The “Kuroda Papers:” Translation and Commentary.

Dwight R. Rider, Dr. Eric Hehl and Wes Injerd.

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Paul Kuroda

The "Kuroda Papers:"
The Kuroda Papers (See: Appendix 1), a set of notes concerning wartime meetings covering issues related to Japan's atomic energy and weapons program, remain one of the few documents concerning that nation's wartime bomb program to ever surface. [1] The pages available, detail the background papers supporting the research program and four meetings, one each. held on; 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944 however, these dates may be inaccurate. Kuroda himself had given a copy of the documents to P. Wayne Reagan in the mid-1950s. [2] Knowledge of the papers held by Paul Kuroda was known in some larger circles as early as 1985. According to Mrs. Kuroda's cover letter returning the papers to Japan, she stated that "Kuroda lectured about the documents to his students and also publicly discussed their existence at international conferences such as the one commemorating the 50th Anniversary of the Discovery of Nuclear Fission in Washington D.C. in 1989, presided over by Professor Glenn Seaborg." [3]

Kuroda is reported to have on occasion; altered, corrected, or edited these papers in the presence of his students at the University of Arkansas during some of his lectures. It is unknown exactly what information contained within the papers Kuroda changed, or his motivations for altering or correcting these notes.

The Kuroda Papers were never the property of the Imperial Japanese government, or it's military, during the war. They were never held or marked as official classified Japanese government information. It was at that time as now, not entirely uncommon for portions of otherwise highly classified and sensitive information, to be held in an unclassified form wherever possible. This ensured ease of handling and distribution, to those with a need-to-know, who worked within such programs, and had been previously fully indoctrinated with the program's overall tasks and goals. The so-called "secret handshake; wink, wink, nod, nod, and specially compartmented shirt pocket" has long since existed in military cultures.

It is more probable that these papers as they currently exist were the draft notes of meeting minutes taken during the four gatherings discussed above. These notes as taken were then subsequently used to produce a more detailed and informative set of conference minutes and should have probably then been discarded. In the case of the Kuroda Papers, they were however, filed away with the typed transcript in the lengthier file. In the 1940s as today, it was not uncommon for defense contractors like Rikken or even Boeing to maintain the original notes of a meeting, to ensure future clarity of understandings reached between civilian and military authorities. This original set of meeting minutes were, in the 1940s, the equivalent of today's back up file. What we as readers, are actually witness to is the file system of Yokoyama Sumi, the secretary of Nishina Yoshio; the Chief of Theoretical Physics for all of Japan's various atomic energy and weapons research program and the head of the "Nishina Group" at the Kokuritsu Kenkyū Kaihatsu Hōjin Rikagaku Kenkyūsho's (Institute of Physical and Chemical Research) (Rikken) atomic research lab. Close examination of the papers supports this conclusion.


Nishina Yoshio

Kuroda retained the documents mostly in secrecy from 1945 through the mid-to-late 1980s simply because he was asked to do so by Nishina who passed him the documents at Rikken that August 1945. Culturally, this act of loyalty on the part of Kuroda reveals a deep and lasting respect for Nishina; a bond that was difficult to break. Later reports suggesting some person other than Nishina as grabbing these documents from a fire and passing them to Kuroda are sadly mistaken; the stuff of legend but not of fact. Though the war had been lost, as Nishina well-knew, a commander still commands. It is unlikely that Nishina would have been found on the grounds of Rikken burning sensitive materials in the immediate aftermath of WWII, which explains the lack of scorch and burn

[1] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.
[2] Telephone conversation/interview between P. Wayne Ragan and Dwight R. Rider. 5 April 2017. 1 hour, 47 minutes.
[3] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

marks on the papers. Ultimately Nishina, who embodied the idea of the "Copenhagen spirit" in allowing researchers to follow their own paths in their research, was a "Meiji Man," stilted in tradition. Write documents yes; burn trash, not going to happen.

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The only persons known to have attended the all of the conferences documented in the Kuroda Papers are Major General Ryokichi Nobuuji, Nishina Yoshio, and Ishida Sakae. Lieutenant General Yasuda Takeo is only known to have attended the first discussion of 2 July 1943 at which it is believed he inaugurated the Joint Imperial Japanese Army-Navy Atomic Bomb Research Program, uniting the various Army and Navy programs, Ni and F-go: Their laboratories and special facilities in China, Korea, Manchuria; the various military-operated logistical supply chains, and the Uranium Mining Program in Manchuria, which comprised Japan's atomic weapons and energy research programs.

Though little is known about the Joint Imperial Japanese Army-Navy Atomic Bomb Research Program, the program may have been created solely to pacify a Navy that was deeply concerned, and far more realistic, about Japan's ability to avoid defeat and surrender. The writer of the Kuroda Papers noted that the Imperial Japanese Navy had been informed of the meeting to be held on 2 July 1943 but had yet to respond. No members of the Imperial Japanese Navy are documented as attending any of the meetings recorded in the Kuroda Papers. Postwar comments made by Navy scientists however suggest otherwise. Others who may have been present at the various meetings are believed to have been primarily scientists – specifically chemists assigned to the Tokyo 2nd Army Arsenal – and brought to Tokyo by Nobuuji from Okunoshima – and army administrative personnel such as stenographers.

The papers primarily describe the efforts at Rikken to develop a uranium hexafluoride production process and through the use of a thermal diffusion column; a product of research conducted and then promoted by Kunihiko Kigoshi and Takeuchi Masa as a means of separating U235 from its more prevalent cousin, U238. All drawings within the papers refer solely to the uranium hexafluoride production process and Rikken's thermal diffusion column. As the papers where closely held by Kuroda from August 1945 through 2002 when they were returned to Japan, these papers are not the same drawings or blueprints reportedly observed by Leon Thompson at the headquarters of the Supreme Commander for the Allied Powers (SCAP) in 1949.[4]

The papers do not describe an atomic bomb as some journalists and scholars who have examined them have claimed. The papers do not contain a blueprint of a weapon nor a weapons design. The papers do not discuss any of Japan's earlier atomic weapons and research programs to include: Project A:[5] Project B;[6] the Electromagnetic Weapons Research Program;[7] F-Research Program (F-GO);[8] Ni-Project (Ni);[9] The Atomic Energy and Weapons Research Program of the South Manchuria Railroad Company (SMRC) – Central Research Bureau;[10] or the Uranium Mining Project in Manchuria;[11] which were all consolidated into the Joint Imperial Japanese Army-Navy Atomic Bomb Research Program on 2 July 1943.[12] The papers never mention the related, additional and ongoing Japanese efforts at Osaka or Kyoto Imperial Universities or the Uranium Mining Project in Manchuria. The papers never discuss the transportation of uranium ore from within, or outside the Japanese Empire. The papers rarely mention Korea.

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[4] *Japan's Atomic Bomb by Leon Thompson*. *Military Magazine*, Sacramento, CA, Dec., 1994.
[5] Coffey, Thomas M. *Imperial Tragedy*. The World Publishing Company. New York. 1970
[6] Coffey, Thomas M. *Imperial Tragedy*. The World Publishing Company. New York. 1970
[7] Ito, Kenji. *Making Sense of Ryôshiron (Quantum Theory): Introduction of Quantum Mechanics into Japan*, 1920-1940. Harvard University. Cambridge, Massachusetts. October 2002.
[8] John W. Dower - *Science, Society, and the Japanese Atomic Bomb Project during WWII*. Bulletin of Concerned Asian Scholars. Volume Ten, Number Two. 1978. http://criticalasianstudies.org/assets/files/bcas/v10n02.pdf
[9] John W. Dower - *Science, Society, and the Japanese Atomic Bomb Project during WWII*. Bulletin of Concerned Asian Scholars. Volume Ten, Number Two. 1978. http://criticalasianstudies.org/assets/files/bcas/v10n02.pdf
[10] Subject: RAMONA (March Summary Report). Formerly TOP SECRET. Shanghai. 24 March 1946. Record Group 226. Stack Area 250. Row 64 Compartment 33. Shelf 2-3. Entry 211. Box 31. The US National Archives and Records Administration, 8601 Adelphi Road, College Park, MD.
[11] Subject: RAMONA (March Summary Report). Formerly TOP SECRET. Shanghai. 24 March 1946. Record Group 226. Stack Area 250. Row 64 Compartment 33. Shelf 2-3. Entry 211. Box 31. The US National Archives and Records Administration, 8601 Adelphi Road, College Park, MD.
[12] Sandler, Stanley. Editor. *World War II in the Pacific: An Encyclopedia* (Military History of the United States) 1st Edition. Taylor & Francis. New York. 2001.

The papers primarily offer documentary evidence that the Japanese had an atomic weapons and energy research program underway during the war. Most previous translations, inaccurate an incorrect, have allowed historians to relegate the Japanese program to that of a minor effort ongoing in a defeated country, grasping for a super weapon beyond the reach of their physicist's understanding of physics, and their nation's level of technology in the last years of the war. A more accurate translation as presented herein and below suggests those previous assessments to be unpardonable. [13]

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The Kuroda Papers were returned to Japan in 2002 by Mrs. Paul Kuroda following the death of her husband, Kazuo "Paul" Kuroda from lung cancer in 2001. The publicity surrounding the return of the papers to Japan has led to them being labeled "the Kuroda Papers." It is likely that other such "handfuls" of papers exist.

Context:
The Kuroda Papers consist of, depending on how they are counted; including or not including Mrs. Kuroda's attached personal correspondence or separating double-sided pages; of between 22 and 26 pages of separate session summaries, documenting four talks held within the confines of, but not necessarily in a building assigned to the Tokyo 2nd Army Arsenal (Tonizo) in 1943 and 1944. The first meeting is believed to have been held in a building within the Tokyo 2nd Army Arsenal that actually hosted a sub-tenant unit assigned to the arsenal. Why these few pages, the Kuroda Papers, were saved remains unknown.

The meetings documented in these papers where held on; 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. As these discussions were held within the boundaries of the Tokyo 2nd Army Arsenal they are sometimes mistakenly referred to as the Tonizo documents. These four meetings should not be confused with those conducted by Admiral Ito Yoji, Chief of the Imperial Japanese Navy's Naval Technical Research Institute's Committee for Research on the Application of Nuclear Physics (CRANP), or any other meetings held under the auspices of the Imperial Japanese Army or Navy under any of its other wartime atomic weapons and energy programs, such as the Ni-Project or F-go. [14] No members of the Imperial Japanese Navy are known to have attended any of the meetings but evidence exists to suggest the contrary. [15]

Despite the lack of additional sections of the greater document that possibly at one time existed, it is likely that more meetings occurred with far greater frequency than most historians have been willing to admit from the few sessions documented in the Kuroda Papers. It is likely that meetings between Nobuuji and Nishina were a weekly, if not daily event. The reported frequency of Nobuuji's visits to Rikken during his tenure as Director Tokyo 2nd Army Arsenal left him with the reputation within Rikken as being somewhat of an irritant, and interfering with Nishina's efforts on his behalf.

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Before continuing, some observations concerning the contents of the papers is in order. The symbol for uranium of any kind appears 106 times within the papers. Within that number, the symbol for nonspecific uranium is mentioned 17 times; UO2 – uranium oxide is mentioned four times. U3O8 or triuranium octaoxide, also known as "yellow cake" is mentioned twice. UF6 – uranium hexafluoride is referred to 21 times. U2 – a shorthand reference to U234 appears only once; in a drawing depicting the Rikken process used to create uranium hexafluoride. UO3, or uranium trioxide, also called uranyl oxide, uranium (VI) oxide, and uranic oxide is mentioned five times. F2 or fluorine is also mentioned, five times, all in discussions connected to gaseous thermal diffusion. U235 is mentioned 33 times.

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[13] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.
[14] The Pacific War Research Society. *The Day Man Lost: Hiroshima, 6 August 1945.* Kodansha International. Tokyo, Japan. 1981
[15] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

Though written in Japanese, English was used to denote common terms for chemical elements such as CO (cobalt), UF6 (uranium hexafluoride), C° (Centigrade) etc. Pitchblende – as a word – is mentioned only once; the word "cyclotron" appears twice. Where the names of European or American physicists and chemists are used, these are also written in English.

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According to legend the papers were spontaneously grabbed from a fire by some person at Rikken (the pre-1945 acronym for the Institute of Physical and Chemical Research); name unknown to Kuroda and thrust into his hands, as Japanese across the nation destroyed classified and sensitive documents between 15 August and 2 September 1945, yet the papers contain no scorch marks or other signs of exposure to fire. As Kuroda said on many occasions he could not recall the name of that friend or coworker who presented him with the papers and his name remains unknown. That's the legend anyway.

In reality however it was Nishina himself who had given the papers to Kuroda. Why Nishina entrusted Kuroda with these and only these few pages remains unknown. Kuroda himself stated to P. Wayne Reagan in the mid-1950s, that the pages in his possession were given to him directly by Nishina to hold "as his name was not mentioned anywhere on them and that no one would be looking for him as a war criminal." [16] At the time Nishina gave the papers to Kuroda, Nishina said that he suspected that he himself would be tried by occupying armies as a war criminal. Why Nishina entertained such thoughts, and what he could have possibly done during the war to attract such attention, remains unknown at this time.

Nagaoka Hantaro

Yagi Hidetsugu

Other than his public support of the war effort (required) and membership on various war-related resource allocation boards, what crime Nishina might have committed, remains unknown. US documents of the time reveal that at one point, except for the grace of Harry C. Kelly; SCAP; Economic and Scientific Section (ESS), Nishina was indeed being considered as a candidate by US authorities to be purged under the Allied Occupation of Japan. Nagaoka Hantaro, a far more famous Japanese physicist, and Nishina's mentor, was indeed purged by the Occupation with Nishina himself dismissing Japan's most famous physicist from Rikken. [17] Yagi Hidetsugu, inventor of the famous Yagi antenna was also purged. [18] Yagi had headed the Agency for Science and Technology during the war.

With the thought of being tried as a war criminal in mind, Nishina may have sought to maintain at least a portion of the original document as a form of personal insurance against future disclosure of some wartime deed or deeds done, that took place in Japan over the course of the conflict. It may have also been simply a desire on the part of Nishina to preserve for prosperity some of Japan's finest research in physics. It is probable that further and additional such papers were given by Nishina to others at Rikken at or near the time these papers were given to Kuroda for much the same reason, their names were not listed within those pages.

As Nishina apparently selected only these few pages to place in Kuroda's care he may have planned to reassemble some larger, more complete, and original set of documents containing the results of all Japan's wartime research at some later point, after the US Occupation and Japan's humiliation at the hands of the Allies ended. Nishina would not however, live to see the end of the US Occupation of Japan, passing away from liver cancer on 10 January 1951. The US Occupation of Japan ended months later on 8 September that year. It is unlikely that, following Nishina's death, the larger set of documents, if they existed at all, were ever

[16] Telephone conversation/interview between P. Wayne Ragan and Dwight R. Rider. 5 April 2017. 1 hour, 47 minutes.
[17] Low, Morris. *Science and the Building of a New Japan*. Johns Hopkins University. Palgrave Macmillan. 2005
[18] Low, Morris. *Science and the Building of a New Japan*. Johns Hopkins University. Palgrave Macmillan. 2005

reassembled. Why the documents were allowed to exist will continue to be a subject of considerable speculation for the foreseeable future.

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The primary reason that these few sections of the possibly larger original document endure today, and are available to researchers, is that they were carried outside of Japan by Kuroda in 1949 during the US Occupation. It is likely that some Japanese scientific papers presented after the war by a few of that nation's top scientists, can be sourced to the hidden research contained within these and other pages of the overall larger suspected document. [19] At least one such paper, written by Kunihiko Kigoshi, drew on research conducted at Rikken on uranium under Nishina in February 1945 titled, *On the Viscosity of the Uranium Hexafluoride*, was published in July, 1950.[20] The Kuroda Papers as a set, are not a report of any kind.

The Kuroda Papers are instead a summation of various sessions; the first believed to have been hosted by Lieutenant General Yasuda Takeo, Inspector-General of Army Aviation (formerly head of the Army Aviation Technical Research Institute) on Friday, 2 July 1943; the remainder were held at the request of Major General Ryokichi Nobuuji, then Director of the Research Lab, Tokyo 2nd Army Arsenal. Nobuuji became chief of the Tokyo 2nd Army Arsenal in December 1943 but had been assigned to manage a portion of the arsenal in 1940. It should be noted before continuing that General Nobuuji had achieved his rank and position primarily due to his solid organizational and administrative skills which were, outstanding.

Nobuuji had previously studied chemistry, a subject that would serve him well in his rise to field rank after the start of war in China. He spent much of his career working within Japan's chemical weapons (CW) program. From 1937 to 1940 he commanded the country's primary CW production facility at Okunoshima; a clandestine, lethal island chemical weapons production facility that went untouched and unknown to the US throughout the entire war in the Pacific, located 30 miles east of Hiroshima, and 1.2 miles off the coast of Honshu.

The island itself was considered so secret by Japanese authorities that it had been removed from all maps covering the area for decades before the war. Though Nobuuji was a solid chemist, adept at organization and administration; when it came to physics, he was not always the brightest bulb in the room. Throughout the discussions documented in the Kuroda Papers, Nishina was forced to resort to terms commonly used in chemistry to explain to Nobuuji the physics behind an atomic bomb. This has resulted in some confusion when translations of the pages as they exist, are attempted as interpreters struggle to infer meaning from the words contained within the papers.

The length of each session remains unknown, but from the contents of the papers it would appear that the gatherings followed some predetermined schedule. The first two sessions were likely all-day affairs. Most military conferences follow an agenda of some form as time is important, and there are other issues that require the attention of those possessing the rank of a General officer.

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The original notes are believed to have been written by Ishida Sakae, a technician at the Tokyo 2nd Army Arsenal Research Lab, however this assessment is probably not entirely true. The list of those in attendance is consistent, meeting-to-meeting with Nobuuji, Nishina and Ishida attending. Ishida is listed in all four meetings as "lecturer" suggesting that he would not have been in a position to take notes of the meetings. Others probably took the notes, to include Paul Kuroda himself; accounting for his ability to continuously edit the papers through the 1980s, and Yokoyama Sumi, Nishina's personal secretary from 1941 onward. After the war, Ishida became by imperial appointment, a civilian official of the Army Arsenal. Following Nishina's death in 1950, Yokoyama Sumi became Secretary to the Nishina Memorial Foundation.[21]

Description: Kuroda Papers.

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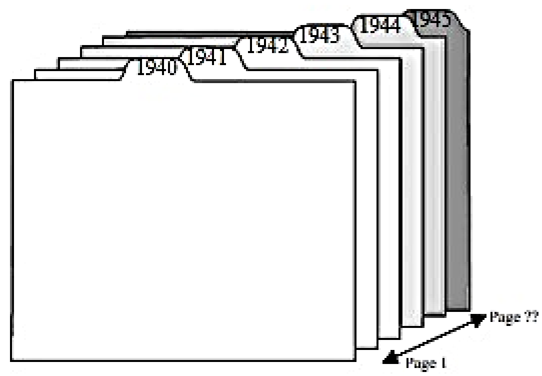
[19] Low, Morris. *Science and the Building of a New Japan*. Johns Hopkins University. Palgrave Macmillan. 2005

[20] Kunihiko Kigoshi, *On the Viscosity of the Uranium Hexafluoride*, Geochemical Laboratory, Meteorological Research Institute, Tokyo. July 1950.

[21] Peierls, Rudolf. *Bird of Passage: Recollections of a Physicist*. Princeton University Press. Princeton, New Jersey. 1988. Page 335

The Kuroda Papers are written in pencil on fragile Japanese paper of a type commonly used during the war. Some of the documents consist of single page notes, others are in a double page format; a left and right page, on a larger sheet of paper.

The pages penned primarily in Japanese are written from top to bottom, right to left, usually in an in-column format. Those pages containing mostly Western references; person-, journal-, and institution-names are read top to bottom, left to right. How many such papers the folder might have contained at one time is anyone's guess. The total number of folders that at one time existed is also unknown.



All the pages of the file were numbered in a Western fashion, 1 to 100, oldest to latest. Thus, the 2 July 1943 meeting initiating the Joint Imperial Japanese Army-Navy Atomic Bomb Research Program which is misleadingly assumed to be the last section of the overall file, was actually written prior to the four meetings that are documented within the Kuroda Papers – meaning that these four meeting were probably held prior to 2 July 1943, under the Army's Ni Project, and the dates were later altered by Kuroda to reflect his perception of the order in which he sought to fit them.

Though the documents on the surface appear to be written in the same handwriting, a deeper examination of the writing contained therein reveals numerous inconsistencies. Examined closely, the letter "U" used throughout the document to denote uranium in any of its forms reveals the presence of several different handwriting styles. Similar differences can be identified in the use of numbers such as 2, 3, 4, 5, etc., throughout the entire document, suggesting that either several different people took down the original meeting minutes, or were responsible for making later changes to the original copy.

As the Kuroda Papers begin at page number 56, it should be assumed that at the least, some 55 other pages of the overall file from which these few pages were removed and given to Kuroda, did at some time exist. From page 56, several pages such as pages 65 and 66, were removed either prior to the point when these few were given to Kuroda, or afterwards by Kuroda himself. The latter case is the least likely scenario. As a set, the papers terminate at page 67. It is likely that additional sheets past page 67 at one time also existed.

In most formats where the entire set of pages as previously obtained by researchers, were it still in one piece, is organized from the oldest material (page 67) to the newest material (page 57). The pages are not pages of a single document or notebook, they are instead documents at one time held in a hardcopy, probably brown, manila folder.

This file was organized from the oldest material in the front, to the newest material in the back. Anyone seeking to familiarize themselves with the project would have opened the file and read about the program from its original background material, to the minutes taken of the final meeting perhaps just days ago.

As the Kuroda Papers were part of a larger file: newest material first, the four meetings as documented, occurred chronologically before the ten of pages of background material were ever presented that Friday, 2 July 1943. The location of this background material within the set of pages currently available, is yet another indicator that the four meeting notes held within the file were actually held at some point prior to the conference that discussed the background material as presented on 2 July 1943. This misunderstanding of the papers as a document and not a file, is why the background or foundational material contained within the pages, are usually found at the end in most presentations. The first two meetings discuss a previously written "Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943." [22]

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[22] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

With this examination of the papers of the Kuroda Papers and the April 1943 background papers in-place, the 2 July 1943 conference between Lieutenant General Yasuda, Major General Nobuuji and Nishina Yoshio began.

Conference notes - 2 July 1943
Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943.
Chronologically, as we know them, the Kuroda Papers begin with a meeting held on 2 July 1943. Those in attendance include Lieutenant General Yasuda, Major General Nobuuji, Nishina Yoshio and Ishida Sakae. Ishida was lecturer or briefer to the group. It is likely that others were in attendance, however the list of attendees in the Kuroda Papers only includes names of the program heads, the chief physicist, and the lecturer.

Apparently, the notes as written are limited to the role of Rikken and Nishina lab in the project at hand. Representatives from other companies, Ziabatsu or Konzerns may have been present and had a speaking role at the meeting but the Koroda Papers concern themselves solely to what the Rikken lecturer presented. The papers contain no mention of any earlier, or then ongoing research project, at any other location other than Rikken. It is possible that, as the overall subject was considered Top Secret, other groups in attendance took notes related to their assignments. The attendance of others at the meeting may have been similarly classified and not to be mentioned in what notes were taken. Judging from the length of the notes taken, it is likely that the meeting of 2 July 1943 lasted several hours if not all day.

The 2 July meeting was held for several purposes, the first of which was the formation of the Joint Imperial Japanese Army-Navy Atomic Bomb Research Program which was assigned to the Imperial Japanese Army. The meeting also served to introduce and familiarize Major General Nobuuji with the program and introduce him to Nishina Yoshio, the program's Chief Theoretical Physicist. At the meeting General Yasuda passed control of the Joint Imperial Japanese Army-Navy Atomic Bomb Research Program to Major General Nobuuji. In effect, this was a change-of-command in concert with the creation of the Joint Imperial Japanese Army-Navy Atomic Bomb Research Program. In military terms, "unity-of-command" had now been established. The various and previously decentralized and independent military and civilian programs throughout the Empire were now under the control of one-man, Major General Nobuuji. Knowledge held or obtained by any previous program would now be shared with all participants; direction would be given, work managed, success emphasized.

It was now Nobuuji's responsibility to manage the research project, establish goals, monitor deadlines and maintain the administrivia associated with the overall effort. Major General Nobuuji was to run the program, not conduct the research.

Yasuda moved on to become the Inspector-General of Army Aviation and in December 1943 Nobuuji took command of the entire Tokyo 2nd Army Arsenal. Yasuda would go on to serve as the Head of Army Aviation Headquarters, the Chief of the Tama Army Technical Research Institute, serve as a member of the Supreme War Council, the General Officer Commanding 1st Air Army, and end the war Attached to Army Aviation Headquarters. Most of the discussion of 2 July appears to be centered on a document "Concerning Uranium."[23] This document was reportedly prepared by the Tokyo 2nd Army Arsenal, and was dated April 1943 (Shyowa 18 Nen). [24] The whereabouts of the document itself, whether or not it still exists, is unknown. The document was subtitled "A Coordinated Opinion toward the Practical Use of Uranium."[25]

Notes from the meeting describe the "study of U-235" as "very necessary" and that "it is important that the study be done rapidly."[26] Such comments are not those normally associated with Nishina Yoshio. The kindly father of Japanese nuclear physics as revealed in most modern-day texts, is apparently the result of a postwar effort by SCAP/ESS to resuscitate Nishina's reputation, in an effort to serve US Cold War purposes.

Similar such discussions had taken place in the early Manhattan Project; and in the subsequent nuclear weapons program the Soviet Union, China, India, Pakistan, and North Korea. Responsibility for the research project was assigned to "a committee headed by the army with governmental representatives and scholars appointed."[27] The

[23] "*Concerning Uranium*," "*A Coordinated Opinion toward the Practical Use of Uranium*." Tokyo 2nd Army Arsenal, April 1943.
[24] "*Concerning Uranium*," "*A Coordinated Opinion toward the Practical Use of Uranium*." Tokyo 2nd Army Arsenal, April 1943.
[25] "*Concerning Uranium*," "*A Coordinated Opinion toward the Practical Use of Uranium*." Tokyo 2nd Army Arsenal, April 1943.
[26] "*Concerning Uranium*," "*A Coordinated Opinion toward the Practical Use of Uranium*." Tokyo 2nd Army Arsenal, April 1943.
[27] "*Concerning Uranium*," "*A Coordinated Opinion toward the Practical Use of Uranium*." Tokyo 2nd Army Arsenal, April 1943.

Kuroda Papers do not list the members of this committee (military or civilian), the universities and institutes involved, the military assets assigned or the branches of the Imperial Japanese military which would provide future support.[28] In the interim, the committee assigned was to serve as "the center of research."[29] According to the notes, as research progressed "the air force and others would join in the effort."[30]

The conference was led by an overall lecturer or session-leader whose name remains unknown. It was not uncommon then, as now that some military officer had been pre-designated to brief the subject matter discussed within the papers presented. The briefer most likely opened the presentation with an overview of the problem at hand; presented all previous research conducted at Rikken, and probably discussed the earlier research efforts under the Army, Navy, the South Manchurian Railway Company, etc.; Rikken itself managed the Uranium Mining Project in Manchuria.[31] Ishida Sakae of course, served as lecture-lead for Rikken.

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The session opened with a discussion about a paper written by Dr. Alfred Stettbacher "*Der Amerikanische Super-Spengstoff U-235*" – "*The American super explosive U-235*," which appeared in the German journal *Nitrocellulose*, dated November 1940.[32] The briefer, probably Ishida, noted that the piece had been widely read. Stettbacher had identified many of the scientist worldwide who were believed to be working on developing an explosive based upon U235 to include Japan's Hagiwara Tokutaro.[33] The conference then turned to Hagiwara's work.

Hagiwara Tokutaro

In May of 1941, as a member of the faculty of the Science Department of the Imperial University of Kyoto, Hagiwara Tokutaro had delivered a lecture entitled "*Concerning super-explosive Uranium-235*" at a meeting held by the Navy, in which he stated that if an appreciable quantity of U235 could be manufactured and if a mixture of this U235 and an appropriate concentration of hydrogen with an appropriate volume could be prepared, U235 has the property of becoming a useful detonator substance."[34, 35]

In his lecture Hagiwara noted that US research on this issue began in 1939 and is developing rapidly. The researchers developing the subject were however, not Americans but German. Their accomplishments had occurred in the same year, 1939, as those of Hahn and Strassman. Hagiwara presented the work of Hahn and Strassman as follows stating that "If a moderate velocity neutron – namely a slow neutron – collides with the atomic nucleus of a mass of uranium, nuclear fission will occur accompanied by the release of an enormous amount of energy."[36] As Hagiwara had reported, the most efficient method of generating primary neutrons for this research is centrifugal acceleration – the cyclotron.[37] It should be noted that this was also the path taken by Bunsaku Arakatsu at Kyoto Imperial University.

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[28] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.
[29] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.
[30] "*Concerning Uranium*," "*A Coordinated Opinion toward the Practical Use of Uranium*." Tokyo 2nd Army Arsenal, April 1943.
[31] Subject: RAMONA (March Summary Report). Formerly TOP SECRET. Shanghai. 24 March 1946. Record Group 226. Stack Area 250. Row 64 Compartment 33. Shelf 2-3. Entry 211. Box 31. The US National Archives and Records Administration, 8601 Adelphi Road, College Park, MD.
[32] "*Der Amerikanische Super-Spengstoff U-235*" – "*The American super explosive U-235*." Nitrocellulose. November 1940.
[33] "*Concerning Uranium*," "*A Coordinated Opinion toward the Practical Use of Uranium*." Tokyo 2nd Army Arsenal, April 1943.
[34] Kuroda, Paul Kazuo. *My Early Days at the Imperial*. University of Tokyo. http://www.omatumr.com/abstracts2005/PKKAutobiography.pdf
[35] Hagiwara, Tokutaro. *Liberation of neutrons in the nuclear explosion of uranium irradiated by thermal neutrons*. Departmental Bulletin Paper. The Physico-Chemical Society of Japan 31 December 1939.
[36] Profile. Otto Hahn. "*One of those Anglicized Berliners*." The New Scientist. 20 June 1957.
[37] Hagiwara, Tokutaro. *Liberation of neutrons in the nuclear explosion of uranium irradiated by thermal neutrons*. Departmental Bulletin Paper. The Physico-Chemical Society of Japan 31 December 1939.

Hagiwara had then introduced his audience to U235 explaining element 92 and its three known isotopes as found in nature; U238 which comprised 99.274% of all uranium: U235 which comprises only 0.720% of all uranium, and U234 which makes up the remainder at 0.006%.[38] As Hagiwara explained it, uranium as it occurs in nature undergoes spontaneous transmutation: U238 is reduced to half mass after a period of 4.5 x 10^9 years. [39] However, according to the work of Otto Hahn, if neutrons were directed at a sufficiently concentrated population of uranium nuclei, fission of these atomic nuclei would occur in a relatively short space of time – an explosion. [40]

Hagiwara continued his description of Hahn's work explaining that when one uranium neutron collides with another, fission will occur and the uranium will then transmute to another element. [41] Additional neutrons will be will be liberated and these secondary neutrons will collide with other uranium nuclei, creating a chain reaction of fission. This process possesses the characteristics of high explosives. However, the process described could only be accomplished through a chain reaction of the isotope U235.

In Ishida's presentation, according to Hagiwara, due to the potential application of such an explosive in a chain reaction of U235, a practical method of creating such a weapon had to be found.[42] This was sufficient reason for Japan to investigate the possibility and devote massive resources to the project.

What Hagiwara thought was needed immediately was a means of separating U235 from natural uranium on a mass or industrial scale. If by any chance U235 could be manufactured in large quantities and the critical mass of U235 determined, then it offered great potential as an initiator for a more powerful hydrogen bomb. Hagiwara had great confidence in the potential development of such a weapon.[43] Hagiwara supposed that it might be possible to iodize of nitrify uranium thus creating a compound that could be exploded by neutron irradiation. This line of research had been underway in the US and France since 1939 however the result of those experiments was not yet known in Japan.

The lecturer, again probably Ishida, then informed the assembled group that Yasaki Tameichi had been doing research on the fission of uranium at the Nishina Physical and Chemical Institute for several years. He, along with Sagane Ryokichi had previously studied under Earnest Lawrence from 1935 to 1936. Once back in Japan, Yasaki was in charge of building Rikken's first cyclotron.

Yasaki had also been a member of the team dispatched from Rikken to work on Berkeley's larger cyclotron in 1940. During that visit Yasaki had actually conducted research on atomic fission in the US under Lawrence at the University of California. Yasaki was then, in 1943, engaged in research on the separation of U235 from U238 and was apparently making excellent progress. The notes mention that under the conditions of the setting where the meeting was held, the attendees could not hear his comments, suggesting that Yasaki was also at the meeting and possibly due to other noise, could not make himself heard; or his efforts were too highly classified to reveal in this setting. According to the briefer, Yasaki's research had already come to the attention of scientists in the US. It was noted that US scientists had already constructed a larger cyclotron, a 152 cm (60 in) 16 MeV machine in 1939, than was available in Japan.

Some statements contained in the Kuroda Papers are vague, so much so that other translators that have simply ignored these entries. Notes written in English are similarly dismissed. However, placed in context of the time and knowledge of the international physics research then available to the Japanese, these comments can be understood and are intrinsically important in understanding exactly what the Japanese were doing in 1943, or possibly earlier.

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[38] Hagiwara, Tokutaro. *Liberation of neutrons in the nuclear explosion of uranium irradiated by thermal neutrons*. Departmental Bulletin Paper. The Physico-Chemical Society of Japan 31 December 1939.
[39] Hagiwara, Tokutaro. *Liberation of neutrons in the nuclear explosion of uranium irradiated by thermal neutrons*. Departmental Bulletin Paper. The Physico-Chemical Society of Japan 31 December 1939.
[40] Profile. Otto Hahn. "*One of those Anglicized Berliners*." The New Scientist. 20 June 1957.
[41] Hagiwara, Tokutaro. *Liberation of neutrons in the nuclear explosion of uranium irradiated by thermal neutrons*. Departmental Bulletin Paper. The Physico-Chemical Society of Japan 31 December 1939.
[42] Hagiwara, Tokutaro. *Liberation of neutrons in the nuclear explosion of uranium irradiated by thermal neutrons*. Departmental Bulletin Paper. The Physico-Chemical Society of Japan 31 December 1939.
[43] Hagiwara, Tokutaro. *Liberation of neutrons in the nuclear explosion of uranium irradiated by thermal neutrons*. Departmental Bulletin Paper. The Physico-Chemical Society of Japan 31 December 1939.

In one comment the Japanese lecturer reveals that a 1940 issue of the journal *U.S. Naval Institute Proceedings* had previously credited Nishina with already transmuting U238 to U235. The lecturer noted that US researchers have shown considerable previous interest in transmuting U238 to U235. However, a review of the 1940 *U.S. Naval Institute Proceedings* reveals no mention of Nishina or uranium. The mention of a journal, and the year, 1940, may provide some insight into the meaning of the comment. 1939 and 1940 had been busy years for physicists.

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From the 6 January 1939 issue of *Naturwissenschaften* announcing of Otto Hahn's discovery of fission to the end of the year, nearly 100 international journal articles discussing uranium fission had been published. In October 1939, President Roosevelt established the Advisory Committee on Uranium which met for the first time on 21 October. That first meeting was actually a planning session. Ultimately, its conclusions; that of finding reliable sources of uranium, developing better methods enriching for uranium-235, making atomic bombs and finally, exploring the possibility of fission as a power source, reached Roosevelt's desk less-than one month later.

The mission of Advisory Committee on Uranium assumed a greater sense of urgency in April of 1940 when it was determined that the Kaiser Wilhelm Institute in Germany, had commenced a broad research program involving uranium. By spring 1940 all American scientific journals had agreed to submit any papers concerning uranium fission or other papers having a bearing on national defense, to the National Research Council for review, prior to publication. This resulted in a near total cessation of publication of any information concerning nuclear physics.

It is likely that, as *U.S. Naval Institute Proceedings* were widely read in Japan, the journal was used at the conference of 2 July to illustrate the dwindling number of papers concerning uranium fission, now appearing in scientific magazines. Only months before, uranium fission was the hottest scientific subject on the planet, by spring 1940, through self- or government-censorship, the brakes had been applied, the tap turned off.

The Japanese had noted the drop-off of publications discussing uranium, as had French, German and Soviet scientists. The self-imposed censorship of Western scientists is probably the single most important event that turned the attention of Moscow Center to the existence of the Manhattan Project, the result of which was the subsequent Soviet penetration of security surrounding the American bomb project. Though the Japanese had also noticed the increasing lack of scientific papers addressing the subject of fission in the international press, Japan's scientists and intelligence services had not considered the withdrawal of such papers as a sign of intense US or British interests in the subject. This failure, within two years, would lead to the events at Hiroshima and Nagasaki.

Meanwhile in Washington, in June 1940, the National Defense Research Committee (NDRC) was organized. Despite being the capital of the United States, in 1940, Washington DC was the eleventh largest city in the nation just behind Pittsburgh, Pennsylvania. Important secrets were harder to keep and famous visitors far more easily recognized but information still, then as now, slipped out.

Just a few short years earlier in 1936, the Army General Staff had reduced its research and development budget by half, in the belief that its range of weaponry was adequate and the funds available could be better used for the repair, replacement, or production of new ordnance. The first executive orders, proposed by the President in the spring of 1938 to assist industry in tooling up for weapons production, were not issued until two years later, in 1940. After nearly four years of inactivity and the filling of critical positions with novices, the US military had little idea of what science could provide in the event of a modern, mechanized war of technologies. For their part, scientists were completely in the dark as to what the military needed. That was rapidly changing.

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On 1 July 1940 the US Navy moved to provide $100,000 to fund uranium isotope separation research. Beginning in the summer of 1940 and moving into 1941 a number of uranium isotope-separation research programs began work in the United States. At the University of Virginia, Jesse Beams began building on his earlier work concerning uranium centrifuge separation methods. At Harvard University, George Kistiakowsky was working to develop a gaseous barrier diffusion methods. Harold Urey at Columbia University was dividing his time between centrifuge and gaseous diffusion separation. Urey was joined by John Dunning, Eugene Booth, G.B. Karelitz, and Aristide von

Grosse (with assistance from student William Nierenberg), and by 1941 Columbia University had become the center of gaseous diffusion separation.

At the Carnegie Institution of Washington, Philip Abelson was working on the liquid thermal diffusion method using facilities at the National Bureau of Standards; in the summer of 1941 he transferred his work to the Naval Research Laboratory. At the time, the leadership of the international physics community consisted of a small group of men who, for the most part, knew each other personally. Nishina was one of those men.

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Nishina's reference to the great interest in the US to transmutation of U238 to U235 was actually a warning to the committee that other scientists, in other countries; some more powerful than Japan, were indeed working on the issue and keeping their findings secret. Japan was for all intents and purposes, in a life and death race with other countries, most notably the heavily industrialized United States for the development of an atomic bomb for use in the current war. Hence, the earlier imperative, the "study of U-235" as "very necessary" and that "it is important that the study be done rapidly." [44] It failed however to register with those present that Japan might lose that race. The lecturer continued.

The attendees were then informed that Kigoshi Kunihiko was at that moment at Rikken, conducting research into the separation of U235 from U238 using a thermal diffusion column, an invention perfected by Klaus Clusius and Gerhard Dickel in 1937. Professor Kimura, of the Imperial University of Tokyo, who was also probably at the meeting, suggested that it should possible to develop a method for the slow, controlled, fission of U235. Kimura suggested that as a form of energy, this energy could be used to propel aircraft and would eventually prove to be extremely impressive. Despite this somewhat out-of-place reference to a reactor at a conference held primarily to discuss atomic weapons, Kimura's comments did address one of the other two proposed research subjects then under study in Japan; a reactor and nuclear energy. However, the conference quickly returned to the subject of the bomb.

As the lecturer briefed the attendees, it was suggested that Radium and Beryllium could provide the primary neutron sources necessary to trigger the weapon. The conference then moved on to discuss world production levels of uranium ore. The Japanese placed production of uranium ore, not uranium itself, at 30,000 to 40,000 tons per year. The Japanese noted that most of this production took place in North America. The lecturer listed production as being derived form:

<u>Ore/Type</u>:		
Uranium ore (pitchblende uranium)	UO_3	75-80%
Uranium ashes ore	UO_3	53-67%
Ashes uranium ore (?)	UO_3	52-62%

The lecturer noted that Japan currently relied upon the United States as the source for all its uranium imports. Prefacing his comments with a warning that Japan's underground resources were largely undetermined, the lecturer listed Japan's known uranium bearing resources as:

Fukushima Prefecture	Date District	Hansaka Village
Fukushima Prefecture	Tawaga District	Maki Village
Amount U_3O_8 per ton of ore: 100 grams.		[About 9% total]
Fukushima Prefecture	Ishikawa City	Fukin
Samarurisu Stone.		[About 20% UO_2]
Gifu Prefecture	Ena District	Naeki
Felguson Stone.		[1-2% UO_3]
Ena Stone.		[11% UO_2]
Seoul	Oukido Kaigetsumen	
Felguson Stone.		[8.4% UO_2]
Manchuria	Kaiki	
Kofusen Stone		[3.8% UO_2]

[44] "*Concerning Uranium*," "*A Coordinated Opinion toward the Practical Use of Uranium*." Tokyo 2nd Army Arsenal, April 1943.

The speaker then made it clear that to date, according to the date of the document, April 1943, no uranium deposits had been discovered in East Asia. The radioactive assets and mineral deposits located in Japan's recently acquired Empire; Burma, China, Malaysia, Vietnam and elsewhere were not mentioned in this report. This is surprising as the existing mining, transport and shipping records compiled by the SCAP/ESS immediately after the war indicated the exact opposite, that uranium ores were being transported from these outlying areas of the Empire to Tokyo, Japan.

This lack of insight on the part of the speaker as to the availability of ores in Japan's newly acquired Empire in a document prepared in 1943, suggests that the information contained in his briefing was drawn solely from research materials dated prior to 1941. It is likely that the July 1943 discussion of radioactive minerals available to the Japanese that July, had been originally assembled by Suzuki Tatsusaburo at the request of General Yasuda in 1940. It was Suzuki's enthusiastic earlier report that generated the interest of the Imperial Japanese Army in the subject of atomic weapons.

The 1940 Suzuki report included an assessment of the availability of uranium in Japan and concluded that the manufacture of atomic bomb was indeed possible. Apparently, Suzuki's original research had been simply recycled to support the 1943 briefing. Suzuki's initial report probably holds numerous important positions in the history of Japan's wartime atomic weapons and energy programs, but none ever admitted. The conference then once again returned to Dr. Alfred Stettbacher "*Der Amerikanische Super-Spengstoff U-235*" – "*The American super explosive U-235*" and expectations for the atomic bomb.

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The notes recall a fictional story, published during World War I in America about the discovery of an explosive which, smaller than the head of a walking cane, when set off, was capable of leaving huge craters in the surface of the Earth. The story was actually H.G. Wells' *The World Set Free: A Story of Mankind*, first published in the US in 1914. [45]

Wells is credited by many for predicting the atomic bomb through science fiction long before it became reality. As Wells wrote of the bomb "Once launched, the bomb was absolutely unapproachable and uncontrollable until its forces were nearly exhausted, and from the crater that burst open above it, puffs of heavy incandescent vapour and fragments of viciously punitive rock and mud, saturated with Carolinum, and each a centre of scorching and blistering energy, were flung high and far." Wells' sources for his knowledge of physics were William Ramsay, Ernest Rutherford, and Frederick Soddy; all three, world renowned physicists, all three were or would become, Nobel Laureates. Ramsay–1904, Rutherford–1908, and Soddy–1922.

Wells had dedicated *The World Set Free*, to Frederick Soddy's work; *Interpretation of Radium.*[46] In 1915, Frederick Soddy, warned publicly of the future dangers of atomic war – meaning that he was aware of the potential development of such weapons at least as early as 1915. [47] Throughout his career Soddy granted only one doctorate; to a Japanese, Iimori Satoysu who studied under his guidance from November 1919 to October 1921. Iimori would later figure heavily in Japan's wartime efforts to create an atomic weapon.

Even then an employee of Rikken, Iimori would rise to become known as the "father of Japanese radiochemistry." During the war Iimori would serve as the Rikken chief of the Uranium Mining Project in Manchuria, head the Japanese Army's search across the empire for good sources of uranium, and refine the uranium obtained at Rikken's Iimori Lab. It is likely that Iimori also attended this first meeting and verbally briefed on the Japanese search for uranium since 1940, explaining the lack of information concerning new resources as listed in the earlier notes presented. The lecturer then mentioned a recently published newspaper article that described the potential of such a new explosive and, unlike Wells' *The World Set Free*, this one was far easier to identify.

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[45] Wells, H.G. *The World Set Free: A Story of Mankind*. E. P. Dutton & Company, New York, 1914. First Ed.
[46] Soddy, Frederick. *Interpretation of Radium and the Structure of the Atom*. University of Oxford. G.P. Putnam's Sons. 1909.
[47] Sclove, Richard E. From Alchemy to Atomic War: Frederick Soddy's "*Technology Assessment*" of Atomic Energy, 1900-1915. The Loka Institute. Science, Technology, & Human Values, Vol. 14 No. 2, Spring; 1989. Sage Publications, Inc. 163-194

The headlines of the article published by the New York Times on 5 May 1940 read "*Vast Power Source in Atomic Energy Opened by Science*."[48] Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." The subtitles continued "*GERMANY IS SEEKING IT*," and ended with the banner "*Scientists Ordered to Devote All Time to Research – Tests Made at Columbia*."[49] What the article said was downright amazing.

The article warned the reader that "A natural substance found abundantly in many parts of the earth, now separated for the first time in pure form, has been found in pioneer experiments at the Physics Department of Columbia University to be capable of yielding such energy that one pound of it is equal in power output to 5,000,000 pounds of coal or about 3,000,000 pounds of gasoline…"[50] In the Kuroda Papers these exact numbers are used to describe the amount of energy contained in one pound of uranium, however all weights mentioned in the New York Times article were translated in the Kuroda Papers from pounds to grams for smaller numbers, pounds to cubic meters for larger numbers.

Whereas the Times had talked about one pound of uranium, the Japanese listed the amount as 454 grams, the actual amount of grams per pound is 453.592 grams. The Japanese reduced the conversion equivalents given as coal or gasoline to Benzine. Where the Times illustrated the equivalent power as 3,000,000 pounds of gasoline, the Japanese illustrated the amount as 12,000,000 cubic meters of Benzine.[51, 52]

As the article read, Professor John R. Dunning of Columbia who headed the research had told a colleague "that improvement in the methods of extraction of the substance was the *only* step that remained to be solved for its introduction as a new source of power." [53]

The article was written by William L. Laurence, the same William L. Laurence who would later be summoned to the Los Alamos, New Mexico in April 1945 by General Leslie Groves to serve as the official historian of the Manhattan Project. Laurence would author many of the first official press releases about nuclear weapons, some of which were delivered by the Department of War and President Harry S. Truman. Laurence was the only journalist to be present at the Trinity test in July 1945, and had prepared press releases to be delivered in case the test ended in a disaster, to include some copies which released the names of famous scientists lost in the "accident." On the atomic bombing mission to Nagasaki, Laurence himself flew aboard the B-29 *The Great Artiste*, which served as a blast instrumentation aircraft for the drop. Laurence was a two-time winner the Pulitzer Prize, the first in 1937, the second for his work on the Manhattan Project in 1946.

Laurence wrote that "A chunk of five to ten pounds of the new substance, a close relative of uranium would drive an ocean liner or an ocean-going submarine for an indefinite period around the oceans of the world without refueling, it was said, for such a chunk would possess the power output of 25,000,000 to 50,000,000 pounds of coal, or of 15,000,000 to 30,000,000 pounds of gasoline." [54] The article listed uranium ore as being found in the "Belgian Congo, Canada, Colorado, England and Germany." [55] Laurence declared that the ore "is 1,000,000 times more abundant than radium, with which it is associated in pitchblende ores." [56]

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[48] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940
[49] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940
[50] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940
[51] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940
[52] It is likely that the number 12,000,000 cubic meters should have read 12,000,000 cubic centimeters. It is unknown whether the Japanese were speaking of benzene as a gas, or a liquid.
[53] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940
[54] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940
[55] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940
[56] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940

The article presciently encapsulated most of what we would today recognize as the history of the then yet-to-be created, Manhattan Project. The Japanese at the 2 July 1943 conference held in Tokyo took the article with deadly seriousness, and much of the actual conference centered on the Laurence article. For a foreign intelligence agency looking for indicators that the US might have started such a program, it was a wealth of information.

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In his article Laurence explained how Alfred O. Nier, University of Minnesota, had isolated a small amount of uranium which was then rushed to Columbia University, where Professor John Dunning had submitted the sample to tests conducted with Colombia's cyclotron. [57]

Nier was an American physicist who pioneered the development of mass spectrometry. In 1940, on the request of Enrico Fermi, he and a few students, including Edward Ney, prepared a pure sample of uranium-235 using an early mass spectrograph designed by Nier for John R. Dunning's team at Columbia University. Nier was the first to use mass spectrometry to isolate uranium-235, which was used to demonstrate that U235 could undergo fission and developed the sector mass spectrometer configuration now known as Nier-Johnson geometry.

Using the sample provided by Nier, Dunning's team was able to demonstrate that U235 was the isotope responsible for nuclear fission, rather than the more abundant uranium-238. Confirmation of this then-suspected information was a critical step in the development of the atomic bomb

The short account of Nier's work which appeared in the April 1940 journal, *Physical Review,* essentially brought the curtain down on open publication about uranium fission until the *Smyth Report* appeared after World War II. To Japan's scientists, this should have been taken as a warning. Scientists at the Tokyo meeting however warned that as production of uranium remained very small, at that moment uranium had no scientific or military applications.

The Laurence article noted the fact that even this small amount had been isolated saying this "has given new hope that a process for isolating the substance in larger quantities, in grams and pounds instead of millionths of a gram will be found in the not so distant future."[58]

The Laurence article also revealed that US industrial labs had also taken up the challenge of producing U235 in larger amounts. This included General Electric (GE). Laurence wrote that scientists working for GE were reported to have set up an apparatus similar to that used by Nier and had already separated "a relatively large sample of U-235."[59] The Japanese scientists at the meeting failed to heed this as a warning of weapons that might possibly make their appearance over Japan before the conclusion of the current war. Evidently, the comments contained in the article about the use of the cyclotron in the US steered the discussion in Tokyo that 2 July instead to the use of Japan's cyclotrons to conduct the same tests as Nier. The need for an industrial scale production process and the involvement of Japanese industries would also become a subject of discussion at the conference.

Surely Japan's scientists realized that if a millionth of a gram could be isolated at some point, given time and supported by adequate funding, the required technologies to separated uranium on a larger scale would begin to be developed, improved, and followed by industrial scale facilities that could produce the materials on a grand scale. If a full gram could be isolated, then a pound could be isolated then, two pounds, then….ten pounds. The Kuroda Papers then noted the various scientists in Japan and abroad who were known to be investigating the issue of U235. The Japanese discussed the works of:

- Nier, A. O., E. T. Booth, J. R. Dunning and A. V. Grosse, "Nuclear Fission of Separated Uranium Isotopes." Physical Review, Volume 57, pp. 546 3 March 1940.
- Hagiwara, Tokutaro. Liberation of neutrons in the nuclear explosion of uranium irradiated by thermal neutrons. Departmental Bulletin Paper. The Physico-Chemical Society of Japan 31 December 1939

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[57] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940
[58] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940
[59] Laurence, William L. "*Vast Power Source in Atomic Energy Opened by Science*." Its subtitle read "*Relative of Uranium Found to Yield Force 5 Million Times as Potent as Coal*." "*GERMANY IS SEEKING IT*." New York Times on 5 May 1940

- Abelson, P. H., An investigation of the products of the disintegration of uranium by neutrons, Physical Review, Volume 56, pp. 1 - 9, July 1939.
- Flerov, G.N. (J. Jhiband) and Petrzhak K.A. (A. Moussa) (I.N. Golovin). "Spontaneous fission of uranium." Physical Review. Volume 58, pp. 89, 1 July 1940.
- Turner, Louis A. The Nonexistence of Transuranic Elements. Physical Review. Volume 57, pp. 157, 5 January 1940

Hahn's discovery of uranium fission had aroused so much interest within the scientific community that nearly 100 papers were published about the subject within a year of its announcement. While Hagiwara and Nier have already been discussed in some detail, comment about the other physicists mentioned above is required.

Though the entry as written reads "J. Jiband., A. Maussa, and I.N. Golovin. c. [circa] 1940. I. 2126, 3888," The names "J. Jiband., A. Maussa," were a somewhat inaccurate transliteration of their names from the Russian language (note the previous translations of the Kuroda Papers). After much research it appears that this entry actually referred to an unusual release of physics research findings from work carried out in the 1940 Soviet Union by Georgy Flyorov and Konstantin Petrzhak.

In 1939, Petrzhak and Georgy Flyorov were asked by Igor Kurchatov to study uranium fission induced by neutrons of different energy levels using Yakov Frenkel's theory of fission as a guide to their work. In May 1940, in an underground laboratory in the Dinamo Station of Moscow Metro (about 50 m below the earth surface) the pair discovered spontaneous fission. Flyorov and Petrzhak were subsequently awarded the Stalin Prize. Despite the enormity of their discovery, there was no international reaction to their announcement by Western scientists.
The mention of I.N. Golovin (actually I.N. Golovin) with that of Georgy Flyorov and Konstantin Petrzhak was however more difficult to understand.

Golovin had graduated from Moscow State University in 1935 and subsequently work at Laboratory No. 2 of the USSR Academy of Science. He would eventually rise to become Igor Vasilyevich Kurchatov's assistant director in managing the nuclear weapons development program of the Soviet Union. Hence, he is overshadowed by his far more famous mentor and apparently, most of his work remains classified in modern-day Russia.

It is likely that the Japanese were more familiar with Golovin, or they possessed some information that enabled them to connect Golivin to Flyorov and Petrzhak. Though unknown to the authors of this paper at this time, Golovin may have been Flyorov and Petrzhak's supervising professor at the time of their breakthrough work on spontaneous uranium fission, or had some other connection to the pair, that justified his mention at the Japanese conference of 2 July 1943. The notes taken in the Kuroda Paper then turned to a somewhat more ominous citation; that of an article published by physicist Louis A. Turner in the January 1940 edition of Physical Review, and titled, *The Nonexistence of Transuranic Elements*.[60]

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In Turner's article, which cited previous work done by the German physicists von Weizacker (a future member of Germany's Uranium Club), he argued that when U238 captured a neutron to become U239 it would decay into a new element that he called "93 Eka Re239" which he conjectured to be the ancestor element to U235. This new element, which would later became known as Neptunium Turner theorized, according to a prediction by Niels Bohr and John Wheeler, would be fissile by fast, as well as thermal neutrons. It would be at least as fissile as U235. Turner then summarized the current results of work on the subject and presented a thorough bibliography of published articles complete until the end of 1939.

Unlike U235, the new isotope would be chemically different from uranium and could be more easily separated from than U235. If, instead of undergoing fission, U238 were to capture a neutron it would then become U239 and might fission. But even if the new element did not fission, it would become unstable and through beta decay, transmute into the yet unknown element 93. This element would then decay into element 94 (plutonium) which Turner

[60] Turner, Louis A. *The Nonexistence of Transuranic Elements* [The missing heavy nuclei]. Phys. Rev. 57, 157 (1940) – 15 January 1940.

predicted would be even more fissionable than U235. Once published, Turner's conclusions were known by the Germans, Japanese and Soviet scientists.

Physicists had long-since believed that transuranic elements could be produced in a reactor, what Turner had done though, was to call attention to the fact that these elements could be more easily produced in a reactor than U235 could be separated from its more abundant cousin U238. Turner had inadvertently, announced a path to the bomb through plutonium, and while some physicists might have missed the implications of the article, the citation of Turner's piece in the Kuroda Papers suggests that Japan didn't, and this is the likely point where the cave at Koto-ri, the underground facilities near Anju, Chongjin, and Kanggy on the Korean Peninsula and other facilities to be built in Manchukuo and China came into the picture.[61] As the document continued, the Japanese next turned their attention to Einstein.

According to the lecturer, if elemental uranium was exposed to radium it would then transmute to lead and helium. During this conversion, energy would be liberated and the mass of the uranium involved would be reduced to $1/1000^{th}$ of its original value. As the lecturer related, the Einstein equation was applicable to the uranium atom (1.9 x 10^{-20} grams).

The fission of 1 gram of uranium would yield 9 x 10^{20} ergs, or liberate about 2.15 x 11^{11} kilocalorie (kcal) energy. The release would be the equivalent to 13,500 kilograms of gelatin dynamite (a high explosive consisting of a gelatinized mass of nitroglycerin with cellulose nitrate added) or 3,400,000m^3 of benzene. As the lecturer explained however, unless the fission was perfect, only a portion of the mass involved would actually convert to energy. As Einstein had predicted only a small portion of the potential energy available would be released.

Despite its inefficiencies, the amount of energy released through a bomb would be – enormous. It was an odd choice of words as the intelligence gathering apparatus of the Soviet Union would similarly label its espionage effort against the American bomb as "ENORMOZ."

The lecturer pressed on, explaining that in nature, the natural transmutation of uranium to lead and helium has a half-life of 4.5 x 10^9. This transmutation was not however, accompanied by any appreciable liberation of heat. As there had yet to be created a method of producing an instantaneous fission of uranium on demand, such an enormous release of energy had never been realized. However, in 1938, using neutrons artificially accelerated in a cyclotron, uranium fission was suddenly realized.

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These mentions of Einstein suggest that, unlike some German scientists who were wedded to Adolf Hitler's anti-Semitism with its stark rejection of the Theory of Relativity as "Jewish science," the Japanese were less inclined to define the future survival of Japan on religious, racial or ethnic prejudices. It should be noted that in Germany, where Otto Hahn and Fritz Strassmann first split the atom were credited with the discovery of fission, the achievements of Lise Meitner, a Jew, who interpreted their discovery and put their discovery in context with the rest of physics research were overlooked. The mention of additional German scientists later on in the paper who were known to be less-than anti-Jewish and then living under Nazi rule, further supports this observation. With that said, the discussion then turned to Siegried Flugge.

From 1929 to 1933, Siegried Flugge studied physics at the Technische Hochschule Dresden and the Georg-August University of Göttingen. In 1933 received his doctorate at the latter, under the guidance of Max Born. Flügge's 1939 paper *Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden*? – *Can the energy of atomic nucleus be harnessed technically?* published the in Die Naturwissenschaft suggested that nuclear weapons were possible. [62] His 1939, *Die Ausnutzung der Atomenergie – The Utilization of Atomic Energy*, published in the Deutsche Allegemeine Zeitung, was believed at the time, to have made Germany's interest in atomic weapons

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[61] Rider, Dwight R. *Burn before Reading: The Japanese Atomic Bomb Program, the Battles of the Chosin Reservoir, and the Cave at Koto-ri.* The Cell. 21 March 2017. http://www.mansell.com/Resources/Rider_Burn_Before_Reading_28May2016.pdf

[62] Siegfried Flügge *Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden?,* Die Naturwissenschaften Volume 27, Issues 23/24, 402–410 (9 June 1939).

evident to all.[63] In the Kuroda Papers the Japanese noted the two influential articles published by Flugge in Naturwissenschaften in 1939 concerning the exploitation of nuclear energy. In a sense, it was a German work of science that guaranteed the subsequent creation of the Manhattan Project.

By the summer of 1939 Flugge was convinced that the energy contained within uranium if set free, could generate a tremendously powerful explosion. In his writings Flugge estimated that the energy contained in one cubic meter of uranium oxide was enough to lift one cubic kilometer of water to a height of 27 kilometers. [64] As it was related to the Japanese at the conference of 2 July 1943 if one cubic meter of uranium was subjected to neutrons for 1/100th of a second, it would release enough energy to destroy 27 x 10^{15} kilometers of land.

Flugge envisioned two different types of reactor-based weapons based on different times, different materials and different neutrons. Flugge's fastest time for an explosion in his reactor-based bomb was 10^{-4} (one ten-thousandth of a second). [65] Niels Bohr and Otto Robert Frisch calculated Flugge's time as too slow and predicted a faster time of 10^{-8}; in the Kuroda Papers Nishina suggested a time of 10^{-9}. [66] In Mother Russia physicist Igor Tamm, reading Siegried Flugge's work told his students "Do you know what this new discovery [fission] means? It means a bomb can be built that will destroy a city out to a radius of maybe 10 kilometers."[67] The two articles authored by Flugge laid much of the foundation for a future world preoccupied with nuclear weapons and dependent upon nuclear energy in which we exist.

Siegried Flugge's work was beckoned interest in atomic weapons worldwide. His publications made it all too clear to too many physicists that Germany was invested in creating an atomic weapon. Shortly after Flugge's works were published, he began to clandestinely work on Germany's nuclear energy project and became a member of Germany's Uranverein (Uranium Club).

Flugge later published two highly sensitive reports in Kernphysikalische Forschungsberichte (Research Reports in Nuclear Physics), an internal publication of Uranverein. His work was classified Top Secret by wartime German officials and saw limited distribution; authors were not allowed to keep copies. All Uranverein reports were later confiscated under Operation Alsos and sent to the United States for subsequent evaluation. Pascual Jordan was also mentioned in the Japanese notes, however the name is likely misspelled and possibly written phonetically. He appears to have been mentioned in connection with Flugge. Jordan was one of the great theoretical physicists of the 20th century; one of the principle creators of quantum mechanics and inventor of quantum field theory and, a member of the Nazi Party.

Pascual Jordan was an ultra-right-wing conservative; an intense anti-communist. After attending Hanover Technical University, Jordan earned a PhD at the renowned Göttingen University in northern Germany. Recognized for his extraordinary mathematical skills, Jordan became assistant to mathematician Richard Courant and then to physicist Max Born. Jordan co-authored with Werner Heisenberg several of the earliest papers on quantum mechanics. He also authored works outside his primary area of study.

Writing under a pseudonym, Jordan wrote bellicose articles for far right-wing magazines dedicated to the spirit of German tradition. When Hitler became Chancellor of Germany in 1933, Jordan joined the National Socialist German Workers Party, also known as the Nazi Party though he was under no pressure to do so. Later that same year he became a storm trooper under the Sturmabteilung (SA), outfitted in a brown uniform, boots that reached to the knee, and a swastika armband. Much to his credit however, Jordan acknowledged the accomplishments of Jewish physicists in his writings, including Einstein's and freely associated with members of the Jewish faith.

During WWII Jordan worked as a weather analyst at the Peenemunde rocket center where he attempted to interest the Nazi Party in numerous schemes promoting technologically advanced weapons. He also urged the government to initiate new research programs into physics for potential weapons for war. The Hitler regime however distrusted

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63 Siegfried Flügge *Die Ausnutzung der Atomenergie. Vom Laboratoriumsversuch zur Uranmaschine – Forschungsergebnisse in Dahlem*, Deutsche Allgemeine Zeitung No. 387, Supplement (15 August 1939).
64 Powers, Thomas. *Heisenberg's War: The Secret History of the German Bomb*. Little, Brown and Company. Boston, Mass. 1993.
65 Powers, Thomas. *Heisenberg's War: The Secret History of the German Bomb*. Little, Brown and Company. Boston, Mass. 1993.
66 Powers, Thomas. *Heisenberg's War: The Secret History of the German Bomb*. Little, Brown and Company. Boston, Mass. 1993.
67 Holloway, D. 1987. *The Soviet Union and the Arms Race*, 2nd ed. (New Haven: Yale University Press): 15

Jordan because of his defense of "Jewish physics," his past associations with Courant, Born, and Pauli (all Jewish) and his support of the likes of Einstein, a Jew, and Heisenberg who had been accused of having been a "White Jew."

Ignored by his fellow Nazis, Jordan ended up politically and scientifically isolated. However, again, the Japanese did not ignore his work and in hindsight, it seems possible that Jordan may have been a source for some of the advanced German technology believed to have been transferred to Japan during the war. It is likely that his duties as a weather predictor at the Peenemunde rocket center bored him; which allowed him to develop his own niche in Germany's weapons technology-sharing program with Japan. Notable in their absence, the Kuroda Papers do not cite any of Jordan's specific publications nor any possible clandestine assistance he might have given to Japan.

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The day's session ended with a discussion on the need for water to support uranium fission. Water was thought to provide the secondary source of energy for the reaction to occur. These comment were probably some of the few made that day in discussing a reactor versus a weapon. The notes end with a comment concerning the use of fission to melt or destroy tanks, while replacing the need for coal depots to support ships.

Whether it was the urgency of the times or the need for urgency in transferring responsibility of the program from Lieutenant General Yasuda to Major General Nobuuji is not known, but the next conference took place just four days later on 6 July 1943. Considering that the 2 July 1943 meeting was held on a Friday, with the next meeting scheduled for the following Tuesday and bearing in mind the military ranks of the attendees, the need for an atomic bomb to end the war and save Japan, may have dictated the momentum at which the next meeting began. Then as now the daily schedules of general officers were usually prepared days in advance, it is unlikely that General Nobuuji had any open time that coming Tuesday, but time was obviously found. The weekend also gave Nishina and Rikken more time to prepare.

6 July 1943 – Meeting Notes:
Research Project Meeting at the Nishina Research Institute.
The meeting of 6 July 1943 was in essence a continuation of the meeting held four days earlier. This meeting was actually scheduled the Friday before to be a progress report on Nishina's research on uranium. In attendance were Doctor Nishina, Major General Nobuuji and Lecturer Ishida, listed in that order and bearing those titles. The lecturer, again, probably Ishida Sakae, picked up where he had probably stopped the Friday before.

As the lecturer paraphrased actual events, at some point in 1941 the subject of uranium had come to the attention of the Army Air Technical Laboratories (located in Tachikawa) (Lieutenant General Yasuda), and the General Affairs and Administrative Department of the Imperial Japanese Army Air Service. They, in-turn, had sought out Nishina. The actual course of events was that General Yasuda had sought out the assistance of Rikken through Viscount Ôkouchi Masatoshi. Rikken had been previously tasked by the Imperial Japanese Government to organize science within Japan to support the war effort. [68] Such entities as the Cabinet Planning Board may have been responsible for request, however it was Rikken who was ordered to complete the task. [69] Okuchi had taken the problem to Nagaoka Hantaro, the then head of physics research at Rikken, Nagaoka had then turned the problem over to Nishina.

According to the lecture, "we (probably Nishina) had been requested to investigate the use of uranium within the following broad research areas: 1) as an engine fuel, 2) as an explosive, and 3) as a fuel."[70] These three headings generally match those previously discussed by the CRANP of the Imperial Japanese Navy's Admiral Ito Yoji and reported in the book *The Day Man Lost*.[71] Under Japan's Navy, only three issues were ever under consideration: The production of an atomic bomb, the development of a nuclear reactor and the development of nuclear power for energy production, in that order. [72] The earlier Japanese Army research had not however been carried out at the Rikken facility in Tokyo.

The research into the use of:

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[68] Low, Morris. *Science and the Building of a New Japan*. Johns Hopkins University. Palgrave Macmillan. 2005
[69] Low, Morris. *Science and the Building of a New Japan*. Johns Hopkins University. Palgrave Macmillan. 2005
[70] The Pacific War Research Society. *The Day Man Lost: Hiroshima, 6 August 1945.* Kodansha International. Tokyo, Japan. 1981
[71] The Pacific War Research Society. *The Day Man Lost: Hiroshima, 6 August 1945.* Kodansha International. Tokyo, Japan. 1981
[72] The Pacific War Research Society. *The Day Man Lost: Hiroshima, 6 August 1945.* Kodansha International. Tokyo, Japan. 1981

- Uranium as an engine fuel (reactor) was conducted at the 1st Army Air Technical Research Institute at Fukuoka.
- Uranium as an explosive (the bomb) was conducted at the 3rd Army Air Technical Research Institute at Fukuoka.
- Uranium as a fuel (atomic energy) was conducted at the 6th Army Air Technical Research Institute at Tachikawa.

The lecturer indicated that the research showed enormous potential, and that the Army had great expectations for the development of a weapon. A recommendation however was made that these projects would be more successfully conducted at Japanese Imperial Air Service Laboratories.[73] A request for information concerning the project had been previously received from the Tonizo Laboratory (Tokyo 2nd Army Arsenal).[74] As it turned out, Tonizo had already funded the project.[75] Rikken had already considered the request. Tonizo was an Army laboratory, not a Japanese Air Service laboratory. Perceptions of a "conflict of interest" had to be considered.

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The reason for the request for information, its authority and the connection between the Army (Tonizo) and the Air Service laboratories was not, as with so many things when working a government contract, immediately clear to the briefer. The Army Technical Laboratories had previously agreed that they were not the appropriate research facilities to undertake the project. The Navy had yet to introduce a proposal. The Air Service Laboratories under Yasuda had already accepted the project. In the discussion that followed, it was made abundantly clear that neither intra- nor interservice rivalries would be allowed to interfere with the project.

The project was to be completed as soon as possible. A sense of urgency loomed over the conference. Nishina would conduct research for the Japanese Air Service.

In the conversation that followed, the contracting issue was clarified. As the required paperwork and funding had been initiated by the Tonizo it was agreed to conduct the research under the contracting vehicle already established. An expense sheet for 2,000 yen had already been issued.

This expense sheet did not cover the requested research, only the initial costs in establishing the original contract vehicle. It was agreed to leave the contract vehicle established with the Tonizo in-place. Nobuuji asked, and Nishina agreed, to make contact with Tonizo after the meeting of 6 July 1943 with the Air Force and Nobuuji had ended. As to the need for additional researchers to assist with the project, it was Nishina who informed General Nobuuji, not vice-versa that two commissioned officer-researchers, probably technical officers, were coming from Koku (the Institute for Army Aeronautics). It is more likely however, that these officers were not actual researchers, but contract managers. The conversation then turned toward the question commitment.

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As the project offered the potential of atomic energy, and a tremendously powerful weapon; one that would be used, was Nishina thoroughly committed? It was an age-old question that military servicemen often have about their

[73] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

[74] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

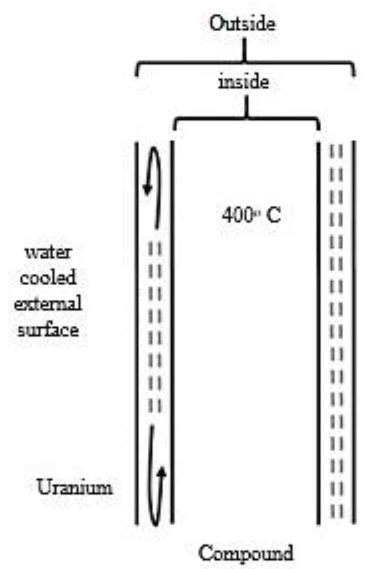
[75] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

civilian counterparts. Are they bound to their duty? In answering the question, Nishina, as a man, a scientist, and the son of a samurai family fully acquainted with the concept of obligation, hedged. [76]

As Nishina explained, at the moment, the beginning of the project, the chances of success were slight, but after more research, it might be possible. It was an honest answer to an honest question. Nishina then took center stage replacing the previous lecturer. He covered ten separate issues. These were numbered in the Kuroda Papers as 1, 2, 3, 4….10. He covered at least two subjects; a weapon and a reactor.

First, Nishina warned his audience, to include General Nobuuji that if the study of uranium was to be successful it would require a huge factory, probably more than one. If there were actual factories or reactors built in China, on the Korean Peninsula or in Manchuria, Nishina's statement of 1943 may have led to their being constructed. It is more likely however that these locations had been under construction for some time. As Nishina did not dwell on this subject as he was to do on other points in his discussion, he may have simply been restating the obvious or attempting to justify the high costs associated with previous decisions made to proceed with the construction of those facilities.

Figure 1.



According to analysts familiar with the project, it is unlikely that those facilities believed to have been constructed underground near Anju, the Chosin Reservoir, near Chongjin, Kanggye, or in the mountains near Hungnam were inaugurated long prior to 1943. [77] They were most likely initiated in 1940-1942 under the Army's previous program, the Ni Project. Nishina then continued on to his second issue.

Nishina back briefed Nobuuji that, to separate U235 from U238 the uranium must first be converted to uranium hexafluoride, an extremely unstable fluorine chemical compound. The chemical would react violently with any amount of moisture.

During the war, Rikken reportedly suffered two accidents while working with the material. The institute had been lucky, there were no fatalities from either. Had either of these accidents been larger, it is unlikely that the effort would have continued.

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After being converted to uranium hexafluoride the gas would then be placed into a pipe, a thermal diffusion column, of 5.2 meters in length. Nishina kept his explanation simple; the interior of the pipe would be heated to a temperature of 400º Celsius. It would be necessary to maintain a rapid flow of gas through the pipe. It was a process that Nishina described as simple in concept, but difficult to achieve in practice. Nishina spent a great deal of his allotted time on the issue of thermal diffusion. It should be understood that, the thermal diffusion columns constructed at Rikken during WWII were never intended to be any more than experimental devices, not operational models. They were research and design models, mostly used as demonstration tools to explain the uranium enrichment process to the stream of near-continuous visitors to the laboratory, visits led by General Nobuuji. (See Figure 1).

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[76] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

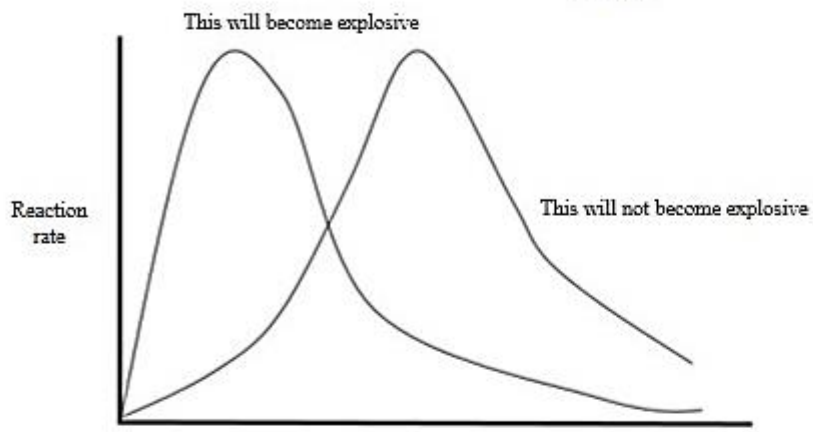
[77] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

As Nishina explained, the heat would be provided electrically. The outside surfaces of the pipe would consume large amounts of electricity but would be cooled with water. With time, a convection system would develop causing the lighter uranium isotope (U235) to rise and leaving the heavier elements (U238) to descend. The lighter isotope, U235, would then be recovered from the uranium hexafluoride in the form of a metal or an oxide. During the middle of his presentation, within the discussion of the thermal diffusion, Nishina allowed his mind to wander into the area of a weapon.

According to Nishina the Japanese had determined that in a mass of 10 kilograms of uranium, few neutrons would be lost and that a chain reaction would occur. Nishina warned his audience however, that the U235 would also react with any U238 or water present. Nishina indicated that Rikken would have to determine the ratio of those reactions. In carrying out their studies, Rikken had included the idea of a cross section number. As Nishina explained, when two particles interact, their mutual cross section is the area transverse to their relative motion within which they must meet in order to scatter from each other. Their scattering cross section, Nishina's number, is related to the geometric size of the particles. Rikken was still in the process of determining the accuracy of their calculations through the use of the Institute's cyclotron.

This was the first, of only two mentions of Rikken's particle accelerator in the entire set of Kuroda's documents. Through Nishina's proposed experiments with the cyclotrons, the physicists at Rikken could predict whether 10, 20 or even 50 kilograms of U235 would be required to create and sustain the desired chain reaction. Due to the rarity of U235 and the expense involved, practical experimentation with the physical material was cost prohibitive. Until the physical material had been created, Rikken would continue to rely on calculations and their particle accelerator.

Figure 2.



For these experiments, concentrations U235 between 0.7 and 10% would be used in experiments however, concentrations of greater than 50% would adversely change the outcome of testing. Rikken had yet to determine the reaction rate of U235, how slowly or quickly a reaction would take place. It would be difficult, at least at that moment, for Rikken to produce a sample of U235 at a purity of greater than 50%. According to Nishina, U235 purification to 100% was impossible. (See Figure 2). The scientist then retreated from his tangential remarks and turned the discussion to his third point. The requirement to the use of U235 in a reactor.

As Nishina explained, U235 would undergo fission by use of slow neutrons whereas the fission of U238 would require the use of high velocity neutrons. The requirement for high velocity neutrons would be difficult to achieve; more likely Nishina meant difficult to predict and control. Nishina then turned to his fourth point and the use of water with uranium in a reactor.

As Nishina discussed the subject, water would be used as a moderator to slow down the neutrons expended from the fission of U235. It is also more likely that while Nishina spoke of water in-general, he more precisely meant the use of heavy water (deuterium oxide). There were three heavy water plants on the Korean Peninsula alone: One at

Hungnam (Nichitsu), the second near the Supung-ho Hydroelectric Power Plant (Namsan Chemical Plant), and the third at Manp'o (Bongoong Chemical Plant).

Each of these plants drew their electrical power from a separate set of hydroelectric power generating cascades, or base-of-the-dam power stations. Nichitsu received its electrical power from the Pujon and Changjin Cascades. The Namsan, or Namsi Chemical Plant received its power from the Supung-ho Hydroelectric Power Station while the Bongoong Chemical Plant would receive its power from the Wiwon Hydroelectric Plant then under construction. The latter two were both located along the Amnok (Yalu) River on the border between Korea and Manchukuo. All three chemical plants and their supporting hydroelectric power stations were at least partially owned and operated by the Noguchi combine, Nichitsu.

It must be kept in mind that, though Nishina and perhaps other physicists were in the room, most of the men in attendance were chemists, as was Nobuuji. Nishina was purposefully keeping the subject at a layman's level so that his entire audience might be able to grasp the ideas and concepts that he was there to brief, and they were there to deliberate. At some point after this discussion of 6 July 1943, Rikken physicists would decide to use pure graphite versus heavy water as a moderator. A graphite plant was later established at Kujang, on the Korean Peninsula.[78] Nishina then turned to his fifth point, critical mass.

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Critical mass is defined as the smallest amount of fissile material required for a sustained nuclear chain reaction. The critical mass of a fissionable material depends upon its nuclear properties (specifically, the nuclear fission cross-section), its density, its shape, its enrichment, its purity, its temperature, and its surroundings. The higher the density, the lower the critical mass. A sphere is the shape with minimal critical mass and the smallest physical dimensions. The critical mass of U235 is a sphere weighing 52 kilograms.

The size must at least include enough fissionable material to reach critical mass. The critical mass for lower-grade uranium depends strongly on the grade: with 20% U235 it is over 400 kilograms; with 15% U235, it is well over 600 kilograms. As Nishina estimated, at minimum, the critical mass of U235 would require at least 10 kilograms of material. As Nishina explained, in any smaller amount of U235 the primary neutrons would be absorbed without assembling a chain reaction.

Chief Cabinet Secretary to Prime Minister Kantarō Suzuki's Cabinet (April–August 1945) Sakomizu Hisatsune had known about Japan's earlier efforts to create an atomic bomb and admitted as much after the war, however he limited his admission to knowledge of the Imperial Japanese Navy's Project A.[79] Lieutenant Commander Ishiwatari Miroshi, Bureau of Naval Affairs of the Imperial Japanese Navy told the Manhattan Projects' Major Furman that in the spring of 1944 the Navy had decided to make an atomic bomb "and from that date attempted to coordination of the research work being done by the Army." Ishiwatari continued saying that "It was thought at that time that if U235 could be concentrated at 10 percent or above, bomb or power possibilities would be likely."[80] The ten percent may have represented an internal benchmark of some kind. If purification of U235 to ten percent could be realized, then the Japanese ability to enrich the product to a higher quality was more easily within reach. The numbers given by Ishiwatari strangely resembled those discussed by Nishina in July 1943, suggesting that the Japanese navy was far more deeply involved with the army's project than previously recognized.

Only a critical mass of 10 kilograms or greater would actually work. Though the conversation as noted in the Kuroda Papers was probably far longer than the few notes we have, Nishina then moved on to his next topic: The release of energy from uranium. At this point however, there is an interruption in the page numbering of the documents with two pages, 65 and 66, missing. Despite the loss of these pages, page 67 picked up where it had left off, suggesting that the two missing pages were an addendum of some sorts. Perhaps several diagrams.

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[78] Korean War 9th Infantry Regiment - History - November 1950. 2nd Infantry Division Korean. War Project Record: USA-81 Folder: 070005 Box: 07 File: 05 National Archives and Records Administration College Park, Maryland Records: United States Army Unit Name: Second Infantry Division Record Group: RG407

[79] Coffey, Thomas M. *Imperial Tragedy*. The World Publishing Company. New York. 1970. Page 282.

[80] Summary Report, Atomic Bomb Mission, Investigation into Japanese Activity to Develop Atomic Power. Headquarters First Technical Service Detachment G.H.Q., AFPAC, ADV., A.P.O. 500 San Francisco, Calif. 30 September 1945. Record Group 331. Stack Area 290. Row 24. Compartment 02. Shelf 1-2. Entry 224. Scientific and Technical Division. Box 1. File: Research, Nuclear, Japan.

Nishina then told his audience that the amount of energy contained in 30 kilograms of water and 10 kilograms of uranium was equivalent to the number of calories present in 10,000 tons of gasoline (1,000 tons heat capacity). Again, Nishina was addressing an audience comprised of mostly chemists and sought to use terms and quantities that would be relevant to those present. As mentioned earlier, other physicists had previously used coal and gasoline in similar such comparisons. Obviously making himself clear, Nishina then turned to his seventh point, the practical applications of uranium.

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According to Nishina's explanation, if uranium were to be used to power an engine, it would be necessary to radically alter the structure of engines as they were then known. However once again Nishina drifted off along a tangent discussing the development of a bomb, and again addressed the issue of assembling or achieving critical mass. Nishina expressed the opinion that using uranium as an explosive would be relatively easy however as he warned; the calculated amount of uranium required to reach critical mass would need to be increased as most of the uranium would not fission but would be lost in the explosion as the weapon would disassemble so rapidly. Despite claims to the contrary that Nishina was a wandering sailor in a sea of army design, it is obvious through his several departures from the briefing as planned, that he was deeply enthusiastic about Japan's potential to create an atomic weapon.

Nuclear weapons generally assemble supercritical masses by uniting or compressing subcritical masses of fissile materials, and by reflecting otherwise escaping neutrons back into those masses, thereby creating additional fissions. The more complete this uniting or the stronger this compression, the better the rate of neutron reflection; the more primary fissions that occur creating secondary fissions; the greater the efficiency and explosive capacity of the bomb.

To achieve this, because the chain reaction could not be contained for long; only a portion of the uranium present would actually undergo fission, the remainder would be lost. (The yield of the Little Boy design dropped over Hiroshima was actually lower than the hypothetical energy density of its uranium-235. Less than a kilogram of uranium-235 underwent fission in the actual explosion over Hiroshima on the morning of 6 August 1945, releasing only 15 kilotons of energy). It is here, in this section of these papers where the great controversy amongst historians concerning the length of time required to detonate the weapon as written in the Kuroda Papers arises. According to what is written within these papers and loosely translated Nishina is most often quoted as saying:

> "In order to achieve the highest temperatures and largest possible explosion, the bomb needs hold together for 1/30 to 1/20 second and to achieve this requires a large and heavy tamper or reflector. The weight of this weapon would be enormous, it is therefore considered impractical and 'as a bomb' not suitable for use [with the current state of military technologies, meaning that, the weapon could not be lifted by an aircraft]."[81, 82]

However, what Nishina had actually said was categorically different.

What Nishina said was that "the temperature required for a bomb reaction would have to be achieved in $1/20^{th}$ to $1/30^{th}$ of a second."[83, 84] Nishina then indicated that this would result in the need for a massive (re: heavy) bomb. This lead Nishina into his eighth topic, initiating the fission of U235.[85]

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[81] Low, Morris. *Science and the Building of a New Japan*. Johns Hopkins University. Palgrave Macmillan. 2005
[82] Telephone conversation/interview between P. Wayne Ragan and Dwight R. Rider. 5 April 2017. 1 hour, 47 minutes.
[83] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.
[84] Telephone conversation/interview between P. Wayne Ragan and Dwight R. Rider. 5 April 2017. 1 hour, 47 minutes.
[85] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

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Nishina lectured that radium, beryllium or polonium could be used as an initiator. It is more likely that Nishina was discussing a radium-beryllium or -polonium trigger as these were, at that time, the two best known neutron sources Nishina explained that when beryllium is irradiated with neutrons, it transmutes to polonium. As Nishina explained, polonium has a half-life of 158 days and would be idea for use as an initiator. Nishina's lecture was presented in 1943.

In the US the use of polonium for the neutron initiator was first proposed by Edward Condon in 1944; perhaps an indicator that, at least in 1943, Japanese planning and calculations surrounding the creation of an atomic weapon were either slightly ahead, or at worst, running parallel to the work being conducted within the US Manhattan Project. The US initiator itself was designed by James L. Tuck.[86] Its development and testing were carried out at Los Alamos National Laboratory in the "Gadget" division's initiator group led by Charles Critchfield, who received the historical credit for the idea.[87]

It should be noted that polonium is an extremely dangerous element that is usually created in a reactor however, can be created through a lengthy and prolonged chemical process.[88] "Beryllium is now used as the reflector material (or 'pit liner') in most contemporary American nuclear weapons and thermonuclear 'primaries.'"[89] As the meeting of 6 July 1943 was actually a continuation of the 2 July meeting Nishina then turned to his ninth issue, Japan's access to uranium.

****

In this, Nishina is thought to have simply repeated what was previously stated on 2 July; with ore being located in China and Korea but, this is not what he said. Nishina said that there are uranium deposits already known to exist in China, Korea and in Daitoa Kyoeikan (the Greater East Asia Co-Prosperity Sphere). That area included all of French Indochina, the Netherland East Indies, Burma, Borneo, the Philippine Islands, etc. As Nagaoka had earlier suggested, and Iimori had subsequently investigated and proved, and Nishina working with Iimori knew; there were substantial deposits of uranium ore in areas outside Japan Proper. The Japanese had been shipping ores and tailings from mines in Southeast Asia to Japan for refining since 1942. With that said, Nishina turned toward his tenth and final issue, devices for the generation on neutrons; his first, and only appeal at this meeting for army support in completing the reconstruction of Rikken's 40-cyclotron.[90]

Hat-in-hand, Nishina, explained to General Nobuuji and the greater audience present that Rikken's 250-ton, 1.5-meter particle accelerator was ready for operations except for certain pieces, which were then unavailable as those parts were being used in the production of munitions. Nishina believed that if the missing parts of the cyclotron were returned, work on the atomic bomb by Rikken physics would take place rapidly and be more successful. As if the chemists present could comprehend his comments as some warning, Nishina informed the group that even as the war began, US scientists were already then constructing an accelerator, ten times more powerful than Rikken's faulty 1.5-meter machine, though Japanese physicist were not entirely sure the US was capable of completing the project. Herein also lies the reason that Japan's cyclotrons were destroyed by US forces on 24 November 1945.

****

Despite claims to the contrary, by early November 1945 US investigators in Japan at that time had come to understand that those same cyclotrons had been used during WWII to support Japan's wartime effort to develop an atomic bomb. While Japan's cyclotrons were incapable of producing the amounts of uranium needed to build a

[86] Ferenc Morton Szasz (1992). *British scientists and the Manhattan Project: the Los Alamos years*. Palgrave Macmillan. pp. 24
[87] "*The Manhattan Project and predecessor organizations*". *Array of Contemporary American Physicists*. American Institute of Physics. Retrieved 2013-03
[88] Dworschak, Manfred. *Where Polonium Comes From*, SPIEGEL Magazine Online. http://www.spiegel.de/international/spiegel/the-ideal-poison-where-polonium-comes-from-a-452706.html
[89] Hansen, Chuck. *U.S. Nuclear Weapons: The Secret History*. Aerofax, Incorporated.1988, p. 34.
[90] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

successful uranium-based weapon: those same machines could, and had indeed had been used, to conduct experiments which confirmed and solidified calculations related to the development of a bomb produced by Japanese scientists. It was the first anniversary of the US bombing of Tokyo.

Early on Tuesday morning, 20 November 1945, US Army officers and soldiers acting under orders written by SCAP entered Rikken, Tokyo; the Physics Department of the Imperial University at Kyoto and the offices of the Osaka Imperial University presenting the authorities of those institutions with orders for the destruction of their cyclotrons.

Using pry bars, arc welders and acetylene torches, the soldiers demolished Japan's five particle accelerators (there were actually only four cyclotrons destroyed, the fifth machine was a Crockcroft-Walton generator). Parts for an additional, yet to be assembled cyclotron at Kyoto Imperial University, escaped notice. The dismantling of the largest of the Japan's cyclotrons required a full five day's work. The walls of buildings were blasted out to allow the rapid removal of the dismantled cyclotrons into nearby courtyards and lawns. Trucks, tractors, and bulldozers pulling cables were used to haul the heaviest parts of the machines through the shattered walls. Once at a safe distance from all nearby buildings, dynamite was used to further warp, or crack the magnets, and largest parts of the instruments. The events of that Tuesday morning, 20 November 1945, confiscating the cyclotrons, were designed to shock Japan's scientific and intellectual community to the core. They succeeded.

By late-October, early-November 1945, US investigators surveying Japan's wartime atomic energy and weapons research program realized that the information they had been given so far, was false. Worse yet, many of Japan's scientists previously involved in the country's wartime program, were continuing their efforts to develop a bomb, after the surrender.[91]

On 24 November 1945 Rikken's two cyclotrons were dumped into Tokyo Bay beyond the 100-fathom mark.[92] The two machines at Osaka (one being the Crockcroft-Walton generator) were dropped into Osaka Bay.[93] The cyclotron at Kyoto found its final resting place at the bottom of Lake Biwa.[94] Japan had been warned, knock it off and cooperate. But in 1943, all of that lay in the future.

The next meeting documented in the Kuroda Papers would not take place until early in 1944.

2 February 1944 – Meeting Notes:
Uranium Project Research Meeting at the Nishina Research Laboratory.[95]
In attendance: Doctor Nishina, Major General Nobuuji, Lecturer Ishida.
Research Progress (Statement of Dr. Nishina)

At this meeting, Dr. Nishina was again at center stage and most probably the sole speaker. He addressed four subjects:

1. The Production of Uranium Hexafluoride.
2. The Separation of Uranium Hexafluoride.
3. The Status of Rikken's Particle Accelerator for use in Neutron Production.
4. The Status of Experimental Research.

Research into the Production of Uranium Hexafluoride.

Beginning with the production of uranium hexafluoride, Nishina explained that experiments were still underway and that Rikken had suffered some setbacks to their research effort. Rikken's scientists had been examining the various

[91] C.L.O. No,261. Information on Uranium. Central Liaison Office. Tokyo The Office of the Supreme Commander for the Allied Powers. 13 October 1945. National Archives and Records Administration College Park, Maryland Records: Record Group 331. Stack Area 290. Row 24. Compartment 02. Shelf 1. Entry 224. Box 6.
[92] LANDSBERG, MORRIE. *Japanese Cyclotrons Are Being Destroyed. M'ARTHUR OPENS JAP IMPORTS; WAR LEADER SURRENDERS*. Oakland Tribune, Saturday, 24 November. 1945. Page 2, section D.
[93] Hirao, Y. *The History of Cyclotrons in Japan* (Banquet Speech). Proceedings of the Eleventh International Conference on Cyclotrons and their Applications, Japan Institute for Nuclear Study. Tokyo, Japan. http://epaper.kek.jp/c86/papers/p-01.pdf
[94] *Main part of equipment for wartime A-bomb study found at Kyoto Univ*. Breitbart. Aug 7 09:24 AM US/Eastern.
[95] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

methods of producing fluorine with the assistance of Professor Aoyama of Tohoku Imperial University and Ishikawa of Kyushu Imperial University since November 1942. This was probably a veiled reference to the Imperial Japanese Army's previous Ni-Project. According to Nishina, Rikken was now producing pure fluorine. Rikken had been however, less successful in producing uranium hexafluoride.

As Nishina explained, because fluorine was so tremendously corrosive, oxidizing with nearly everything it came into contact with, surface oxidation or contamination from the material in which it was contained, was interfering with their efforts to produce uranium hexafluoride. In an attempt to completely avoid the use of fluorine, Rikken had endeavored to obtain pure uranium by electrolysis as proposed by Fermi, however this had proven more difficult than working with fluorine. Nishina admitted that, at the moment, Rikken had yet to produce uranium hexafluoride. This does not however, mean that other organizations involved in Japan's atomic energy and research program had not had more success and were not producing uranium metal.[96] Rikken suspected at that time that the cause of the problem was the interaction between the fluorine and the copper used in the construction of their thermal diffusion column. In their earliest experiments with the thermal diffusion column at Rikken, the column could not maintain the pressure required for successful separation. It leaked. This led Nishina into his second subject, the separation of uranium hexafluoride.

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Somewhat upbeat, Nishina indicated that Rikken was about midway in the development of a process for the separation of uranium hexafluoride. Nishina indicated that the project was nearing completion. There was a light at the end of the tunnel. Processing the brass required to create an airtight system was proving difficult but by using brass wax, they had finally succeeded. Solder could not be used due to the corrosive nature of the fluorine. Nishina then turned to the operational status of Rikken's particle accelerator for use in neutron production. In the notes, Nishina never indicated that this "process" was another effort at thermal diffusion. Arakatsu Bunsaku, under contract to the Imperial Japanese Navy, at Kyoto Imperial University was working on centrifuges. [97] At Tokyo Imperial University, Sagane Ryokichi working under contract to the Imperial Japanese Army concentrated on gaseous diffusion and plutonium production reactors.[98] As for Nishina's cyclotron, this was his second pitch to the Army for assistance in completing the reconstruction of Rikken's 1.5-meter cyclotron.

At this point Nishina informed General Nobuuji that Rikken had as yet, been unable to create a superior neutron source for use in additional experiments to advance their knowledge, or create a trigger for the bomb. Rikken asked the army for assistance in having Munitions Ministry return those parts of its 1.5-meter cyclotron that had been earlier taken and diverted for the production of munitions. Unable to use the larger cyclotron, Rikken was relying on its smaller 27-inch machine, and been operating this cyclotron at the limits of its design specifications. Further use of this cyclotron at these higher rates was likely to result in the complete breakdown, if not total loss of that machine.

To return the larger cyclotron to operational status, the higher voltage tubes that were originally designed to control the device, needed to be returned to Rikken. The lower operating voltages of the smaller machine limited the number of high energy neutrons Rikken could produce. In effect, the future course of the war could depend upon the return of high voltage vacuum tubes previously taken by the Munitions Ministry. Where these vacuum tubes were physically located at that time, and what they were being used for was not discussed. A question and answer session then followed.

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In this session Nobuuji inquired about the additional 10 kilograms of uranium needed to create the conditions where fission and a chain reaction would occur. He asked why the additional 10 kilograms of uranium would not fission. In

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[96] Search by Japanese Military for Uranium in Manchuria, Apr 44 to Mar 45. General headquarters, Far East Command, Military Intelligence Section. Technical Intelligence Detachment. 1 December 1948. Record Group 331. Stack Area 290. Row 24. Compartment 2. Shelf 1. Entry 224. Box 2. The US National Archives and Records Administration, 8601 Adelphi Road, College Park, MD

[97] BASIC: Memo for Record, Subj: "Interview with Tetsugo Kitagawa,"dtd. 8 March 1946. Signed: Major Russell A. Fisher. Record Group 331. Stack Area 290. Row 24. Compartment 02. Shelf 1. Entry 224. Scientific and Technical Division. Box 2

[98] Ballaban, Michael. New Documents Found Pointing to Japan's WWII Atomic Bomb Program. 5 August 2015 http://foxtrotalpha.jalopnik.com/new-documents-found-pointing-to-japanese-atomic-bomb-pr-1722338915

answer, Nishina explained that while a slow reaction would create a chain reaction, it was best to contain the energy released (assembled) as long as possible.

If the explosion could not be contained for some amount of time, the mass of the concentrated uranium would expand, decreasing the overall concentration of uranium. This would allow the neutrons undergoing fission to escape through the surface of the mass without creating the secondary fissions required to sustain the chain reaction. However, the exact conditions had not yet been determined by Rikken scientists and further experiments would be required. It was Nishina's hope that advances in this area of science, would bring about advances to other areas of science. It would. However, not immediately for the Imperial Japanese Army or Japan. True to contracting with the government, Nishina was promising as little as possible, hoping in the end to deliver more than expected. Nobuuji then asked how Nishina would get the uranium required to complete the experiments suggested.

Nishina answered that Rikken was considering using natural uranium containing about 0.7% U235. As Rikken was not yet at the stage of testing a weapon, nor desired an explosion, this less-than pure U235 would suffice. The U235 in natural uranium would react to neutron radiation. As Nishina explained, other countries, such as France, were using 300 kilograms of uranium and getting good results. Obviously the continuing state of war in Europe was not interfering with the transfer of scientific findings from France to Japan. As for the US, Nishina explained that they were not using 300 kilograms of uranium, but were conducting various other tests and experiments. The comment was prophetic.

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Nobuuji's next question concerned the development of an engine (reactor) (the term "reactor" did not exist in 1944), as he explained, he was under the impression that a uranium-powered engine could be developed using 10 kilograms [of uranium] or even less. Nobuuji was apparently interested in bypassing the immediate problem of developing a weapon to achieve some far easier accomplishment, that of creating a reactor. Government managers worldwide are generally impatient. Nishina evaded the question concerning an engine and struck directly at the heart of Nobuuji's question, answering that if a mass of 10 kilograms would not work in a bomb then it had no use as an explosive at all. Nobuuji, a chemist, continued pressing Nishina for answers.

As a chemist Nobuuji explained, in order to make a conventional high explosive more useful on the battlefield, it was necessary to use liquid oxygen. Nobuuji did not ask if liquid oxygen was needed in an atomic explosion, but if the weapon would work without oxygen. Nishina agreed with Nobuuji's understanding of conventional explosives but explained that uranium would burn or explode without the presence of oxygen or air. With the question and answer session over, Nishina then turned to a discussion about the status of experimental research. His recorded comments were primarily directed to Rikken's research into the production of uranium hexafluoride. Nishina clarified his earlier statements made in previous meetings.

Nishina noted that when the reaction [probably concerning fluorine] reaches equilibrium in an atmosphere of carbon monoxide, the reaction continues once the carbon monoxide was removed. This suggested to Nishina that the work would have to take place inside a vacuum. Due to the corrosive nature of uranium hexafluoride Nishina planned to use molybdenum as a resistance material in the electric furnace [probable reference to the heat source of the thermal diffusion column]. The next documented meeting would not take place until nine months later however, undoubtedly, other meetings took place.

17 November 1944 – Meeting Notes:
Uranium Project Research Meeting at the Nishina Research Laboratory. [99]
In attendance: Doctor Nishina, Major General Nobuuji, Lecturer Ishida.
Research Progress Report of Dr. Nishina.

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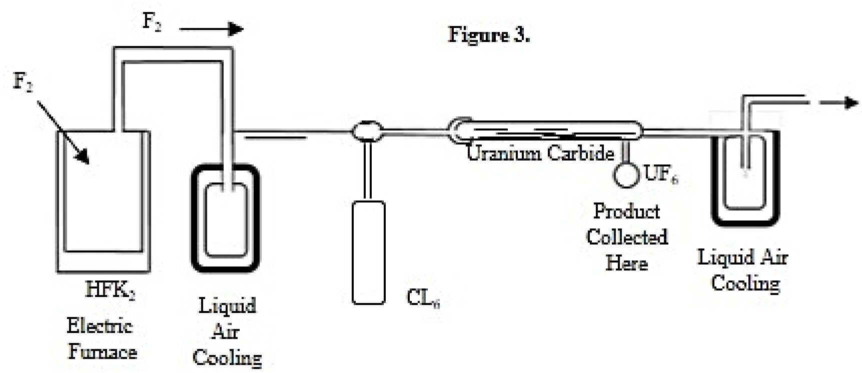
[99] Uranium Project Research Meetings at the Nishina Research Laboratory and the 2nd Tokyo Army Arsenal. Background: Concerning Uranium. Tonizo Laboratory: Shyowa 18 Nen – April 1943. Five sections, dated: 2 July 1943, 6 July 1943, 2 Feb 1944 and 17 Nov 1944. In Japanese. Obtained from the Riken Nishina Center for Accelerator-Based Science in 2006. Translation: Dwight R. Rider, Dr. Eric Hehl and Wes Injerd. April 2017.

As with the documented meeting of February 1944 Dr. Nishina was again the primary lecturer. He addressed four subjects:

1. The Production of Uranium Hexafluoride.
2. The Purification of Uranium Hexafluoride.
3. Isotopic Separation of Concentrated Uranium Hexafluoride.
4. Separation of U235 from U238.

Nishina returned to the same subject he had first briefed in February 1944; the production of uranium hexafluoride. Nishina's tone was upbeat.

According to Nishina Rikken's research had shown that carbide was the best means of manufacturing uranium hexafluoride. As Rikken had discovered, when uranium oxide and carbon were placed in a Tanman furnace and heated to a temperature of 1,600 to 1,700º Centigrade, carbon monoxide was released thus forcing any air from the system. The uranium carbide was then immediately removed from the furnace and placed in a vacuum vessel. Fluorine was then added. The uranium carbide then reacted with the fluorine to yield uranium hexafluoride. Chlorine was used as a catalyst. All of this was carried out inside a quartz pipe which allowed the progress of the reaction to be further observed by the scientists working the problem. As the fluorine was so toxic, the work was dangerous.



In carrying out their process there had already been one explosion at Rikken when contaminates associated with fluorine had gotten into the conversion system. These contaminates had increased the temperature of the reaction. The gas had expanded and this had resulted in the explosion. Apparently, injuries were minor, there were no fatalities. Nishina now turned to his second subject, the purification of uranium hexafluoride. (See Figure 3).

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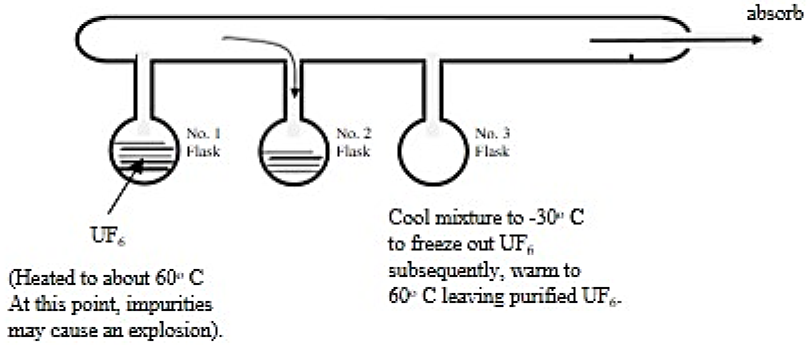
Due to the process Rikken had developed, the extracted uranium hexafluoride contained impurities; fluorine, hydrogen fluoride, and other silicon compounds, these contaminants had to be removed before pure uranium hexafluoride would be created. Rikken removed these impurities through a gaseous distillation process using pumps to evacuate the system and remove the impurities. Repeated reprocessing was required to remove all the contaminants. The uranium hexafluoride was then captured by freezing, lowering the temperature of the entire system. The system was made of glass and was of course, subject to breakage. (See Figure 4 and Figure 5). Nishina then turned the conversation to his third point, the isotopic separation of concentrated uranium hexafluoride.

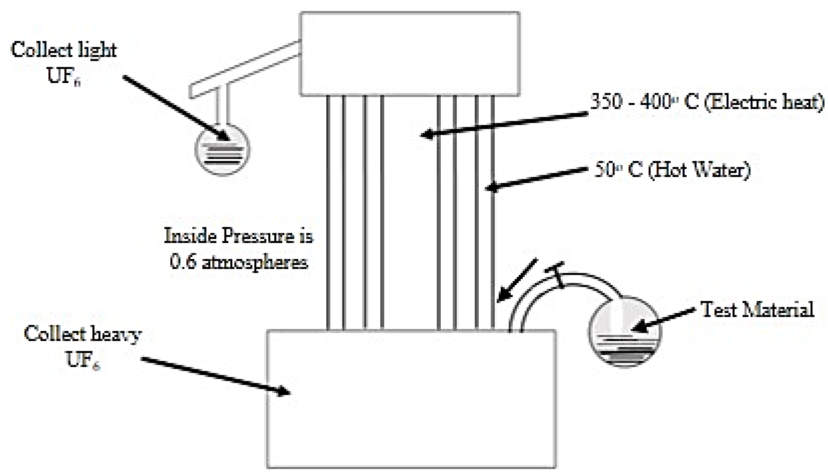
The thermal diffusion column illustrated in Figure 2 was raised to a stable temperature of 60º Centigrade before the sample uranium hexafluoride was introduced into the system. The temperature of the inner part of the piping was then heated to 350-400º Centigrade. The outer part of the column was maintained at a temperature of 50º Centigrade. With these conditions established, the thermal diffusion process began. As uranium hexafluoride is extremely corrosive, the scientists introduced on 200 to 300 grams of test material into the column. However, they were only able to recover 150 grams of test material. Again, Rikken's thermal diffusion column leaked.

Figure 4.



The whereabouts of the other 150 grams had yet to be determined. At this point, there is a break in the papers with some materials obviously missing, however the subject as discussed continues with no break in the next page available. It is likely that the missing page is a diagram, drawing or other illustration used in the briefing. As the missing section is referred to as “PWR,” it may have meant “power,” “power water reactor,” “pressurized water reactor,” etc. It may also simply be the initials of the translator.

Figure 5.



In examining their process, Rikken’s scientist suspected the cause of the loss to be the faulty materials used in the construction of their thermal diffusion column. Rikken subsequently replaced its entire thermal diffusion system with a new system built with more highly refined metals. This was Rikken’s second complete thermal diffusion column. Once put to the test however, the uranium hexafluoride had also eaten away at parts of the new column. To continue using this column, Rikken reduced the pressure to two to three millimeters Hg (mercury) per hour to offset the ongoing corrosion. The issue of corrosion was difficult to overcome, requiring the use of special materials in two of the valves, even glass and brass were subject to the corrosive effects of uranium hexafluoride. The material extracted was tested through the use of Rikken’s particle accelerator, its cyclotron.

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Using the cyclotron slow neutrons were generated and then directed at the sample U235. The intensity of the resulting fission within the produced material would then be compared to the fission of a sample taken from the original material that had been ran through Rikken's thermal diffusion column.

The difference between the intensity of the fission that had taken place between the two samples would reveal Rikken's level of success, or failure, in producing U235. In most cases, the materials sampled had been contaminated by water, which reacted with the purer uranium creating additional contaminants which added to the corrosion. Despite this, Rikken had succeeded in producing a sample of uranium hexafluoride of moderate purity. Further research had revealed the thermal diffusion column's optimum operating pressures; 0.6 atmospheres. As Nishina spoke the thermal diffusion column at Rikken was in continuous operation.

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Nishina concluded his presentation indicating that Rikken's efforts to separate U235 from U238 were about midway to a practical solution. Their primary difficulties in producing uranium hexafluoride had revolved around water contamination. These issues had been solved. Converting the purer U235 Rikken had produced in their thermal diffusion column into to UO3 (Uranium trioxide) posed no unresolved issues. Rikken was, at that moment, producing equipment that would be capable of producing U235 enriched from 0.7% to abut 10%. At that Nishina, as in earlier sessions, opened the meeting to questions. Nobuuji had a few.

General Nobuuji opened by inquiring about the state of Rikken's 1.5-meter cyclotron, had the previous issues surrounding the use of the unit's vacuum tubes been resolved? Had the electrical power voltages required to produce high energy neutrons been provided? To this Nishina replied that some vacuum tubes had indeed been provided but were not sufficiently powerful to allow the safe operation of the accelerator.

The voltages required were on the order of 14,000 to 15,000 volts, operating the machine at anything less would short out the tubes provided. Rikken had attempted to solve this problem by decreasing the vacuum required to operate the instrument in stages, but apparently this was difficult. Nobuuji then returned to a subject that had been covered on 6 July 1943, why 10 kilograms of U235 was required, and if conventional explosives could be used to initiate the required chain reaction? It was a good question.

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As a chemist, Nobuuji's question was not entirely contradictory with the training he had previous received. Bureaucrats always seek the fastest, cheapest and easiest alternative to difficult problems. To this, Nishina replied that such an idea was nonsense. If the Japanese attempted to use conventional explosives to initiate a chain reaction, the neutrons contained in the U235 would simply escape and fail to collide with other nuclei. The chain reaction required would simply collapse. While some historians have commented that Nishina's reply to Nobuuji was insulting, to two men from the Meiji era who were familiar to each other, it was simply common conversation. It is likely that the conflict surrounding the question as recorded lay within the meaning of the word "explosives." Nobuuji was a chemist, Nishina a physicist. They were both Japanese but, in a sense, spoke different languages. With that, the Kuroda Papers ended.

Summary:
Why were these and only these papers given to Paul Kuroda? What happened to the larger file from which these papers were drawn? Why was Nishina concerned that he would be tried as a war criminal? Why was Major General Ryokichi Nobuuji selected to head the effort?

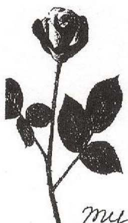
As Japan had known through the papers of L.A. Turner about the possibility of creating fissionable plutonium, had that knowledge led to the creation of reactors in the area of the Chosin Reservoir, Chongjin, Kanggye or elsewhere in China or Manchuria? Why the mention of I.N. Golovin? How deeply was Pascual Jordan involved in transferring German technologies to Japan? What role, if any, did he or Germany's Uranverein play in the Japanese effort to build an atomic bomb during the war?

Why was Lieutenant General Yasuda Takeo, at the time of the first meeting on 2 July 1943 the Inspector-General of Army Aviation and not the director of the Tokyo 2nd Army Arsenal, the arsenal he had previously headed, involved in creating the Joint Imperial Japanese Army-Navy Atomic Bomb Research Program, uniting the various Army, Navy and Manchurian Programs that had previously made up Japan's atomic weapons and energy research programs? Why was General Yasuda involved at all in turning the joint program over to Major General Nobuuji Ryokichi?

What was Yasuda's later degree of involvement in the program? Why, though it was considered a joint Army-Navy project, was the Navy never known to have been involved in the meetings, but worked closely with Suzuki Tatsusaburo through Captain Kitagawa Tetsuzo (sometimes referred to as Tetsugo)? It is obvious from postwar interviews with naval personnel that the navy was knowledgeable of the program, how deeply they were involved remains a mystery. What role did these, and other possible papers hidden and the end of the war, play in the later international publications of Japanese physicists? Apparently, few know.

APPENDIX A:
THE KURODA PAPERS

April 25, 2002



A note from...

Louise M. Kuroda

Dear Professor Yamazaki,

It is unfortunate that my letter of March 29 was returned to me unopened yesterday.

I enclose the same letter and will try again.

I do not have a fax-machine myself, but my family in Las Vegas will be glad to give me your message, if you like, at:

Kurumi Kuroda

FAX: 1-702-435-3375
(USA)

Sincerely yours,

Louise Kuroda

Las Vegas, March 2[illegible], 2002

Professor Masakatsu Yamazaki
Tokyo Institute of Technology
2-12-1 O-okayama, Meguro-ku
Tokyo 152-8552, Japan

Dear Professor Yamazaki,

On behalf of the Kuroda family I thank you for your letter of March 14. Please excuse me for writing in English, since my knowledge of the Japanese language is very limited.

The Kuroda family certainly agrees that the original, historical "Nishina Document" should be returned to Japan, where it belongs, and we shall be happy to donate it.

However, it is not up to us to decide at which institution in Japan it should be preserved. In this regard I have to explain that about 3 months ago, in January 2002, I had a 2-day visit here in Las Vegas, from Professor Koh Sakamoto, retired (emeritus) from Kanazawa University, accompanied by Mr. Yukihiko Takahashi, president of the "Tokyo Creative, Inc.", a photographer and artist, who is in the process of making a filmed documentary of my husband's life. They knew about the Nishina Document and were particularly interested in seeing the original papers, which I showed to them. I also told them that the Kuroda family would donate them. They also discussed probable institutions in Japan, among which a Japan National Museum (?).

Today I am also sending a letter to Dr. Sakamoto, including a copy of your letter in Japanese, explaining your desire to preserve the Nishina Document at the Riken Archives.

I have known Dr. Sakamoto and his family ever since he was one of my husband's post-doctoral assistants at the University of Arkansas more than 30 years ago.

Dr. Sakamoto could be contacted at the Faculty of Science, Kanazawa University, Kakuma-machi, Kanazawa 920-1192. His home phone and fax number is 81-76-224-8253.

I am sure that an agreement can be arranged.

For the Kuroda family, Sincerely yours,

Louise M. Kuroda

Dear Mrs. Katsurai,

Thank you for your letter of June 30. I am sorry for this delay. After the publication in Japanese newspapers about the return of the "Nishina Documents" to Japan, I received numerous phone calls from reporters and the Associated Press in Tokyo, all asking the same question: "Who gave those papers to my husband?" I answered truthfully: "I do not know".

I met my future husband in 1951, soon after my arrival in the U.S. from Europe. I had a 2-year contract to serve as a research assistant to professor I. M. Kolthoff at the University of Minnesota School of Chemistry in Minneapolis. Dr. Kuroda had held this position before me, and was asked to give me instructions as to how to start the job. The next year he moved to Arkansas where he was offered a position as assistant professor at the University of Arkansas in Fayetteville. We were married there in September 1953 and lived there for 34 years until Paul's retirement at the age of 70. and the move to Las Vegas, where he continued his research.

I was not aware of the precious documents until several years later (after our wedding) when we moved to another location. That is when he showed me the locked briefcase and asked me to be careful not to lose it. That is also when I learned that the documents should have been destroyed on order of the Japanese Army before the surrender on Sept. 2, 1945, but had been entrusted for safekeeping to my husband by "a friend", not knowing of course, that they eventually would end up in the U.S. It certainly did not occur to me to asked my husband the name of his "friend", since I did not know any of his friends in Japan yet. The subject of "who" never came up again.

When the news of the return of the "Nishina Documents" was published in several U.S. newspapers too, most of them stated that my husband had been secretly keeping the documents for more than 50 years. That may have been true in the beginning, but later in life P.K.K. lectured about the documents to his students and also publicly at international meetings such as the one commemorating the 50th anniversary of the Discovery of Nuclear Fission in Washington D.C. in 1989, preseded over by professor Glenn Seaborg. I was there.

My husband wondered sometimes if "his" documents were the only authentic ones in the world, or could there be others somewhere? As far as I know, nobody approached my husband during his lifetime to ask for their return, although there were plenty of opportunities, since he (and I) attended numerous scientific meetings in Japan during the last 20 years.

When my husband became seriously ill with lung cancer in 2001, it was not a time to ~~discuss~~ discuss the documents, but I knew what he would have wanted me to do and I was glad I had help in finding the right place for them to be kept for history, namely at RIKEN. Thank you.

Respectfully yours,

Louise W. Kuroda

4191 Del Rosa Court
Las Vegas NV 89121-5011
U.S.A.

仁科研究室ニ於ケル研究打合事項　昭一八・七・六

一、出席者　仁科　信氏　吾田　三氏

二、ウラン研究ニ関スル事務的事項

仁科

七月二日航本技術部長及総務課長ニ呼バレタル所ウランノ研究ニ関シ安田航本部長ガ航技研所長時代昭一六年四月仁科氏ニ依託セル関係モアリ現在航本ノ航技研ニ於テハ発動機ニ関シ航三研ニ於テ、爆薬トシテ又第六航研ニテハ燃料トシテ研究ヲ依託致シ度キ希望モアリ、コノ方ガ綜合シ航本一本トシテ研究依託セバ効果アル（コト）トノ見地ヨリ斯様ニ要望サレアリ

其ノ際東ニ造ヨリ研究依託アル事、其ノ経緯ニ関シ話シオキタリ。尚兵政本総務部長ヨリ理研所長宛研究依託ノ書類受領シアル旨話シタル所、前記ノ主旨ニヨリ航本ヨリ兵政本ヘ連絡スル旨話アリタルモ未ダ之ガ返事ナシ

3. 二三五ノUヲ利用スル理由

U_{235}ハ中性子ノ速度小ナルモ分裂崩壊シ連鎖的ニ次々ヘ進ムモ

U_{238}ノ方ハ大ナル速度ノ中性子ノ衝突ヲ必要トス、

従而分裂崩壊セシムルニ困難ナリ

4. Uヲ爆薬トシテ利用スル際水ヲ必要トスル理由

Uノ二次的ニ放出セル中性子ハ水分子ニ衝突シ其ヲ

遅滞セシムルト共ニ速度ヲ小ナラシムルニ作用ス

5. Uヲ実用スルニ其ノ限定量10瓩デ常ニ存置セシムル

ヲ避スル理由

U10瓩以下ニ於テハ放出サレシ中性子ハ自然ニ消滅シ連鎖

反応ヲスルニ至ラズ

之ガ為メ一百Kニ増加セルUノエガ実際ノ働(外界ニ作用スル

エネルギー」)トナル

6. Uノ放出スル「エネルギー」

U_{235}ヲ一〇Kニ水三〇Kヲ加ヘタモノハ石炭一万トンノ熱量「ガソリン」
一〇〇〇トンノ熱量ニ相当ス、

7、Uノ実用効果

U_{235}ヲ発動キニ利用スルニハ「発動キノ構造ヲ全ク変更スルヲ要スル関係上近キ二実用化ハ困難ナルモ爆薬トシテノ利用ハ頗ル容易ナリト認メアリタルモ前述セル如ク其ノ薬量10瓩ヲ必要余分ニ必要トスル事ヲ以テ爆弾トスル場合運搬ノ10瓩ヲ損失スルコトニナル関係上爆弾トスルコトハ不得策トスル目下ノ実[illegible]ナリ更ニ爆弾トナルコトノ不得策ナル理由ハU_{235}ガ水ヲ分解シ爆発威力大ナル成分ヲ溜ムトナス為ニ1/100乃至1/100秒ノ時間ヲ要シ従テ之ヲ保持スル強力ナル「ボムベ」ヲ必要トス、即チ「ボムベ」ノ重量甚大ナルモノトナルヲ以テ適当ナラザルベシトノ見解ナリ

8、U_{235}ヲ分裂崩壊セシムル原動力

「ラヂウム」ナルモ「ベリリウム」「ポロニウム」ニテモ可ナリ

ベリリウムニ中性子ヲ衝突セシムレバポロニウムヲ生ズ
ポロニウムノ生存ハ約一三八日ニシテ半減期ニ三ヲ補ヘバ可ナリ

9. 資源

大東亜共栄圏ニ目下ハ少キモ朝鮮ノピッチブレンドハ見込アリ

10. 中性子発生装置

直径一、五米、マグネット二五〇トンノ装置運転中ナルモ未ダ完成セズ、所要資材ガ軍需ニ廻ル為却々進捗セズ
本装置完成セバ各種ノ重要ナル仕事ヲナシ得ルモノナリ
米国ニ於テハ目下三ノ十億ボルトノモノヲ計画シアリト云フモ完成セルヤ否ヤ不明ナリ

B-5

航研トシテハ完成セバ必要ナ個所ニ於テ利用サルベク、随意ニ於テ（既在海軍ニテハ中止アラズ）要ハ能率的ニ一日モ早ク研究ヲ完成スルニアルトノ見解ナリ

従而仁科トシテモ航研ト一体トシテ受託スルガ好都合ナリ

(信) 東道大尉ヨリ依託セルモノハ已ニ事務的手続完了アルヲ以テコノ儘トナサレ度（費用二〇〇〇円也送付済）

(仁) 航研ト相談ノ上返事ス

(信) 如何ナル方法ニテ航研ト連繋ヲ密ニシ研究状況ヲ聴取シ得ルヤ、但シ直接連絡シ得ル事項ハ仁科ニ連絡ス、東研ヨリハ研究依託ヲ遠慮ス

研究者ノ問題ハ如何

(仁) 航空ヨリ将校二名通勤シアリ

(信) 爆薬ヲ動力ニ利用スル為現在ニ於ケル研究ニ差アリヤ

(仁) 差無シ 但シ後ニ至リ利用研究ニ進マバ差ヲ生ズ

仁科研究室ニ於ケルU研究状況（昭和十九年二月二日）

一、出席者

仁科博士

信久少將

石田技師

二、研究進捗状況（仁科博士説明）

1. ウランノ弗化物製造

目下研究中ナリ 本邦ニ於イテハ未ダ之ガ研究ナキ為困難シアル現況ニシテ弗素ノ製造ニ関シテハ一昨年十一月頃ヨリ研究ヲ始メ東北帝大青山教授石川教授其ノ他ノ援助ヲ受ケ漸ク昨年八月頃ヨリ純粋ノ弗素ヲ製造シ得タルモ更ニ進ンデウランニ該弗素ヲ作用セシメウラン弗化物ノ製造ヲ行ヒタルモウラン弗化物ヲ未ダ得ルニ至ラズ 之ハウランハ酸化シ易キ為酸化ウランガ表面ニ出来弗素ト反応ヲ妨グルモノナルコトヲ知ル

ウランハ酸化ウランヨリ電解法、テルミット法ニテ得アルモ尚純粋

ノウランヲ得ルコトニ苦心シアリ
従ッテウラン弗化物ハ未ダ得ラレザル現状ナリ

2. ウラン弗化物分離器

目下製作中ニシテ概ネ完成シアリ
氣密ヲ要スル関系上真鍮鑞ヲ使用シアルモ真鍮鑞ハ加工角
シキモノアル為小孔ヲ生ジ困難シタルモ漸ク出来上リタリ 普通ノ半
田鑞ガハ弗素ニテ腐蝕サルルヲ以テ使用シ得ズ

3. 中性子発生装置

高周波発生用眞空管ノ上等ノモノハ得難ク即チ現在使用シ
セルモノハ電圧ヲ高メル場合グリッド・フィラメントガ接觸シテ壽
命短ク従ッテ高周波ハ程度低キノモニシテ実験用ニシアル関
系上軽イ水素ノ発生サノキ憾アリ 強度ノ中性子ヲ沢山発生
セシムルニハ高周波発生用眞空管ノ強力ナルモノヲ必要トスルモ入手
シ得ザル状況ニアリ

三、質議應答

（信氏）分子崩壊ガ連鎖反応的ニ行ハルル為ニハ常ニ一〇Kハウランヲ余分ニ必要トスルモノノ如クナルモコノ際一〇Kノモノ迄モ連鎖反応及バザルヤ

（仁科）起動力的ニ徐々ニ行ハザル場合ニ於イテハ一〇Kノ分迄連鎖反応スルコトナレ

計算ニ依ルトエネルギー発生セシムル示徐々ニ行ナハシムルガ良シト思ハル。即チ反応ノ為発熱ヲ伴ヒ膨張シ従ッテウランノ濃度ヲ低下スルコトトナル、濃度薄クナレバ反応ガ止マル迄ニナルノデハナイカ

然ル場合温度低クナリ再ビ濃度ヲ増ス関係上反応行ハル、

以上ハ理想的ノ場合デアッテ実際ハ未ダ不明ナリ

兎ニ角実験デヤル必要アルヲ以テウラン弗化物ノ分離実験ニノミ捕ハル、コトナク之ト同時ニ各種ノ実験ヲ進ムル意向ナリ

（信氏）其ノ実験ニ用フルウランハ如何ニスルヤ

（仁科）自然ニ存スルマヽノモノヲ使用スル考ナリ　此ノ中ニハU_{235}ヲ約〇・七%含ムミアリ　尤モ爆発現象ヲ起スコトナキモ中性子ヲ當テレバ反應ノ状況ハ正確ニ獲ルコトガ出来ル

外國デハ例ヘバ佛國デハ已ニウラン三〇〇K位モ使用シテ実験成績ヲ得テオリ米國デハソレ程便ハナイガ各種ノ実験テヤリアリ

（信氏）爆薬ニハ　エネルギー源ノウラン一〇Kモ使ハルルコトトナルモ発動機ナラバ一〇Kハ保存サレル理ト解ル

（仁科）ウラン一〇Kガ爆発シナクテハ爆薬トシテノ利用ハ出来ヌ　又

（信氏）液体酸素ヲ爆薬トシテ戦場デ使用スルニハ相当強度大ナルボンプヲ必要トスベク　ウランノ場合ニ於イテモコノ程度ノボンプヲ必要トセン

（仁科）ソノ通リト思フ　ウランハ酸素又ハ空氣ナシデ爆発スル

四　実験ノ状況

一　ウラン弗化物ノ製造研究

弗化カリト弗化水素ノ複塩ヨリ電解ニテ弗素ヲ得ルコトニ成功セルモウランニ之ヲ作用セシメUF6ヲ得ントセルモ反應セズ若干得タルモノノ如クナルモUF6ハ水ニテ容易ニ分解スルヲ以テ未ダUF6ヲ取得スルニ至ラズUF6ノ代リニウランカーバイドヲ使用シ得ルヲ以テ別ニウランカーバイドノ製造研究ヲナシアリ

2 Uノ製造研究

酸化ウランヲ原料トシ之ニMg、Al等ヲ加ヘテルミット法ニテ製造シタルモ未ダ良品ヲ得ズ表面ニ酸化物ノ残レアルガ如シ
グリーンソルト(UF4)ヲ食塩塩化カルシウムト共ニ電解スル方法ヲ研究シアルモ目下容器ニ生成スルUノ熔着シテ之ガ取出シニ困難シアリ

3 ウランカーバイドノ製造

酸化ウランニ炭素ヲ混合シタルモノヲ真空ノ下電氣炉(堀氏一五〇〇度ニテ製造スル如ク目下炉ノ組立ヲ終リ温度測定中ナリ

反應ニ平衡アルモ一酸化炭素ヲ除去セバ反應ハ一方ニ進行スルヲ以テCO除去ノ爲眞空下ニテ行フモノトス

電氣炉ノ抵抗材トシテモリブデンヲ使用シアリ

C

仁科研究室ニ於ケル U 研究状況（昭一九、二、一七）

一、出席者

仁科博士　信氏中将　石田技師

二、研究進捗状況（仁科博士説明）

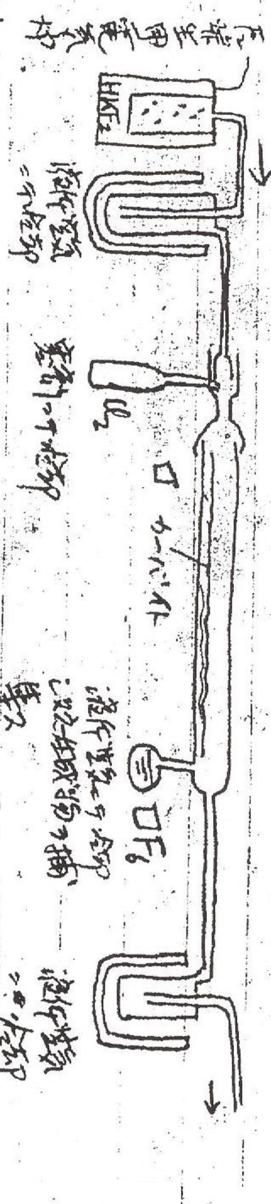
本年二月以来余リ進捗シテ居ナイガ左ノ通リデアル

1. U 弗化物ノ製造

UF_6 ヲ作ルニハカーバイト法ガ一番良イコトガ分ツタ

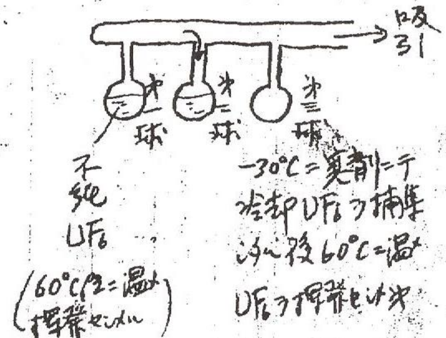
タンマン爐ニ酸化ウラント炭素ヲ入レ摂氏一六〇〇—一七〇〇度ニ加熱スルト CO ガ一気圧以上ニナツテ出テ来ルカラ空気ガ入ル余地ガナイ、出来タカーバイトハ急イデ取リ出シテ真空ノ容器ニ入レルコノ間未反応生成物ハ CO ヲ出シテ居ルカラ酸化物トナル恐レナイ 之ニ F_2 ヲ作用セシメルガ F_2 ハ有毒ナ為取扱ニ困難シタガ図様ナ石英容内デカーバイトト F_2 トヲ反応セシメテ UF_6 ヲ作ツテ反応ノ進行ハ外カラヨク見エル 塩素ヲ使フノハ触媒ノ意味デアル 生成シタ

UF6ヲ捕集密封シタモノガ一気ニ爆発シタコトガアツタガ其ノ中ニF_2、HF等ガ混ジテ居テ温度ノ上昇ト共ニ膨脹シテ爆発シタモノト認メラレル

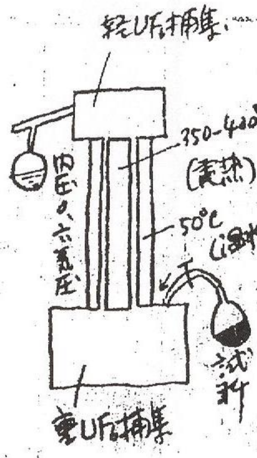


2. 弗化物ノ精製

前項ニテ出来タUF_6ニハF_2、HF、Si等ガ混在シテ居ルノデ図ノ如キ硝子装置ヲ用ヒポンプデ排気シナガラ精溜ヲ繰返シ不純物ヲガス状ニテ排出セシメ純UF_6ヲ寒剤デ冷却シテ捕集スル如クス 蒸溜ニガラスヲ使フガ硝子ヲ蝕ス故壊レ易イ



3. 軽及重六弗化物ノ分離濃縮



図ノ如キ分離塔ニ試料ヲ60°Cニ加温シテ入レタ後内套ヲ摂氏三五〇—四〇〇度ニ熱シ外套ヲ摂氏五〇度ノ温水デ冷却シテ蒸溜シタルニUF6ハ色々ノモノヲ侵蝕シ二〇〇—三〇〇瓦仕込ミタ試料ハ約一五〇瓦食ハレテ行衛不明ニナッタ、銅壁ヤ気

容用パッキングニ使用シタ銅粉（一部ニ於テ内部ニ残存シタモノ）ニ作
用シタモノト思ハレル 硝子モ蝕カサレルノデ之ヲ使ハナイ所中ノ不純物ニ
基クモノカトモ思ハレタガ最近精製出来ルヤウニナツタノデ之ヲ用ヒタガ
ヤハリ食ハレル 即チ圧力ハ一時間ニ水銀柱ニ一三粍位減ガス
ニ箇所ノバルブハ硝子モグリースヲ使ハナイデ特別ナ型式ノ金属
ヲ用ヒテヰル
分離操作ニ至ツテハ サイクロトロンデ遅イ中性子ヲ当テヽ試験シテヰル U_{235}
ノ方ハ遅イ中性子デモ放射性トナルノデ其ノ強度ヲ分離濃縮前後ノ
モノニツキ比較スレバ濃縮程度ガ分ル 先般コノ試験ヲ昼夜兼行
ニテヤツタ結果不純物ガ入ツテヰタタメ少イ所ヲ氷ニ入レルト非常ニ[illegible]
スルガ容器トシテ用ヒタ硝子ヲ蝕シテ不純物ヲ生ズルモノト思ツテヰ
ル 今コノ純度ヲ測定中デアル
尚蒸気ノ圧力ハ〇・六気圧ガ良イト云フコトガ分ツタノデ之ヲ用ヒテ現在ヤ
ツテヰル所ナリ

UF_6ハU_{235}トU_{238}ヲ分離スル為ノ中間行程ノモノデ実用スルノハ濃縮シテU_{235}ノ多クナッタUF_6ヲ加水分解シテUO_3トシタモノヲ用ヒル 斯様ニシテU_{235}含有率〇、七%ノモノガ三八―一〇%程ニナル

続イUF_6ヲ更ニ蒸溜濃縮スル為分離塔ヲ更ニ一基建設中デアル

三、質疑応答

問 サイクロトロンヨリ強力ナル中性子ヲ出ス為ニ真空管ノ強力ナモノノ入手困難ナリトノコトデアッタガ其ノ後ハドウカ

答 真空管ハ其ノ後大キナモノヲ入手シタガ未ダ充分デナイ 電圧一四〇〇〇―一五〇〇〇ボルトヲ必要トスルガ之デハ壊レルノデ今デハ更ニ強力ナスル為技デ真空ニシテヤッテヰル

問 Uハ甚ダ少ナイモノトシテ一〇Kヲ必要トスルモ爆薬トスル場合ニハ其ノ一〇Kニ依テ一般ノ爆薬ヲ用ヒテハ駄目カ

答 夫リ駄目ダ 少量ノUデハ連鎖反応ガ止ンデシマフ 即チ中性子ハU_{235}ニ当ラナケレバ他ヘ逃ゲテシマフノデアル

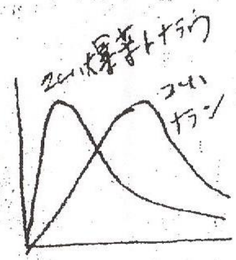
一〇kgアッテ始メテ中性子ガ外（逃ケズ）ニ内部デ次カラ次ヘ連鎖式ニ作用シテ行クデアル

中性子ハU_{238}ニモ喰ハレル又Uニ他カラ加ヘルカラ中性子ハ水ニモ食ハレル、此等ノ割合ヲ測定スル必要ガアル

尚U_{235}ヲ一〇%含有シテオルモノガ一〇kg位必要デアルコトハ計算カラ出タノデアッテ計算ノ中ニハ常数ヲ考慮ニ入レテアル

従ッテ之ノ計算ガ正当ナルヤ否ヤヲサイクロトロンヲ使ッテ測定シテオル

測定ノ結果一〇kgデ足リルカ或ハ一〇〇kg、五〇〇kgモ要スルカモ知レヌ U_{235}含有率〇、七%ト一〇%トノ間ニハ其ノ数量ニ依リ異リハナイガ含有率ガ五〇%以上ナレバ大分異ッテ来ルカモ知レヌ 然シ五〇%ニスルコトハ相当困難デアル 一〇〇%ニスルコトハ不可能ダラウ



Uガ爆薬トナルカドウカニ多ク速度ヲ調ベナケレバ分ラナイ

速度ガ速イト実際ハ出来ヌカラ計算デヤル外仕方ガナイ

ウラン(U)ニ就テ

東二造研究所
昭十八年四月

実用化ニ對スル總合意見

U―235ニ関スル研究ハ必要ナルヲ以テ次ノ方針ニ依リ研究ヲ促進スルノ要アルモノト認ム

一、研究ノ実施ハ委員編成トシ軍カ主宰シ官民ノ學者ヲ以テ之ニ當ツ

二、目下ノ所當所ヲ主務トシ研究ノ進展ニ從ヒ航空関係其ノ他協力ス

1. 昭和十五年十一月獨誌 Nitrocellulose 上ニ"アメリカノ超爆薬U―235"ト題シ A. Stettbacher ノ通信ノ記載(別紙参照)アリ。ソノ中ニ世界中ノ"ウラン"研究者ノ名前ヲ挙ゲアル中ニ日本萩原氏ノ記載アリ

2. 昭16.5. 京大理学部講師タル前記萩原篤太郎ガ海軍ニ於テ"超爆発性原子U.235ニ就テ"ト題スル講演ヲナシタリ。ソノ記事ハ当時迄ノ概況並ニ同氏ノ意見ヲ識ルニ足ルヲ以テ以下其ノ要旨ヲ述ブ

イ. 米国ハ昭14.(1939年)以来該研究ヲ極秘ニ実施シ現在迄大ニ発展進歩セリ

但シ該問題ノ基礎ノ発見者ハ米国ニアラズシテ実ニ独国ナリ。(同年一月独人 Hahn 及 Strassmann)

ロ. 其ノ発見事項トハ「ウラン」ニユルイ速カノ中性子即チ Slowneutron ヲ衝テタルトコノ中性子ハ「ウラン」ノ原子核ニ吸収サレテ之ト同時ニ所謂"重原子核ノ分裂"ヲ起シコノ際莫大ナル「エネルギー」ノ放出ヲ伴フノ事実ナリ

(尚スベテ原子核ハ「プロトン」即チ水素原子核トコノ中性子トノニカラ構成セラルルコトヲ一般ニ認メラルルニ至レリ)

ハ、是等ノ研究ニ最モ強力ナル中性子源或ハ放射線源トシテ活躍シアルモノガ Cyclotron ナル装置ナリ

ニ、U_{235} トハ何カ

ウラン（U）ハ現在同位元素三種知ラレアリテ自然界ニ在ル普通ウラン中ニ於ケル割合ハ昭14米国ニ於テ測定ノ結果ニヨレバ次ノ如シ

同位元素	$_{92}U_{238}$	$_{92}U_{235}$	$_{92}U_{234}$
普通ウラン中ノ存在割合 %	99.274	0.72	0.006

（92ハ原子番号即チ核電荷数
235ハ原子量）

又コノ0.720%存在ノU_{235}ガ分裂能旺盛ナルコトモ米国ニ於テ研究サレタリ

ホ、ウランハ夫々ソノママニテモ絶ヘズ自然ニ崩壊シツツアルモノニシテ例ヘバ$_{92}U_{238}$ハソノ半減期4.5×10^{9}年ナルガ如シ

但シ人工的ニUニ中性子ヲアツルト比較的短時間ニ原子核ノ分裂ヲ起スコトトナル

ヘ、爆裂機構ノ概略

Uガ中性子ニアタリ分裂シテ他ノ元素ニナル際追剰ノ中性子ガ生ジコノ二次中性子ガ更ニ他ノUニ作用シ逐次連鎖反応的ニ全Uノ分裂ヲ起ス可能性アリ

是即チ強爆薬トシテノ性状ナリ

ト、但シ前記ノ如クコノ爆裂的連鎖分裂ハU_{235}ノミガ旺盛ナリ

故ニ爆裂ノ連鎖反応ノ応用ノ為ニハ何レカ適当ナル実用的方法ヲ考案シテ普通ウランヨリコノU_{235}ヲ大規模ニ分離製造スルコトガ目下ノ極メテ重要ナル課題ナリ

チ、若シ万一コノU_{235}ガ相当量製造スルコトガ出来、之ト適当ナ重水素トノ混合物或ハ~~相当~~適当ノ大サノ容積ガ実現サルル暁ニハU_{235}ハ有用ナル起爆裂性物質トシテ其ノ可能性ヲ多分ニ有スルモノト期待セラル

リ、又ウランヲ炭素ノ窒化物ニ混合シテ之ヲ中性子照射ニ依リ爆発セシムル研究モ昭14、米国、独国ニ於テ実施セラレタルモソノ後ノ経過不明ナリ　萩原氏ノ事項以上通リ

3. 理研仁科ノ所デハ若年ノ矢崎為一氏ハ仁科ト共ニU原子核崩壊ニ関スル研究ヲナシアリテ已ニ米国留学中ヨリモ注目サル。矢崎ハ在米間ニ於テモ同ノ研究ヲナシアリ。帰朝後アメリカニ次グ大ナルCyclotronヲ完成セルハ一般ニ知ラレアル処ナリ

4. 矢崎ハ理研ニ於テ目下U_{235}ノ分解ニ就キ研究中ニシテ相当ノ進展ヲナシアルモノノ如シ。
(内氏ノ部会ニテヨリ意見ヲ聞クヲ得ナリキ)

5. U.S. Naval Institute (1940年号)ノ報告ニ依レバ
ト仁科ガU_{238}ヨリU_{235}ニ変ズルコトニ成功セリト報ジアリテ、コノ能ノコトニ関ハ確ヲ得ザル如シ

6. 目下仁科ノ所ニテ木越氏ガU_{235}トU_{238}トノ混合物ヨリ熱拡散法ニ依リ分離スル方法ニ就テ研究中ナリ。

7. 東大木村(健)教授ノ話ニヨレバU_{235}ノ分解ヲ縦続的ニ起サシムル方法アリテコノ全エネルギーヲ発行機ノ燃料的ニ利用シ得バ恐ルベキコトナリ。
而シテUノ分解セシムル中性子源ハラヂウムトベリリウム」ヨリモ得ラルルモノナリ。

世界ニ於ルウランノ鉱石ノ産額ハ年3〜4万トニシテソノ大部分ハ北米合衆国ナリ。

Uノ主ナル鉱石

内ウラン鉱(瀝青ウラン) pitchblend	UO_3	75〜85%
ウラン灰鉱	〃	43〜69
灰ウラン鉱	〃	4?〜62

因ニ本邦ニ於ケルウラン鉱産地ハ次ノ如ノナルモ未ダ採取実用スルニ至ラズ。
凡テアメリカ」ヨリ輸入ニ仰ゲルモノナリ。
(本邦ニ於ケル埋蔵量不明)

○福島県伊達郡飯坂村
~~1石ノ雲母~~
福岡県田川郡安英木村
1石ノ雲母 U_3O_8 100gr.
(U_3O_8 約90%)

福島県石川町附近 サマルスキー石(UO_2 約20%)

岐阜県恵那郡苗木地方
フェルグソン石 UO_3 1〜2%)
恵那石 UO_2 3〜11%

○朝鮮黄海道海州 フェルグソン石 UO_2 8.5%
満州国錦城 ユークセン石 UO_2 3.8%
ハ有望ナル産地トス。

東亜共栄圏内ニ目下ノ所資源発見サレアラス．

Dr. Alfred. ~~Stet~~Stettbacher カ「アメリカ」ノ超爆薬 U_{235} ニ就キ Nitrocellulose 1940 Nr. 11 ニ記載セル所ヲ摘録セバ下記ノ如シ．

第一次欧州大戦ノ際「ステッキ」頭部ノ大サニテ地面ニ大キナ孔ヲ掘リ得タルトイフ不思議爆薬ガ「アメリカ」ニ発見サレタリトイフ夢物語的ナル報道アリタルカ最近「アメリカ」新聞ハ驚クベキ性能ヲ有スル新爆薬ノコトヲ報シアリ．即チ「ウラン」元素ヨリ原子量235ノ「ウラン」同位元素ヲ Minneapolis 大学物理教室ニテ分離ニ成功セリトノコトニシテ該 U_{235} ガ当ノ爆薬ナリ．

発見者 Dr. Nier ノ説明ニ依レバコノ「ウラン」454 gr ノ有スル「エネルギー」ハ 1200 万立ノ「ベンヂン」ノソレト同一ナリ．「ウラン」ハ 99.27 % ノ U_{238} 0.72 % ノ U_{235} ヨリナルモノニシテ当時其ノ製造ハ極メテ僅少ナリシ為料金的或ハ軍事的價値ハ無カリシモノナリ．然シ多量ニ製造出来ルコトトモナレバ（不可能ナルニアラズ）兵器工学ヤ火薬学方面ニ一大変革ヲ来スベシ．

U ノ人工崩壊ニヨル「エネルギー」ニ就テハ昔年来火薬学専門家ノ知ル処ニシテ次ノ如ク沢山ノ研究者ニヨリ問題トシテ取上ゲラレアリ．

Alfred. O. Nier. phys. Review 57 54[illegible] (1940)
（分離セル「ウラン」同位元素ノ核分裂ニ就テ）

萩原氏（京大） C. 1940 II. 10
（中性子照射ニ依ルウラン核爆発ニ於ケル中性子ノ分離ニ就テ）

Ph. Abelson phys. Review 56 1–9 (1939)
（中性子照射ニテ分離セル「ウラン」分裂生成物ニ就テ）

J. Thibaud, A. Moussa, I. N. Golowin C. 1940 I. 2126, 3888

L. A. Thurner phys. Rev. 57 157 (1940)

文献ヲ引用スルニ「ウラン」元素ハ「ラジウム」ヲ放射シツツ自然崩壊シテ鉛ト「ヘリウム」トニ

変化シ其ノ際「エネルギー」ヲ放散シ1/1000ノ質量ヲ減ズ。Einsteinノ説ニ依レバ「エネルギー」ノ単位一「エルグ」ハ「ウラン」1.9×10^{-20} grニ相当シ1grノ「ウラン」ガ完全崩壊ニ於テ9×10^{20}「エルグ」即チ215億kCalノ「エネルギー」ヲ出ス。「ゼラチン」ダイナマイト」ノ3500 kg. 又ハ「ベンヂン」ノ3400,000立ニ当ル。但シ実際ハ照射分裂操作ニヨルモ僅少ノモノガ完全崩壊シテ「エネルギー」ヲ放射シ大部ハ低原子量ノモノトナルニ過ギズ。従テEinsteinノ云フガ如キ数量ノ「エネルギー」ヲ出スニ至ラズシテ前述ノ如ク1grノU_{235}ハ $\frac{1200万}{454}$ = 27,000立ノ「ベンヂン」ニ相当スル「エネルギー」ヲ出ス程度ナリ。ソレデモ尚莫大ナル「エネルギー」ヲ出スモノト云フヲ得ベシ。「ウラン」ノ鉛ト「ヘリウム」トノ自然崩壊ハソノ半減期約4.5×10^{9}年ナルガ為之ニ伴フ熱量ハ顕著ナラズ。今日迄之ヲ瞬間的ニ崩壊シ得ル方法ナカリシガ為爆発セシムルガ如キ莫大ナル「エネルギー」ヲ放出シ得ザリシナリ

然ル所1938年人工的ニCyclotronヲ用ヒ生成セル中性子ノ照射ニ依リテ「ウラン」ヲ急激ニ崩壊セシメ得ルニ至ル由。

Flugge (Nat. wissenschaften 27 402—410 (1939)) 計算ニヨレバ瀝青ウラン鉱一立方米(重量4.2ton)ガ中性子ニテ崩壊スルトセバ1/100秒ニテ27×10^{15}米・瓩ニ相当スル「エネルギー」ヲ発生スルコトナリGolddaneノ山崩レノ300倍ノ仕事ニ当ル。コレラノ事柄ヲ確認センガ為「サハラ」ノ某地ニテ実験セントノ企テアリタリト云フ。「ウラン」同位元素U_{235}ヲ水ニ浸漬スルコトニ依リ原子分裂ノ生ネルギー」ヲ生スルモノニシテ之以外ニ支底ヲ起ス方法ナキガ如シ。水ガ斯ノ如キ状況ニテ「エネルギー」発生源トナルハ全ク了解シエズ。

此ノ原子崩壊ノ現象ハ軍事的ニ期待セラレアルモノニシテ希望ノ崩壊時期ニ該元素ノ「エネルギー」ヲ[illegible]ニ消ス「タンク」ヤ船ノ石炭庫ヲ一瞬ニシテ熔シ壊スニ利用スルニ成功スルノ日ノ到来スルヲ思ハシム。

以上.

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About the Author:

Originally from Douglasville, Georgia, Dwight R. Rider is a Senior Intelligence Associate with Intelligence Decision Partners, and Shadowblade Technologies of Virginia. He possesses more than 30 years military-civilian experience as a targeting intelligence specialist, electronic warfare officer, electric power, weapons of mass destruction, and underground facilities analyst specializing primarily in East and Southeast Asia. He holds a Master Degree in Strategic Intelligence awarded by the Defense Intelligence Agency, and is a Magna Cum Laude graduate of the University of Nebraska. He is the author of Hog Wild-1945: The True Story of How the Soviets Stole and Reverse-Engineered the American B-29 Bomber and Tsetusuo Wakabayashi, Revealed which discuss Japan's wartime atomic energy and weapons programs. He currently resides in South Carolina. He can be reached at: dwrider24@gmail.com