Early Days of Nuclear Physics at Notre Dame and the Manhattan Project

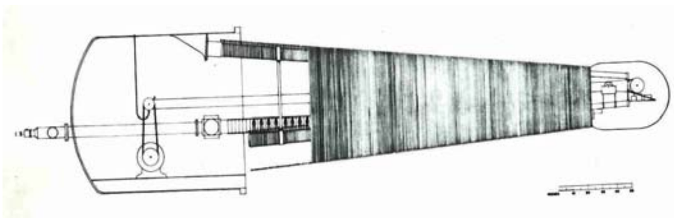
Philipp Wiescher

Notre Dame's second electrostatic generator (the fourth accelerator at ND) holds a special place in the Physics department's history. From 1942-5, its operation came under the direction of the Manhattan District Project, as part of the United State's efforts to create the first atomic bomb. The importance of the experiments run on the Van de Graaff accelerator to the development of the bomb are difficult to assess, as the Manhattan Project's final success depended not on any one breakthrough or laboratory, but on the coordination and integration of all pertinent information from participating labs around the country. Its results give credence to the maxim that the whole is greater than the sum of parts, and Notre Dame's contributions were one of the many essential "parts."

The assembly of Notre Dame's first electrostatic accelerator was completed in 1938, although it ran from as early as 1935 and till 1942. The experiments in this open-air accelerator primarily concerned the acceleration of electrons. Those met with considerable success, as Drs. George Collins and Bernard Waldman achieved the disintegration of beryllium with electrons at 1.75 million volts- the first experiment demonstrating the disintegration of a nucleus via electron bombardment. Furthermore, x-ray excitation, a novel process, was discovered. These x-rays were produced by aiming electrons at a lead source. Other highlights include the first pair production by electrons, and examinations of the tip of the Bremsstrahlung spectrum.

The second accelerator at Notre Dame - called the "Atom Smasher" in the local press – was located in the basement of the Science Building, now La Fortune Center from 1942 to 1953.

Construction on the vault of the second accelerator began in 1940. The need for advancement over the open-air accelerator was apparent: its open-air nature made it difficult to reach high voltage outputs when uncontrollable conditions such as humidity infringed on its performance. Dr. Raymond Herb of the University of Wisconsin realized as early as 1935 that placing an accelerator in a pressure tank would alleviate such problems. Notre Dame physicists followed his lead, completing a scaled-up version of the Wisconsin pressurized accelerator in early 1942. It was at the time one of the largest in the world, and was expected to generate 8 million volts. However, there is no evidence that it ever topped 4 million volts.



Technical drawing of the accelerator column and a picture showing the column support structure.

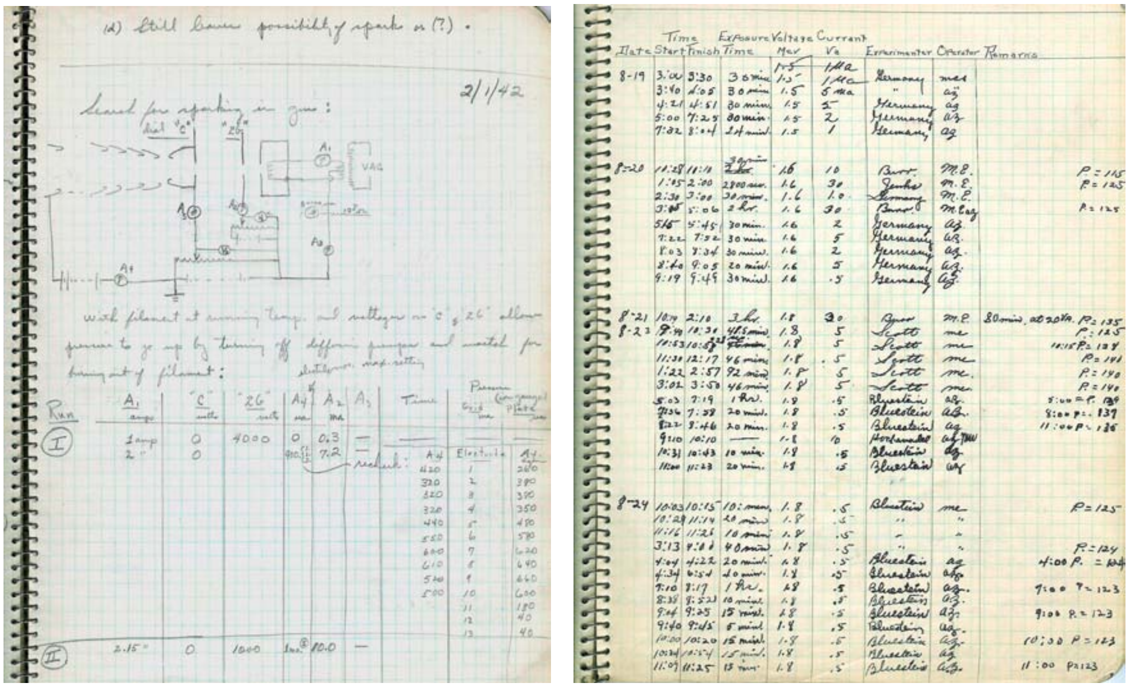
Shortly after the pressurized accelerator was completed, the Manhattan District Project took over its operations in 1942, so fundamental research had to wait. The M.D.P. co-opted a number of laboratories with state-of-the-art equipment around the U.S. in order to guide experimentation that would aid the development of a nuclear bomb.

Notre Dame's accelerator was at the time one of the largest in the world, and so a natural choice for WWII driven atomic research. There was a team of two Notre Dame graduate students involved for the daily operation of the machine. However, researchers arrived from the Chicago site of the Manhattan project daily by tram bringing with them the samples to be irradiated and tested. The results they took with them back to Chicago daily.

Photograph of the streetcar by which the researchers from the Chicago Manhattan Project arrived daily on campus.

The utmost secrecy involved is illustrated by the fact that the accelerator logbooks during this time were not made "public" till well after WWII, and even then, often contained no data from the time between 1942-5. Furthermore, even after the war, it was not immediately made public whether ND's facilities were even involved with the development of the bomb. Later in August of that year, Dr. Marc Wiedenbeck stated that they were not "permitted to disclose the methods in their contribution to the atomic project." The general secrecy at the time renders a technically detailed historical reconstruction difficult, even today.

But there are some vague clues. Dr. Bernard Waldman, a N.D. physics professor at the time, writes that the generator was used a source of x-rays and electrons during WWII, in order to examine the effects of beta and gamma radiation "on all materials that were to be used in the Hanford pile and the chemical separation system for plutonium. Among others, Rev. Henry J. Bolger and Dr. Wiedenbeck were involved in running these experiments during the war. At the time plutonium was created in nuclear reactors by forcing atoms of ^{238}U to capture neutrons. Hundreds of pounds of uranium had to be irradiated with neutrons in a cyclotron to produce just micrograms of plutonium. Hanford, Washington was chosen as a site for an industrial scale plutonium pile, and it first went critical in September 1944 after initial difficulties; by early 1945 it was shipping kilograms of high quality (i.e. 95% purity, low uranium content, low gamma



Copy of runbook pages before the war and during war operation. On the left hand copy a technical drawing of the electron source. These kind of drawings were not permitted during war operation.

activity) of plutonium to Los Alamos. Its smooth operation was instrumental to the construction of the plutonium bomb (the “Fat Man” bomb dropped on Nagasaki, and which some historians contend forced the Japanese surrender), and the wartime experiments at Notre Dame contributed to the Hanford pile’s production efficiency. The Notre Dame Physics department returned to a fundamental research program in 1946.

Dr. Waldman, employed in the Notre Dame Physics department since 1938, also played an interesting role in the war effort, working at the Los Alamos Science Laboratory for the Manhattan Project from 1943-5. He arrived in Los Alamos in 1943 at the behest of J.R. Oppenheimer, the director of the Manhattan Project, or Project Y as it was called. Waldman was assigned to Project Alberta, or Project A, whose objective was to design and organize the “delivery” of the atomic bombs. This ranged from determining appropriate airplanes for the drop, to designing stable-flight bomb shells, to the actual bombing of Hiroshima and Nagasaki itself. Indeed, it was “part science, part engineering, part military and part cut and paste.” Within Project A, Waldman was assigned to the Ordnance Division of group E-7, charged with the “integration of design and delivery.” Norman F. Ramsey was the group leader, with Sheldon Dike being the other group member. In essence, they were asked to make atomic bomb delivery a practical reality, to check flight stability, fuzing equipment, and the ballistics of the bombs. Naturally many technical difficulties arose, among them being: the bomb release mechanisms didn’t release, bombs missed their targets due to defect in tail fins, and great wobble in bomb flight paths occurred. However, due the work of E-7 and extensive testing at such sites as Muroc Army Air Base and Wendover Air Base, these complications were all addressed.

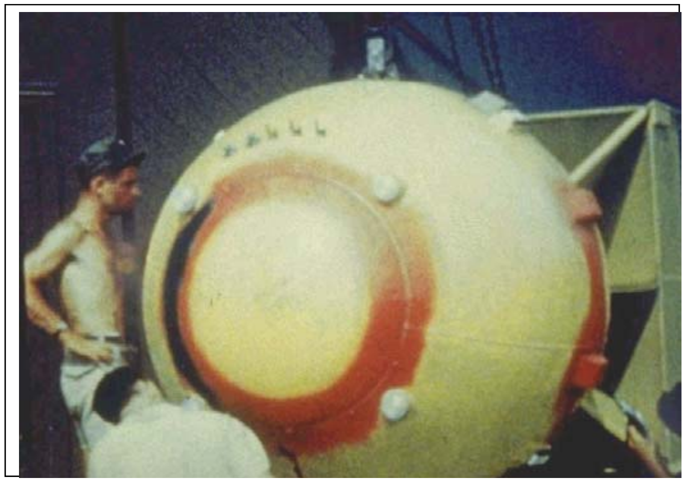
In April 1945 Oppenheimer realized he hadn't developed a method to measure the energy output of the bombs to be dropped. Luis Alvarez, of University California-Berkeley, had completed earlier projects, and volunteered for this work. He chose Waldman, Harold Agnew, and Larry Johnston to comprise this group (all were also finished with prior projects). They would eventually become the only 4 civilians to observe the first atomic bomb drop from "above."

The straightforward task proved to be complicated. The "standard" tests for measuring energy release would involve gauging gamma rays, neutrons, and the expansion rate of the nuclear bomb. This would be impossible under combat conditions, since the bombs were to detonate 30,000 feet beneath the plane, a distance so great that both gamma rays and neutrons would be absorbed before reaching the plane. There also wasn't a reliable way to observe fireball expansion- filming proved sketchy from such a distance. To prepare, Alvarez's group had to "practice" measuring the energy output from an airplane at the Trinity test site to pre-create combat conditions, and so they were forced to come up with an inspired measuring system. They did. Calibrated parachute microphones would be dropped from a trailing instrument plane at the exact time the bomb was dropped; those would then radio via FM transmission to their B-29 instrument plane an oscilloscope record which would show a calibration pulse of known pressure and thereafter, from the exploding nuclear bomb, the blast-wave pulse. This data could then be used to calculate the energy release. Although the trial run during the Trinity test was not flawless, the measuring apparatus proved to be satisfactory.

The sober work of creating the most destructive weapon in history did not mollify the high spirits of most when the Trinity test on July 16, 1945 succeeded. General Farrell, second in command to General Leslie R. Groves, involves loftiest prose when painting the scene of the original atomic explosion: "No man-made phenomenon of such tremendous power had ever occurred before….The whole country was lighted by a searing light with the intensity many times that of the midday sun. It was golden, purple, violet, gray, and blue. It lighted every peak, crevasse and ridge of the nearby mountain range with a clarity and beauty that cannot be described but must be seen to be imagined. It was that beauty the great poets dream about but describe most poorly and inadequately…it had to be witnessed to be realized." A week after successfully testing their device at the Trinity test, Waldman and Co. traveled to Tinian Island, a B-29 base part of the Marianas Island chain and only 1500 miles from Japan.

Trailing the B-29 bomber *Enola Gay* was the *Great Artiste,* the instrument plane carrying the four scientists. The operation went off without a hitch, and the group was able to record one excellent measurement of the blast. Waldman also brought along a Fastax camera, a high-speed camera with hundreds of feet of film, in the hope of capturing the different stages of explosion; unfortunately, much of the film didn't turn out (and story of it being jacked?). Shortly after the event, and before the physicists could calculate the energy output, President Truman announced that the bomb exploded with the force of 20,000 tons of TNT. This was clearly a politically "calculated" estimate, as the force according to the data Waldman's group recorded could not have exceeded 13.5 kilotons of TNT.

On August 8, 1945, while still on Tinian Island, Waldman describes the event in a letter to his wife: "It certainly was an experience…the bomb was dropped and it was another Trinity except that I was in the best possible observation position. The sight was magnificent but the destruction horrible…it was a fiendish device. I hope we do not have to use (it) again." A day later, the Fat Man plutonium bomb, the bomb Notre Dame ran experiments indirectly helped create, was dropped on Nagasaki.



Fat Man bomb being prepared for loading on the B-29 Bock's Car.
Source: http://nuclearweaponarchive.org/Usa/Med/Lbfm.html)