

Heavy water. History of one priority. Part 1.

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Participation of German scientists and specialists in the Soviet atomic bomb project became widely known after the removal of a number of documents from the list of classified materials in the post-Soviet time.¹ The top-priority goal of the project was the production of fissile isotopes, i.e. plutonium-239 and uranium-235, and also of nuclear bombs, by the same methods and approximately in the same terms as in the American Manhattan Project. Creation of the uranium-heavy-water reactor and the production of heavy water for it (which for conspiracy had been referred to as "product 180" and later "hydroxyline") had become, accordingly, a second-priority task; however, it was carried out as hastily and in the same style of management as the main one. There were also small differences. Different methods and processes can be utilized to obtain hydroxyline, and it was not clear on which of them the main efforts were to be focused.

The well known physico-chemist Max Volmer, professor of the Technical Institute in Berlin-Scharlottenburg, was not engaged in the "uranium project". He had joined those who began to cooperate with the USSR on their own initiative. "Volunteers", namely, Manfred von Ardenne, Peter Thiessen, and Gustav Hertz were offered the supervising positions in the institutes "A" and "G" in Sukhumi. Work there was focused mainly on the separation of isotopes of uranium. All German scientists worked under contracts, under control of the Beria's assistant, general A.P. Zavenyagin. Volmer had decided to take part in the development of the new process for hydroxyline production that included distillation of ammonia. This process had been offered in due time Paul Harteck and Victor Bayerl. Zavenyagin had crossed Volmer from institute "G" to Moscow where in the NII-9 institute organized a special laboratory for him. Bayerl had found in Germany and had invited here to work. A little bit earlier the same method began to be practiced in GIAP^a. There was a mentioning about Volmer and his compatriots working with this method in a number of publications, some of which belong to A.M. Rozen (Rosen), the Soviet participant in the project.^{2, 3}

Besides, in the framework of the "Osoaviakhim" company,^b the specialists engaged in the "Leuna-Werke" (*Eng.* Leuna works) on producing heavy water (i.e., the Paul Herold's group) were forcibly evacuated to the USSR. They were already under the supervision of the Ministry of Chemical Industry. To the best of our knowledge, no written mentioning about this group in the USSR had been made. P.V. Oleynikov only gives a citation from the declassified document of the US Central Intelligence Agency (CIA).¹ Herold's name does not appear in the declassified Soviet documents, and when it comes to discussion of the dual-temperature exchange between water and hydrogen sulfide, it is quite difficult to guess that German specialists were involved in the process development. This fact continued (and continues still) to be ignored in the works published when there were already no any restrictions on such information.^{4, 5}

The text below describes the different versions of the Herold's group history and related events. Besides literature, in this essay the author relies on the information gained from the conversations with people who had worked in the Karpov Institute in the post-war years.

^a GIAP is the State Institute of Nitrogen Industry.

^b Osoaviakhim is a voluntary Society of Assistance to Defense, Aviation and Chemical Construction,

The prototype

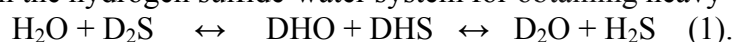
It will be easier to get acquainted with the underlying chemistry from an example of GS process which fits well as the prototype. The manufacture of heavy water, D₂O, is a laborious and a power-consuming process. The natural abundance of deuterium is rather small; it is approximately 150 ppm (~0,015 %). The boiling temperatures for the natural compounds and their counterparts with deuterium differ only slightly. The difference is 3,5 °C for D₂\H₂; 2,5 °C for ND₃\NH₃ and 1,4 °C for D₂O\H₂O, therefore at the initial stage, simple distillation of water would be ineffective. The chemical properties of natural and heavy water are also close except for reactions in which slow stages hydrogen atoms participate, for example, electrochemical decomposition of water. Electrolysis provides the largest separation factor, *q* (the ratio of final to initial concentration of heavy water), but for this purpose it is necessary to spend a lot of electric power (see the Table). An essential advance in extraction of deuterium from natural sources is achieved by use of D/H isotope exchange reactions run with various compounds. It is favourable to use a combination of different methods in one technology.

Table

Characteristics of various methods of heavy water production⁶

Separation method		Temperature, °C	Separation factor	Energy consumption, MW h/kg D ₂ O
Electrolysis of water		~ 90	5-7	120 - 150
Distillation:	water	80 ÷ 100	1,043- 1,026	80
	hydrogen	- 250	1,47 - 1,52	4-5
Dual-temperature method in the system: H ₂ S-H ₂ O		30	2,34	2,8
		130	1,82	

Data on the GS-process were declassified a long time ago. Here we shall use the detailed report which was prepared for the 50th anniversary of the creation of a Savanna River nuclear complex in the USA.⁷ In the Columbia University where Harold Urey in 1931 had discovered deuterium, his colleague Jerome Spevack had proposed to use the dual-temperature scheme and isotope exchange reaction in the hydrogen sulfide-water system for obtaining heavy water:



In 1943 he had applied for the patent. The theme, certainly, was classified, his main patent was published only in 1957 (US patent 2,787,526). The method of invention was coded as S or GS process. In this method, hydrogen sulfide serves as a carrier for deuterium; hereafter the method will be referred to as hydrosulfide process.

As the *q* value depends on temperature, the gaseous hydrogen sulfide which had donated deuterium at a low temperature, further, in contact with water of natural composition under conditions of equilibrium at elevated temperature, will again be enriched with deuterium (see the Figure). For deeper extraction of deuterium, the process is organized with interstage cascading.

In 1942-43, Spevack constructed the laboratory installation in glass, then the corrosion and feasibility studies were performed, but the pilot plant was not constructed. High corrosion activity of hydrogen sulfide and, accordingly, large consumption of stainless steel for the equipment confused engineers. Besides, the heavy water problem (in the USA the code name for heavy water was “project 9” or “P-9”) had soon lost urgency when it was found out that uranium-graphite reactors can be produced much more quickly and with lower material costs. DuPont which had got the contract for the delivery of P-9 had in two years produced at three plants 32 t of heavy water which was more than enough for the planned manufacture of the pilot

reactor in Argonne National Laboratory. From this quantity, 1 kg, and then more 0,1 kg of heavy water⁸ were sold to Soviet Union as the ally. The DuPont heavy water facilities employed the combined scheme: production included vacuum distillation of water followed by electrolysis for final concentration with the use of the hydroelectric power. At the close of the war the DuPont units were closed down.

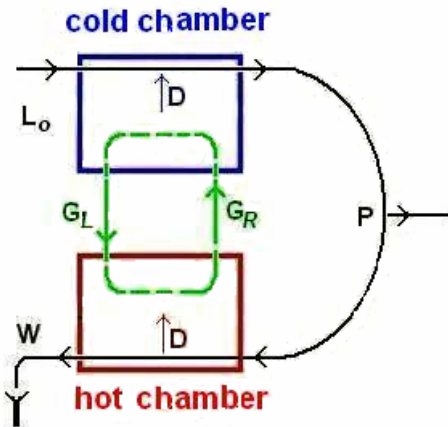
After the end of WW2 and of the Manhattan Project, the Atomic Energy Commission of the USA (AEC) had reconsidered the position about nuclear reactors, therefore the uranium-heavy-water reactor came to be regarded as more economically effective and promising. In 1948, Spevack had finished the work (ordered by AEC) and presented the report on the improvements made. Later Girdler had considered a question of using GS process for producing heavy water at the standing idle DuPont factory. The decision was that this process deserved more development. After analyzing feasibility of converting the old DuPont P-9 facility to a low-pressure dual-temperature production plant it was estimated that a new, more efficient, high-pressure facility could be constructed at the same cost as the conversion of the existing facilities. In the end of 1950, Girdler had become a subcontractor to DuPont, constructed the pilot plant for the hydrosulfide process and obtained additional data. Former abbreviation GS began to be interpreted as "Girdler-sulfide" or "Girdler-Spevack". While Girdler's studies were ongoing, the AEC also funded work with the hydrogen distillation process, requesting that Hydrocarbon Research, Inc., design a plant based on this process.

DuPont again became the main supplier of heavy water. When DuPont contracted with the AEC to construct the Savannah River Plant with two huge reactors, they evaluated the three methods:

- vacuum distillation of water,
- distillation of liquid hydrogen,
- GS process

and decided that the Girdler sulfide process showed clear advantages, as long as three drawbacks were addressed. These drawbacks were difficulty in process control, the toxicity of the gas, and its tremendous corrosive power. The first demonstration plant in Dana, Indiana included six parallel-working GS units, each with a capacity to produce 40 t of heavy water per year, a distillation (DW) plant, and an electrolytic (E) plant. Each of GS units had five separation stages of cold-hot tower systems. Except for the first stage, they contained one pair of cold (30–35 °C) and hot (120–140 °C) towers each; the first stage of each unit contained four pairs of towers. Their height reached 35 m, diameter ranged from 3,5 m to 0,75 m, the towers were stacked with 70 (cold) and 60 (hot) bubble-cap trays. D₂O concentration after the 5th stage was 15–20%

As an example, the Figure shows the principle flowsheet of the two-stage installation. Heat exchangers, blowers, pumps, and other details are omitted, but even without them the flow diagram can give an idea of the complexity of such process in operation. Initially the developers were really afraid that the process would turn out to be difficult in operation. For the system to work, very tight control of the ratio of flows of gas and liquid was needed. This problem was solved by the DuPont's engineer, Dale Babcock, who observed that if the concentration of deuterium at the middle plate of the cold towers is the same as at the middle of the hot tower, then the flow ratio was correct. This principle – the comparison of mid-column concentrations as a basis for process control was used to guide the pilot planning, and the ratio was used regularly during production.



Flow diagram of the hydrosulfide process (top) and the two-stage unit (bottom)

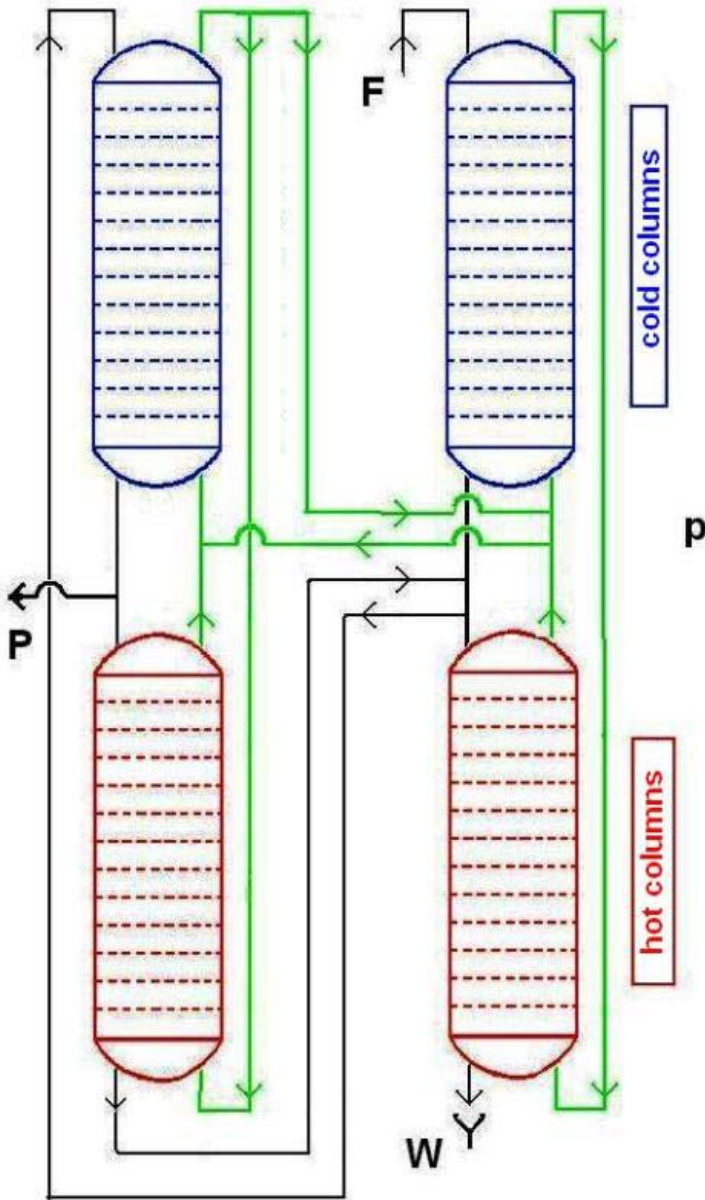
L designates water, black color
 G designates gaseous hydrogen sulfide, green color

Indexes:

R designates rich
 L designates lean

Streams:

F designates initial water
 P designates product
 W designates waste



The first startup of a Dana GS unit in the winter of 1951–1952 was unsuccessful. The cold weather caused the hydrogen sulfide and water to form a solid hydrate, collapsing the column trays; alongside with corrosion, destroyed were bubble caps. Strongly corroded were also internal roller bearings and rotating details of blowers. The true problem was the stress-corrosion cracking of metal under action of mechanical loads. It required additional research. To overcome this problem, all equipment after manufacture was exposed to thermal treatment to remove stress. Bolts, apart from the thermal treatment, were tightened with torque wrenches; the units subjected to loads were isolated from hydrogen sulfide. There were no mistakes in the technological part of the project, thus after elimination of the specified above and some other malfunctions, in the summer 1952 the first of GS units went into operation.

The choice of Girdler and DuPont specialists had proved to be the right one. The hydrosulfide method had formed the basis for heavy water production. Later on it was applied in many countries, e.g. Canada, India, People's Republic of China, and Argentina. In 1996, the capacity of factories had exceeded 1300 t D₂O per year.⁶

There is one detail which was skipped in the anniversary edition of Savannah River. On 24 August 1965 Spevack had addressed the court with the claim to AEC on indemnification of the damage caused by infringement of his copyrights. The point was as follows.¹⁰ Spevack had been not once involved in cooperation with AEC under contracts, including the start-up of the plant in Dana since May 1951 till January 1953. Before signing this contract he had proposed a method for decreasing hydrogen sulfide corrosion in water by special processing of feeding water. The method began to be used in Dana since March 1953 and had been in use till the plant closure in 1957; at the facility in Savannah River it was not applied but was tested in 1955–56. Spevack stated that he had got to know all this only on 15 September 1959 from the publication in Chemical Engineering Progress magazine which became available after the materials on creation and operation of heavy water technology in Dana and Savannah River were excluded from the classified list in 1957. In due time AEC had not given to the author the confidential information, but his claims were rejected. Consideration of the case was complicated by that the claimant had for some reason addressed too late - only one month prior to the termination of the established six-year validity of the legislative norms in similar cases.

The problems with intellectual property associated with development of the methods for heavy water production, as it will be seen from below, had arisen also in other countries.

"Not a light water"

In Germany, deficiency of heavy water had determined the general course and the failure of the whole military nuclear program, or the uranium project. By fatal accident, German physicists have found graphite a bad neutron moderator because they have started the work with insufficiently pure material. They saw no alternative to heavy water. According to Werner Heisenberg, for the industrial reactor using uranium with natural abundance of isotopes 5 t of SH.200 (the German code name for heavy water) were required. In such quantities SH.200 was planned to be produced in the occupied Norway where before the WWII the Norsk-Hydro company had first managed its production. They utilized cheap electric power for electrolysis of water. Further it was entrusted for supervising to IG Farbenindustrie (IG) concern. However, by means of sabotage, diversions, and bombardments, the Norwegian patriots, special services and pilots of the Western allies succeeded to destroy this project. The events around this "not light water" have accounted for the true extremely dramatic story which is much more fascinating than the made-up ones (for example, see Ref. 9).

One of initiators of the German uranium project was the Austrian, Paul Harteck. He was the first in Germany to whom came an idea of the uranium pile, and his student Hans Suess proposed to use in it heavy water as neutron moderator. For the first time, Harteck with his own hands prepared the compounds of deuterium already in 1934, in Cambridge. Then together with

Ernest Rutherford and Mark Oliphant, he had discovered tritium. After returning to Germany long before war, Harteck with Suess got occupied in the development of the method to obtain heavy water by isotope exchange with hydrogen:



Unlike Norway, Germany lacked cheap electric power. Now the work was renewed, and the Harteck-Suess method became the first industrial method of water separation by isotope exchange.^c Under pressing of Germans, Norsk-Hydro was to increase capacity by an order of magnitude, up to a level of 5 t D₂O per year, by means of including two additional electrolysis plants at the first separation step and by extension of high-concentration heavy water plant in Vemork. There with the production efficiency was also increased due to waste hydrogen recycling by the Harteck-Suess method. The Germans had boosted heavy water production at Vemork by optimizing the 1st electrolysis stage and by installing burners in up stream cells to recover the tailings of the cells for use in downstream cells. They also developed a catalytic isotope exchange process to further improve efficiency. Suess had the time to assemble the pilot unit for selecting and testing catalysts for the dual-temperature scheme. It was essentially the same with that presented for the GS process, the only difference is that each isotope exchange step uses a catalyst. For the first time reaction (2) had been carried out by Michael Polanyi and Juro Horiuti with platinum black as a catalyst, and in IG the nickel catalyst was used. The catalyst must meet specific requirements, and its development for D₂O technology presents the most difficult technical task (the catalytic process was limited by lack of platinum and the fact that below concentrations of 1% it was not all that helpful). The Suess process was launched successfully in September 1943 but for the reason specified above, its operation was not long. Sabotage of the electrolysis cells and heavy water storage tanks completely delayed the program while destruction of the product in transport destroyed any hope of getting the full 4–5 tons.

In the beginning of 1944, the Germans had lost their last hopes for this source of heavy water: during all the fight for it they managed "to squeeze out" from Norway only 2,6 t D₂O (based on 100% product). The rest of the precious liquid and a part of the equipment for SH.200 production were taken out to Germany. In the end of the year, Reichscommissar officially stated the closure of works in Vemork. Time was missed.

Besides Harteck, Karl Clusius had also worked on obtaining SH.200. Together with Linde engineers he had developed a method based on the low-temperature hydrogen distillation. To implement the Clusius-Linde method, the installation in Munich had been constructed. It worked with faults. The main difficulty was the need in extra-deep purification of raw materials. In liquid hydrogen any impurity crystallizes and fouls the equipment. There were also other variants to solve the problem of heavy water, but we will not discuss them all. To put it shortly, "as it happens, German efforts were too half-hearted to bear fruit".¹¹

In February 1943, in the Kaiser Wilhelm Institute of Physics took place the meeting in which Herald, Karl Bongoffer, Harteck, and Suess participated.⁹ During the war, Herold was a director of a scientific division of Leuna-werke. As this post suggested (and, perhaps, not only for this reason), he was a member of Nationalsozialistische Deutsche Arbeiterpartei (NSDAP). IG Farben's property Leuna-Werke formed a base of the chemical military potential of Germany; in the times of the WWI, here Carl Bosch had started the production of synthetic ammonia and later of "Leuna-gasoline" synthetic motor fuel which was synthesized by coal hydrogenation. Raw material, i.e. technical hydrogen, was abundant. Herold proposed to organize here the production of SH.200. Because of secrecy, he and even the general director Heinrich Buete fish did not know for which application SH.200 was needed, but they counted on large governmental orders and grants in future. IG had agreed to invest 150 thousand Reich marks ($\mathcal{R}M$) in the

^c In the beginning of 1944, in Trail, Canada had been started up another plant based on H₂-H₂O isotope exchange in combination with electrolysis.⁸

construction of the pilot plant for a dual-temperature water-hydrogen exchange. To lower costs, the pilot scale version of the plant was erected: it yielded product containing one instead of five percent of D₂O, with the capacity of only 50 *l/year*. Nevertheless, the thing turned out to be bulky with many vertical columns and pipes, owing to which it had received the code name “Stalin’s Organ”.^d

However this direction had no further development. There were disagreements in the estimated cost for the 5 *t/year*-capacity industrial plant construction: 2,5 million *ℳ* (Harteck) against 20 million *ℳ* (Buetefisch). Greater grants were unlikely - the budget of 1943 had allowed 3 million *ℳ* for research in nuclear physics.¹² The concern could further invest its own funds but according to Irving, the point was not essentially in finance:⁹

“There was an unseemly wrangle behind the scenes over patent rights for the Harteck-Suess process...”^e

In 1943, Karl-Herman Geib under Harteck’s supervision started working on the hydrosulfide method development. There are some indications referring to the archive of the USA, that the plant had been built under the town of Kiel.¹³ However, under the pointed circumstances the authors did not actively advance the work:⁹

«... one of Harteck’s most promising students, Dr. K. Geib, had evolved at Leuna an entirely new process for manufacturing heavy water - the dual-temperature exchange process using hydrogen sulphide (a process now widely used in America). The plant installation and energy requirements would be cheaper than those of the Harteck-Suess process; on paper, it looked ideal, because the separation factor of hydrogen sulphide would be so high. Harteck discussed it in detail with Geib, but both agreed that it was now too late to transfer to the new process, because of the corrosive nature of hydrogen sulphide and the consequently extensive design problems».

It really was late – the war was rapidly moving to its end. Leuna-Werke was strenuously bombed. Allies tried, first of all, to deprive the enemy of gasoline, and Germans defended desperately. The Magdebourg-Leuna area was attacked similarly to Hannover or Leipzig. The “Stalin’s Organ” had been drastically destroyed.^f

The war was finished. Post-war life was not equally peaceful for everybody. Harteck was simply stolen from the British zone of occupation by two officers of the Alsos mission – a special division of the intelligence department created by the chief of the Manhattan Project, general Leslie Groves. They tracked him down, changed his clothes for the American uniform, put in a Jeep and drove without stops to Paris; further, with a short change in Belgium, he was brought to the place near Cambridge. There the “camp” to gather semi-captive atomic physicists before transporting to the USA was arranged. Afterwards, Harteck continued to leave in America. In 1950, Suess also immigrated to the USA.

Buetefisch, the convinced nazi, a member of “Circle of Friends of Himmler” and SS-Obersturmbannführer had been committed for the “IG Farben heads trial” - the Nuremberg tribunal which took place in 1947-48. The tribunal also known as “USA against Karl Krauch, etc.” process had sentenced him to six years of imprisonment.

To the destinies of Herod and Geib we will turn below.

Version 1 (from researchers)

The above-mentioned Rozen’s article⁴ does not include the considerable part of information which in those days could be pretty safely given in the open press (about the history

^d So Germans nicknamed the famous “Katyusha” mortar.

^e Irving had the opportunity not only to use papers from Harteck’s file, but also to talk to him personally.

^f There is still a lot of discussion around this operation, in particular we can find rather interesting speculations regarding its main goal based on evidence available.¹⁴

of the development of hydroxylone production in the USSR by hydrosulfide method). Nevertheless, it is convenient to begin with it. Here are some fragments of the article:

“The history of the question is as follows. In 1945 M. I. Kornfel'd^g proposed to three specialists on processes and apparatus of chemical technology, A. D. Domashnev, V. F. Kalinin, and the author of the present paper, to develop at the design level three methods for producing heavy water which are based on isotopic exchange: staged two-temperature water-hydrogen exchange, staged two-temperature water-hydrogen sulfide exchange, and finally two-column two-temperature^h water-hydrogen sulfide exchange. <...>

M. I. Kornfel'd knew the deuterium distribution coefficients between the gas and liquid phases for two values of the temperature (measurements performed by M. Ya. Kats, L. Ya. Suvorov, and P. V. Shestikin), whose ratio β in the two-temperature process plays the role of a single separation factor (more accurately \sqrt{B}), as well as Landau's formula for determining the total degree of separation (L. Landau was on friendly terms with M. I. Kornfel'd and derived the formula at his request<...>

The possibility of modeling the two-temperature process of isotope separation in nonisotopic systems as a combination of the standard absorption and desorption, as established by the present author together with V. F. Kalinin, played a large role in the development of the first plant for the production of heavy water by the two-temperature method. In January-March 1946 this possibility was realized: a glass two-temperature two-column setup was assembled. This set up concentrated ammonia water; air was chosen as the circulation agent (for this system the required physical-chemical data was known). <...>

An engineering theory of the process was developed by the author of the present paper. The theory made it possible to calculate the two-column process both theoretically and graphically. It was reported at a meeting of the Scientific Council of the L.Ya. Karpov Scientific-Research Institute of Physical Chemistry in 1947, and published only in 1956, but still before the analogous theory was published abroad. <...>

The success of the experiments was one of the most important justifications for the decision made at the time not to check the technology on a prototype apparatus and to construct immediately a commercial aggregate with a capacity of about 4 tonnes/year. The design, developed by V.F. Kalinin and the present author <...> After the technical task was confirmed by the Technical Council of the Ministry (at the time called the First Main Directorate in Sovmin of the USSR) in 1946 the technical and working projects were developed by Neftzavodproekt (the scientific director was M. I. Kornfel'd,...) <...>

After the mechanical problems were eliminated and all required apparatus was delivered, the plant was started up successfully. <...> it had been reported in the domestic press that the method of two-temperature isotopic exchange between water and hydrogen sulfide was first realized on a commercial scale in the Soviet Union. A large industrial plant, which could be operated successfully even nowⁱ, was constructed in 1946-1949. However, there are no citations to this report in the worldwide literature, probably because it was not supported by specific data. The objective of the present paper is to present this material and thereby confirm the priority of the USSR in the development and commercial implementation of the method“.

Let's give the citation from the memoirs of Kalinin:⁵

^g Kornfel'd was the Kurchatov's colleague in Laboratory No.2, he was engaged in heavy water still with 1943.

^h The term "two-temperature" in the cited text is equivalent to "dual-temperature".

ⁱ In 1980s the manufacture was already stopped.⁶

"Having returned from army to the Institute of Nitrogen, I, on behalf of Narkomat, have got engaged in the development of two-temperature process for heavy water manufacture. The work was, certainly, confidential, therefore there could not arise any question about its patenting; but interestingly, the similar method based on the two-temperature process had been patented much later in Canada. And we with A.M. Rozen, the doctor of sciences who now works in the Institute of Inorganic Materials, can be only satisfied knowing we have made it before Canadians".^j

Version 2 (based on materials of CIA)

The report of CIA gives an absolutely different story:^{1, 15}

"Following the war the Soviets showed considerable interest in German research in the production of heavy water. The principal German pilot plant was located in the Leuna Works at Merseburg. In October 1945, under the auspices of the MVD, a number of individuals specializing in heavy water were assembled at Leuna under the leadership of Dr. Herold. This group drafted the preliminary plans of an H₂S-H₂O exchange plant capable of producing five tons of heavy water per year. Upon the completion of these plans, the Leuna group was evacuated to the USSR on October 21, 1946. Herold and his top men were housed in the small town of Babushkin near Moscow. These people worked at the Institute of Physical Chemistry named after L.Ya. Karpov until mid-1948, when they were sent to Rubezhnoye in the Ukraine. It is believed that at this time [1955] the group's connection with the Soviet heavy water project was terminated and that it was detailed to do engineering work on the construction of the Lisichansk Nitrogen Plant. Whether or not the Soviets constructed the H₂S-H₂O exchange plant is unknown".

The "preliminary project" in the citation, obviously, corresponds to the "detailed design" level of a project - during the Soviet period it was the first design stage (which was followed by the "working drawings" stage). In the case of three-stage design, the second stage was the "contract design (technical project)". If the Leuna-Werke specialists did not have time to complete the detailed design, they would have been nonetheless crossed to the USSR. The CIA report pointed the date of the closing stage under the code name "Osoaviakhim".

This was dictated by the threat of inspection from Allies in the East (Soviet) zone. The facts of infringement by the Soviet side of the earlier reached agreement became known to the command of the Allies. Internment from the countries of the East Europe and Germany of about 200 thousand civilians of German nationality was impossible to prove - all of them already were in special camps and settlements far away from the borders of the USSR. But the reanimated strategic objects were, in contrary, close by. In order to avoid worsening of relations, it was decided to simply quietly withdraw these objects together with the necessary staff. The company was carefully prepared in advance:¹⁶

"Crossing to the USSR was fully unexpected by Germans. All had occurred very quickly. In the early morning on 22 October 1946 army lorries approached the houses where German specialists lived. The worker of counterspionage accompanied by interpreter and group of the soldiers read to the Germans the order on their immediate evacuation to Soviet Union for continuation of work. Trains ready to receiving people were already waiting at stations. German engineers and workers were allowed to take to the USSR members of their families and also the subjects of family life and even furniture".

Transportation of about 2200 specialists and 5000 members of their families required more than 90 trains. The operation was coded "Osoaviakhim" with a good deal of humour. The specialists were mostly the rocket and aviation engineers. The Ministry of Chemical Industry

^j to the Memory of A.M. Rozen (1915–2001)

<http://www.springerlink.com/content/r0u04jk614544378/>

was responsible for people assigned to Karpov Institute and to the factories, i.e. Karbolit (Moscow region), P.b. 96 (Dzerzhinsk), and Rubezhanskii Chemical Enterprise (Donbass). Unlike people having contracts from the Volmer's group, the Zavenyagin's division did not supervise "Osoaviakhim" specialists and was not responsible for their work.

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