

DR. FRITZ J. HANSGIRG AND HEAVY WATER PRODUCTION: THE UNTOLD STORY

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Hansgirk deserves the credit for being first to file a patent that exploits the [catalytic exchange] reaction. He was clearly a knowledgeable, inventive and energetic man, and could have led a team to design a heavy water plant if given the opportunity (1).

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Abstract

During World War II, both the Germans and the Americans produced heavy water in large quantities by combining two well-known chemical processes: catalytic exchange and electrolysis. Several years earlier, before scientists understood the value of heavy water as a moderator in a nuclear reactor, an Austrian-born electrochemist by the name of Dr. Fritz J. Hansgirk had patented the catalytic exchange and electrolysis heavy water process in a number of countries throughout the world, including the U.S. Patent Office in Washington, DC, and the patent offices of Nazi Germany and Imperial Japan. And yet, despite his international fame as a wartime expert in magnesium production, Hansgirk's accomplishments vis-à-vis heavy water production have yet to be fully recognized by scientists or historians.

Introduction

Dr. Fritz J. Hansgirk of Yonkers, New York, the Austrian-born chemical engineer who invented the

internationally-known "Hansgirk method" of metallic magnesium production, an important strategic material during WWII (2), died at Columbia-Presbyterian Medical Center's Harkness Pavilion in upper Manhattan on Saturday evening, July 23, 1949. He was 58. He also held patents in countries throughout the world for a heavy water production process known as catalytic exchange and electrolysis. While Hansgirk's obituary in the *New York Times* (below) emphasized his brilliant career as an electrochemist and his world-renowned magnesium process, it failed to mention his heavy water patents (3):

At the age of 28, in a Viennese laboratory, Dr. Hansgirk devised a new and quicker process for extracting pure magnesium from the ore. After several years of unsuccessful efforts to reap financial rewards for his improvement, he left Austria in 1934 and tried his fortune in various other countries.

During his six-year stay in Japan before the war, Hansgirk supervised the construction of a magnesium plant for the Japanese at the industrial port city of Konan in northern Korea; and later, he served as technical advisor to the South Manchurian Railway Company. The Japanese magnesium plant at Konan was built for Nippon Magnesium Metals Company, Ltd., an industrial firm formed by American Magnesium Metals Corp. of Pittsburgh, Pa., for which Hansgirk served as its vice-president.

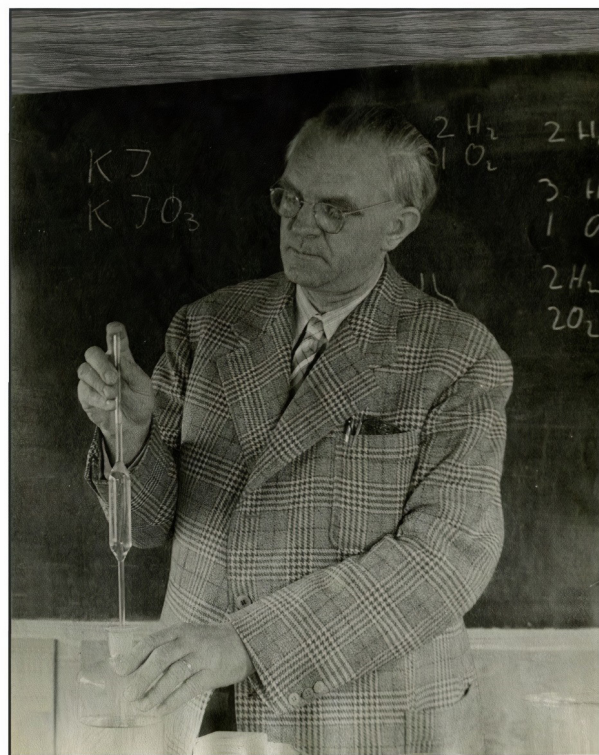


Figure 1. Fritz Hansgirg at Black Mountain College. Photo courtesy of Western Regional Archives, Department of Natural & Cultural Resources, Asheville, NC.

As noted in his obituary, Hansgirg arrived in California at a time when aircraft manufacturers throughout the world were “intensely interested” in magnesium due to the high strength-to-weight ratio of magnesium alloys. There, Hansgirg secured the attention of Henry J. Kaiser, an internationally-known industrialist, who engaged Hansgirg’s talents and inventions for the new Permanente Corporation plant located near San José, California. Kaiser had secured a \$3 million loan to start the enterprise, to which another \$20 million was later added. Before his arrival in California, prior to the U.S. entry into World War II, Hansgirg had already erected a pilot magnesium plant in Austria and a large, full-scale magnesium plant for the Japanese in northern Korea (3).

Then on December 17, 1941, ten days after the Japanese attack on Pearl Harbor, and nine months after Hansgirg had begun working for Kaiser in California, he was arrested by FBI agents and deputy sheriffs as a “dangerous enemy alien.” Despite being incarcerated in the San José jail, Hansgirg continued to advise Kaiser on the magnesium plant in California under construction. Two months after his arrest, Hansgirg was reportedly directing chemical operations at Permanente by tele-

phone from jail, using the Sheriff’s private telephone. The Sheriff declared his prisoner a “charming man” (3).

According to Natasha Goldowski (Renner), an expert metallurgist and former Manhattan Project scientist, Hansgirg had developed a new process for the production of heavy water “in his spare time”—this was several years before President Roosevelt signed an order creating a secret project to develop a nuclear weapon, later dubbed the “Manhattan Project.” In addition to his U.S. heavy water patents, Hansgirg also obtained patents for that same invention in Austria, Nazi Germany, and Imperial Japan.

Before WWII began, and shortly afterward, Hansgirg’s patents came to the attention of a Japanese industrialist in what is now North Korea and to top German and American experts on heavy water production and. And yet, Hansgirg’s important achievements vis-à-vis heavy water production seem to have slipped through the cracks of history, barely mentioned, if at all, in books on heavy water production and the wartime race to develop an atomic bomb. After providing some background on deuterium and heavy water and filling in more detail on Hansgirg’s life, this paper will focus on his patents for heavy water production and on wartime programs for large-scale production of heavy water.

The Discovery of Deuterium and Heavy Water

The discovery of deuterium (heavy hydrogen) in 1931 was hailed by scientists the world over as “one of the most significant discoveries of modern science” (4). Since its discovery, it was known that hydrogen occurs naturally in the form of two stable isotopes; protium (H) and deuterium (D), both of which are present in combination with oxygen (O) in natural water. “Heavy water,” a combination of deuterium oxide (D_2O) and HDO, however, is extremely rare in nature; only a few drops are present in a liter of water (5). Likewise, the ratio of deuterium to hydrogen (D/H) in water is only 155.76 ppm (6).

Dr. Harold C. Urey, a Columbia University professor of chemistry, was the 1934 recipient of the Nobel Prize in Chemistry for his discovery of deuterium—an isotope of hydrogen but with about twice the atomic weight (7). The newly-discovered substance was coined “deuterium,” from the Greek word meaning “second.”

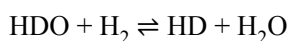
Earlier that same year, Urey was also awarded the Willard Gibbs Medal for his discovery of “heavy wa-

ter.” Awarded annually by the Chicago Section of the American Chemical Society, the Willard Gibbs Medal is considered one of the highest scientific honors. At the time of the announcement, the *New York Times* suggested two potential uses for the ‘deuteron,’ the nucleus of the newly-discovered deuterium atom, originally called ‘deuton’ (8). For one, the deuteron was useful for bombarding the nucleus of atoms—even if erroneously hyped as the heaviest “atom-gun” so far discovered. Another potential use involved yeast cells, which biologists had found grow much more rapidly in ordinary water than in heavy water. Since yeast cells possess the quality of multiplying very rapidly, a quality also of cancer cells, biologists were hopeful that heavy water would prove valuable in the study of cancer (4).

Columbia University’s announcement of the Willard Gibbs Medal said Urey’s discovery promised to rank among the great achievements of science. “No scientific accomplishment of the present day,” the statement read, “has had so immediate and so widespread an influence on research programs, or has given rise to a more highly-competitive race among men of science” (4). Indeed, following Urey’s discovery, scientists from around the world began experimenting with various methods of production—the extraction of deuterium from hydrogen and heavy water from ordinary water.

During the early months of 1931, Urey conceived and worked out a method for the concentration of a possible heavy hydrogen isotope (deuterium). Later, a sample of deuterium was extracted for the first time by the fractional distillation of liquid hydrogen; the feat was accomplished in collaboration with George M. Murphy and Ferdinand G. Brickwedde at the National Bureau of Standards (NBS) in Washington, DC. Gilbert N. Lewis, Urey’s mentor at Berkeley, later isolated the first *sample* of pure heavy water by electrolysis (9). The first two patents relating to heavy water production, however, were obtained by others.

Albert Edgar Knowles of London, a chemical engineer, filed in Great Britain for a patent for heavy water production by electrolysis at the British Patent Office on February 21, 1934, and later at the U.S. Patent Office (10). Another heavy water process, the catalytic exchange between water and hydrogen—later utilized by the Germans at Norsk Hydro and in Canada by the Americans at Trail, BC—was first patented in Austria by Fritz Hansgirg, also from a 1934 filing. Catalytic exchange is represented by the following chemical equation:



Hansgirg filed for a pair of patents related to heavy water production by catalytic exchange at the U.S. Patent Office, each before the discovery of nuclear fission by the Germans in 1938. His first application, “Production of Water Enriched with Heavy Water” (11), was filed in December 1935, and his second, “Production of Heavy Water” (12) was filed about a year later. Hansgirg also filed for patents (for that same pair of inventions) in a number of other countries including Germany (13), Japan (14), and Great Britain. When Hansgirg was issued his second Japanese heavy water patent, he was employed by the Japanese in Kantō-shū Dalian (Manchuria) (15).

Before the decade would come to a close, both Nazi and American atomic scientists began engineering the catalytic exchange process as part of their countries’ respective wartime heavy water projects. Some of the latter would later join the Manhattan Project. By this time, heavy water was known to be an effective moderator in nuclear fission, and fission reactors would eventually be used to produce material for nuclear weapons. In fact, nearly pure D₂O could moderate fission even from natural uranium, in principle eliminating the need for isotopically enriched uranium. After the war, heavy water remained in demand for nuclear programs.

At first, heavy water cost about \$60,000 per pound. In 1934, following the discovery of a new process developed at Columbia University, the price fell to about \$6,000 per pound.⁴ During the war, however, the average production cost per pound fell to only \$186 (16). What had caused this precipitous drop? According to an article from the 1950s on the preparation of heavy water by catalytic exchange, “With the development of nuclear engineering, heavy water has advanced from an academic curiosity to a vital chemical product” (17). We will return to methods of production in some detail, in particular to their implementation during the war.

“In his Spare Time”

Born on June 20, 1891 in Graz, Austria’s second largest city, Fritz Hansgirg received his Ph.D. in Chemistry in 1914 from the University of Graz. And in the fall of 1928, he invented a method of using carbon to extract nearly pure magnesium from its ore at his private laboratory in Vienna. Hansgirg would later describe his patented carbothermic magnesium reduction process as “simple and immediately successful” (18). With the financial assistance of Emil Winter (1857-1941), an American industrialist and one of the original founders of Pittsburgh Steel, Hansgirg built the world’s first magnesium plant

to utilize the “Hansgirg Process” at Radenthein, Austria, the home of Winter’s \$10 million magnesite mine (19).

Since Winter felt he was too old to build a plant on his own, he offered Hansgirg’s patents to other countries. When Hansgirg felt he was no longer able to work amidst the growing Nazi menace in Europe, he was commissioned to design and erect a large magnesium plant for Japan, and his Japanese magnesium patents were disposed to a newly founded company, Nippon Magnesium Metals Company, Ltd. (20). Hansgirg also managed to help his Jewish patent attorney, Richard Reik, like so many other Jewish refugees, flee Austria and certain death at the hands of Adolf Hitler and the Nazis (21).

Dr. Hansgirg and his wife, Josephine “Maria,” left Radenthein “for good” in the fall of 1934 for the U.S., and from there, they sailed to Japan in December of that year (22). And from there, they traveled to the industrial port city of Konan, Korea, where the Japanese wanted their magnesium plant built. From 1910 until the end of WWII, all of the Korean peninsula was a colony of Japan.

At Konan, Hansgirg erected for Jun Noguchi (1873-1944), the Japanese engineer-turned-entrepreneur industrialist, large plants for the production of magnesium and other strategic materials. In 1927, Noguchi had established *Chosen Chisso Hiryo K.K.* (Korea Nitrogenous Fertilizer Co., Ltd.), the largest and most heavily capitalized enterprise in colonial Korea, with over twenty subsidiary companies in diverse industries (23).

At one point during the Japanese industrial build-up of Konan, Hansgirg traveled to the United States where he discussed the Korean project with Winter in Pittsburgh. In New York, Hansgirg and his wife were introduced to Miss Frances Grant, the vice president of the Roerich Museum in Manhattan. When Grant later received a Christmas card from the Hansgirgs in Korea, she noted on the back: “Exceedingly interesting couple met at RM [Roerich Museum]—they went on to Japan and Korea” (24). By the time the Hansgirgs arrived at Konan, Nicholas Roerich, a world-famous artist, explorer, author, scientist, philosopher, and the Museum’s founder, had already passed through Korea en route to Manchukuo (25), Japanese-controlled Manchuria.

About seven months after arriving at Konan, Hansgirg wrote a 12-page handwritten letter to Grant dated September 23, 1935 (26). (See Figure 2.) In it, he addressed the situation in Europe. Calling it “rather alarming,” Hansgirg said it made him think “every day” of the “basic idea of the foundation of the Roerich Museum, to

preserve all [of] the real science and beauty of the world.” And by way of his work at Konan, Hansgirg confessed he was “always thinking of the [Roerich] Urusvati Research Station”—located high in the Himalayan Mountains. “To retire to this place for more work is also a dream of mine,” Hansgirg wrote (27).

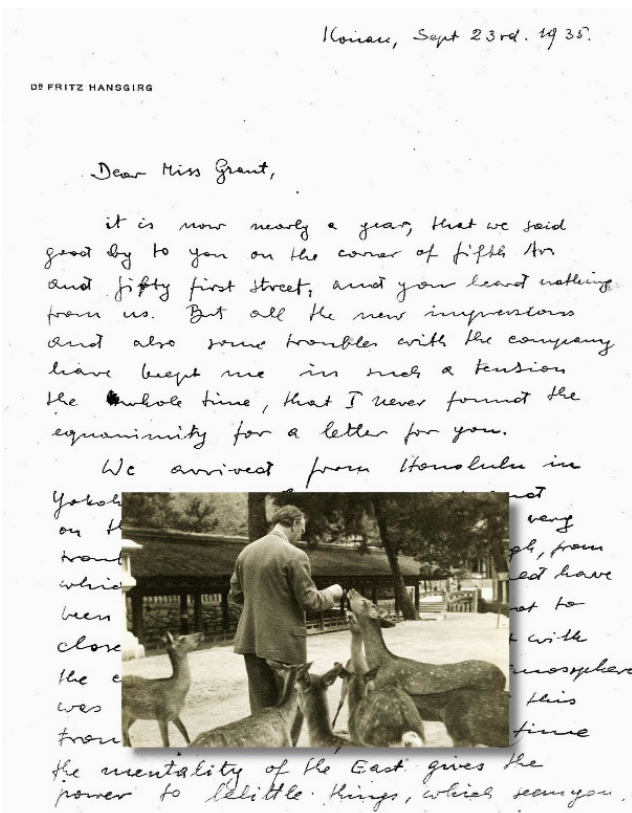


Figure 2. The first page of Hansgirg’s letter to Frances Grant and a photo of Hansgirg feeding tame deer in Japan. MC 671: Papers of Frances R. Grant, Special Collections and University Archives, Rutgers University Libraries.

Before returning to a discussion of Roerich’s ideas and philosophy, Hansgirg’s letter turned briefly to Noguchi, who he said was “very trusting” in him, closing a number of contracts based on Hansgirg’s Japanese patents. By 1938, the magnesium plant—two units of 1,000 ton yearly capacity each—was operating successfully. Hansgirg also erected for Noguchi a cracking plant, an electro-iron process, and a plant for the production of synthetic precious stones (28). He also suggested to Noguchi that a heavy-water production facility be built at Konan, which Hansgirg described in his letter as a “quite unique opportunity to produce this substance in large scale” (27).

Hansgirg was later hired as a chemical consultant to the Japanese-controlled South Manchurian Railway in Dairen, Manchukuo (now Dalian, China), where he

remained in contact with his Japanese industrial projects in Korea until 1940. However, when Japan became completely pro-Axis and hostile to foreigners, he and his wife decided to depart Japan for the U.S. in the hope of helping to develop the magnesium industry there. And in December of that year, Hansgirg was approached by the American industrialist Henry Kaiser who hired him to set up the enormous Permanente magnesium plant in California using his patented carbothermic magnesium reduction process (29).

Following the Japanese attack on Pearl Harbor and the German declaration of war on the U.S., Hansgirg, who by then was considered a German national following *Anschluss*, the German annexation of Austria in March 1938, was arrested by the FBI as a “dangerous enemy alien” (30). Following his arrest, Hansgirg was interned at various enemy alien camps in the U.S. High on a list of enemy aliens, he was transferred first to Sharp Park Detention Station near San Francisco; then onto the Fort Sam Houston Internment Camp in San Antonio, Texas; and finally, to a camp in Stringtown, Oklahoma (31). Eventually, he was paroled into the custody of Black Mountain College in North Carolina where he taught chemistry and physics until 1947 (29).

While interned at Fort Sam Houston, Hansgirg authored a memorandum entitled “The Permanente Magnesium Plant” in which he described his role in the development of magnesium, but his heavy water invention is also mentioned. In it, he wrote (20):

In 1934, I was also granted the patents for the manufacture of heavy water and heavy hydrogen [deuterium] in connection with my hydrogen process, using several catalysts for the adjustment of equilibria to concentrate the heavy hydrogen isotope. This process is at present only theoretically developed and no plant has been built yet.

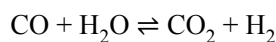
When Hansgirg died suddenly on July 23, 1949, at the age of 58, he was living in New York where he was serving as chief engineer for the American Electro Metal Corporation and the Bach Corporation, and consultant for the Standard Oil Company of New Jersey. The following year, Natasha Goldowski (Renner) presented a glowing tribute to her friend and colleague, Fritz Hansgirg, at a Conference of State Academies of Science, which included this comment (32)

In the midst of his work on the production of magnesium, he became interested in the chemistry of isotopes and in his spare time devised a method for the production of heavy water.

Catalytic Exchange and Electrolysis

Since deuterium is, chemically speaking, a form of hydrogen, it would have been natural for Hansgirg and other top chemists to have taken an interest in the newly-discovered hydrogen isotope (deuterium), and would have begun by reviewing everything known about hydrogen production, reactions, catalysts, etc. (33). During the 18th and 19th centuries, hydrogen as a gas, fuel, and chemical

reactant was already known to be useful and valuable. Hydrogen can be produced by a well-known water-gas shift reaction.



That reaction was discovered in 1780 by Italian physicist Felice Fontana (34). As more applications for hydrogen were being invented during the early 20th century (e.g., the Haber process), there was a need for more efficient methods of hydrogen production. Research on hydrogen production using a nickel catalyst and coke’s interaction with steam was conducted at BASF in 1913. Another patent by I.G. Farben in 1927 elaborated on the idea of coke reacting with steam by means of a high temperature steel tube and catalyst (35).



Figure 3. “SAN JOSE, CALIF — Permanente’s magnesium expert is Dr. Fritz J. Hansgirg (above), 52-year-old Austrian, who helps direct the plant from the San Jose jail where, as ‘enemy alien,’ he has been given comfortable quarters with his wife.” [World Wide Photos, San Francisco Bureau, Feb. 6, 1942; from Hansgirg’s FBI file]

Hansgirg was likely aware of these early patents. Nevertheless, his contribution was to apply this already-known “steam reforming process for hydrogen” as a more efficient means of separating the hydrogen isotopes (that is, hydrogen from deuterium) using catalytic exchange. Though Hansgirg was the first to patent a process to enrich the deuterium content in water by catalytic exchange, he may not have been the first to experiment with the process. In 1933, the British scientific journal *Nature* published the results of an experiment concerning the catalytic exchange between hydrogen and water (36). Hansgirg, who began with the well-known chemical techniques for extracting, manipulating, distilling, and separating hydrogen from water (steam), tweaked some of these well-known techniques a bit to separate the heavier deuterium from the lighter hydrogen.

As the name suggests, catalytic exchange reactions require the use of a catalyst. At room temperature, the equilibrium reaction is so slow that for practical purposes it doesn't occur. Even at 200°C, a catalyst is required for the reaction to be fast enough to be practical (1). As Hansgirg explained in his May 1939 “Production of Heavy Water” U.S. patent (12):

As catalyzers for establishing the distribution equilibrium of deuterium between hydrogen and water there may be employed for example the metals of the nickel and platinum group, platinum preferably in the form of platinum-black.

These are the same catalysts, nickel and platinum, that were later used by the Germans at the Norsk Hydro heavy water facility in Norway and by Manhattan Project scientists at the heavy water plant operated by Consolidated Mining and Smelting Company of Canada, Ltd., or COMINCO, at Trail, British Columbia. Worthy of note is that both nickel and platinum were already well known as catalysts in hydrogenation reactions.

By carefully choosing the optimal temperature, pressure, catalysts, etc., Hansgirg was able to shift the reaction equilibrium, to favor the separation of deuterium at the product side of the process. Only by utilizing his expert knowledge of chemistry and equilibrium reactions, could a significant and useful amount of deuterium fractionation occur.

In all likelihood, Hansgirg was the first to detail in writing (in the form of an Austrian patent application) how catalytic exchange between hydrogen and steam could efficiently fractionate the deuterium isotope. The first was filed at the Austrian Patent Office on December 6, 1934 (37) and the second on December 23, 1935.

Incidentally, both patents carried the same title: “Verfahren zur Darstellung von schwerem Wasser [Process for the Production of Heavy Water].” These Austrian applications provide the priority dates for Hansgirg's U.S. patents related to heavy water production. This was Hansgirg's contribution to the field. Other chemists of similar caliber may have arrived at the same conclusion, or would have done so shortly thereafter, but it appears Hansgirg's patent is the earliest written record we have of that idea (33).

In January 1935—that is, after Hansgirg had filed for a patent for his heavy water process in Austria—Urey published a 61-page monograph on deuterium and heavy water titled “The Hydrogen Isotope of Atomic Weight Two” (38). Quoting Adalbert and Ladislav Farkas (39), Urey suggested that the $\text{H}_2\text{O} + \text{DH} = \text{HDO} + \text{H}_2$ exchange reaction “might easily be adapted to a countercurrent process by use of an apparatus similar to fractionation columns,” for the purpose of separating deuterium from hydrogen. This is similar to the apparatus described in Hansgirg's catalytic exchange heavy water patent. But Urey's prediction came with an important caveat: “Even without the electrolytic method of separation, pure deuterium could be prepared at the present time without prohibitive effort,” Urey said. “The electrolytic method, however, is so simple that as yet no chemical method gives great promise of displacing it” (38).

Hansgirg, Heavy Water, and Japan

Hansgirg had offered to erect a heavy water plant for the Japanese in northern Korea and in Manchukuo, but neither took him up on his offer. The details of negotiations between Hansgirg and the Japanese at Konan came to light after the war, when the Economic and Science Section of the OSS (the predecessor of the CIA) interviewed Saburo Tashiro, the Director of the Noguchi Institute in Japan. As Tashiro explained, Hansgirg was at Konan to erect a magnesium plant based on his patented carbothermic reduction process. At the time, Tashiro was Chief of the Research Department at the Konan plant. Tashiro said Hansgirg had encouraged him to conduct test production of heavy water by catalytic exchange and electrolysis, Hansgirg's patented heavy water process; he had even seen articles on the subject and was interested. However, “because of problems concerning equipment, etc., the plan was dropped” (40).

Others believe Hansgirg may have gone so far as to draw up plans for a heavy water plant at Konan, and that the construction of a pilot plant may have actually

begun. According to an article on Japanese wartime nuclear weapons research in *Historia Scientiarum*, a peer-reviewed journal of the History of Science Society of Japan, “Although preliminary plans were drafted for the construction of a heavy water pilot plant...Nitchitsu apparently terminated the project due to problems encountered with the prototype equipment” (41). Although Hansgirg’s Japanese heavy water patent (Figure 4) (42) contains no drawings, his 1938 U.S. patent contains an illustration of the apparatus. (See Figure 5.)

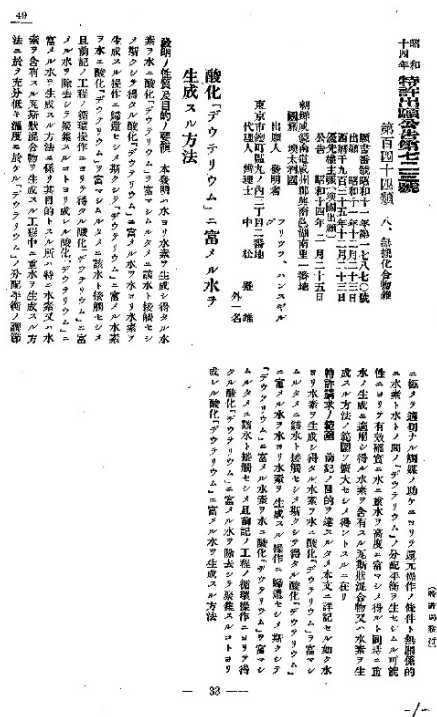


Figure 4. Hansgirg’s Japanese heavy water patent.

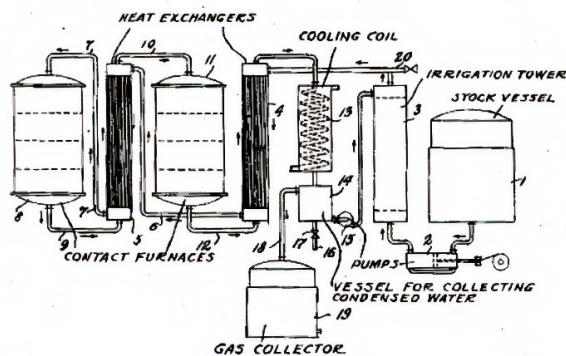


Figure 5. Hansgirg’s heavy water apparatus from U.S. Patent #2,134,249.

Later, Tashiro offered another (but frankly less credible) explanation for abandoning the idea of constructing

a heavy water plant at Konan: “There was talk from Hansgirg about doing it [conducting heavy water research] in Konan, but he gave up the idea thinking it was better not to do it just for fun.” He also said the project was dropped due to “circumstances” (43). Perhaps Tashiro was being intentionally vague.

Did the Japanese later engage in heavy water production at Konan? An article in *Tokyo Shimbun* titled “Atom Bomb Experiment Undertaken by Former Japanese Armed Forces in Korean Peninsula Just Prior to the End of the War — According to Secret Investigation by GHQ [U.S. Army, General Headquarters],” discovered at a U.S. archive by the Washington, DC, Bureau of *Jiji Press*, the Japanese news agency, may shed light on this topic. According to *Tokyo Shimbun*, the secret, 300-page GHQ/SCAP report shows the U.S. ordered a thorough investigation in nuclear activities at Konan. Their investigation concluded that the Chosen Nitrogen Fertilizer Plant at Konan “produced heavy water jointly with the Japanese Navy” since “pre-war times” (44).

The demand for heavy water from Japanese university scientists began around 1940, around the time Hansgirg and his wife departed Korea for California. During the war, Japan had two, largely independent nuclear programs. One was led by Dr. Yoshio Nishina at Tokyo Imperial University who intended on using it for experiments utilizing the large cyclotron at Riken (41). Though it is known that Nishina’s program never advanced very far, he was quoted in *Hankyoreh 21*, a weekly Korean journal, having made the following bold assertion: “If I succeeded before America, we would have been the ones who dropped the bomb” (45).

Japan’s other nuclear weapons program was led by Dr. Bunsaku Arakatsu, a professor at Kyoto Imperial University. After the war, Arakatsu told post-war Atomic Bomb Mission investigators that heavy water was “obtainable in Japan from electrolytic plants in Kyushu and Korea” since Japan Nitrogenous Fertilizer Corporation (Nitchitsu) had heavy water plants at both locations (46). Nevertheless, without the addition of catalytic exchange, Japan’s wartime heavy water production remained pitifully small when compared to the German and American programs.

By September 1941, the Nobeoka laboratory of Noguchi Enterprises, the parent company of Nitchitsu, was producing heavy water for commercial sale, but it could hardly be considered large-scale mass-production. The processing equipment consisted of five 100-liter and five 32-liter electrolytic cells utilizing 0.01 percent

deuterium as the base material to produce 40 liters at concentration of approximately 0.4 percent heavy water per production cycle (41).

Despite plans to increase production to 100 milliliters per month of 100% pure heavy water, even after the laboratory at Nobeoka had gradually increased production, only about 10 milliliters of 90% pure heavy water per month, or somewhat more, was produced by the end of 1942. Even after further improvements were made, the Nobeoka plant could still only produce some 50 milliliters of 90-100% pure heavy water by April 1944 (41). By comparison, the plant at Trail, BC—which produced heavy water by the patented catalytic exchange and electrolysis process—had a capacity of 6 Mg/y (or 6 metric tons per year); and by the end of 1945, production had averaged more than 1,100 pounds of 99.8% pure heavy water per month (47).

“No Invention over [Fritz] Hansgirg”

As part of the Manhattan Project, heavy water production was referred to as the “P-9 Project.” A good percentage of the heavy water produced during the war was by water distillation (48). DuPont built heavy water production facilities in three cities: Morgantown Ordnance Works, near Morgantown, West Virginia; Wabash River Ordnance Works, near Dana and Newport, Indiana; and Alabama Ordnance Works, near Childersburg and Sylacauga, Alabama. The water distillation systems, the largest ever built, were designed and constructed at record speed. For example, Morgantown’s decision to build was made in December 1942. Design, construction, commission, and startup took less than two years (49).

Heavy water was also produced in Trail, British Columbia. The heavy water plant at Trail was built as an addition to the COMINCO plant to take advantage of the existence of the electrolytic units which provide hydrogen for ammonia synthesis for use in the production of fertilizer. So in that respect heavy water must be regarded as a by-product, since the major portion of the plant was in existence and operating for many years prior to the commencement of heavy water production.

Prof. Hugh S. Taylor of Princeton, a British subject, knew that COMINCO was the largest producer of electrolytic hydrogen in North America. Before the end of 1941, Taylor had visited Trail and convinced Consolidated management that it would be practical to operate heavy water equipment as a loop in the Trail ammonia plant. And thus, the deuterium would be extracted from

the hydrogen supply. Experiments showed that by early 1942 it would work well, but entirely too slow. So Taylor suggested using steam at atmospheric pressure in place of water in the exchange process (50)—the same process Hansgirg had patented years earlier.

The plant at Trail comprised three parts. The first was known as the “primary plant” of four stages including the original electrolytic hydrogen plant, plus certain modifications, and the catalytic exchange towers, in which the catalytic exchange between hydrogen and water vapor was accomplished. A secondary plant, a three-stage, batch electrolysis operation, was built especially for heavy water production (51). Heavy water production at Trail began in January 1944 (52).

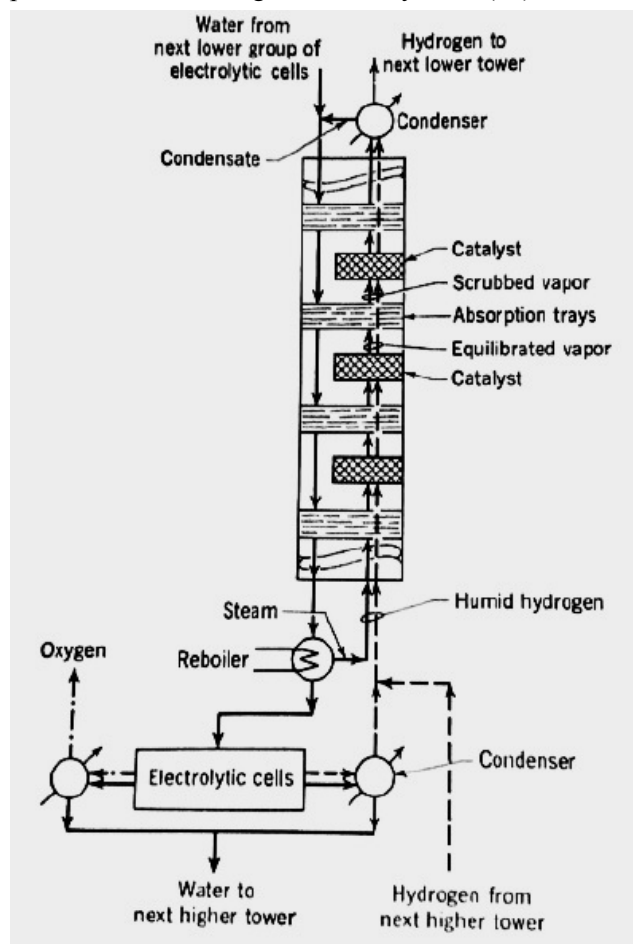


Figure 6. The heavy water plant configuration at Trail, BC (Canada).

In the catalytic exchange of hydrogen atoms between hydrogen gas and [liquid] water, the water contains between three and four times as great a concentration of deuterium as the hydrogen gas in equilibrium with it. With hydrogen and water vapor, the effect is of the same general type but equilibrium is more rapidly established.

The above is from *Atomic Energy for Military Purposes*, the official post-war report on the development of the atomic bomb by Henry De Wolf Smyth, a nuclear physicist with the Manhattan Project, written under the auspices of the U.S. Government (53). The “Smyth Report” was released to the public on August 12, 1945, just days after the atomic bombings of Hiroshima and Nagasaki.

Just as Hansgirg had suggested nearly a decade earlier in his “Production of Heavy Water” patent, the most effective catalyst for the above exchange reaction (used in the first three exchange towers) was found to be platinum-on-charcoal. A nickel-chromium catalyst was used in the fourth. Trail adapted the above to a continuous countercurrent flow arrangement (53), with the catalytic exchange units arranged in the form of a tower—with liquid water flowing from the top and steam rising from the bottom. Why hadn’t Hansgirg thought of that—or had he?

Hansgirg undoubtedly understood that a tapered countercurrent cascade (vertical or otherwise) was required. The cascade would have had large “stripping” stages in the front end recovering (stripping) a small amount of deuterium from a large volume of feed material, and progressively smaller “enrichment” stages concentrating deuterium into a small heavy-water product stream. This type of arrangement is standard chemical engineering know-how (54).

The designer of such a plant would have had to consider many more factors than the cost of materials and a simple drawing, like the one that appeared in Hansgirg’s patent application. The economic viability of the process, for example, would depend on equipment and operating costs. Technical viability would need to be demonstrated in successful pilot plant operation. Constructability would depend on availability of materials for plant construction, skilled workers, suitable location for the plant, inexpensive energy, etc. Finally, in any capital project, one always evaluates risk of failure, and sometimes a conservative and proven technology is preferred because it is the lowest risk option, even if there might be advantages in a new technology (54).

Like the plant at Trail, Hansgirg’s patent suggested his heavy water process be repeated any number of times, up to a certain level of enrichment. Then the process was finished off with electrolysis. “In this manner,” Hansgirg wrote, “it is possible to obtain not only water very rich in deuterium compounds, but also, given a sufficiently

large number of repetitions of the process, even pure deuterium oxide [D₂O]” (12).

Urey, who led the Manhattan Project’s heavy water project, understood that to achieve a heavy water concentration of 100%, the catalytic exchange scheme be repeated or be finished by fractional distillation, or “the well-known electrolytic method” (55).

According to a 1969 status report titled *Production of Heavy Water* from Battelle Northwest Laboratories, once the primary plant raised the concentration of deuterium in the water to 2.37%, a secondary plant, consisting entirely of electrolytic cells, increased the purity of heavy water to 99.8% (56). Only heavy water enriched to this level, or higher, is suitable for use as a moderator in a nuclear reactor that uses natural uranium—for the purpose of generating electric power or to produce plutonium for use in a nuclear weapon. When energy is produced in a reactor that uses ordinary water, known as a light-water reactor, the uranium needs to be highly enriched.

Unaware that Hansgirg had patented the same heavy water process nearly a decade earlier, Manhattan Project scientists attempted to patent the catalytic exchange process at the U.S. Patent Office. In November 1942, Urey, who by then had assumed responsibility for formulating and coordinating all federally-funded academic and industrial work in isotope separation and heavy water production (57), along with Aristid V. Grosse, a German nuclear chemist, filed a patent for heavy water production on behalf of the Manhattan Project (55). Later, however, P. W. Shepard, Urey’s patent examiner at the U.S. Patent Office, returned with bad news.

In a letter to the applicant on October 5, 1943, the patent examiner initially rejected all of Urey’s patent claims. Some were rejected for technical reasons; but others, including Claim Nos. 1-6, 13, and 14, were “rejected as involving no invention over [Fritz] Hansgirg” and “Eley and Eley et al.” Daniel Douglas Eley, a British chemist and Professor of Physical Chemistry at the University of Nottingham, had previously suggested nickel, tungsten, or platinum catalysts. Shepard also said, “to support the catalyst on a material which is unreactive [just as Hansgirg’s heavy water patent had mentioned] appears to be the obvious thing to do” (58). In the end, the patent examiner required Urey’s heavy water patent, “Process for Production of Deuterium Oxide as a Source of Deuterium,” to cite one and only one patent: Hansgirg’s “Production of Heavy Water” (12).

Another patent that cites Hansgirg's heavy water patent is Raymond N. Fleck's 1957 "Isotope Separation Process." In it, Fleck laid out some of the current methods of isotope separation. "The advent of atomic energy processes on a commercial scale" had created, and in the future would continue to create, large demands for relatively pure single isotopes. Many methods have been proposed and employed for isotope separation, he said, such as fractional distillation, gaseous diffusion, electromagnetic methods, mass spectrographic methods, chemical isotopic exchange reactions, selective electrolysis, etc. (59).

Hansgirg's U.S. heavy water patent was not without problems, however. According to the patent, hydrogen can be produced by a well-known water-gas shift reaction ($\text{CO} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + \text{H}_2$). Although the above process converts "essentially" all of the carbon monoxide (CO) to harmless carbon dioxide (CO_2), some CO remains; and CO would poison a platinum catalyst, thereby reducing its effectiveness. Hansgirg should have known this, and likely did know this, but for some reason neglected to mention the need for a separate process to strip the residual CO from the hydrogen before proceeding to the next step in his heavy water process (60).

Alistair Miller, Researcher Emeritus at Atomic Energy of Canada Ltd. (AECL), was surprised to learn that Hansgirg's patent failed to mention a follow-up step, a process "known to those skilled in the art," needed to remove the remaining traces of carbon monoxide. Perhaps there was no need to explain how this was to be accomplished, Dr. Miller said, but the patent would have been strengthened if Hansgirg had been exhaustively explicit (60).

During the war, the U.S., and to a lesser extent Germany, exerted a very large effort to evaluate and develop the various methods of heavy water production; among these were two promising chemical exchange processes: the water-hydrogen process examined above in detail, and dual-temperature water-hydrogen sulfide exchange. The former was the basis of the first heavy water production at a reasonable cost from industrial-scale plants. The latter, known as the GS (Girdler-Sulfide or Geib-Spevack) process, though superior to the Hansgirg process in a number of ways, only became popular post-war.

Norsk Hydro and the German Heavy Water Project

The hitherto secret details of the grisly race between Germany and the Allies to find a weapon so destruc-

tive that it would insure absolute victory—a race not only between scientists but also between under-cover agents—were recounted in London tonight after it had been disclosed that the atomic bomb had been dropped on Japan (61).

"Report by Britain"
New York Times, August 6, 1945

As noted, the Japanese at Konan became aware of Hansgirg's Japanese heavy water patent when he traveled to Korea to set up a large magnesium plant there. Likewise, Manhattan Project scientists became aware of Hansgirg's U.S. heavy water patent when two of them attempted to obtain a patent for that same process. One question remains: Did the Germans, who famously produced heavy water during the war at Norsk Hydro, also become aware of Hansgirg's heavy water patents?

A few short years after Urey discovered heavy water, Norsk Hydro, a Norwegian chemical company, began construction of the world's first commercial plant designed specifically to produce heavy water, a byproduct of hydrogen electrolysis at the company's ammonia plant. In fact, for nearly a decade, all worldwide commercial-scale production of heavy water was by electrolysis (62). At the time, Norsk Hydro was the only company in the world producing heavy water on an industrial scale (63).

Much of the history of the German heavy water program that follows is from a book titled *The Virus House* by David Irving, an English writer and historian. When war broke out in Europe, the only firm capable of producing heavy water was the Norsk Hydro hydrogen-electrolysis plant at Vemork, just outside of Rjukan, Norway. In a friendly letter to Prof. Werner Heisenberg, a German theoretical physicist, on January 15, 1940, Paul Harteck said he thought heavy water production was "every bit as vital as that of uranium," adding (64)

From my own experience of our War Office, the production of large quantities of heavy water will certainly take several years if we leave it to them; but I can well imagine that if I personally take this up with the right gentlemen in our heavy industry the time could be cut to a mere fraction of that.

When "it seemed unlikely that the Norwegian plant would meet all the requirements of the German [heavy water] project," Irving wrote, Harteck and his assistant, Dr. Hans Suess, were preoccupied with the development of catalytic exchange, the "new heavy-water process" that Irving said was developed several years earlier (64). In a book review of *Virus House* in the June 1968 issue of *Bulletin of the Atomic Scientists*, Suess called the catalytic exchange process "common knowledge" (65). Had

Harteck and Suess learned of Hansgirg's heavy water patents at some point, and if so when? They may have seen one in the 1939 U.S. Patent Office's "Official Gazette" or perhaps in the Austrian or German equivalent.

On January 24, 1940, Harteck wrote to the War Office suggesting that the catalytic exchange between hydrogen and water, which proved to be far cheaper than electrolysis alone, be examined because, as Irving said, "Heisenberg's calculations suggested that the reactor would probably need about equal quantities of uranium and heavy water; in other words many *tons* would be needed." But if Norway refused to supply Germany with her need for heavy water, Irving said their only alternative would have been to use steam-generated electrolysis; but this would have required 100,000 tons of coal to produce just one ton of heavy water (64).

"The War Office was suitably shaken by this estimate," Irving said, "but sternly rebuked Harteck for his temerity in communicating directly with Heisenberg." The project, they said, was "covered by security regulations... the transmission of such reports direct from one institute to another is in [the] future forbidden. In each case they will be forwarded through the Army Ordinance Department" (64).

According to *Heavy Water And Nonproliferation—Topical Report*, by Marvin M. Miller, by May 1940, with the German occupation of Norway, "the efficacy of heavy water as a moderator—particularly in a heterogeneous arrangement with natural uranium—was well appreciated; the idea having occurred to several German scientists; Paul Harteck and Werner Heisenberg in particular, during the fall of 1939" (66).

Harteck, one of the key players in the German atomic bomb project during the war, "had gained first-hand knowledge of heavy water production via electrolysis while working under Lord Rutherford at the Cavendish Laboratory in England in 1934" (66).

From its founding in Germany in 1925 until its dissolution by the Allies after WWII, I.G. Farben was the world's largest chemical concern, or cartel (67). One of I.G. Farben's numerous plants was Leuna Ammonia Works in Merseburg, an industrial city in eastern Germany, near Leipzig. When Harteck first proposed the construction of a pilot heavy water plant at Leuna Ammonia Works, he was advised to discuss the idea with Prof. Dr. Karl-Friedrich Bonhoeffer, a German chemist and a professor of Physical Chemistry at the University of Leipzig. The German War Office agreed, so Harteck took up his idea of appending a catalytic exchange plant to an

existing hydrogenation plant there—hydrogen being key to the catalytic exchange process. The construction of a hydrogen plant at Leuna, capable of generating six million cubic feet of hydrogen per hour, had begun over a decade earlier (68).

Around six months after the outbreak of war in Europe, initiated by the German invasion of Poland on September 1, 1939, and the declaration of war by Britain and France in retaliation, Bonhoeffer sent an inquiry to the Leuna Ammonia Works. In his letter, Bonhoeffer requested information concerning the speed at which their heavy water equipment operated. (By "speed," I presume Bonhoeffer meant "level of production" or "capacity.") The inquiry was addressed to Dr. Heinrich Bütetisch, an industrial physical chemist and head of Leuna Works. A major in the SS, Bütetisch was also one of the youngest members of I.G. Farben's managing board (69).

In their March 5, 1940 response to Bonhoeffer's letter, Leuna Works Merseburg said they recently became aware of some "interesting patents" by Dr. Fritz Hansgirg of Dairen, Manchukuo. One (Figure 7) was Hansgirg's German patent #674,965 ("Method of Producing Heavy Water") (70). The other (Figure 8) was German patent application #H148186 IVb/12i ("Process for the Production of Heavy Water") (71), submitted on July 8, 1936 (72). The letter concluded with these words (73):

This patent describes working methods for the production of heavy water, as they were also discussed when you visited us in Leuna. In this context, we would like to draw your attention to these patent specifications.

In a letter marked "Destroy after reading," Bonhoeffer reported to Harteck having discussed the idea with



Figure 7. Hansgirg's German heavy water patent (13).

I.G. Farben's ammonia plant at Merseburg who were "all in favor of the idea." Leuna Works had no objections in principle. As Bonhoeffer noted, "the whole idea stands or falls by the catalyst." Meanwhile, the German government approached Norsk Hydro directly (74).

B/2	I.-G.-Nr	125	19 40	D.R.P.	vom
H 148 186 IVb/121(1/02)				Erteilt	Plachr. ausgg.
Priorität Österreich 23.12.35.				Erforschen	
Ergebnis 3. 7. 36.					
Bekanntgemacht 18.1. 40.					
Einspruch bis 18.4. 40.					
Zurückgezogen	Versagt				
Ne/M. Daten nach dem Patentblatt					
Dr. Fritz Hansgirk, Dairen, Korea, Japan					
Verfahren zur Darstellung von schwerem Wasser					
PATENTANSPRUCH					
<p>1. Verfahren zur Darstellung von schwerem Wasser im Zuge, der Herstellung von Wasserstoff oder wasserstoffhaltigen Gasgemischen durch Reduktion von Wasser, dadurch gekennzeichnet, dass die Reduktion des Wassers zu Wasserstoff, bzw. wasserstoffhaltigen Gasgemischen und eine Anreicherung von Wasser mit Deuteriumverbindungen durch Berührung des Wasserstoffs mit Wasser, gegebenenfalls in Gegenwart von Katalysatoren, in zwei hinsichtlich der Reaktionsbedingungen unabhängig voneinander geregelten Teilverfahren durchgeführt wird, wobei das mit Deuteriumverbindungen angereicherte Wasser zur Gänze oder zum Teil in das erste Teilverfahren (Reduktionsprozess) zurückgeführt und dem in dieser Weise gewonnenen, mit Deuterium angereicherten Wasserstoff neuerlich im zweiten Teilverfahren durch Wasser oder bereits mit Deuteriumverbindungen angereichertes Wasser Deuterium entzogen wird.</p> <p>2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass die Reduktion des Wassers im Zuge der Herstellung von Wassergas durch Zersetzungen von Wasser an Kohle erfolgt.</p> <p>3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass bei der Herstellung von Wasserstoff durch die Konversion von Kohlenmonoxyd in wasserstoffhaltigen Gasgemischen mithilfe von Wasserdampf in Gegenwart von Katalysatoren die Zurückführung des angereicherten Wassers in den Reduktionsprozess in der Weise vorgenommen wird, dass ein Teil des angereicherten Wassers in Form von Wasserdampf in die Reaktion eingebracht, ein anderer Teil an Kohle zu Wasserstoff und Kohlenmonoxyd zersetzt und dieses Gas neuerlich der Konvertierung zugeführt wird.</p> <p>4. Verfahren nach den Ansprüchen 1 bis 3, dadurch gekennzeichnet, dass in jeder Verfahrensstufe Wasserstoff und Wasser, bzw. an Deuterium angereicherter Wasserstoff und an Deuteriumverbindungen angereichertes Wasser von gleicher isotopischer Zusammensetzung miteinander in Berührung gebracht werden.</p> <p>5. Verfahren nach den Ansprüchen 1 bis 4, dadurch gekennzeichnet, dass dem mit Deuterium angereicherten Wasserstoff in Teilstufen durch Berührung mit Wasser, das in jeder folgenden Teilstufe stets eine niedrigere Konzentration an Deuteriumverbindungen besitzt als in der vorhergehenden, Deuterium entzogen wird.</p> <p>6. Verfahren nach den Ansprüchen 1, 3 und 5, dadurch gekennzeichnet, dass die Konversion von Wassergas mit Wasserdampf in mehreren Stufen durchgeführt wird, sodass in der ersten Stufe nur ein Teil des GG umgesetzt wird und in jeder folgenden ein weiterer Teil, und</p>					

Figure 8. Hansgirk's German heavy water patent application.

In a follow-up letter to Bonhoeffer (75) dated March 12, Leuna Works Merseburg again referenced Hansgirk's two patents: "In our reply of 5 March, we referred to two patent specifications, which concern the extraction of heavy water." The letter went on to say that they had since learned—through a phone call from Bonhoeffer to Dr. Paul Herold—that Bonhoeffer was able to obtain Hansgirk's patent, but not the patent application mentioned above. "You asked on the telephone [for us] to help you get this document, since you see no way to get it into [Herold's] possession." So they enclosed a photo of the account. "...but we would like to point out that the application has been filed, and that we are obliged to treat it confidentially and therefore ask you to handle the matter accordingly" (75).

Both letters closed with the obligatory "Heil Hitler!" Meanwhile, copies of that follow-up letter were distributed to various key I.G. Farben scientists including Bütefisch, Herold, and Director Dr. Hans Adolf von Staden. Who was Dr. Staden?

During the Nuremberg Trials after the war, Curtis G. Shake, Presiding Judge in the I.G. Farben trial, asked Bütefisch who Dr. Staden was, when he spotted his name on the distribution list of another document. "Now, who is Dr. Staden?" the judge asked. In response, Bütefisch said, "Dr. von Staden was the head of planning matters for Auschwitz, in detail... He was also a plant leader at Leuna" (76). Auschwitz was the notorious Nazi concentration camp and extermination center where over 1.1 million men, women, and children were gassed to death.

Apparently, the heavy water process discussed by the Germans at Leuna, and later implemented at Norsk Hydro, was similar to the one patented in Germany by Hansgirk in April 1939. According to Rainer Karlsch, the author of *Hitlers Bombe*, "I agree the Harteck-Suess process (which [was] based more or less on Hansgirk's work) was the key element to increase the heavy water production in Norway" (77). Nevertheless, despite their success in producing heavy water during the war, Norsk Hydro never achieved full capacity due to British sabotage and a subsequent U.S. bombing raid.

The request for confidentiality over the patent application by Hansgirk still in process is somewhat ironic,

Klasse 12 a	Ausgegeben am 25. November 1938
	
DEUTSCHES REICH REICHSPATENTAMT, ZWEIGSTELLE ÖSTERREICH PATENTSCHRIFT NR. 155029	
DR. FRITZ HANSGIRK IN KONANYU (REGIERUNGSBEZIRK KANKYONANDO, KOREA, JAPAN).	
Verfahren zur Darstellung von schwerem Wasser.	
Angemeldet am 23. Dezember 1935. — Beginn der Patentdauer: 15. Juni 1938.	
Die vorliegende Erfindung betrifft ein verbessertes Verfahren zur Darstellung von schwerem Wasser im Zuge der Herstellung von Wasserstoff und wasserstoffhaltigen Gasgemischen.	
Den Gegenstand des Patentes Nr. 148974 bildet ein Verfahren, bei welchem Wasser an Deuteriumverbindungen in der Weise angereichert wird, daß man durch Reduktion von Wasser-Wasserstoff stoffgas liefernde Reaktionen, die (allenfalls unter katalytischer Beschleunigung) bis zum Gleichgewicht oder annähernd bis zum Gleichgewicht verlaufen, bei möglichst tiefen Temperaturen vor sich gehen läßt und das bei der Reaktion zurückbleibende an Deuteriumhydroxyd und Deuteriumoxyd angereicherte Wasser wiederholt in die Reaktion zurückführt. Das Bestreben, die Reduktion des Wassers bei möglichst tiefen Temperaturen zu bewirken, ist dadurch bedingt, daß der Übergang des Deuteriums aus 10 Wasserstoff in Wasser bzw. Wasserdampf nach einer Gleichgewichtsreaktion verläuft, bei welcher das Gleichgewicht von der Temperatur in der Weise abhängig ist, daß mit fallender Temperatur die Ausbeute an Deuteriumverbindungen in Wasser steigt. Eine Grenze ist diesem Bestreben durch die bei den Reaktionen auftretenden Temperaturen bestimmt, von denen die	

Figure 9. Fritz Hansgirk's 1938 Austrian (Österreich) heavy water patent (78).

for the invention had already been published by a patent office of the German Reich (78). By the time Hansgirg's second Austrian heavy water patent (Figure 9) was issued in November 1938, Nazi Germany had annexed Austria (on March 12, 1938) in a process known as *Anschluss*. The application filed with the Austrian patent office in December 1935 was granted by the Austrian branch of the German Reich's patent office (Reichspatentamt, Zweigstelle Österreich). Thus the Third Reich was the issuing authority of the Austrian patent, which had a swastika at the top. The application under discussion by Herold and Bonhoeffer was a version of the same invention filed in Germany before the *Anschluss* and not yet granted.

Atop Hansgirg's post-*Anschluss* Austrian heavy water patent (#155029, issued Nov. 25, 1938) are the following words, handwritten: "Account closed for Prof. Bonhoeffer." Why was Hansgirg's patent account closed when it was? As the result of extensive research (in German) by Alfred Lang, in cooperation with Christian Laufer of the Austrian Patent Office, there is no need to speculate.

We now know that annual payment requirements start when the patent application is published in the Austrian *Patent Gazette* (*Österreichisches Patentblatt*). Since Hansgirg's patent application was made in December 1935, and based on the publication cycle of the *Gazette*, the payment liability for the first annual payment began in

January 1936. From that time on, annual payments were required. Evidently, payments were made by Hansgirg through 1941, which was the sixth annual fee for this patent. According to a note in the Austrian Patent Registry dated July 24, 1942, however, Hansgirg's patent "expired due to non-payment of the seventh annual fee" (79). Having been arrested by the FBI on December 17, 1941,

following the Japanese attack on Pearl Harbor, Hansgirg was in no position to make a payment to the Austrian Patent Office. But even if Hansgirg had managed to write out a check, it would have been confiscated by the FBI.

Figure 10 is Harteck's Norsk Hydro heavy water production chart. It is published here with permission from the Institute Archives and Special Collections at Rensselaer Polytechnic Institute (RPI) where Harteck taught between 1953 and 1982, when he retired (80). How RPI obtained Harteck's heavy water production chart is a long story, which began in 1945 shortly after the German surrender.

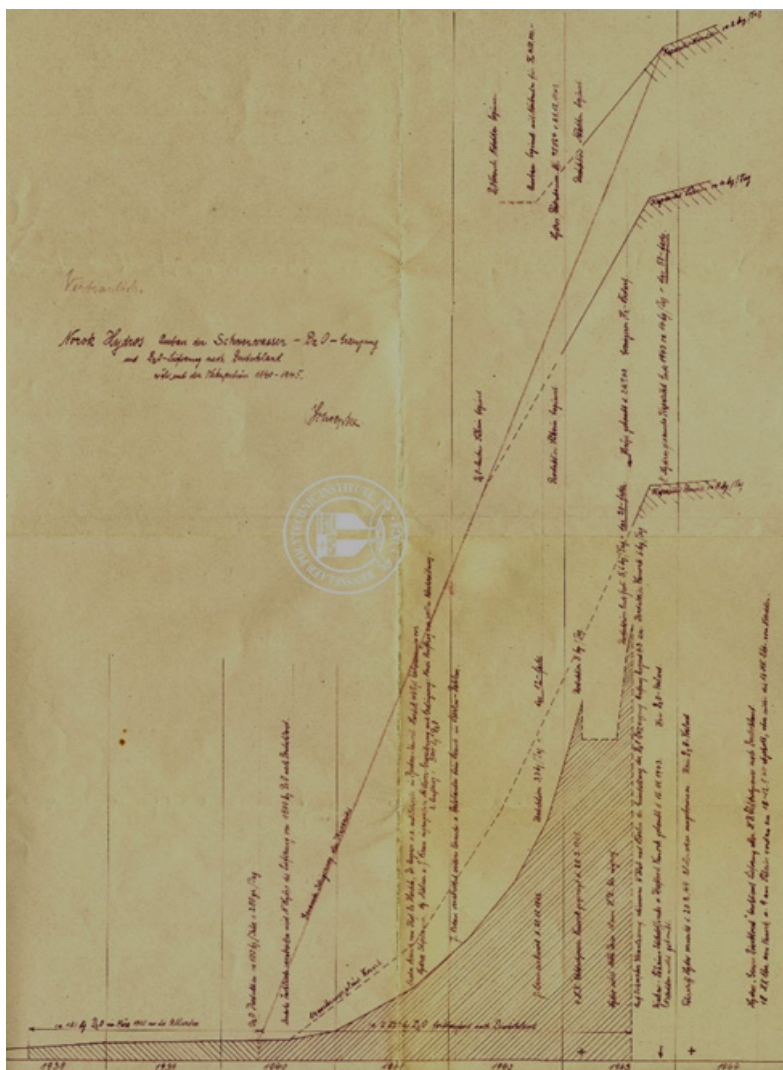


Figure 10. Paul Harteck's Norsk Hydro heavy water production chart. Institute Archives and Special Collections at Rensselaer Polytechnic Institute.

Following his arrest, Harteck was detained by the Allied Armed Forces for six months at Farm Hall near Cambridge, England, as part of Operation Epsilon, the investigation of German efforts to manufacture an atomic bomb. Three years following his release, in 1948, Harteck was appointed Rector of the University of Hamburg. Then in 1951, he emigrated to the United States, later to become the Distinguished Research Professor of Physical Chemistry at RPI, where

he “provided leadership in chemical kinetics, and especially in atom and radiation chemistry.” He retired from RPI in 1982 and died three years later (81).

Harteck’s chart graphically represents many of the key events concerning heavy water production at Norsk Hydro. As seen on the chart, relatively small quantities of heavy water were produced by electrolysis through 1940. A handwritten note (in German) says Harteck and others paid their first visit to Norsk Hydro in 1941, where they suggested improvements (“*schlägt Verbesserungen vor*”) to increase the level of heavy water production at Norsk Hydro. That same note registered the fact that the Germans had recently increased their demand for heavy water to 5,000 kg (up from their previous order of 1,500 kg (82)).

Then around 1942, when, in an effort to increase heavy water production, the Germans began the installation of a catalytic exchange unit at Norsk Hydro, the conversion was interrupted by a commando raid (62). Upon the installation of a catalytic exchange unit, the chart shows how production levels increased substantially through early 1943; that is, until the early-morning hours of February 28 when twelve British saboteurs conducted a daring raid on the facility. The men climbed down a gorge, across a frozen river, and up the rock face on the other side, where they emerged by the railway track to the hydrogen plant. Upon entering the plant, two members of the explosive team mounted the explosive charges, and lit 30-second fuses (83).

The chart shows how the explosion resulted in a sharp, albeit temporary, reduction in the level of heavy water produced. Once the plant was repaired, however, production resumed; that is, until the night of November 16, 1943 when 140 U.S. bombers swooped in and totally demolished the Vemork power station and electrolysis plant. At that point, German heavy water production at Norsk Hydro ceased (83).

Another handwritten note at the bottom of Harteck’s heavy water chart (“*ca. 185 kg D₂O im März 1940 an die Allierten*”) makes reference to a lesser-known episode in Norsk Hydro history, how the Allies acquired the total stock of heavy water at Norsk Hydro (as of March 1940): 185 kg (about 410 pounds). The Norwegians had previously refused to sell their entire stock of heavy water to the Germans, when the Germans refused to say why they wanted it (84).

In 1940, as the commercial and military potential of heavy water sank in, French military intelligence (the

Deuxième Bureau) learned that there was considerable German interest in not only obtaining existing Norwegian stocks, but in a contract for large and regular supplies. Prior to the German invasion of Norway (April 9, 1940), *Deuxième Bureau* removed the 185 kg of heavy water in 26 canisters from then-neutral Norway.



Figure 11. One of the containers used for shipping Trail heavy water, now in the museum at Rosslund, BC. Photo courtesy of Chris Waltham (52).

The 26 canisters were transported first to Oslo, and then on to Perth, Scotland. When the heavy water landed safely in Scotland, it was transported to the French Military Mission in London, and across the English Channel, where it was installed in a special air raid shelter in the Collège de France. Eventually the heavy water returned to London, where it was deposited in Wormwood Scrubs prison. It was later moved to the Cavendish Laboratory in Cambridge, where the Collège de France team were setting up to continue their experiments (52).

Back in March 1940, Lieutenant Allier of the *Deuxième Bureau* departed Paris for Oslo to negotiate with Norsk Hydro. The resulting agreement ensured that France was to acquire not only Norsk Hydro’s entire stock of heavy water at the time, but also a priority claim to the plant’s entire output (52).

Postscript: Postwar Heavy Water Production

By 1949, the U.S. Atomic Energy Commission required larger quantities of heavy water for construc-

tion of reactors that might prove more economical than the light-water, graphite-moderated reactors then used exclusively in the U.S. for the manufacture of plutonium. Over the years, hundreds of methods have been proposed for the production of heavy water, many of which were tried at least on a small scale, but only a few had shown any real promise. A 1953 survey carried out by a group at the Esso Research and Engineering Company (on behalf of the U.S. Atomic Energy Commission) examined 98 potential processes for the production of heavy water.⁸⁵

The factors which dictate the choice of a process for use in the laboratory or a small-scale plant, where flexibility and low capital cost are important, however, are very different from the factors governing industrial scale plants, in which low energy and materials use, ease of operation, and high reliability tend to be more important.

By 1978, heavy water was only being produced on an industrial scale by a limited number of chemical processes. At a symposium on the separation of hydrogen isotopes, H. K. Rae of Chalk River Nuclear Laboratories, Atomic Energy of Canada Ltd., said, “so far plant operating experience has been obtained with [only] five processes” (86) some of which remain in use today.

According to John Augustus Ayres, the author of *Production of Heavy Water*, a 1969 status report by Battelle Northwest Laboratories (now Pacific Northwest National Laboratory) in Benton County, Washington, “The GS process appeared to be a very attractive candidate for producing large amounts (hundreds of tons per year) of heavy water because of low energy requirements and rapid exchange rate” (87). The GS process (the dual-temperature chemical exchange between hydrogen sulfide (H_2S) and water) had several advantages over the Hansgirg process. For one, the feed (liquid water) is cheap, universally available, and unlimited. Another advantage is the GS reaction is “ionic,” and therefore proceeds rapidly without a catalyst; and the temperatures and pressures required are moderate (88). And yet, despite the advantages of the GS process over Hansgirg’s, plus the fact that the GS process was one of the candidate processes considered by the Manhattan Project in 1942, the GS process was not utilized during the war. Why is that? It was thought that some difficult corrosion problem might arise when the hydrogen sulfide came into contact with the materials of construction, especially since there was a shortage of stainless steel at the time (87).

After the war the world-wide use of catalytic exchange (plus electrolysis) fell to just 6%, having been replaced by more efficient heavy water methods such as

the GS process (89). By 1968, the fraction of world-wide heavy water production by water-hydrogen catalytic exchange, the process Hansgirg had patented decades earlier, had fallen to only 4.4%.⁸⁵ The GS process dominated because it had the cost advantage of not requiring an expensive precious metal catalyst for the exchange reaction.

In Conclusion

Had the Japanese at Konan missed an opportunity to erect the world’s first plant capable of producing heavy water on a large scale by means of catalytic exchange, or had they secretly done so after Dr. Hansgirg departed Korea? The electrolytic hydrogen plants at Trail and Norsk Hydro only began gearing up heavy water production after the German discovery of nuclear fission on December 17, 1938, and Lise Meitner’s subsequent analysis. Hansgirg, however, had offered to erect a pilot heavy water plant in Korea in the mid-1930s; it is likely that this plant would have been the first.

By late 1945, the American effort had yielded 55 tons of heavy water; 23 tons by water distillation and another 32 tons by the “Trail process” (48). The German heavy water project, utilizing a 24-hour production schedule at Vemork, had only managed to produce, in round numbers, some 3 tons of heavy water (48)—at first by electrolysis and later by the combination of catalytic exchange and electrolysis.

In any event, both the American and German wartime programs made use of Hansgirg’s process for producing heavy water. Furthermore, it is clear that important figures in those programs became aware of Hansgirg’s patents on the subject, whether or not they conceived the same ideas independently.

Just as Dr. Fritz J. Hansgirg’s obituary in the *New York Times* failed to mention his heavy water patents, and their connection to the wartime heavy water projects in Germany, Japan, and the United States, the obituary of Dr. Paul Harteck, who died at his home in Santa Barbara, California at the age of 82, also neglected to mention his role in the German heavy water project at Norsk Hydro (80).

The obituary of Harteck, the co-discoverer in 1934 of tritium and later the co-designer of the world’s largest atmospheric simulation chamber, said he was “known for his research on radiation, upper-atmosphere chemistry, isotope exchange reactions including those involving

nitrogen, nitrogen reactions with hydrocarbons, and the application of kinetics to nuclear chemistry” (80).

Harteck received his doctorate from the University of Berlin in 1926 under Prof. Max Bodenstein, his doctoral advisor. He later worked at the Kaiser Wilhelm Institute in Berlin with Karl Friedrich Bonhoeffer, providing experimental support for the emerging quantum theory (80). Incidentally, Bonhoeffer, who had urged I.G. Farben to implement catalytic exchange at Norsk Hydro, was also the one who became aware of Fritz Hansgirg’s “interesting” heavy water patents.

Acknowledgments

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Bill Streifer, MBA (Beta Gamma Sigma), is the only American on the Editorial Board of *Vostok* (Journal of Asian Studies) published by the Russian Academy of Sciences, Moscow. He is currently writing Fritz Hansgirg's biography titled *Dr. Fritz J. Hansgirg: The Father of Heavy Water Production* (co-authored by Dr. Kenneth N. Ricci, PhD Physics, Stanford). Some of Streifer's previous publications include "Vindicating the USS Swordfish" (co-authored by Irek Sabitov) in *Acta Asiatica Varsoviensia* (2020), Institute of Mediterranean and Oriental Cultures, Polish Academy of Sciences; "'Improbable Allies': The North Korean Downing of a U.S. Navy Reconnaissance Plane and U.S.-Soviet Cooperation" (co-authored by Irek Sabitov) in *U.S. Navy War College Review* (2020); and "Anything Could Happen: Newly Declassified CIA Documents Tell an Entirely Different North Korea 'Pueblo Incident' Story," *North Korean Review* (2016), McFarland & Co.

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