterpart. Colonel Nichols was paired with Tennessee Eastman's Works Manager, Dr. Fred Conklin. A Second Lieutenant was my counterpart. This type of organization seemed to me to be a questionable use of badly needed technical personnel.

THE ELECTROMAGNETIC OR CYCLOTRON PROCESS

Next let's discuss the Electromagnetic or Cyclotron Process. We'll begin by looking at several pictures that might help us understand what a Cyclotron looks like and what it does.

The Cyclotrons in a Racetrack Buildings are built around a huge magnet that has the shape of an oval racetrack. Using the name "Racetrack" for the Cyclotron Magnets was another security measure.

Above we have a picture of an Alpha Racetrack building early in its construction.



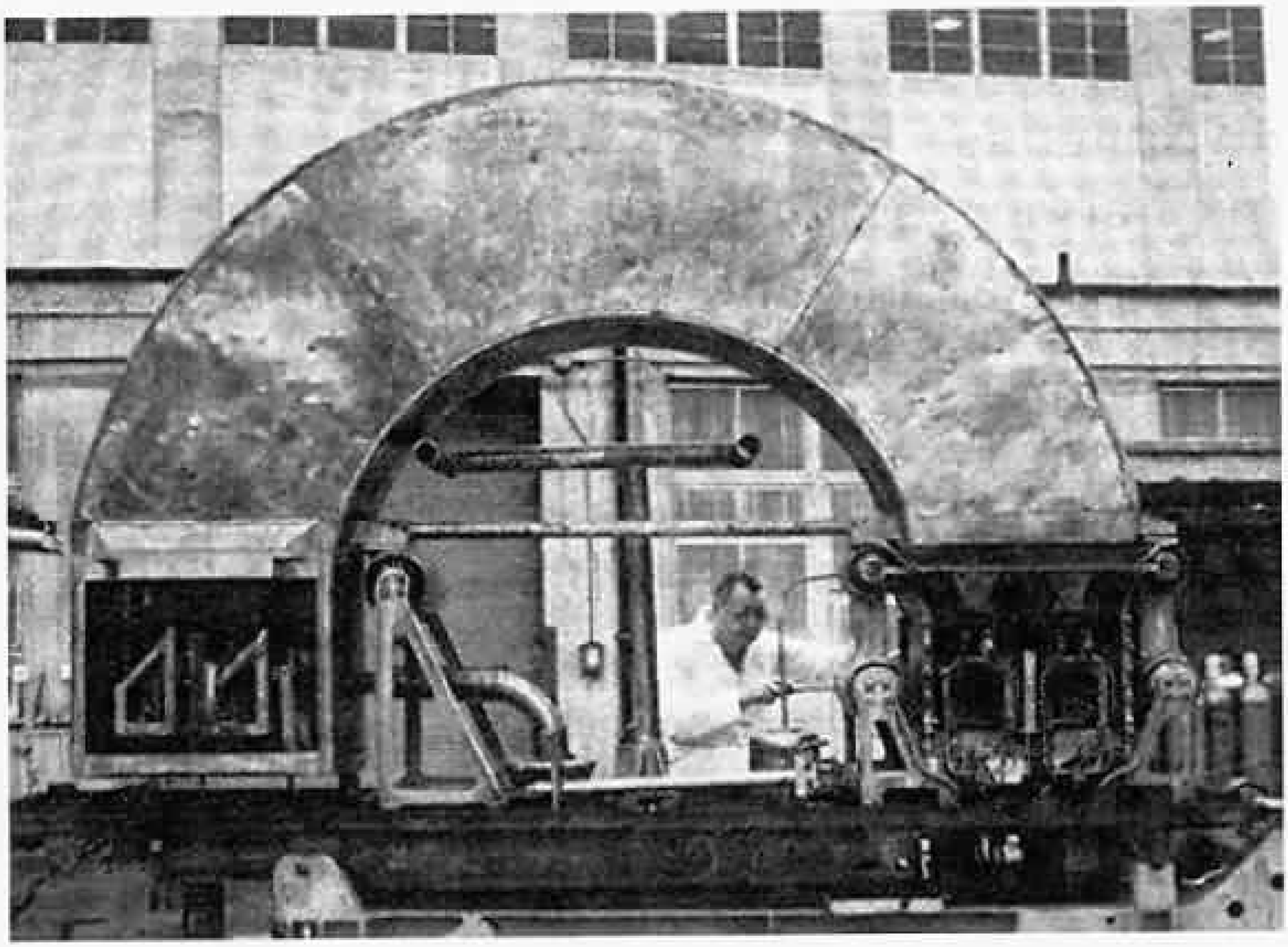
This is a view of a completed Racetrack.

The production of U-235 with bomb grade purity requires a two-stage treatment with Cyclotrons. The "first stage" or Alpha Cyclotrons used natural Uranium as feedstock. Their product was the feed stock for the second stage Beta Cyclotrons. The product of the Beta Cyclotrons was Bomb Grade U-235.

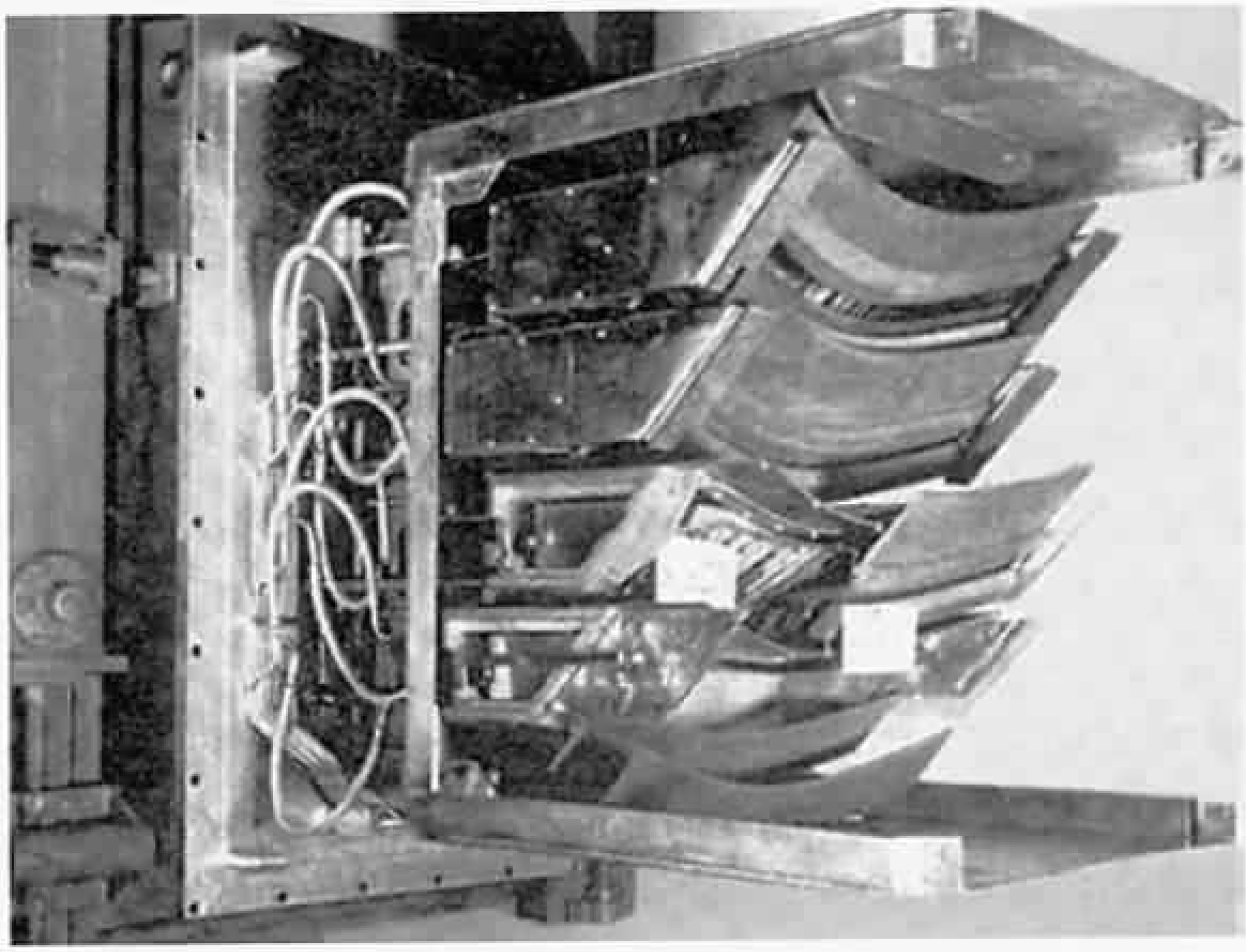
At the end of the war Y-12 had three Alpha racetrack buildings, 9201-1, -2 & -3. Each building housed 2 race tracks and each track contained 96 independent Cyclotrons

In February, 1943, construction work, primarily earth work for roads and utilities, was started at the Cyclotron Plants Y-12 site. Stone & Webster and Tenn. Eastman did the engineering and construction work for the Y-12 Cyclotron and Chemical Plant areas in over a year less than did the other two projects. In November, 1943, only nine months after construction started, the Electromagnetic Process began operation, and the Chemical Plants had feed ready for them. That has to be a record time for engineering and construction in any ones book. I know first hand that completion of the Chemical Plant area in that time was the nearest thing to a miracle that I've seen.

It was extremely important to the project that Tennessee Eastman's Y-12 Cyclotron Plant produced "bomb" grade U-235 a little over a year before any other plant accomplished that feat. Even a small quantity of bomb grade Uranium-235 was invaluable, since it enabled the physicists at Los Alamos to obtain data that they needed to start work on the design of an atomic bomb. This work included determining the amount of U-235 needed for a critical mass.



This is a photograph of a Cyclotron before installation in a racetrack magnet.



Here is a photograph showing a Cyclotron's Collectors for U-235 and U-238. The collector unit was called an "E" Unit as a security measure.

This is a view of a Beta Racetrack building. The insert shows the vacuum system for the Cyclotron. Both the Alpha and Beta Cyclotrons were operated at a higher vacuum than had ever before been achieved in a commercial operation. This was necessary for two reasons. First, it is necessary in order to sublime the Uranium tetra chloride feed stock at a reasonable temperature. Second, all the molecules of nitrogen and oxygen had to be removed so that the U-235 ions would have no collisions with those molecules that would deflect the Uranium particles from their proper path.

As I have mentioned before, a big advantage of the Cyclotron Process is flexibility. Cyclotrons Units could be added or removed from a racetrack at will, without shutting down the huge magnets. Each cyclotron worked for a number of days on its own schedule. Then it was shut down in order to remove the receivers that collected the separated isotopes. The fruit of this expensive operation seemed pitifully unspectacular to the workers—all that the graphite receiving baskets contained at the end of a run was a small amount of a blackish powder. Actually, on a good day, a single Cyclotron could produce about 10 grams of product.

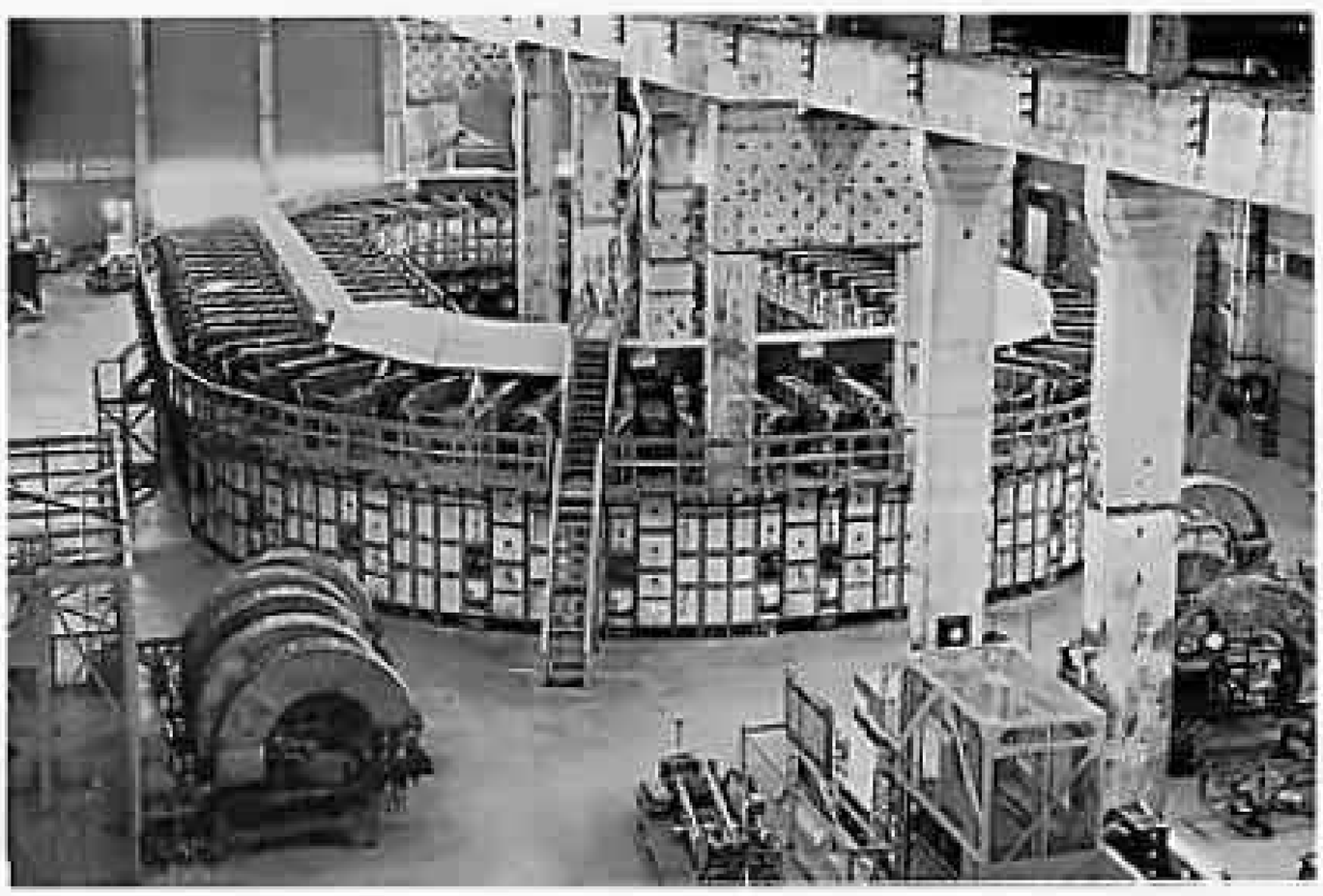
One time, early in an Alpha track's operation, a high vacuum couldn't be obtained in a particular Cyclotron. The vacuum system checked out OK, no leaks could be found, but the required vacuum just couldn't be obtained in the Cyclotron. Finally the Cyclotron was removed from the magnet and opened for inspection. Inside they found the fur and bones of a badly dehydrated mouse. No one knew how the mouse got inside the Cyclotron, but the vacuum system worked fine after the mouse was removed.

The Alpha tracks were 230 feet long, and their magnets were 100 times as large as the mightiest magnet then in existence. The magnetic field around the tracks was so strong that the magnetic pull on the nails in the heels of ordinary shoes made walking by the magnets difficult. Obviously, workers could not safely carry nails, nuts or bolts on their person.

Complete kits of non-magnetic tools made of beryllium copper were obtained for use around the tracks. The severe magnetic field could snatch an ordinary tool from a workers hand, and did when a worker carelessly brought such a tool near one of the magnets. Mechanics often had bruised knuckles brought about by such a mistake. More than a few female operators came to work with carefully done hair-dos and walked too close to one of the magnets. The wire hairpins flew out their hair and stuck on the magnets, leaving behind some very weird hair-dos.

Here, I'd like to make a comment about something that I observed during the start-up of the first Cyclotron. Because the recovery of U-235 from the Cyclotrons was the responsibility of the Y-12 chemical personnel, my pass permitted me to enter the Cyclotron Area, so I watched some of the best Ph.D. physicists in the world try to operate the first cyclotron to go into operation. They did their very best to produce purified U-235, but at the end of three or four days, they hadn't produced a smidgeon. Disgusted, the physicists put marks at the control points of all of the instruments and told the girls from the Tennessee hills to hold the needles on the marks while they figured out what to do next. They didn't have to do much figuring. The girls didn't have any idea what they were doing, or accomplishing, but they had the patience and concentration to hold the instruments on the marks and production of U-235 was underway. From then on, the ladies operated the cyclotrons and the physicists helped whenever problems developed.

START-UP PROBLEMS AT CYCLOTRON AREAS



As we mentioned earlier, construction of the Y-12 area began in February 1943, and the first Alpha Track Cyclotron (Bldg. 9201-1) began operation in November, 1943. Unfortunately, just days after the start up, the operation of the cyclotrons became erratic, then more erratic, and finally the magnetic field just disappeared. All equipment and instruments were checked and rechecked and the Army sent in a special team looking for sabotage. When General Groves finally ordered one of the heavily welded steel casings of the magnet to be cut open, the problem was found. In the hurry to get the magnets shipped to Oak

Ridge, some rust, scale and dirt had been left in the magnet. As the cooling oil circulated through the magnet it deposited iron particles between the conductors of the coils and shorted the magnet. General Groves had a "first class fit" and ordered the magnets to be removed and returned to Allis-Chalmers in Milwaukee to be cleaned and rebuilt. The conductor bands were unwound, then rewound with a greater space between them. A special pickling plant was built at Y-12. Every piece of pipe in the cooling oil system was taken out of the Cyclotron units, passed through an acid pickling plant, filled with dry nitrogen, sealed and then reassembled. In addition, special oil filters were added to the system. The cyclotrons were then restarted in January, 1944.

As part of the "fall-out" of the debacle, Stone & Webster's manager at Oak Ridge was replaced with Frank Creedon, a civil engineer. Mr. Creddon had worked with Gen. Groves before. During the several weeks that the clean up work required, construction continued on Alpha II and Beta I cyclotron buildings. The brief respite also enabled the Chemical Area to build up a reasonably comfortable stockpile of UCl_4 feed stock.

SHORTAGE OF COPPER FOR THE CYCLOTRONS

One of the severe shortages of a material during World War II was copper. Many new homes and businesses had to be wired with aluminum. The cyclotron magnets, and the bus bars used to bring power to them, required many tons of conductor material. Although the Manhattan District's priority was one level higher than anyone else had, it still couldn't provide a product that just wasn't there. Silver is also a good conductor of electricity and the United States Treasury had lots of it. Colonel Nichols, the Army officer in charge of Y-12, was given the job of borrowing the amount of silver needed at Y-12.

I've heard it said that when Colonel Nichols met with Under Secretary Daniel Bell at the Treasury Department to request borrowing the silver for the Cyclotron plants, he had to say that he couldn't reveal it's use or even where it would be used. He could only say that it would be used for an important war project with the very highest priority. When asked how much he needed, he said "six thousand tons." Under Secretary Bell is reported as saying, "young man, you may think of silver in tons, but the U.S. Treasury will always think of silver in troy ounces." In the end, Y-12 used 14,000 tons of silver, figured in Troy ounces, and worth $400,000,000 at the time that it was borrowed.

2. CONVERSION OF URANIUM OXIDE TO URANIUM TETRACHLORIDE

Since the Cyclotrons require a volatile feed, it was necessary to convert the Uranium Oxide to Uranium Tetrachloride. While Uranium Oxide is non-volatile, Uranium Tetrachloride is a compound that sublimes when heated (goes from a solid directly to a vapor). The conversion was accomplished by reacting the Uranium Oxide with carbon tetrachloride at its boiling point at 500 psig.

UO_2	+	$2CCl_4$	→	UCl_4	+	$2COCl_2$	@ 500 psig and 150 deg C
Uranium Dioxide		Carbon Tetra Chloride		Uranium Tetra Chloride		Phosgene	

As can be seen by this reaction equation, a by-product of the reaction is phosgene, which is the very poisonous gas that was used in World War I.

After the chlorination reaction was complete, the Uranium Tetrachloride was recovered from the slurry using Bird basket centrifuges followed by high centrifugal force Sharples centrifuges. Then, by using rotary dryers to evaporate the remaining carbon tetrachloride, finely divided UCl_4 was obtained. At this point only trace amounts of other metals remained in the product.

3. SUBLIMATION OF URANIUM TETRACHLORIDE

To further purify the UCl_4 to "Cyclotron feed quality," the UCl_4 from the dryers was sublimed in specially designed units under extremely high vacuum (less than one micron of Hg pressure). This operation removed all traces of the non-volatile metal salts of iron, copper, chromium, nickel, etc. The vacuum of less than one micron of Hg required by the sublimation units was higher than any that had ever been used commercially and rivaled the highest ever produced in laboratories.

The vacuum was achieved in two stages. The first stage pumps were commercially available Kinney oil vacuum pumps. The final vacuum stage used mercury venturi pumps of our own design. These venturi diffusion pumps boiled mercury at a higher pressure than the first stage vacuum and sent the mercury vapor through a venturi. The heavy mercury atoms dragged most of the remaining air molecules through the venturi and produced a vacuum of less than one micron of pressure. The high vacuum enabled the UCl_4 to sublime at a reasonable temperature, leaving behind all of the trace metals. The UCl_4 was condensed on a cold surface. This product was the feedstock used by the Alpha Cyclotrons.

It has since been said that only a "nut" would use boiling mercury to produce a vacuum, but by then we were all "about nuts" from designing and constructing the chemical plants with the data, or mostly the lack of it, that was available to us. At the time, all that really mattered was that it worked.

To my knowledge the use of government silver at Y-12 was hidden from all who didn't need to know. The borrowed silver was converted into bus bars and conductor coils by an outside supplier. The finished silver was then routed through a fake address so that even the supplier did not know where it went. Once each month Colonel Nichols had to sign a statement that he had all of the silver down to the last hundredth of a Troy ounce.

I had an interesting experience concerning the use of silver in electrical bus bars. While going to a meeting in the last Alpha track to be built (Bldg. 9201-3), I noticed some electrical bus bars (about 4" x 16" in cross section) that were in plain sight under the magnets. This was usual, except that these bus bars didn't have the appearance of copper. When I talked with the buildings superintendent, he confirmed that the bus bars were solid silver. He asked me to say nothing to anyone about it. I asked about the safety of leaving a fortune out in the open, and he said that he would look into it. Several weeks later, the bus bars were encased in steel, although I don't know if my comments had anything to do with it. It does seem to me that being able to leave a fortune out in the open for a number of days, without any loss, says a lot about the honesty, dedication, and quality of the people who worked at Y-12.

THE CHEMICAL FACILITIES AT Y-12

Now let's turn our attention to the Chemical Plants. Except for Cyclotron cleaning, they were housed in Building 9207 chemical complex.

After the war General Leslie R. Groves wrote these comments about the Y-12 chemical facilities in his book entitled "Now It Can be Told." He said, "The chemical side of the electromagnetic process, in fact of the entire Oak Ridge project, has often been treated as a simple auxiliary to its more eye-catching atomic physics aspects. Actually, chemistry was the beginning and the end of each of the separation processes. Production efficiency could be won or lost in chemistry, as well as in physics. Each was indispensable. The chemists and the chemical engineers had to keep constant pace with the possibilities unfolded in the new developments in physics. They, too, had to design processes without adequate information. And the chemical facilities had to be ready in

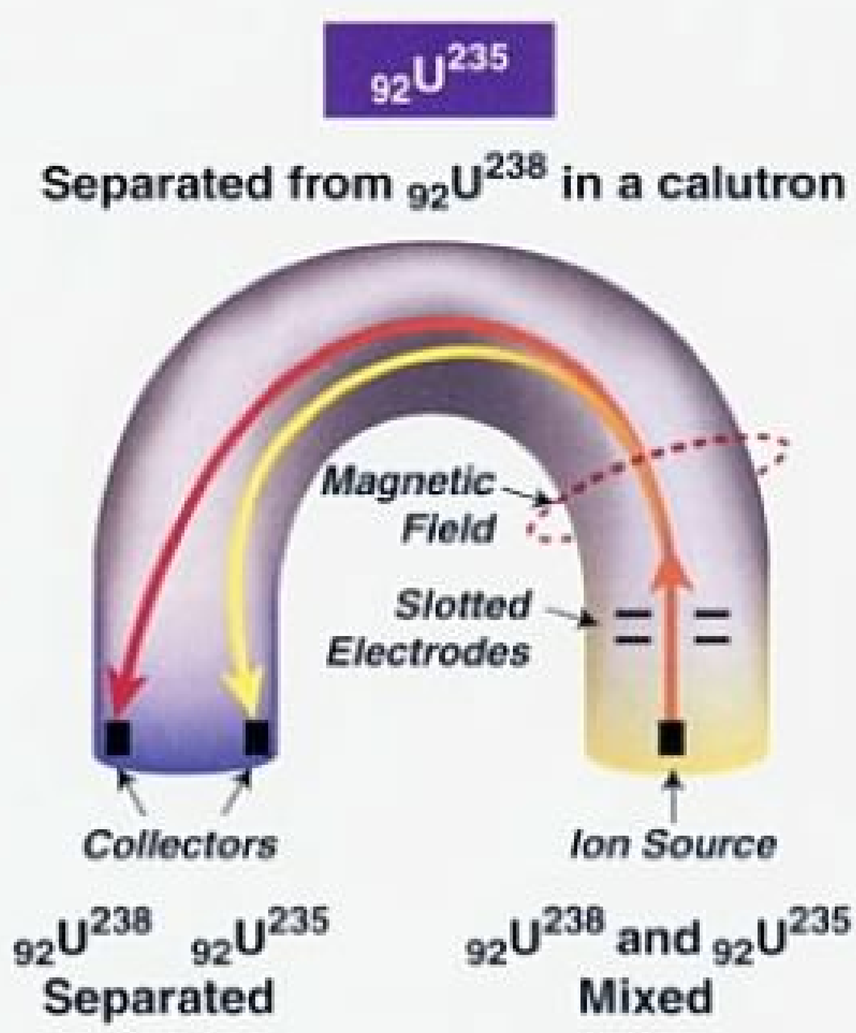
time to meet the rest of the schedule. They always were." In this photograph the Chemical plants can be seen in the background."

Now lets take a short step back in time. On the first weekend after receiving the telegram that requested me to go to Boston, I went to the MIT library to bone up on the chemistry of Uranium. I could hardly believe what I found—absolutely nothing. Then I went to the Boston Public Library, and even after getting a librarian's help—again nothing. We had to develop all of the chemical reactions needed, and doing what General Groves described above wasn't an easy job. The Army did not give chemical areas the much attention. It seemed that they just expected the chemical facilities to be there. All of the chemical reactions had to be developed during the engineering period, as the needs were determined. The consensus "best guess" was that the conversion of crude U_2O_3 into UCl_4, Cyclotron feed stock, could be accomplished with five separate chemical plants.

ALPHA CHEMICAL PLANTS NEEDED

Five chemical plants were needed to process purchased and recycled Uranium into feed for the Alpha Cyclotrons. Partially enriched and bomb grade Uranium was processed in laboratory like glassware in another area. The five plants listed below contained commercial sized equipment and were the facilities for which I was responsible from design to construction and finally to operation.

1. Conversion of Crude Uranium Oxide to Purified Uranium Oxide.
2. Conversion of Uranium Oxide to Uranium Tetrachloride.
3. Final Purification of Uranium Tetrachloride by Sublimation.
4. Recovery of Partially enriched U-235 recovered from the Beta Cyclotrons.
5. Salvage of Enriched U-235 from contaminated Filters, Gloves, Clothing, Equipment, etc.

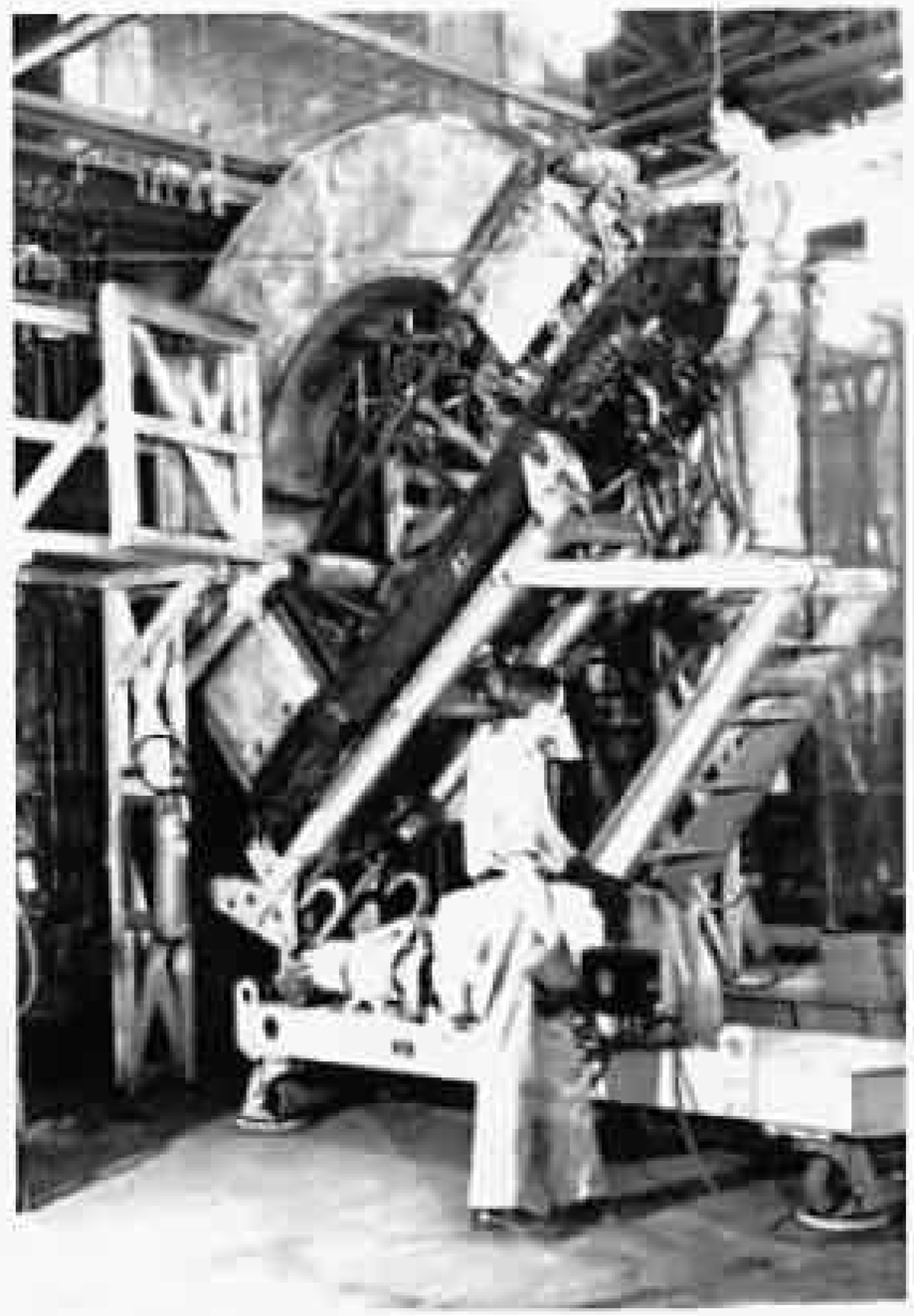


It was apparent that these Y-12 chemical plants would have to be designed on bases that were significantly different from those for a normal chemical plant. Usually an engineer has good data and information with which to design a plant. In this instance, however, there was practically nothing in the literature on the uranium chemistry and only very sketchy laboratory data.

Inorganic chemists at Oak Ridge and at the University of California at Berkley were assigned the job of developing the chemical reactions needed for each plant. They did a superb job.

4. RECOVERY OF URANIUM FROM THE CYCLOTRONS

A part of the responsibility of the Chemical Plants was the recovery of Uranium from the Cyclotrons. The U-235 Cyclotron receivers were processed in a facility much like an oversized laboratory. The graphite receivers, from both the Alpha and Beta Cyclotrons, were incinerated in large muffle furnaces fed with oxygen. The product of this operation was processed in glassware. The Alpha Cyclotrons product was feedstock for the Beta Cyclotrons. Product from the Beta Cyclotrons was "Bomb grade" U-235.



Uranium recovered from the interior surfaces of the Alpha, first stage, and Beta, second stage, Cyclotrons had a great difference in value. Recovery of feedstock scattered on interior parts of the Alpha Cyclotrons had little importance. It was recovered just to supplement our supply of Uranium ore. On the other hand, the Uranium scattered on the interior of the Beta Cyclotrons was precious, partially enriched U-235. Since only about ten percent of the feed used by the Cyclotrons reached the receivers, the other 90 percent of the feed was scattered throughout the interior of the Cyclotrons. The need for zero loss applied to this material.

The partially enriched U-235 to be recovered from the Beta units at the end of a run included that remaining in the ion source, that deposited on the accelerating electrodes, that on the walls of the magnet chamber, and that on the walls of the receiver area. The cleaning process consisted of mechanical scraping of contaminated surfaces followed by a thorough scrubbing of those surfaces with steam, followed by treatment with hydrochloric and nitric acids. On a less frequent basis, the interior walls and parts of the Beta Cyclotrons were treated by electrolysis to recover the partly enriched Uranium that was embedded in them.

All of the partially enriched uranium had to be recovered, but unfortunately, in doing so appreciable amounts of iron, copper, chromium, nickel and other metals were also removed. The recovered product was a mixture of oxides, chlorides and nitrates of uranium and the other metals. To purify the partially enriched U-235 it was processed in small scale, laboratory like facilities. After purification and conversion to UCL_4, the partially enriched U-235 was again fresh feed for the Beta cyclotrons.

Bomb grade Uranium-235 was recovered from the Beta receivers, and processed in a special laboratory. This product was then taken in brief cases, by special couriers, to Los Alamos, NM, where it would be used as the active component of an atomic bomb. This

Now we will take a brief look at the chemistry that was proposed to be used in each of these plants.

1. PRODUCTION OF PURE URANIUM OXIDE

The Uranium Oxide ore that was our starting point came in 55 gallon drums. The Uranium ore was free of silica but contained a number of impurities such as iron, copper, nickel and chromium, and other trace elements.

The first step was to dissolve the crude Uranium oxide in a mixture of nitric and hydrochloric acids. This acid mixture, known as aqua regia, will dissolve gold, so there wasn't much doubt about it dissolving all of the metal salts in the crude Uranium. We were concerned about what materials of construction could be used in such a plant. Glass lined reactors and storage vessels together with porcelain or pyrex glass piping seemed to be our best choice, even though they were not commercially available or even designed yet.

The next reaction that was developed seemed like a stroke of genius. Dr. Clarence Larson, who was on loan to us from the University of California, found that if a strong acid solution of Uranium was first neutralized with ammonia, Uranium Oxide could be precipitated from the solution by the addition of pure hydrogen peroxide. No other metals were precipitated. The first attempt, at room temperature, resulted in almost all of the hydrogen peroxide being decomposed by iron in the solution. Fortunately, cooling the solution to about thirty-five degrees Fahrenheit prevented the decomposition of the peroxide, and the reaction worked. The Uranium was precipitated as four-valent oxide while all other metals remained in solution. I believe that this was the key reaction in the chemical plants that enabled them to produce Cyclotron feed stock.

The chemical reactions for these steps are shown below.

Dissolve crude UO_2 in HCl & HNO_3 acids

$HCl + HNO_3 + 2NH_3 \rightarrow NH_4Cl + NH_4NO_3$

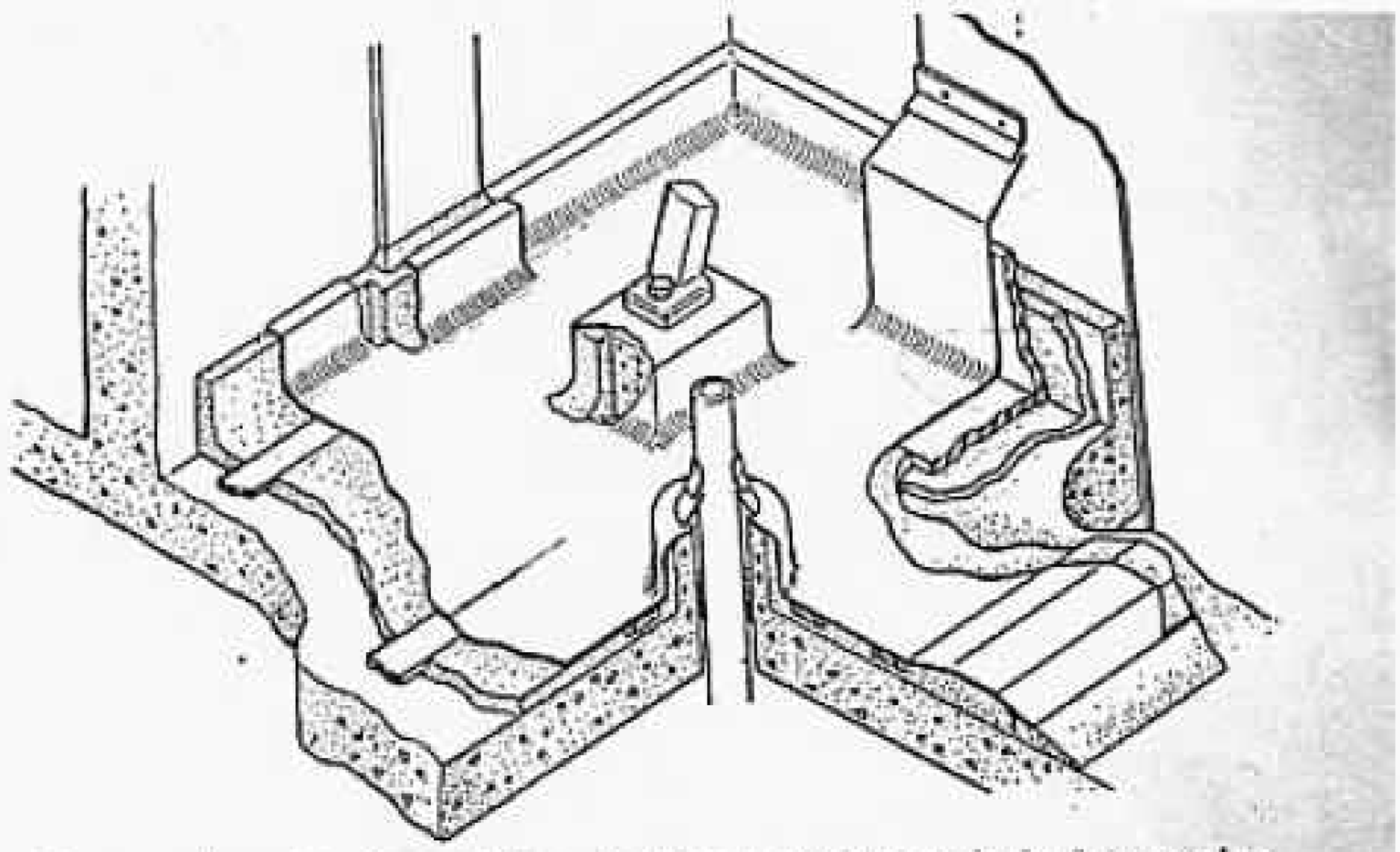
$UCl_4 + 2H_2O_2$ (@ 35 °F) $\rightarrow$ Solid $UO_2 + 4HCl$ (all other metal compounds stay in solution)

The UO_2 solid was recovered with plate and frame filter presses. The filter cake, while still in the filter press, was washed with deionized water. The filter cake was then dried and used as feed stock for the UCl_4 production plant.

reminds me of a letter that our Purchasing Dept. at Oak Ridge received from the President of the Southern Railroad. The letter said that their records indicated that the Southern Railroad was receiving a fair share of incoming shipments to Oak Ridge, but that outgoing shipments were almost non existent. The letter went on to say that the Southern Railroad would like to receive a bigger share of our outgoing shipments. What the railroad's President didn't know was that they were already receiving all of our outgoing business in the form of passenger tickets for the couriers.

5. SALVAGE RECOVERY OPERATIONS.

An extensive salvage plant was built as a part of the chemical facilities at Y-12. The salvage plant used incineration to recover partially enriched Uranium from combustible materials. Such items included contaminated work clothes, rubber gloves, filters, hoses and other combustible materials that contained traces of partially enriched U-235. The recovered product was a mixture of oxides, chlorides and nitrates of uranium and the other metals. The partially enriched U-235 was purified in laboratory like facilities that we have already mentioned. Like other enriched U-235 that was recovered, after purification and conversion to UCl_4, this partially enriched U-235 was again fresh feed for the Beta cyclotrons.



Cutaway view of typical stainless steel floor showing method of supporting it and way it can be built around various equipment

Early in the Y-12 operation, a flask containing partially enriched U-235 was dropped onto a concrete floor. The entire floor was removed and dissolved in hydrochloric and nitric acids to recover the Uranium it contained. After that incident all floors in areas in which enriched U-235 was handled had a stainless steel surface. This was true of the chemical plants as well as the laboratories. This slide is a drawing of the floor in a typical room. To avoid buckling of the stainless sheets they were welded to steel straps embedded into the concrete. At walls and anything attached to the floor stainless steel coving six inches high was installed.

DESIGN AND CONSTRUCTION OF THE CHEMICAL PLANTS

A lot of my time was spent coordinating and scheduling both design and construction work for the Y-12 chemical plants. Early in the project I asked for the estimated time schedule of when the Cyclotrons would come on line, and converted this to a chart that showed the

amount of feed that the Cyclotrons would need with time. I also gave Stone & Webster information on the order in which the chemical plants would be needed, and asked them for their schedule for the completion of each chemical plant. This information was updated each week, or whenever a significant change took place in any of the data.

As you can imagine, chemical plants such as those we were building, could be improved almost continuously. We wanted to build the best plant that was possible, but too many improvements along the way could delay a plants completion and result in failing to meet the needs of the Cyclotrons for feed. When we thought that we had a workable design, posters were put up throughout the Engineering and Production Departments saying:

"BETTER IS THE WORST ENEMY OF THE GOOD"
Engineering Design on the xxxx Plant
Will be Frozen on ----, ---, 194x

At first the slogan got a lot of questions from our Engineering and Production Staffs. Then they realized that the slogan simply meant that when a design was good enough to do the job we needed to finish the engineering and construction without further changes. We would wait to use the "even better" designs in the next plant.

SESSION THREE

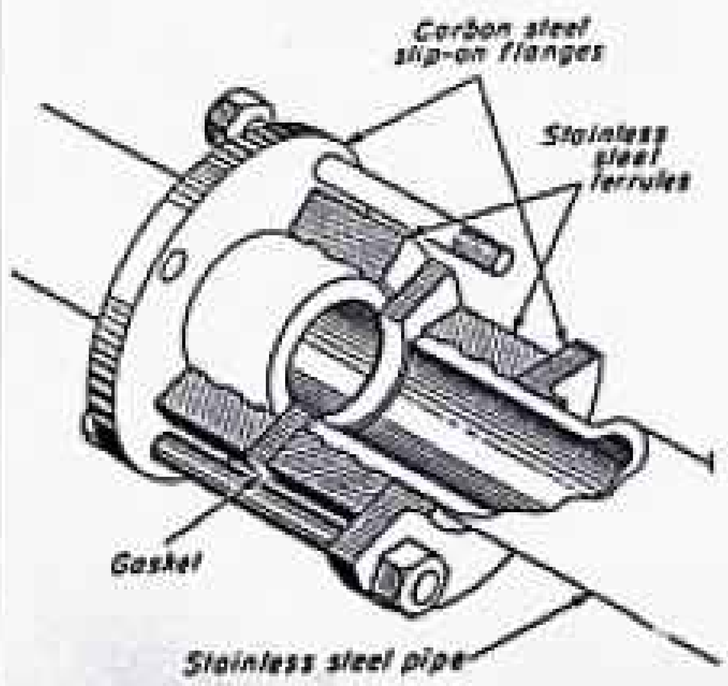
Let's turn our attention today to the design of the Chemical Plants at Y-12. These plants were all built in the Building 9202 chemical complex. We will also discuss the design of the Atomic Bombs that were dropped on Hiroshima and Nagasaki, and other events that occurred at Oak Ridge.

We'll begin with a discussion of some of the solutions to corrosion problems that were developed during the design and operation of the Y-12 chemical plants. It was an ongoing activity until the end of the war.

Because of the corrosive nature of most of the solutions processed in the chemical plants and the need for zero losses, new equipment designs and unique materials of construction had to be developed. Since most of the solutions to be processed contained various concentrations of hydrochloric and nitric acids, the suitable materials of construction varied with the concentration and temperature of these acids. Hydrochloric acid reacts with most metals and strong nitric acid is a vicious oxidizing agent that attacks rubber and most organic materials.

Materials of Construction:

This is a partial listing of materials that were used satisfactorily to combat corrosion in the Y-12 chemical plants. We will briefly review the problems and advantages of each of those listed. Some of this may seem ""old hat" to today's younger engineers, but it wasn't sixty years ago.

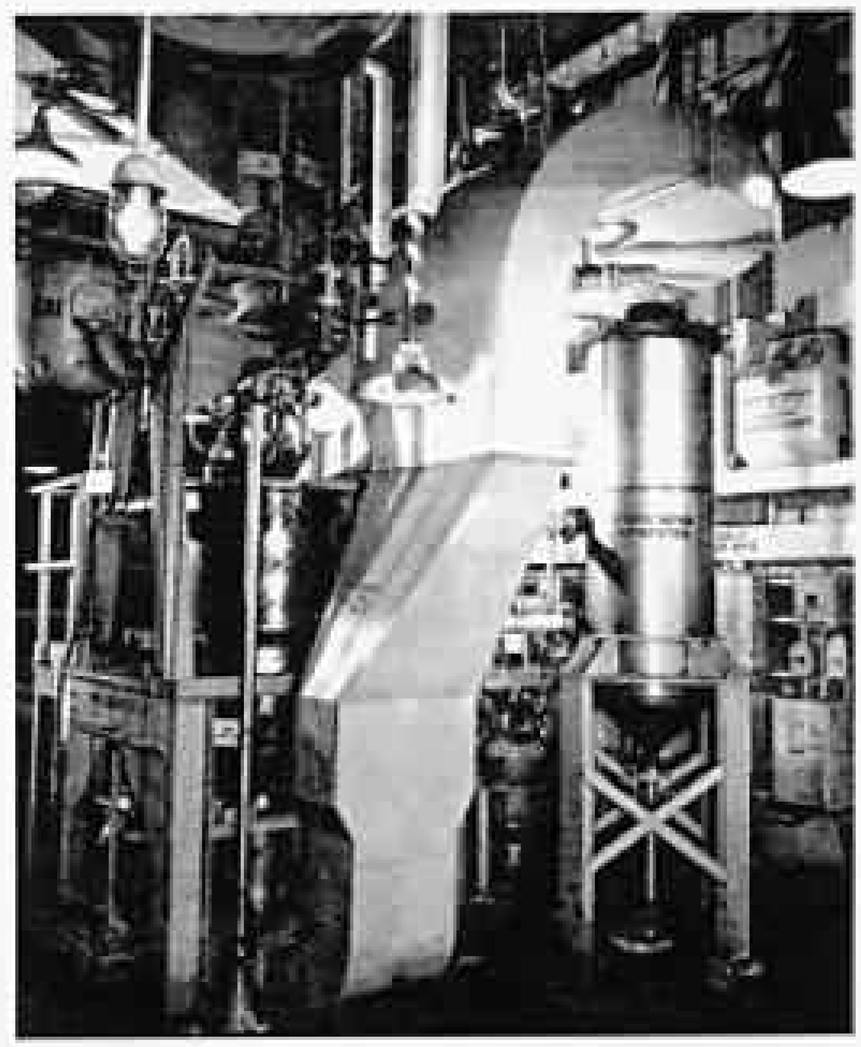


Typical ferrule joint used for type 316 stainless steel piping

1. **Use of Corrosion Resistant Metals: For solutions containing strong acids, high nickel alloys like Hastalloy-C and Inconel were suitable for cast pump and valve housings, but their supply was very limited.**

2. **Stainless Steel: Type 316 stainless steel was used for dilute acid solutions. A major disadvantage to the use of stainless steel was the care that had to be used in making welds. Unless each weld was annealed by carefully controlled heat treatment, the metal adjacent**

to the stainless steel welds would have a structure containing large grains and would be subject to inter-granular corrosion. This problem was solved by using ferrule flanges, in which the stainless steel pipe was physically rolled into grooves which were machined into the interior of the flanges. Stainless steel lens rings were used as a gasket between sections of pipe. As you can see from this 60 year old sketch, no welding was needed in a ferrule flange joint.

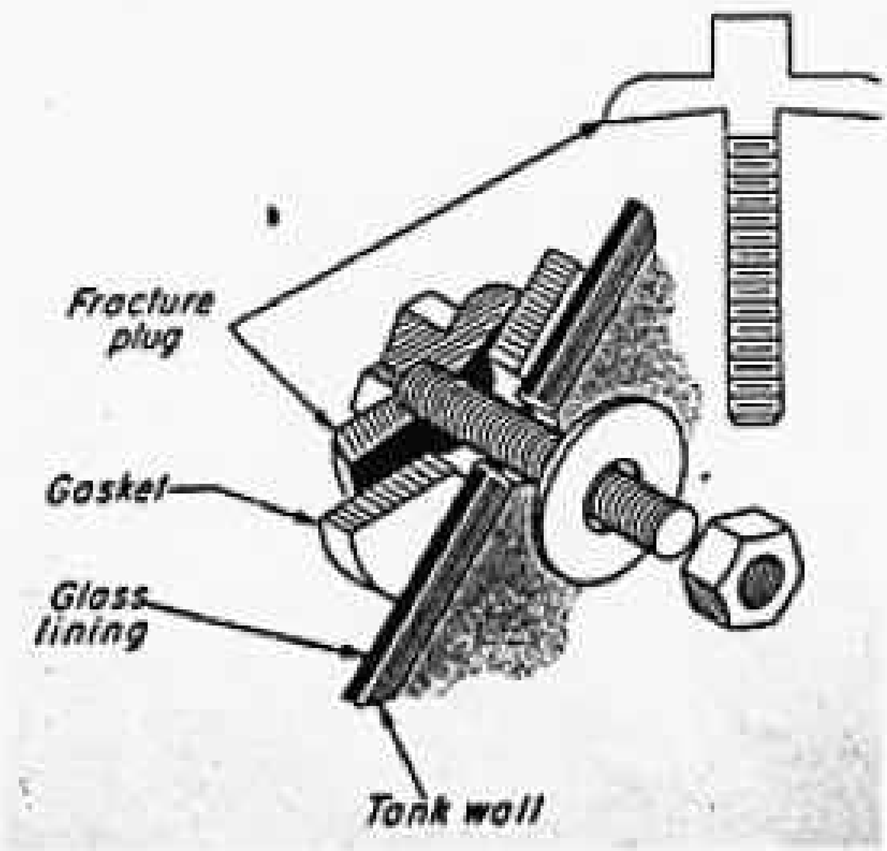


This photograph shows a stainless steel centrifuge with stainless steel piping and duct work.

3. Saran: Saran pipes and fittings were used for carrying deionized water throughout the chemical plants. The deionized water was so pure that it had a lower content of contaminants than did triple distilled water used in laboratory work.

4. Glass Lined Equipment: The Pfaudler Co., in Rochester, N.Y., was the primary manufacturer in the United States of glass lined vessels and diaphragm valves. None of their production was pin hole free. Over several months, because of our AAA priority, Pfaudler learned how to greatly reduce, but not eliminate, the pin hole count.

All pinholes found in newly delivered equipment were repaired before the equipment was installed. A dentist from Knoxville repaired the pinholes with gold fillings, much as he would fill a cavity in a tooth. We also learned how to use specially designed titanium fracture plugs used to repair leaks that occurred through the glass and steel to the outside. Keeping the glass-lined equipment in service was a fight that lasted to the war's end.



This is a drawing of a "Titanium Fracture Plug" used to repair a major failure in glass lined equipment.

One day the temperature in a small hydrogen peroxide feed tank on the top floor of the chemical building (Bldg. 9202) started to rise out of control and the foreman told the operators to leave. The area was cleared of personnel just before the tank ruptured and blew a hole in the roof. Management had a meeting to review the mishap, but found nothing wrong. Just as we were leaving the meeting someone said "Everything looks all right, the explosion must have been a freak." At that there was another bang and another hole in the roof. This time, we carefully inspected all of the piping and found that a pipe fitter had changed the vent lines from the H_2O_2 tanks in a way that allowed small amounts of dirty rain water to flow back into the system. We could, and did, clean all of the piping and small feed tanks, but the question was had any contamination gotten back into the 30,000 gallon storage tank? If that large storage tank started heating up, its drain was too small to empty the tank quickly. If the tank blew up, there would be no Bldg. 9202 chemical plant left. If we dumped our only supply of H_2O_2, we would have to shut down chemical plant operations. Either way there would be no supply of uranium tetra chloride feed stock for the cyclotrons.

We couldn't find anyone from the Army to help us decide what to do. I told my boss that I believed that we should dump the tank right now. He agreed, and we dumped all of our hydrogen peroxide. Then a Captain appeared and said "not to worry," he knew the management at BECCO and he would get a tank car on the way. The problem he ran into was that it was January and Buffalo was having one of the worst blizzards in history. Rail transport was at a stand still, and probably would be for some days. This was one time that an AAA priority didn't help. We called all the major chemical companies (DuPont, Carbide, Monsanto, etc.) but none of them used bulk 30 % H_2O_2 or knew of anyone who did. We asked the Army to put out an emergency request to Universities, industrial laboratories and anyone who had carboys of 30% H_2O_2 from BECCO. The next day the carboys started arriving, and we carried them to the third floor of Bldg. 9207 and emptied them directly into the feed tanks. That continued for over a week, until a tank car finally got through. No cyclotron ever went without feed.

Now, we had only two major weaknesses in our design capabilities for handling enriched Uranium solutions. First, we needed gaskets with better resistance to nitric acids oxidizing ability and second, we needed a truly leak-proof pump.

1. Gaskets: Although Pyrex glass was fully resistant to corrosion at all of the low pressure conditions found in the chemical plants, a major problem was finding gaskets that had adequate resistance to oxidizing acid solutions. Rubber and Tygon were satisfactory only for non-oxidizing solutions at low temperatures.

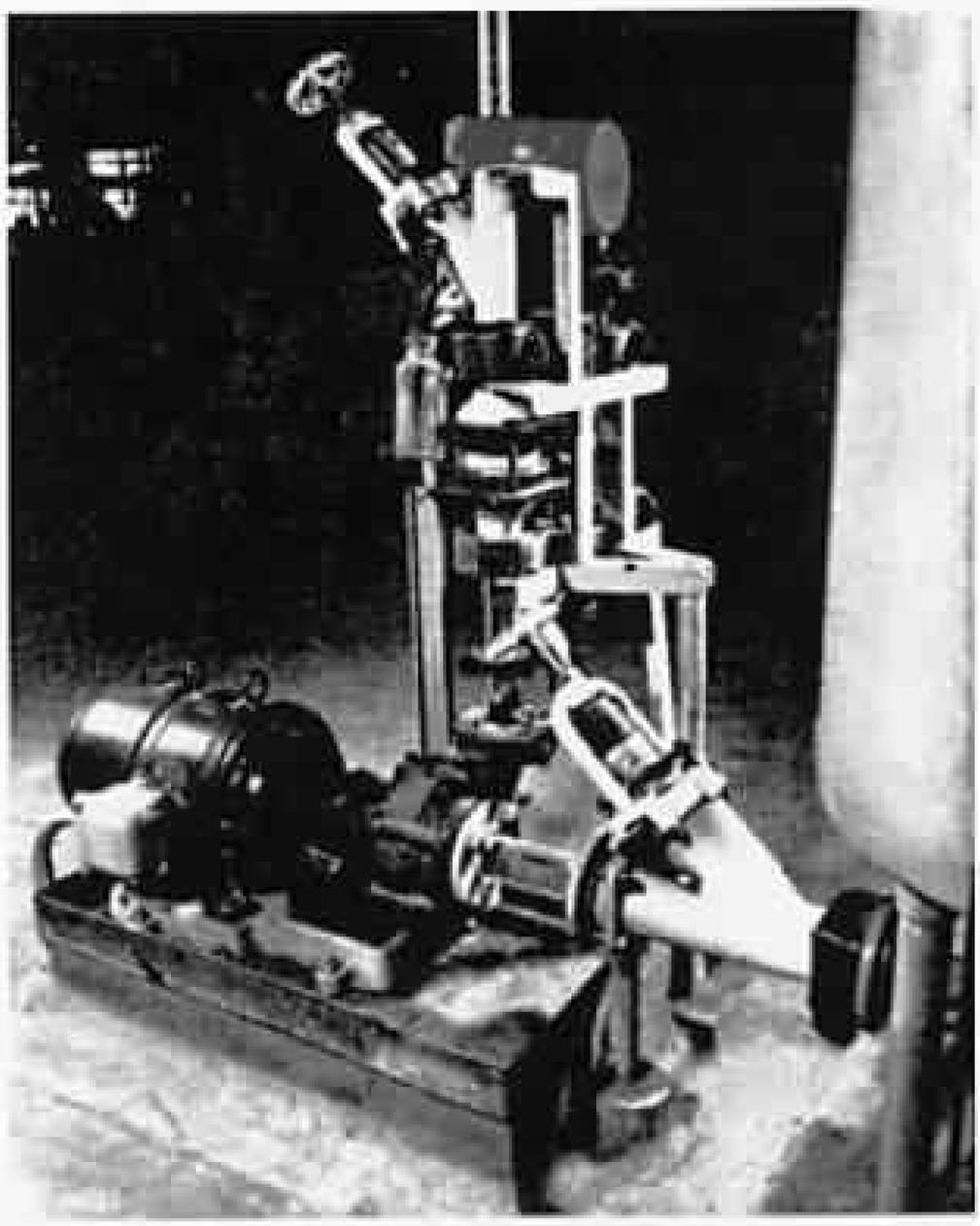
   Then we had some badly needed luck. At an AIChE meeting in New York I had lunch with an ex-classmate who was a research chemist at DuPont. He told me that DuPont had developed a plastic that had unusual resistance to nearly all chemicals, and that could withstand quite high temperatures. It was being produced in a pilot plant. We tested a sample of the material and found that it was the gasket material we had dreamed about. Our AAA priority obtained DuPont's entire output of what is now known as Teflon.

   Teflon was delivered to us in the form of rods and tubes of the appropriate sizes to enable gaskets to be machined in our shops.

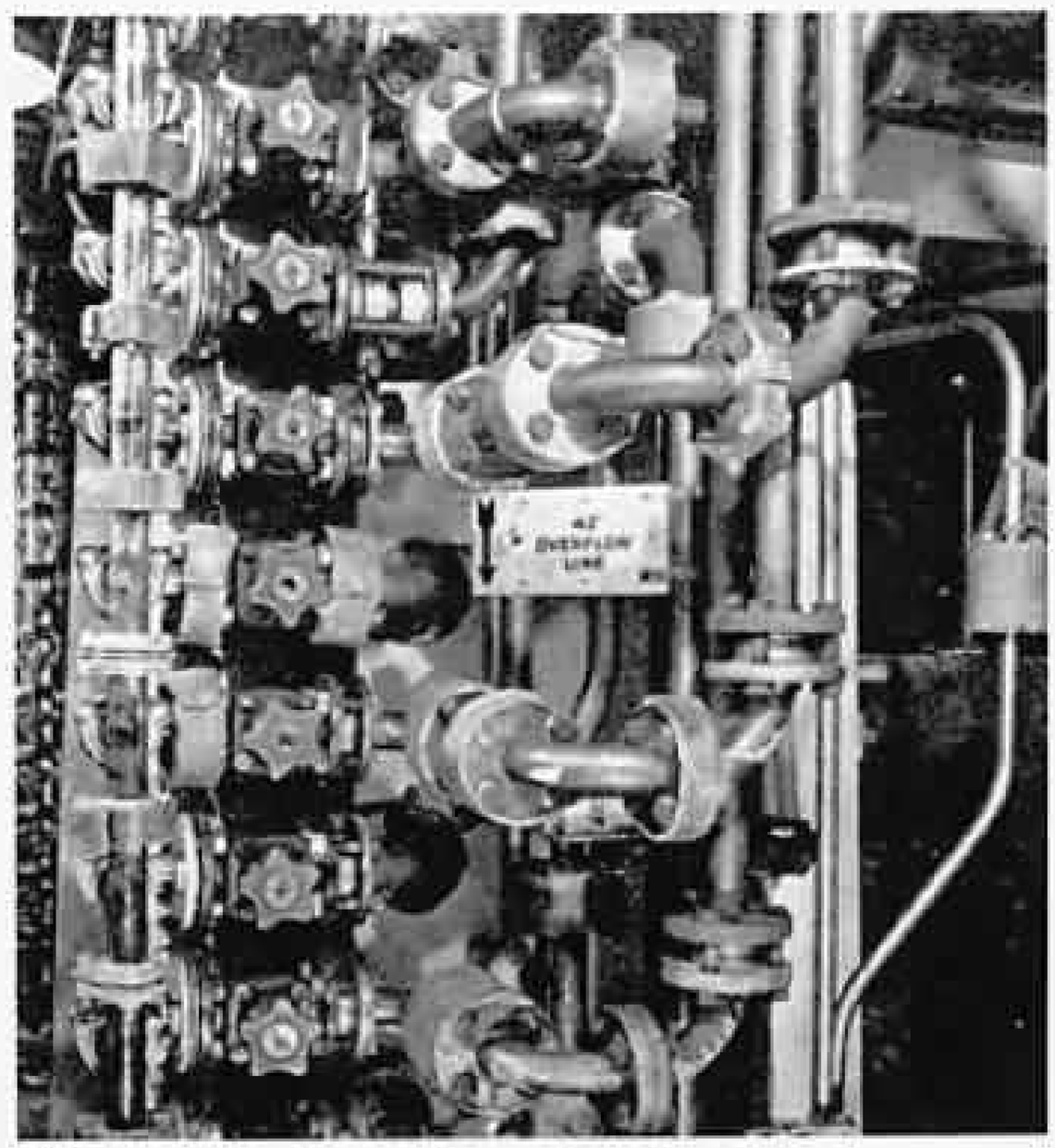
   We soon found that solid, washer-like, Teflon gaskets were too hard to be used successfully between sections of glass pipe. A successful gasket was produced when our machine shop machined thin Teflon gaskets that had a slit cut from the outside of the gasket to almost the center. Then, by putting a ring of soft asbestos in the slit we had a gasket with only Teflon exposed to the solution in a pipe, but flexible enough to enable a good seal to be made between glass pipe sections. Just in case a leak might occur, though, each gasket joint was wrapped with a sheath of 1/16" lead sheeting, which localized any leaked material.

2. Leak Proof Pumps: One of the pieces of equipment needed most in the chemical plants which processed partially enriched uranium, was a pump that was leak proof. All the pumps available commercially at the time used an exterior motor. The motor was coupled to an impeller pump shaft that went through either a packing gland or a rotary seal. The glands and seals were exposed to the suction pressure of the pump, and after a time, the seals would invariably develop a leak.

   We worked with Garlock to develop a double, rotary seal assembly in which the inner seal was exposed to the pump suction pressure, and the outer seal was exposed to the atmosphere. The space between the two seals was filled with clean water or solvent, depending upon what the pump was handling. An instrumented system held the pressure between the seals at one or two pounds above the pump suction pressure. If a leak occurred at the inner seal, clean liquid would go into the pump. If the outer seal leak should leak, clean liquid would leak to the outside, but no Uranium would be lost. The double seal assembly worked quite well, but it was not considered to be completely safe for solutions of "enriched" U-235.



5. <u>Porcelain Piping</u>: Because of its early availability porcelain pipes and valves were used in the early construction of the chemical plants. The porcelain was brittle and heavy, and had to be installed in such a way that no severe stresses were ever put on it. Even spring loaded pipe hangers and supports were not always satisfactory. This is a photograph of a hard rubber pump with porcelain valves and glass piping.



6. <u>Pyrex Glass Piping:</u> Pyrex glass piping had never been used, or even produced, before. Our AAA priority got Owens Corning Co. to work with us on designing flanged joints in Pyrex pipe. Glass was used in place of porcelain as soon as it was available. Glass piping could be fabricated in the field and had better fracture resistance than porcelain. In most cases glass piping could be supported in the same manner as stainless pipe and fittings. In critical locations the glass was supported in spring loaded, angle iron supports in order to give better protection. An entirely new technique of field cutting and welding the glass pipe was used, including the ability to anneal all welds in the field. The result was the duplication, in glass, of all the advantages of welded, stainless pipe installations. This photograph shows a header of glass lined valves and Pyrex glass piping.

This photograph is a typical view of an area where partially enriched U-235 is processed. In this case the installation is a plate-and-frame filter press. Note that it is installed on a stainless steel floor and has a shield around the press to contain any leaks that might spray from the filter press.

CONGRESSIONAL COMMITTEE INSPECTION

It doesn't take a lot of imagination to guess that the amount of money that Congress had to appropriate for the Manhattan Project was more than enough to attract their attention. Finally, some members of Congress got so upset about the appropriations that they insisted that they be given an explanation of what the expenditures were being used for. President Truman, General Groves and Congress finally agreed to appoint a special committee of scientists and businessmen who were satisfactory to everyone involved. The committee would investigate what was going on and report to Congress their opinion of the wisdom of the expenditures. There were about seven members on the committee.

I got the assignment of taking the committee on a tour of the chemical plants. It was explained that there would be no introductions of the committee members, for security reasons. When they arrived for the tour, I didn't need an introduction to the Committee Chairman—it was Doc Warren K. Lewis, my professor from MIT. He never acknowledged knowing me during the tour. Afterwards, though, he took me aside, and said, "Bob, is this thing going to work?" I told him that I knew that some of the best physicists in the world were working on the bomb and that I had confidence in them. I also said that the Cyclotrons were working smoothly, and that I was sure that the chemical plants would always keep adequate feed going to the cyclotrons. He thought a minute and said, "I believe that's good enough for me."

We never did hear what the committee's report was, or what the members of Congress said, but the money kept coming. I think, though, that all of us at Oak Ridge pretty much agreed that if the bomb turned out to be a fizzle, we'd probably all spend the rest of our lives testifying in Congressional investigations, or worse.

BUILDING 9207 COMPLEX FOR PROCESSING UNION CARBIDE'S GAS DIFFUSION PLANT PRODUCT

About one year before the end of the war General Groves came to Y-12 and asked Tennessee Eastman to design and build chemical plants to process the output of Union Carbide's Gas Diffusion Plant (K-25) into feed for our Beta Cyclotrons.

He said that Union Carbides present K-25 plant could not purify Uranium-235 all the way to bomb grade product. His request was for us to chemically convert the K-25 product to UCl_4 feed stock for our Beta cyclotrons, since these cyclotrons had some unused capacity.

One night I had an idea, and the next day I went to Knoxville, where I bought a pair of roller skates, a bicycle wheel, and a bicycle inner tube. As I recall the Accounting Dept. took a dim view about reimbursing me for those items. At the Y-12 shop a pattern maker put together a rigid wooden frame in the shape of a "U," with a groove around the inside. Into the groove, we placed a section of the bicycle inner tube, and fastened the ends of the rubber tubing to the inlet and discharge piping. The skate wheels were attached to the outside of the bicycle wheel rim. This wheel assembly was fastened to the wood frame in such a manner that when the wheel turned the skate wheels would flatten the inner tube into the groove in the wood frame. As the wheel assembly was rotated, the skate wheels pushed slugs of liquid ahead of them through the tube. For obvious reasons, we called the unit a "slug pump." The flexible tube was replaced each week in order to prevent wear from causing a tube failure. The used tubes were incinerated to recover any enriched uranium that they contained.

About a year after we first used the slug pump, a government lawyer brought a patent application to be signed. He said that the idea was novel as far as existing patents were concerned. It was the first to be issued in my name and I was given a crisp one dollar bill for it. Pumps of that simple design were used to pump all of the enriched uranium solutions, at least until the end of the war.

After the war, the patent was made available to the public. The basic design has been used in a number of applications, including the pumps in intravenous injection units and in hemodialysis units at hospitals. In this type of service, conditions must remain sterile, and the tubing in the slug pump has no joints where contamination might occur. The tubing is inexpensive and can be easily replaced and discarded between treatments.

STORY OF A PROBLEM AT BUILDING 9202 CHEMICAL PLANT

The process for recovering pure uranium oxide from solutions recycled from the "race tracks" involved precipitation of the uranium oxide using some very unusual reactions. The acidic solution was first neutralized with ammonia. Then the Uranium was precipitated using concentrated hydrogen peroxide (30% H_2O_2) at temperatures near freezing. While the Uranium oxide was completely precipitated, iron and all the other metallic impurities stayed in solution. The hydrogen peroxide was obtained from the Buffalo Electro Chemical Co. (BECCO) in aluminum tank cars. It was stored in a large, refrigerated, aluminum tank located just outside of the chemical plant building. The entire piping and metering tank system was also made of Grade 2S aluminum (a very pure grade), since even trace amounts of iron and other metals would cause the H_2O_2 to decompose rapidly.

The existing Y-12 chemical plants were operating smoothly, and I was assigned the responsibility for the design of the new plants. Back to Boston I went, this time with the title of Superintendent of the Y-12 Chemical Engineering Dept.

Building 9207 Chemical Plants
(The bomb was dropped on Hiroshima ten days before Bldg. 9207 was scheduled to start. It was never put into operation)

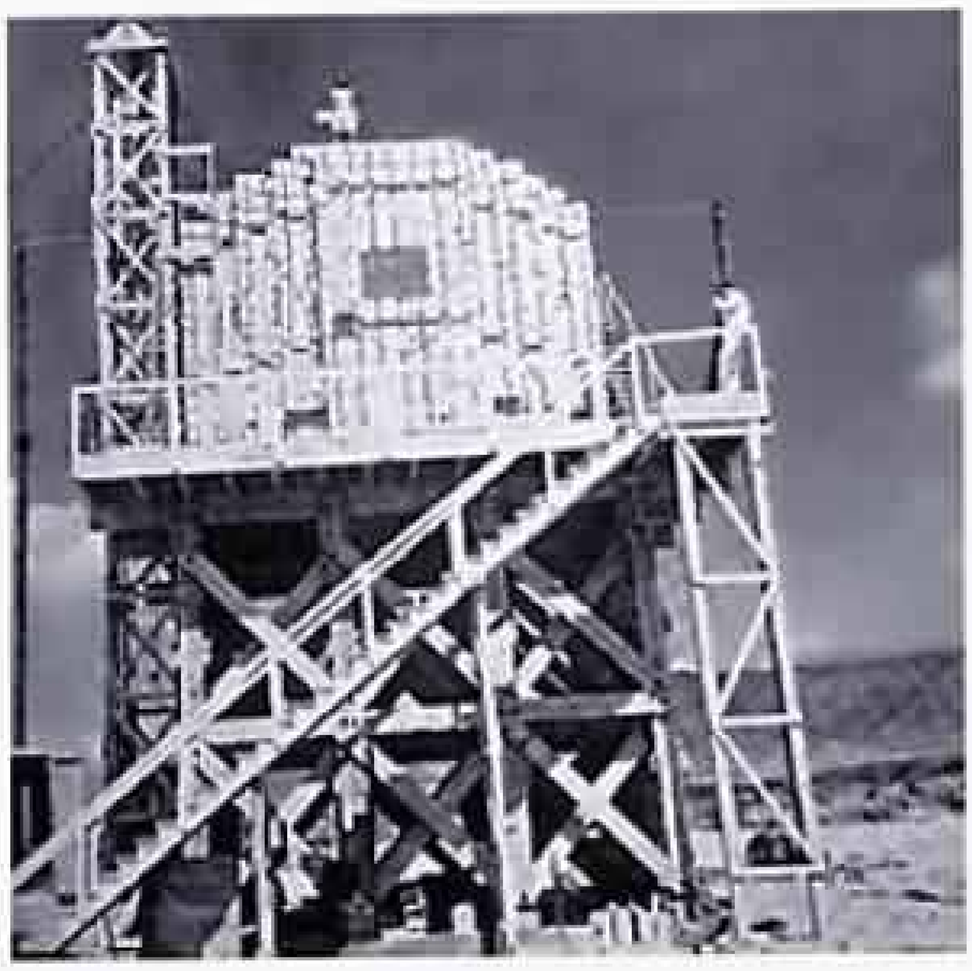
The new Chemical Plants were to be installed in a Building complex named 9207. These new plants included all of the "Better Design Features" that had accumulated since the design of the original plants was frozen. The new plants were also designed using data provided by Los Alamos physicists, to size and space equipment so that fission would not Occur. A computer control system would have been a wonderful aid, but we had only pneumatic and hard-wired instruments to use.

The chemistry used in the new chemical plants was identical to that used in the original plants. Instead of using a single line of equipment, however, the new plant was built with smaller size equipment in multiple lines to prevent the occurrence of a critical mass.

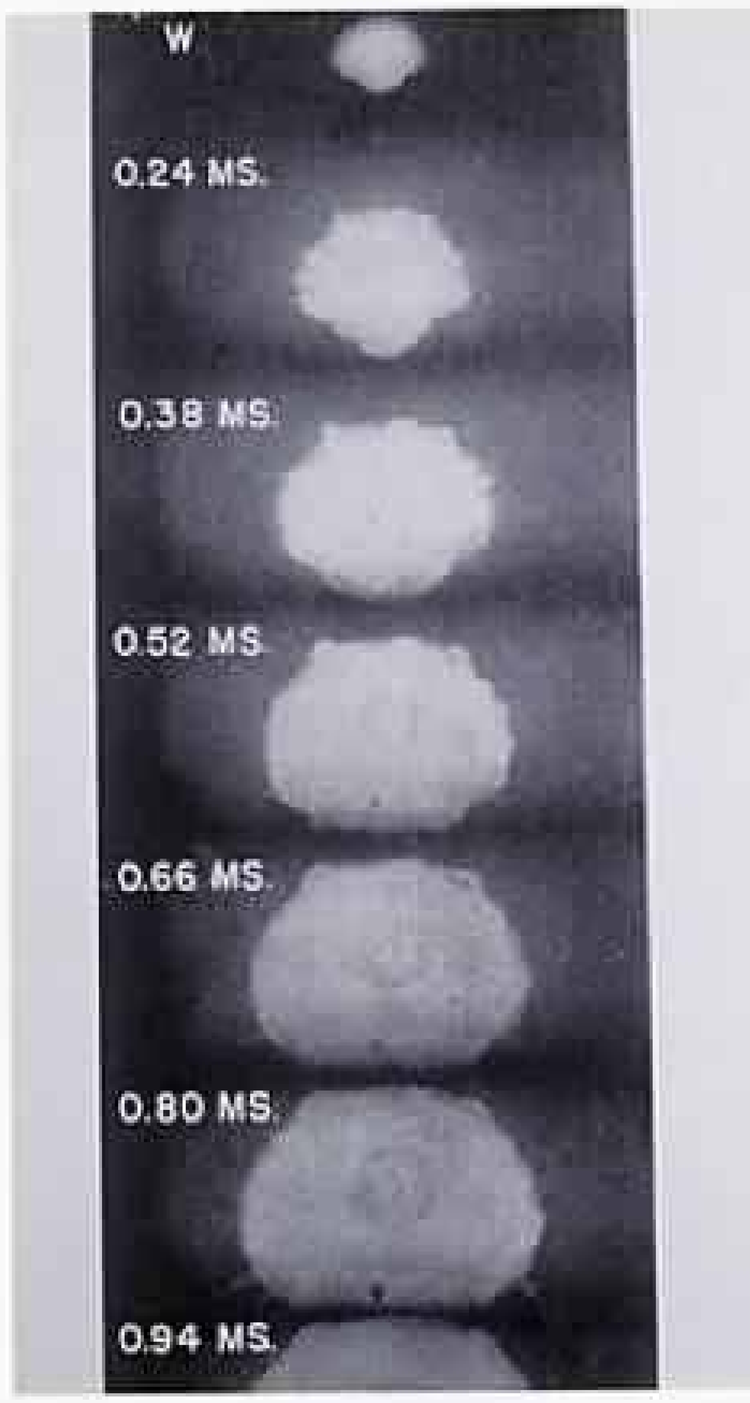
We designed the plants with double interlock systems for safety. Every step of an operation was protected twice. For example, to prevent a vessel from being over filled, the vessel was mounted on scales and it was protected by a level indicator in the vessel as well. If either interlock was activated, inlet and outlet valves closed automatically and any associated pumps were shut down. The interlocks had to work. Should fission start anywhere in the plant because of improper design, operator error, or for any other reason, a tragedy worse than the one that occurred at Chernobyl in Russia would almost surely take place. The new plants were repeatedly tested with water to train the operators and to be certain that all of the interlocks were working correctly. We were within about ten days of charging Union Carbides partially enriched U-235 to the new plant when the bombs were dropped on Hiroshima and Nagasaki. In order to avoid spending a dollar that we didn't have to, the army ordered that all operations at Oak Ridge be shut down. At the chemical plants we quickly prepared procedures for shutting down and mothballing all of the chemical plants. The Army approved the plan. As a result, the Building 9207 plant that we had built to process Union Carbide's partially enriched Uranium-235 was never started. We will talk more about that a little later.

LOS ALAMOS & ALAMAGORDO

Now we will show some photographs of events at Alamagordo, New Mexico. All photographs were taken six miles from bomb site:



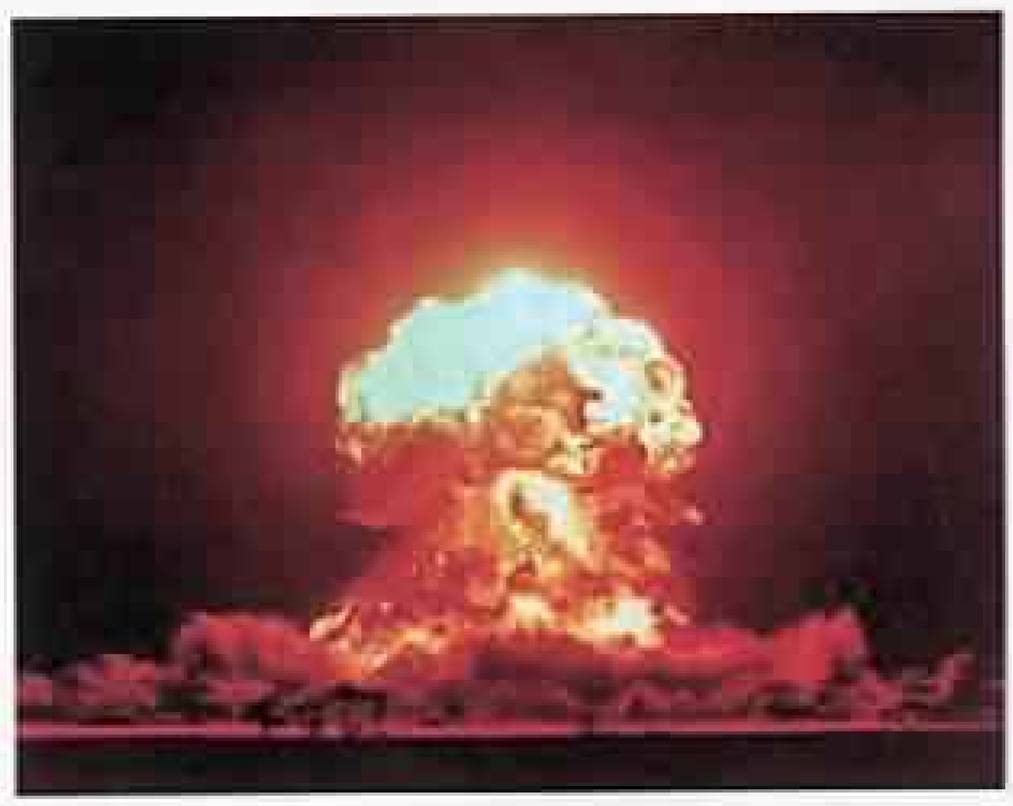
A test explosion using 100 Tons of TNT was carried out in order to later evaluate the effective size of an atomic bomb in terms of TNT. This shows the setup for that test.



Atomic Bomb Test—This image on the right shows the start sequence of the bomb explosion in microseconds.

Extrapolation data from the test with 100Tons of TNT showed that the Atomic Bomb was equivalent to over 10,000 Tons of TNT.

The only color photograph taken at Trinity Site

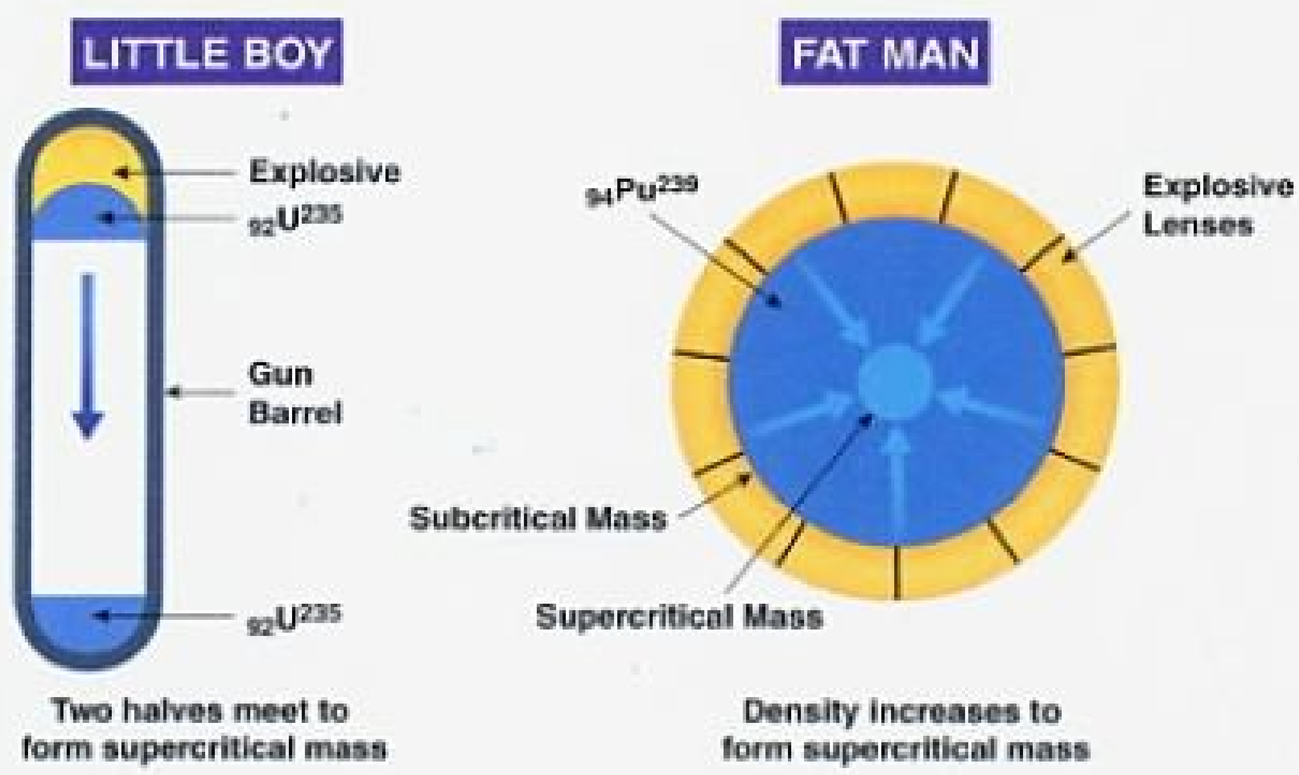


As you know, the title of this paper is "The Manhattan Project," which was the code name for "The Atomic Bomb Project." We've talked primarily about producing Uranium-235 or Plutonium. I think it would be appropriate to talk a little about how I believe that these materials were used in an Atomic Bomb.

By definition, an explosion is a sudden and violent release of a large amount of energy in a small region. Since a "critical mass" must be avoided until the bomb is to ready to explode, the bomb must consist of separate pieces each one of which is below the critical mass either by reason of small size, unfavorable shape, or location. To produce detonation, the parts of the bomb must be brought together into perfect contact very suddenly.

In the case of "Little Boy," shown on the left, the so-called "cannon" design was used. It was a simple approach with small risk. In the cannon design one piece of Uranium-235 is blown into a second piece to form a solid sphere, which is the most efficient shape for a chain reaction to occur.

In the case of the "Fat Man" bomb, at the right in the photo, used at Nagasaki, the cannon approach could not be used because Plutonium contains a small amount of an isotope that continuously emits a stream of neutrons. A cannon bomb using Plutonium would be too large to be carried by even a B-29 aircraft. The Los Alamos group came up with a stunning answer to that problem. It is my understanding that by forming the Plutonium into a thin-shelled sphere, the loss of neutrons would be so great that no fission would occur. Carefully designed shaped charges of explosives were placed around the thin Plutonium sphere. The simultaneous explosion of the shaped charges blows the Plutonium into a solid sphere that is a critical mass, and the explosion takes place. This technique is called "implosion." An explosive shock wave can move so much faster than a bullet that the shell of Plutonium was crushed into a solid ball, with a density twice that of normal Plutonium. This greatly reduced the amount of Plutonium needed for a critical mass.



By surrounding the fissionable material in either bomb with a layer of graphite, a large number of neutrons, that would otherwise escape, can be reflected back into the bomb. This also lowers the size of a critical mass. Such material is called the Reflector or Tamper in a bomb. Use of a tamper enables a longer lasting, more energetic, and more efficient explosion. Although the bombs dropped on Hiroshima and Nagasaki did a pretty good job and ended WWII, I know that many improvements have been made in the design of bombs since then.

PRESIDENT TRUMAN'S DECISION TO DROP THE BOMB

I believe that this presentation would not be complete without a discussion of President Truman's decision to drop the atomic bombs on Japan without warning.

After President Roosevelt's death on April 2, 1945, President Truman was completely briefed on the Manhattan Project two weeks after taking office. As Vice President he had known nothing about the project.

Many of you can recall that President Truman personally made the decision to drop the atomic bombs on Japan without notice. Each of you may have personal opinions about the wisdom and morality of that decision. I know first hand that after doing the work to produce an atomic bomb, a number of Chicago and Los Alamos physicists thought that before dropping a bomb on Japan, we should first demonstrate an atomic explosion to them in the hope that they would then surrender. They wrote a petition asking President Roosevelt to do just that. The petition was passed throughout the Manhattan Project for signatures.

I asked the physicist that brought the petition to me if he had any family or a close friend in the armed forces that was on the way to attack Japan. He said no. I told him I had a brother on the way to attack Japan. I also told him, that based on the attitude of the Japanese people towards the Emperor, I didn't think that a demonstration to Japanese politicians or their Army Officers would be effective in ending the war. I thought that Pearl Harbor and Kamikaze attacks showed the type of people we were dealing with. I refused to sign the petition, as did nearly everyone on my staff. Somehow General Groves bottled up the petition and it never got to President Truman.

Dr. Wayman Norman is a retired ear, nose, and throat doctor in Longview. He is a history buff and has done a considerable amount of research on estimating the number of servicemen men who would have lost their lives in a land attack on Japan. He believes that by dropping the bombs on Hiroshima and Nagasaki we saved the lives of over 400,000 of our servicemen.

I'll save the punch line on President Truman's decision for a little later, and go on to the worst security fright that I've ever had.

MY WORST SECURITY FRIGHT

The title of this section is "My worst Security Fright." It's probably also "My Worst Fright ever, of any kind."

At bridge parties and almost any get-to-gather at Oak Ridge, the non-employees (mostly wives) made guesses about what we were doing or making at Y-12. It was almost a game. They never came close to a correct guess, since atomic energy wasn't exactly a common word then. One day while I was in a meeting concerned with the startup of the new chemical plants which would process partially enriched Uranium-235 from the Union Carbide Gas Diffusion Plant, my secretary interrupted to say that my wife was on the phone. Since my wife hardly ever called me at the plant I was sure that something very bad had happened. When I picked up the telephone she just said "I know what you're making—it's an atomic bomb." I know that my hair stood on end, and that I nearly dropped the telephone. I was sure that I could hear all of the security telephone monitoring connections clicking. When I began to stutter and tell her to shut up, she said "don't worry, it's on the radio that an atomic bomb has been dropped on Japan, and that the uranium for the bomb was produced here at Oak Ridge." That ended the meeting, but I don't think that I was ever shocked that much by anything, either before or after. That telephone call was probably the worst scare and the best news that I've ever had had in my life.

PICTURES AT HIROSHIMA

This is the "Enola Gay" just before it took off for Hiroshima.

After the bomb had done its work the Enola Gay circled back over the target and these pictures show the almost complete destruction of the city.

STONE & WEBSTER'S COMPLIMENT AT THE WAR'S END

Those of you who heard the first session will remember my discussion with Mr. Gus Klein, Stone and Webster's "head man on the Manhattan Project." When Kodak first assigned me to represent them in Boston in 1943, I had told him that either they had the wrong Schrader or someone had made a big mistake. He had assured me that I was the choice of both Kodak and Stone & Webster. He had been very helpful in getting "the student who had never been in a chemical plant," off on the right foot." At the end of the war he came to see me, and gave me a compliment that made up for a lot of hours of hard work that had gone into building the Y-12 Chemical Plants. He said that he had never been involved in a project where the information and directions needed for Stone & Webster to do an effective job of designing some very complicated plants had come to them in a more straight forward and timely manner. He believed that we had saved months over their normal time for designing such plants.

Now let me brag about Kodak a little bit.

KODAK HONORED WITH THE "EE" AWARD BY THE WAR DEPARTMENT

After the war, Eastman Kodak was one of the few companies given the "EE Award" for outstanding work in the war effort. I had the honor of being one of the five Kodak representatives who went to Washington to receive the award. **I think that it is unfortunate that many of today's employees know little about Kodak's contribution to the war effort in WW-II. After the war the press agents for both Union Carbide and DuPont did such an excellent job for their companies that authors of books about the Manhattan District published later give little mention of Tennessee Eastman's Y-12 plant. It is a fact that Kodak's Y-12 plant provided Los Alamos physicists with bomb grade material over a year before anyone else was able to so. Work at Los Alamos on the design of an atomic bomb would have been delayed if the Y-12 bomb grade U-235 had not been available to them. It is true that the Gas Diffusion Process is the most economical way to produce U-235, but Y-12's Cyclotrons made all of the bomb grade U-235 that was produced during the war.**

CHICAGO TRIBUNE'S REVIEW OF THE MANHATTAN DISTRICT

Shortly after the war the Chicago Tribune printed a story and some trivia about the Manhattan Project. In the "trivia section" they listed me as being the youngest Department Superintendent in the Manhattan Project, at age 26. I have to take their word for that.

FACTS ABOUT THE OAK RIDGE PROJECT

In summarizing facts about the Oak Ridge Project, we can say that after three years of work, with a peak employment of 82,000 workers, and the expenditure of $1,106,393,000 the Cyclotrons at Oak Ridge had produced the material for an atomic bomb that brought WW-2 to an end. As far as the Chemical Plants are concerned, we can also say with pride that the Cyclotrons were never once short of feed. Expenditures at Hanford, Washington and Las Alamos, New Mexico probably more than doubled the expenditure of money spent on the Manhattan Project at Oak Ridge.

MANHATTAN PROJECT LEADERS AFTER THE WAR

You may be interested in what became of General Groves, Colonel Nichols, and Dr. Oppenheimer and the Y-12 facilities after the war:

Dr. Oppenheimer was a hero for a while. Then he lost his "security clearance" because of Communist connections, and was no longer involved with atomic energy work.

General Groves lost control of the Atomic Energy Project and became a businessman. He died of heart disease in 1970.

Colonel Nichols was an effective leader at a difficult time. He was thoroughly respected by most of us at Y-12. He justly received his countries Distinguished Service Award. I don't know what he did after the war, although I assume that he stayed with the Armed Services. They needed men like him.

Kodak's presence at Oak Ridge ceased with the end of WW-II. The government contracted with Union Carbide to take over all manufacturing operations at Oak Ridge. I believe that the more cost efficient Gas Diffusion Plant was expanded after the war and produced any needed bomb grade U-235.

OAK RIDGE AFTER THE WAR'S END

Oak Ridge was in a state of limbo after the war ended. All production facilities were shut down, and I sat around for a number of months, with nothing much to do. The management of the Manhattan Project refused to release me from my Oak Ridge job. In fact, they asked me to transfer to their organization. All I wanted was to be released so that I could go to work for Kodak.

Since I had trouble with my wisdom teeth, I arranged for the teeth to be removed by an oral surgeon from Knoxville. He came to the emergency room at Oak Ridge to do the job. Surgery to remove the teeth was free, but I remember thinking that a little more money should have been spent on anesthetic. While removing the last tooth, the supply of anesthetic ran out. The doctor tried to complete the job in a hurry and broke off the tooth, leaving the roots still in my jaw. He removed those several weeks later, after the supply of anesthetic had been renewed.

Then to keep from being bored, I talked the Superintendent of the Y-12 Shops into letting me come there and learn how to weld. I spent about four to six weeks doing that.

LEAD ARTICLE FOR "CHEMICAL & METALURGICAL MAGAZINE"

Special Materials Solved

CORROSION PROBLEMS

After learning about welding I got the Army's permission to write an article describing the unique chemical engineering designs and materials of construction that we had used in the Y-12 chemical plants. Army Intelligence gave their approval, and it was the cover article for a special issue of Chemical and Metallurgical Engineering Magazine. The first page of that article is shown here.

The Army was still dragging their feet on my release when I got an offer from Dow Chemical Co. to work for them, and Dow promised to expedite my release from the Manhattan Project. When I showed that offer to Dr. Fred Conklin, Plant Manager at Y-12, and Dr. James McNally, Asst. Works Manager, they got things moving. Several days later, Dr. McNally told me that he was to be the new Director of Research at Tennessee Eastman and that he could give me the job of Supt. of Pilot Plants in the Kingsport Research Laboratory. He said to just be patient, and that he believed that the Army would release me in several weeks. We accepted his offer, and the release came through.

MEETING WITH LOS ALAMOS PHYSICIST AFTER THE WAR

Now I'll end this presentation by revealing some information that I don't believe has ever been documented anywhere.

At a meeting in New York a year or so after the war, I had lunch with the physicist from Los Alamos who had worked with us during the design of Bldg. 9207. As you recall, Bldg. 9207 complex contained the plants that were built to process Union Carbides partially enriched Uranium-235, but were never started. In order that the plant could be operated safely, he had provided us with the data that we used for sizing tanks, spacing equipment, designing interlocks and cladding equipment with cadmium to absorb radiation. During lunch he said: "Did you ever charge Carbides partially enriched Uranium 235 into Bldg. 9207?" When I told him that we had shut down all of the plants at Oak Ridge about 10 days before Bldg. 9207 was scheduled to start, he said, "I was sure that you had not charged feed to 9207. We have much better data now, and if you had charged partially enriched U-235 from the Gas Diffusion Process into the Building 9207 complex, it would have most certainly "gone hot." The quantity of radioactive material released would have wiped out Oak Ridge and Knoxville, and with the prevailing winds, damaging radioactive material could have gone as far as Chicago."

Those who believe that the United States should not have used the bomb without warning to end the war in the Pacific, are probably not aware of this close call. For that matter I don't believe that anyone in responsible charge, either in the Army or in our Government, is aware of this information. However, the fact is that a lot of us, our families and those who lived within many miles of Oak Ridge, are alive today only because Harry Truman made the decision to drop the bomb.

CONCLUSION

Today I would like to end this reminiscence of Oak Ridge and the Manhattan District with the conclusion that Tennessee Eastman's "Y-12" plants wrote their part of WW-2's history *on August 6, 1945, over Hiroshima, Japan. This painting shows the Enola Gay coming home after helping to write its part in that history. Thank you for the privilege of being invited to speak to you about The Manhattan Project. I've thoroughly enjoyed dredging up memories of that part of my life.