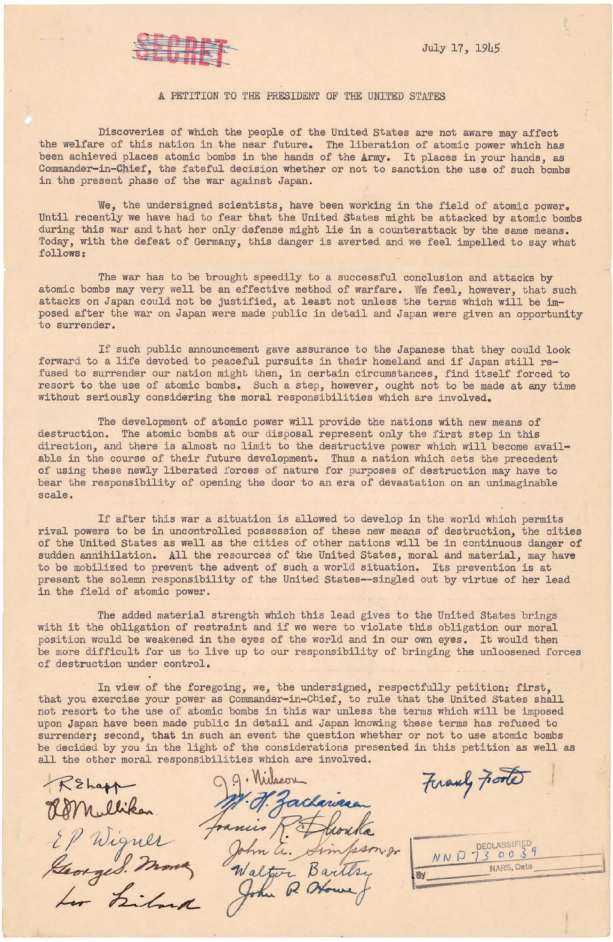
Zachariasen and the Manhattan Project

By Mario Affatigato

Numerous ceramists played hidden but key roles in the Manhattan Project. This article remembers the work of one such scientist, William Houlder Zachariasen.



SECRET

July 17, 1945

A PETITION TO THE PRESIDENT OF THE UNITED STATES

Discoveries of which the people of the United States are not aware may affect the welfare of this nation in the near future. The liberation of atomic power which has been achieved places atomic bombs in the hands of the Army. It places in your hands, as Commander-in-Chief, the fateful decision whether or not to sanction the use of such bombs in the present phase of the war against Japan.

We, the undersigned scientists, have been working in the field of atomic power. Until recently we have had to fear that the United States might be attacked by atomic bombs during this war and that her only defense might lie in a counterattack by the same means. Today, with the defeat of Germany, this danger is averted and we feel impelled to say what follows:

The war has to be brought speedily to a successful conclusion and attacks by atomic bombs may very well be an effective method of warfare. We feel, however, that such attacks on Japan could not be justified, at least not unless the terms which will be imposed after the war on Japan were made public in detail and Japan were given an opportunity to surrender.

If such public announcement gave assurance to the Japanese that they could look forward to a life devoted to peaceful pursuits in their homeland and if Japan still refused to surrender our nation might then, in certain circumstances, find itself forced to resort to the use of atomic bombs. Such a step, however, ought not to be made at any time without seriously considering the moral responsibilities which are involved.

The development of atomic power will provide the nations with new means of destruction. The atomic bombs at our disposal represent only the first step in this direction, and there is almost no limit to the destructive power which will become available in the course of their future development. Thus a nation which sets the precedent of using these newly liberated forces of nature for purposes of destruction may have to bear the responsibility of opening the door to an era of devastation on an unimaginable scale.

If after this war a situation is allowed to develop in the world which permits rival powers to be in uncontrolled possession of these new means of destruction, the cities of the United States as well as the cities of other nations will be in continuous danger of sudden annihilation. All the resources of the United States, moral and material, may have to be mobilized to prevent the advent of such a world situation. Its prevention is at present the solemn responsibility of the United States--singled out by virtue of her lead in the field of atomic power.

The added material strength which this lead gives to the United States brings with it the obligation of restraint and if we were to violate this obligation our moral position would be weakened in the eyes of the world and in our own eyes. It would then be more difficult for us to live up to our responsibility of bringing the unloosened forces of destruction under control.

In view of the foregoing, we, the undersigned, respectfully petition: first, that you exercise your power as Commander-in-Chief, to rule that the United States shall not resort to the use of atomic bombs in this war unless the terms which will be imposed upon Japan have been made public in detail and Japan knowing these terms has refused to surrender; second, that in such an event the question whether or not to use atomic bombs be decided by you in the light of the considerations presented in this petition as well as all the other moral responsibilities which are involved.

R E Shapp
D R Millikan
E P Wigner
Leo Szilard
J. J. Nickson
W. H. Zachariasen
Francis R. Bitchcock
John A. Simpson
Walter Bartky
John R Howe
Frank Foote

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By NARS, Date

Credit: National Archives and Records Administration

Figure 1. Scan of the Szilard Petition, which asked President Harry S. Truman to inform Japan of the terms of surrender before using atomic weapons.

The popular movie "Oppenheimer" has provided a new generation of the U.S. public with a powerful recount of the events surrounding the Manhattan Project and the end of the Second World War.

In September 2023, Lisa McDonald—in a *Ceramic Tech Today* article—highlighted the role of Massachusetts Institute of Technology ceramists in the Manhattan Project,[1] based on the work of Whittemore and McCreight. In this article, we seek to remember the work of William Houlder Zachariasen, a multifaceted physicist who made a seminal contribution to glass science and played an important role in the Manhattan Project.

Zachariasen was born in Langesund, Norway, in 1906. The town, near Oslo, gave Zachariasen (known as "Willie" to many) access to the fjord and the many islands there. This location is especially relevant because these islands had many mines rich in rare earths, sparking an early interest in mineralogy for Zachariasen. He studied at the University of Oslo under the guidance of the great geochemist Victor Moritz Goldschmidt,[2,3] focusing on the X-ray characterization of minerals. Incredibly, Goldschmidt owned one of the islands and had a picnic there with Einstein in 1920!

After publishing his first paper in 1925, Zachariasen published 19 more papers before receiving his Ph.D. in 1928 at the age of 22. He followed this accelerated pace with a postdoctoral position in the lab of Nobel laureate Sir Lawrence Bragg, an expert on X-rays and crystal structure. During this one-year postdoctoral work, Zachariasen focused on silicates, perhaps impacting his later insights on glass structure.

After the postdoctoral fellowship, Zachariasen returned to the University of Oslo. Within a year (and upon Bragg's recommendation), University of Chicago professor Arthur Compton offered Zachariasen a physics professorship at UChicago, which he accepted. He would stay at UChicago for 44 years.

Zachariasen was 24 years old when he left Norway in 1930. The early years in Chicago were tough. He had little money for research. Going to conferences, he would sleep on trains—coming and going on the same day—to save the hotel room cost. Using his prior work on silicates, he published his first (and only) paper on glass, "The atomic arrangement in glass" (1932). Yet this publication arguably became the most influential paper in the history of glass science. As Alfred R. Cooper wrote in his introductory paper to the 1980 Borate Glass Conference,[4]

"We dedicate this session on glass structure to Frederik William Holder Zachariasen because his single contribution to glass literature, 'The atomic arrangement in glass,' may be the most influential paper on glass structure in this century."

Yet Zachariasen had no further interest in glass. Later in life, he had to be reminded that he published in this subject.

By 1943, Zachariasen had joined the Manhattan Project after becoming a U.S. citizen in 1941. Why was he needed? Fermi, working on the nuclear pile at UChicago, had demonstrated the chain reaction of uranium. Zachariasen was already involved in UChicago's Metallurgical Laboratory. In the words of Robert A. Penneman,[3]

"Plans were being rushed for the pilot plant at Oak Ridge, Tennessee, and the production reactors at Hanford, Washington. This meant that the new element, plutonium, would be made in large quantity using neutrons from a nuclear reactor. Before this, plutonium could be made only in microgram quantities by tedious cyclotron irradiation."

But plutonium metal had to be separated from uranium. Under Glenn Seaborg's leadership, 60 chemists were put on this challenge. Zachariasen, with his expertise on rare earths, was to provide the X-ray analysis and "... deciphering single-handedly the composition of countless samples that were prepared by the chemists."[3]

Seaborg wrote that on June 21, 1944, a 10-microgram sample that was thought to be neptunium dioxide (NpO_2) was sent to Zachariasen. By 11 a.m. on June 22, his X-ray analysis had confirmed that it was NpO_2. In his report, Zachariasen wrote:[3]

"The radius of Np^{+4} is thus 0.0158 Å larger than that of Pu^{+4}, 0.016 Å smaller than that of U^{+4}, and nearly identical with that of Ce^{+4}. I believe that a new set of 'rare earth' elements has made its appearance. I believe that the persistent valence is four, so that thorium is to be regarded as the prototype just as lanthanum is the prototype of the regular rare earth elements."

In a later interview, Zachariasen noted how hard the work was:

"We had a very exciting time struggling with all these patterns over the various plutonium compounds, identifying what the chemists had made and, hence, getting information about the chemistry of plutonium that was essential ... I remember working like hell on New Year's Day and all holidays: often I worked late for many, many hours to get the work done. I had a wonderful time..."

Zachariasen was also a signatory (see middle column in Figure 1) to the Szilard Petition. The petition, drafted in July 1945, asked President Harry S. Truman to inform Japan of the terms of surrender before using atomic weapons. After much discussion (with Oppenheimer opposing it), the petition was brought to soon-to-be-named Secretary of State James F. Byrnes. He also was not sympathetic, and, therefore, President Truman never saw the petition.

Late in 1945, Zachariasen was appointed chair of the physics department at UChicago, and he also published a book titled "The Theory of X-Ray Diffraction in Crystals." He was chair from 1945 to 1950, until an untimely heart attack, and then again from 1955–1959. Under his leadership, he brought Enrico Fermi, Edward Teller, Robert F. Christy, Walter H. Zinn, Maria Goeppert-Mayer, Gregor Wentzel, and other distinguished physicists to UChicago as professors of physics (Figure 2).

Figure 2. Seated (from left) Zachariasen, Urey, Smith, Fermi, Allison. Standing: Teller, Hogness, Zinn, Zener, Mayer, Schutz, Christ, and Eckart. Three were Nobel laureates: Zener created the Zener diode; Allison read the countdown to the Trinity test; and Zinn was the first director of Argonne National Laboratory.

Credit: University of Chicago Photographic Archive, [apf1-05555], Hanna Holborn Gray Special Collections Research Center, University of Chicago Library

During his time at UChicago and after, Zachariasen led a 37-year effort to elucidate the structure and chemistry of transuranic elements (metals and compounds). In 1948 alone, he published 26 papers. After retiring in 1970, Zachariasen consulted with friends at Los Alamos National Laboratory after moving to Santa Fe, N.M. He died on Dec. 24, 1979, aged 73.

Zachariasen's contributions are memorialized in a variety of ways. The UChicago physics department holds one of its most significant lecture series in his name. But perhaps the most notable commentary on Zachariasen's work was given by Linus Pauling (Nobel Laureate in Chemistry, 1954), who wrote:

"I have known Professor Zachariasen for nearly fifty years. His principal field of work has been the determination of the structure of crystals of inorganic substances by use of the X-ray diffraction technique. This is a field in which I have also done a large amount of work, and I believe that I am in a position to form a sound opinion about his ability and his contributions. It is my opinion that he has been and is the world leader in this field. I feel that he is to be classed among the outstanding scientists of the twentieth century, and at the top of the field in inorganic crystal structures."

About the author

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[3]"Memorial to professor (Fredrik) William H. Zachariasen," article written in *Los Alamos Science*, by Robert A. Penneman, Summer 1980 issue. https://fas.org/sgp/othergov/doe/lanl/pubs/00818116.pdf

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