German Scientists in the Soviet Atomic Project

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The fact that after World War II the Soviet Union took German scientists to work on new defense projects in that country has been fairly well documented.[2] However, the role of German scientists in the advancement of the Soviet atomic weapons program is controversial. In the United States in the 1950s, Russians were portrayed as "retarded folk who depended mainly on a few captured German scientists for their achievements, if any."[3] Russians, for their part, vehemently deny all claims of the German origins of the Soviet bomb and wield in their defense the statement of Max Steenbeck (a German theorist who pioneered supercritical centrifuges for uranium enrichment in the USSR)[4] that "all talk that Germans have designed the bomb for the Soviets is nonsense."[5] The US intelligence community was able to make its own judgment on the subject when it debriefed German scientists and prisoners of war returning from the USSR in the 1950s, but it did not make public its evaluation.[6] This article attempts to resolve the controversy by drawing on both the stories later told by these German scientists and the recently declassified Soviet accounts of the atomic project. It seeks to determine the real extent to which German participation in the atomic weapons program changed the balance of nuclear power and influenced the course of the Cold War.

This article first addresses what the Soviets knew at the end of World War II about the German bomb program and then discusses their efforts to collect German technology, scientists, and raw materials, particularly uranium, after the war. Next, it reviews the Soviets' use of German uranium and scientists in particular laboratories working on different aspects of atomic weapons development. It discusses the contributions and careers of several German scientists and their possible motivations for participating in the Soviet bomb program. The importance of the Germans' contributions was reflected in the awards and other acknowledgments they received from the Soviet government, including numerous Stalin Prizes in the late 1940s and early 1950s. Their contributions were particularly numerous in the area of uranium enrichment, especially on the technology of gaseous diffusion plants. After reviewing these developments, this article concludes with an evaluation of the political and historical significance of the use of German material and scientists. While the Soviets did not need the Germans' help to build an atomic weapon, their contributions certainly accelerated the Soviets' push to become a nuclear weapon state.

DID THE SOVIETS BELIEVE THE GERMANS HAD AN ATOMIC BOMB?

In the latter stages of the war in Europe, the US Army initiated efforts to investigate whether the advancing Allied troops could be threatened by a German radiological weapon.[7] However, the Soviets did not appear to share this concern. Whether because the Russians' intelligence worked better than that of their British or American counterparts,[8] or an atomic bomb was not believed feasible before the test in Alamogordo in July 1945, none of the published documents from the early stage of the Soviet atomic project (1943-1945) speaks of any such threat from Germany. However, there are indirect hints of possible Soviet concern.

The US forces in Europe conducted an extensive environmental sampling program to determine the location of possible atomic facilities. The recently declassified and published letters of Georgy Flerov to Igor Kurchatov, scientific director of the Soviet atomic project, show that the Russians also undertook such an investigation. Flerov, a nuclear scientist, was in Germany in May 1945 trying to find out whether the Germans had been able to make an atom bomb.

In a letter sent from Dresden circa May 21, 1945, Flerov wrote in an ambiguous manner to protect secrecy about his plans to use Geiger counters in the search:

> Today or tomorrow we are going to fly in the direction that you know. I am taking with me Dubovsky's instrument, but its sensitivity is, probably, too low. If we determine on site that there are objects of interest for examination and sensitivity of the instrument is the issue, I'll send you a cable.
>
> You will have to assign Stoljarenko or Davidenko (if he gets back by then) to this work. Instruct them to assemble the instrument in the lightweight option: powered from the mains by 220 volts.... Along with the instrument, let them pack the tables for finding the appropriate periods.…[9]

Unlike the US airborne Geiger counters, the Soviet counter was not portable because it was to be powered from 220-volt mains. Flerov was going to search for radioactive isotopes with a short half-life (what he refers to as "appropriate periods"). At the time, the only way to determine the presence of an isotope was to take consecutive measurements several days in a row and use special reference tables to calculate what the measurements revealed.

In another letter sent from Dresden on May 29, 1945, Flerov gave more clues that suggest he was looking for evidence on whether the Germans had conducted an atomic test. In this letter, Flerov discusses his desire to interview certain individuals being repatriated to the Soviet Union from Soviet-occupied Germany:

> ...the repatriation has begun. So far there are 10-15 thousand people a day crossing the demarcation line at three checkpoints. Later this number will rise to 50 thousand, until all former Soviet citizens (1-2 million) will be moved away from here. We have visited some of the checkpoints, talked to former prisoners of war. Unfortunately, people from various locations are mixed in the most peculiar way. …
>
> Nevertheless, there should be organized systematic filtration of all arriving people based on their location: in such and such area, in such and such year, particularly because the respective [Soviet intelligence] agencies are conducting similar filtration in order to determine whom to send to what camp. [*Here Flerov made a footnote*: In each camp we shall have 1-2 people focusing exclusively on debriefing people brought from a specific location. After the first superficial questioning, the only people left will be those that we will speak to personally.] After selection, people are kept for several days until somebody from us arrives to speak to them.
>
> Possibly, you can send somebody from the staff to help me. I think that as a result of such search we will be able to find what we need—a person who occasionally was there nearby, as there were a lot of escapees wandering through forests at the time. If successful, we will get objective confirmation of the fact, tantamount to as if we personally had been at that site. This must be done right here and right now, because afterwards all people crossing the border are dispersed through camps in Germany and then are transferred to the Soviet Union, and then even such an enthusiast as myself would question our ability to catch the right people….

> The second direction is connected to what I wrote you in the previous letter. In order to determine finally what was really tested there, we shall of course look after artificial, not natural radioactivity. Unfortunately, a lot of time has passed since, but I think that with [our instruments] we will be able to attain the required sensitivity.[10]

Obviously Flerov was not trying to find confirmation of reactor criticality because such an event does not create visual effects that could be observed by people in a forest. Therefore, Flerov must have thought that escapees could have witnessed something resembling an atomic bomb test, accompanied by a bang and a flash of light.

No documents have come to light that describe the results of Flerov's findings. What is known is that V.A. Stoljarenko (who was mentioned in the May 21 letter) indeed traveled to Germany, together with M.I. Pevzner and A.K. Krasin, some time after Flerov, probably to do the Geiger counter survey. Thus, the puzzle of whether Soviet physicists believed the Germans had developed an atomic bomb remains unsolved. However, it is clear that both the Soviets and Americans eagerly sought information from German scientists and their laboratory equipment.

RUSSIAN "ALSOS"

In 1944, alarmed by the uncertainty regarding German atomic developments, several agencies in the US government established a specialized group—the ALSOS[11] mission—charged with finding and investigating atomic scientists and laboratories in the territories yet to be occupied by US forces.[12] A year later, the Soviets initiated a similar effort to search out and recover valuable installations, equipment, and scientists in Germany associated with atomic physics. The Soviet efforts were conducted on at least as large a scale as ALSOS; hence the use of the American title to refer to the Soviet effort, for which I have not been able to ascertain the Russian code name, if one existed.

The Russian ALSOS group borrowed a lot in its operations from "trophy brigades" established in the Soviet army. These looting teams were formed in January 1945 when the Soviet army finally broke the German defenses and opened the way to Germany. During their advance, Soviet troops encountered almost no Germans east of Stettin: most of the inhabitants had fled, leaving behind virtually all their possessions. In order to collect all the abandoned wealth, the Soviets formed special trophy brigades charged with requisitioning any property of value to the Soviet Union.[13]

The Soviets said the official justification for the trophy brigades came from agreements reached at the Yalta and Potsdam conferences in February and July 1945, respectively. However, the Soviet government did not generally base its actions on respect for international agreements, and the memoirs of Nikolai Dollezhal[14] suggest the decision to launch the brigades was made even before these conferences took place. In May 1945, Dollezhal was assigned the rank of colonel and sent to Germany in order to "collect technical archives of enterprises of the chemical machine building industry."[15] His identification stated that he acted under a decree from GOKO[16] of January 31, 1945, No. 7431. The papers he received stated that Dollezhal should be "granted unobstructed access for inspection of industrial sites."[17]

While the trophy brigades were generally good at confiscating livestock and grain from the Germans, their treatment of elaborate pieces of machinery was too rough, often resulting in damage to the equipment or loss due to chaotic packaging. The Soviet leadership seemed to totally neglect the intellectual value of the German materials. According to Boris Chertok who, like Dollezhal, was promoted to the rank of colonel and sent to Germany in April 1945 to inspect missile navigation equipment:

> We had received guidelines and instructions that God knows who had come up with: during inspections of German plants and laboratories we should not be sidetracked by intellectual achievements, but first of all should make a list and compile an inventory of the types and quantities of machines, technological manufacturing equipment, and instrumentation. In terms of documentation and specialists, the matter was up to us and initiative was not punished.[18]

As described below, the Soviet atomic search groups demonstrated a different pattern: while they engaged in the removal of equipment, they also removed documentation and scientists who were considered to be equal in value to, or even more valuable than, machines. The difference in agendas resulted from the fact that the atomic weapons program was managed and controlled by a specialized organization that was created inside the ubiquitous NKVD.[19]

Origin of the Atomic Search Teams

From a technological perspective, in 1945 the Soviet atomic bomb project was still "in the cradle." The first kilogram of metallic uranium had been manufactured in the fall of 1944, and the first cyclotron brought in pieces from Leningrad and reassembled in Moscow. There was a lot of intelligence on the US atomic bomb, but the information had yet to be tested.

At the outset of the Soviet project, the atomic scientists had been left to work on their own, with only the Soviet Academy of Sciences supervising them. However, the NKVD became involved in the Soviet atomic project at the same time that the uranium problem was first discussed in the USSR. One of the heads of the project was Avraamy Pavlovich Zavenyagin, who was also the head of the 9th Chief Directorate (*Glavnoje Upravlenije*—GU) of the NKVD. This choice of directorate was not a coincidence but a logical consequence of administrative functions of the 9th GU. As early as 1939,[20] the 9th Directorate already was a part of a larger Chief Directorate of Camps for Mining and Metallurgy Enterprises (GULGMP).[21] In 1940, when the need for uranium to use in weapons development was first discussed in the Soviet Union, the emphasis was on surveying new uranium deposits and increasing production from existing mines. Naturally, this task fell into the realm of GULGMP, and thus that organization became involved in the uranium problem. Thus, in spring 1943, when the first atomic laboratory[22] was set up in Moscow (Laboratory No. 2, later known as LIPAN, now the Kurchatov Institute of Atomic Energy), its NKVD supervision was also assigned to the 9th Chief Directorate.[23]

Understandably, NKVD chief Lavrenty Beria and the head of the 9th Directorate, A.P. Zavenyagin,[24] were interested in exploiting what resources they could find in occupied countries. The first indication of their intentions to engage German scientists emerged in a decree of September 18, 1944, which established a specialized task force within the 9th Directorate and commissioned it to "support the work of German physicists invited to the USSR."[25] At that time, there had been only two German physicists working in the Soviet Union: Fritz Lange, who specialized in centrifuge separation first in Kharkov and then in Sverdlovsk in the laboratory of Isaak Kikoin, and F. Houtermanns, a theoretical physicist. According to the NKVD's plans, very soon they would be accompanied by many more.

In December 1944, another decree transferred the mining and processing of uranium from the Ministry of Ferrous Metals to the NKVD. At the same time, to provide scientific support to operations with uranium, a Moscow-based Institute NII-9 (now known as Bochvar All-Russia Institute of Inorganic Materials, or Bochvar VNIINM) was created within the 9th Chief Directorate.[26] The first director of NII-9 was Victor Shevchenko, who also came from GULGMP. From 1943 until his appointment at NII-9, he had been the director of the Norilsk nickel mining combine, a facility that was infamous for the large number of convicts who had died during its construction.[27]

The next reported milestone in the Soviet atomic project occurred on March 23, 1945. On that day, during a meeting in Stalin's office, Beria suggested that specialized teams "grope in Germany and search there for novelties of German atomic technology and for its creators."[28] The next day Beria instructed the head of Laboratory No. 2, Academician Kurchatov, to "submit suggestions on formation of several search teams" to be sent to Germany, Austria, and Czechoslovakia. The same day Beria signed a secret directive putting his deputy Zavenyagin in charge of the operation to locate and deport to the Soviet Union German scientists privy to the German uranium project or who could be of use to the similar Soviet project. The operational issues were assigned to SMERSH military counterintelligence,[29] while two members of Laboratory No. 2—Lev Artsimovich and Yuli Khariton[30]—were to provide scientific guidance to the operation.[31]

The Austrian Bridgehead

The majority of German physical research institutes were situated in Berlin, and thus were inaccessible to the search teams until April 25, 1945, when the defense ring around Berlin was broken. However, the occupation of Austria and Vienna in particular, which had occurred prior to the occupation of Berlin, offered the first opportunity to evaluate the state of the "uranium project" in Germany. From past experiences, the Soviet authorities knew that Austrian institutes practiced a high level of science and could be involved in the uranium problem. They thought that the information from Austria could potentially be instrumental in the planned search activities in Germany. Until the fall of Berlin, Austrian institutes would be the only real information that the Soviet government would have on the German bomb project.

Thus, as soon as Soviet troops were established in Vienna, the NKVD leadership dispatched Vladimir Shevchenko, director of NII-9, and Igor Golovin, a leading scientist of Laboratory No. 2, to Austria. In their activities, Golovin and Shevchenko were assisted by the NKVD units in Vienna. As Kruglov[32] stated, "In April 1945, V.B. Shevchenko and representative of Laboratory No. 2 I.N. Golovin were sent to recently liberated by our troops Austria (Radium Institute) to find out the feasibility of removing equipment and various chemical reagents."

Golovin and Shevchenko stayed in Vienna from April 13 to May 10, 1945.[33] During their stay, they conducted debriefings[34] of the scientists from the Radium Institute of the Vienna Academy of Science and from the Second Physical Institute of Vienna University, and provided Moscow with the first overview of organizations involved in the uranium project. Golovin's report to Kurchatov was finally declassified and published in the proceedings of the Kurchatov Institute in 1998.[35] In the report, Golovin identified the location of the three cyclotrons that were built in Germany during the war[36] and named the companies potentially engaged in production of metallic uranium: Auer Gesellschaft, I.G. Farbenindustrie, Treibacher Chemische Werke A, and Mauer A.G. Radium Chemische Industrie und Laboratorium. As both Golovin and Shevchenko would discover later when they moved to Germany to assist with the work there, their information was correct and Auer Gesellschaft was indeed the main producer of metallic uranium. In addition to documents, the group in Austria retrieved nearly 340 kilograms (kg) of metallic uranium.[37]

The achievements of the Vienna group would have been remarkable if they had not been dwarfed by what followed later in Berlin and its surroundings.

The Search for People and Equipment in Germany

Although Russian sources do not indicate Soviet leaders' expectations for the search mission, the scope of the missions indicates that for some time scientists' trips to Germany became more important than the research conducted in Russian laboratories. According to Heinemann-Grueder,[38] the total number of Soviet atomic scientists who went to Germany was close to 40. Given that the entire staff of the only atomic laboratory in the USSR at the time—Laboratory No. 2 in Moscow—numbered less than 100, inspections of Germany must have stopped almost any work in Moscow for approximately two months.

Evidently, Red Army regiments entering Berlin received instructions on the importance of scientific institutions and some scientists. On April 24, 1945, the head of the chemical laboratory of the 1st Ukrainian Front sent a dispatch describing his inspection of the Kaiser Wilhelm Institute of Physics and noting the absence there of the famous Otto Hahn.[39] By the time the main search group, headed by A.P. Zavenyagin, arrived in Berlin on the evening of May 3, all scientific institutions of interest were already guarded by Soviet forces. As Isaak Kikoin[40] recalled, "Obviously, the Army intelligence had such an intuition."[41]

In his memoirs,[42] Manfred von Ardenne wrote that for the sake of safety, his employees had posted on the Kaiser Wilhelm Institute's entrances signs in Russian[43] announcing that this was a scientific institute. However, the first contact with Soviet authorities occurred not due to that sign, but owing to a colleague. On April 27, Peter Adolf Thiessen, director of the Institute of Physical Chemistry and a friend of von Ardenne, arrived in a Russian armored car together with a major of the Soviet Army. The major had handed to von Ardenne a protective letter or "schutzbrief."[44] That major turned out to be a leading Soviet chemist.[45]

The main search group that arrived on May 3 included Zavenyagin, V.A. Makhnjov[46] (both had the rank of colonel generals of the NKVD), Kikoin, Lev Artsimovich, Yuli Khariton (dressed in NKVD colonel uniforms), and probably others.[47] If any group had arrived in Berlin ahead of this one, it must have included Georgy N. Flerov: as mentioned above, Kurchatov Institute archives contain his letters to I.V. Kurchatov describing his search in Germany.[48] Nevertheless, I.K. Kikoin does not recall any meetings with a vanguard group; his initial inquiries were to army intelligence only.

Surprisingly, Kikoin does not recall any guidance for the trip from Russian foreign intelligence sources:

> On board the plane, when A.P. Zavenyagin for the first time announced to the group its goal, he approached I.K. Kikoin with a question about what German institutes, in principle,

> could be involved in the solution of the problems of interest.[49] Such a list was immediately compiled. First on this list was the Kaiser Wilhelm Institute of Physics, followed by Berlin University, Berlin Technical School, and others.[50]

Upon arrival in Berlin on May 3, the group occupied a whole building in Berlin-Friedrichschagen. The building had armed guards and was big enough to house not only the team members, but also some of the German scientists recovered by the group.[51]

The first place the group went the next day, May 4, was to the Kaiser Wilhelm Institute of Physics. Its most recent director was Werner Heisenberg, the head of the German nuclear weapons program. The institute was empty: most of its equipment had been evacuated to Hoechingen in southern Germany (where it was captured by the US ALSOS team). Owing to some confusion, Ludwig Biweloga, the deputy director of the institute, had never received the expected instructions to destroy the archives and so all documents in the institute fell intact into the hands of the Russian team. In its size and importance, this find was equivalent to German documents that were captured in Strasbourg by the US ALSOS team: it gave a complete description of the German uranium project and the accomplishments of the German team.[52] However, the level of atomic physics in the USSR by that time was, in at least some areas, more advanced than the information given in the German reports:

> Among the captured materials were Heisenberg's calculations of the critical sizes for a nuclear reactor. The corresponding formula—the so-called "three arctangents formula"—worked its way to Laboratory No. 3.[53] It was of little use to us: it was for fairly simple geometry while we were able to do numerically much more complex problems. Nevertheless, A.D. Galanin tried to reproduce it, and initially failed. Only several years later did he manage to prove it.[54]

According to Kikoin, although there was not much to take at the Institute of Physics, "some of the equipment remaining in the Kaiser Institute we had dismantled and sent to Moscow (electric switchboards, instruments). Several very naïve installations for isotope separation we also had sent to Moscow…."[55]

Despite Kikoin's low opinion of the equipment found, other sources state that it was good enough to be installed in a new building at his laboratory in Moscow:

> This building was completely refurbished within several months. The works received the best equipment, both indigenous and obtained under lend-lease from the US. … The laboratory rooms were outfitted with trophy equipment from the German Kaiser [Wilhelm] Institute selected by D.L. Simonenko—an employee of I.K. Kikoin.[56]

However thorough Russian Occupation Forces might have been at the Institute of Physics, they left enough traces for Sam Goudsmit, head of US ALSOS, to figure out the scope of work at the institute when he arrived there in late July after that sector of Berlin had been turned over to the Americans:[57]

> Our chief visit was, of course, to the now empty Kaiser Wilhelm Institute for Physics, where the uranium research had started in 1939. It was one of the few buildings wholly intact. …A US military officer at the site did not understand our interest in this building.
>
> "It's all empty," he said. "Everything, even switches and wiring, has been removed by the Russians. We found some junk which we dumped in the backyard. The sub-basement looks queer. It seems to have been a swimming pool. Go around and take a look."
>
> We inspected the place thoroughly. The backyard "junk" contained various pieces of equipment for nuclear physics as well as blocks of pressed uranium oxide. There were also some notebooks indicating the type of research that had been going on. The sub-basement was the bomb proof bunker laboratory of which the Germans were so proud. It looked as if it had been excellently equipped. The "swimming pool" was the pit in which the pile had been constructed. Metal containers and frames for the arrangement of the uranium cubes were still standing near by.

The Russian search team's next recorded accomplishment was its visit to the laboratory of Manfred von Ardenne in Berlin-Lichterfelds. Von Ardenne writes that on May 10, 1945, he was visited by Col. General Makhnjov accompanied by Kikoin, Artsimovich, Flerov, and Migulin. The visitors praised the research conducted at the laboratory and the complete and intact equipment: a new electronic microscope, registering mass-spectrometer, 60-ton cyclotron, and plasma-ionic isotope separation installation. Right after Makhnjov arrived, armed guards were put around the laboratory. At the end of the conversation, Makhnjov suggested that von Ardenne continue his research in the Soviet Union. Von Ardenne agreed, putting it in writing in a memorandum.[58]

On May 19, von Ardenne had a meeting with Zavenyagin where the two discussed plans for the future.[59] Zavenyagin suggested that von Ardenne establish a physical-technical institute in the Soviet Union. The meeting even progressed to a stage where the two agreed on the topics of future research. Those were:

- investigations of fine structures (electronic microscopy, sweeping electronic microscopy, development of microanalysis by means of electronic-microprobe);
- development of an indicator method for radioactive and stable isotopes (measurements in nuclear physics, magnetic separation of isotopes, and mass-spectrometry); and
- topics of personal interest to von Ardenne.

On May 21, on a trip that he was told was for the purpose of signing the agreement on the creation of the institute, von Ardenne, together with his secretary Elsa Suchland, Alexander Bergengruen, and Wilhelm Menke, flew to the Soviet Union.[60] The first question of a female interpreter—"Haven't you brought your children with you?"—at the Vnukovo airfield in Moscow gave him a hunch about future events. Indeed, 22 days later, the rest of the institute's personnel joined von Ardenne in the "Silver Forest" spa near Moscow. As Gerda Langsdorff, von Ardenne's sister described it, 10 minutes after von Ardenne left for the airport, nearly 100 soldiers came to the laboratory and ordered everybody to pack. The soldiers filled about 750 boxes with equipment. When they ran out of the wood needed to pack large-size pieces (a 60-ton cyclotron, a one-million-volt power supply, a transformer from the highest-voltage electronic microscope), they resourcefully took the timber from a nearby bowling alley.[61]

It is very likely that von Ardenne or Peter Thiessen directed the Russian group to another scientist of interest, Gustav Hertz. Hertz, the head of the Siemens Research Lab and winner of the Nobel Prize in physics in 1925, was of great interest to Kikoin and others because of his pioneering experiments in separation of neon isotopes by gaseous diffusion conducted in 1932. Gustav Hertz had been in close contact with von Ardenne and Peter Thiessen, and they had made a joint decision in 1944 to go to the USSR after the war.[62] Thus, when Heinz Barwich reached Berlin and tried to contact Hertz, he was not really surprised to discover that Hertz had already gone to the Soviet Union (despite the fact that he was nearly 60).[63] Probably, Peter Thiessen and Max Vollmer also had few hesitations in following the path of von Ardenne.

Other important goals of the search team were to secure uranium and uranium experts. Prior to World War II, the German company Auer Gesellschaft (or Auer Company) had used its experience in operations with rare earth metals and its large stock of "waste" uranium to take the lead in uranium production. Trying to avoid the raging war, its chief scientist Nikolaus Riehl[64] and some of his staff moved to a village west of Berlin (in hopes of being occupied by troops from either Great Britain or the United States). However, in mid-May, he was found there by two NKVD "colonels"—Lev Artsimovich and Georgy Flerov—assisted by Riehl's colleague, Karl Gunther Zimmer. As Riehl recalled, "the colonels requested that I join them for a 'few days' of discussions in Berlin. The few days lasted for 10 years."[65]

Riehl was very important to the Russian team. After initial discussions, the Russians did not allow him to return to his family; instead he was put in a guarded house (the headquarters of Zavenyagin's group) in Berlin-Friedrichschagen. After living there for a week, Riehl was taken to the headquarters of the Auer Company in Berlin where the disassembly of all removable plant equipment and apparatus was well underway.[66] Before his departure for the Soviet Union, on two occasions the Russians took Riehl to the Auer factory in Oranienburg north of Berlin where "demounting and loading of everything that was not nailed down or riveted proceeded at full speed."[67] On June 9, 1945, Riehl, his family, and some of his staff were flown to Moscow. The fact that Zavenyagin's emissaries did not release Riehl after their original encounter and were ready to fly his entire group to the Soviet Union (while in von Ardenne's case the personnel arrived by train) shows how highly he was regarded. Moreover, Riehl spoke fluent Russian, having been born in St. Petersburg where his father was an engineer for Siemens.

As Kikoin later recalled of this period, "we fulfilled the task for the Government and invited for work in the

USSR Professors Hertz, Manfred von Ardenne, and Thiessen. Another group of our scientists had engaged Professor Riehl, prominent specialist in uranium metallurgy, and other German scientists."[68]

An Offer They Could Not Decline

While the Soviet official history maintains that all German scientists went to the USSR willingly under contract, the real story is somewhat different. There were "volunteers," but there were many others who went under duress. Germany was full of rumors about atrocities that Russian soldiers were committing against the civilian population: rape, murder, plunders. Could Nikolaus Riehl have slammed the door in the faces of Artsimovich and Flerov when the two came to take him to Berlin in May 1945? He probably could have, but he must also have been aware of the consequences in the form of soldiers coming to arrest him, and all the trouble this could create for him and his family.

The massive deportation that began at 4:15 a.m. on October 21, 1946, left no place for freedom of choice. Every house was identified by authorities in advance, surrounded by soldiers, and then the owners were ordered to pack and proceed to a railway station where they were to board a train to the Soviet Union.

In terms of motives among the "volunteers," there was a very clear divide between the ideologists of German science such as Gustav Hertz and the average scientists and engineers. According to David Holloway, Gustav Hertz felt that he would be unable to compete on a par with American physicists, and he did not want to accept any charity.[69] Thus, he thought that he would be more appreciated and feel more comfortable in the Soviet Union.

In the case of Manfred von Ardenne and Peter Thiessen, they thought that their stay in Russia would be very short, just long enough to assist in setting up new research institutions near Moscow. They did not mind cooperating with the Russians, but the 10-year "sojourn" was certainly not something they could foresee.

For less well-to-do Germans, working for the Russians was really a "flight from hunger."[70] This motive was evident in the actions of the scientists who elected to work for the USSR, and for the United States under Project Paperclip. In fact, the scientists' relatives made comparisons, and often the United States came out behind in this "food race." As an example, the wife of one scientist reprimanded him for agreeing to work for a wage of $6 a day in the United States: "Do you think your adventure would be a success even if you were permitted to stay in the US under such sad conditions, whereas in Germany you could be a manager of a plant? Even with Russians, in fact even in Russia, it would be better than living the way we do."[71]

Many people believed Soviet promises of very short-term employment (one or two years only)[72] and did not mind making a "business trip" to eke out a living. Whether the Germans did not realize the inherent dangers or did not mind facing them, the Soviet authorities never had problems recruiting technical personnel. In general, the scientific community did not show much concern about moral issues. The issue of regular deliveries of food parcels to relatives in Germany was always of paramount importance for German groups in Russia. "Unfortunately, scientists are very much like prostitutes," remarked one German scientist who worked at Sukhumi when he was young, when asked about the motivations.[73]

THE URANIUM STORY

One of Germany's most important contributions to the Soviet bomb program was not scientific know-how, but uranium. The uranium confiscated from Germany greatly accelerated the pace of the Soviet atomic project. Despite all its efforts, the Soviet Union was catastrophically short of uranium for its atomic project. Even after some intensification of mining and the establishment of Mining Combine No. 6 (which reported to the 9th Chief Directorate of the NKVD), I.V. Kurchatov reported that the total amount of uranium available to Laboratory No. 2 by May 1945 was only seven tons of uranium oxide.[74] Heinemann-Grueder[75] has noted that in the spring of 1943, the USSR had bought limited amounts of uranium (10 kg of metallic uranium, and 300 kg of uranium oxide and nitrate) from the United States under the Lend Lease arrangement. Approval of this shipment of uranium to the USSR caused some controversy for US General Leslie Groves in the form of a congressional inquiry after the war, but it did not have a major effect on the Russian program:

> In January of that year [1943], the Lend Lease Administration had received an order from a Russian purchasing agent for over 450 pounds of uranium compounds. Several US companies offered to supply the Russians with this com-

> modity, but uranium had been placed on the War Production Board's critical list. Therefore, the Russian order was, at first, turned down. Groves heard of these negotiations and intervened to honor the Russian request. He reasoned that to refuse would provide the Russians with inferential knowledge of the status of the United States' atomic program. More important, Groves hoped that the uranium shipment could be tracked to its destination, thus identifying the location of the Russian atomic research center.[76]

It was not a secret to the Russians that Germans had large amounts of uranium, including some acquired from the Belgian Congo. Unsatisfied with their "recruitment" mission, Khariton and Kikoin decided to start their own search for that uranium. Kikoin might have been more content if he had been aware that the group operating in Oranienburg had found, despite the heavy bombing of the plant by American aviation, nearly 100 tons of fairly pure uranium oxide with all technical specifications, contractual information, and descriptions of technology.[77] But, evidently, Khariton and Kikoin had departed on their search before they received this news (and this ultimately worked to their benefit). The story of their search was kept in the archives of the Institute of History of Science and Technology in Moscow and was made public only during a conference on the "History of the Soviet Atomic Project" (HISAP), held in 1996.[78]

Doing a random search through Berlin, Khariton and Kikoin came to a plant in the district of Grunau. Before the war, the plant had produced paint, but during the war, it was charged with producing gas masks. By mere chance, Kikoin talked to a young woman who worked as a bookkeeper, and she directed him to a small building where some experimentation with uranium took place. From inspecting the plant's records, Khariton and Kikoin learned that a company named "Rohes" had shipped several hundred tons of uranium, but they could not at first locate the shipment's final destination.

Khariton and Kikoin continued to wander through Germany and, in Potsdam, they learned the name of the head of the Belgian office of Rohes. Through the Soviet military counterintelligence system (SMERSH), Kikoin requested that this person be arrested. Soon thereafter the Rohes manager was brought in front of the physicists. The manager admitted the existence of the uranium and the orders of Rohes to transfer the metal, but he refused to answer any questions that might reveal the actual location of the uranium. Kikoin returned the manager to SMERSH and asked that group to interrogate him. The next morning SMERSH representatives informed Kikoin that the manager had confessed the location: the uranium was stored in a town named Neustadt. There were about 20 towns with that name in Germany; 10 of them were in the Soviet zone of occupation.

After fruitless visits to the first nine towns, Kikoin and Khariton arrived at the last one, Neustadt am Glewe. The main target of their inspection was a leather tanning plant (which was already sending its products to the new owner—the USSR). Going through the plant's warehouse, the physicists saw nothing but barrels of lead used to tan the hides. Discouraged, they went to talk to the chief engineer of the plant. The engineer told Khariton and Kikoin that the company Hoffman und Moltzen had placed some goods in the plant's warehouse and these goods were in the barrels next to the barrels of lead. Upon examination these goods turned out to be the uranium! This discovery led to more than 100 tons of uranium oxide being sent to Moscow.[79]

Overall, the Soviet's acquisition of uranium from Germany may have been the most important factor that accelerated (or made possible at all) the Soviet atomic program. As Kurchatov described it in 1946:

> In the middle of the last year, comrade Beria had sent to Germany a special group of coworkers from Laboratory No. 2 and NKVD headed by comrades Zavenyagin, Makhnjov, and Kikoin to search for uranium and raw materials containing uranium. As a result of their extensive work, the group has found and brought to the USSR 300 tons of uranium oxide and other uranium compounds. That fact has substantially changed the situation not only regarding the uranium-graphite pile, but also regarding all other uranium installations.[80]

This number, 300 tons of uranium oxide and its compounds, agrees with the estimates of findings at Oranienburg and Neustadt am Glewe.[81]

According to Khariton, Kurchatov believed that the uranium found in Germany during May to June 1945 saved the Soviet atomic project one year.[82] The uranium load of the first research reactor "F-1" in the USSR was 46 tons; the first load of uranium in the plutonium production reactor "A" built in the Urals in 1948 was 150 tons. Thus, it would be safe to conclude that the uranium seized in Germany prior to the fall of 1945 was enough to run both reactors at the initial stage. Soviet reactors continued to bear German "birthmarks" even after the initial period: German materials dominated in their fuel. It is clear that Russia benefited from German materials, but it also benefited from the contributions of German scientists.

THE EVOLUTION OF THE GERMAN SCIENTIFIC GROUPS IN RUSSIA

Scholars of atomic history observe two distinct stages in the Soviet atomic project. The first one started in late 1942 when Kurchatov familiarized himself with more than 200 intelligence reports on almost every aspect of the US atomic bomb program and established Laboratory No. 2 of the Academy of Sciences on April 12, 1943. The second started after the nuclear explosions at Hiroshima and Nagasaki and was initiated by the decree of August 20, 1945, creating the Special Committee and the First Chief Directorate (*Pervoje Glavnoje Upravlenije*—PGU).

When the first German groups arrived in the Soviet Union, the atomic program was still in the first stage and thus relatively dormant. During the summer of 1945, the German groups spent their time on initial preparations and recreation. When von Ardenne arrived on May 22, 1945, he was placed at the "Silver Forest" spa near Moscow; his children and other employees arrived by train 22 days later. Riehl's group was placed at the so-called dacha "Osyora," which once had belonged to NKVD chief Yagoda and was later used as a residence for imprisoned Field Marshal Friedrich von Paulus and his officers captured after the German surrender at Stalingrad. According to Riehl's memoirs, their groups were soon joined by Gustav Hertz, Leipzig nuclear physicist Robert Doepel, and distinguished physical chemist Max Vollmer.[83] Several days after Riehl's arrival, Gustav Hertz, Manfred von Ardenne, Max Vollmer and he, along with their wives, were invited by Russians to attend a ballet performance in Bolshoi Theater.[84] Based on the number of foreign guests at the performance, this event must have taken place on the eve or right after the famous Victory Parade in Moscow that was held on June 24, 1945. The Soviets apparently felt there were no urgent tasks for the Germans, and they could afford the luxury of taking them to Moscow to show off to British and American guests.

In the following weeks, the German groups slowly started preparations for future work in the Soviet Union. Von Ardenne reported a meeting at the end of June when he was offered a choice of places for his future institute: the Crimea, the Moscow region, or Georgia.[85] Von Ardenne selected Georgia with its subtropical climate. Rudenko reported a decision on June 24 to send Hertz's group (and von Ardenne's) to Georgia, but he did not mention any freedom of choice.[86]

Riehl and his co-workers started to travel around the country to select a place for the future uranium factory. Riehl traveled through central Russia and the Volga region. His co-worker Gunther Wirths was sent even farther afield to inspect a location near Krasnoyarsk in Siberia.[87]

This summer's tranquility abruptly ended with the bombings of Hiroshima and Nagasaki. Stalin was furious and demanded quick actions:

> Stalin was really enraged, that was the first time during the war that he lost control of himself…. What he perceived was the collapse of his dream of expansion of socialist revolution throughout all Europe, the dream that had seemed so real after the capitulation of Germany and was now invalidated by the "carelessness" of our atomic scientists with Kurchatov at the top.[88]

Soon after creation of the PGU and Special Committee,[89] leaders of the German teams were invited to a high-ranking meeting of a newly established committee. Both Riehl and von Ardenne recall it as the first meeting with Beria. As Riehl described it, "Beria had invited Hertz, Vollmer, von Ardenne and me to visit him in order to become acquainted with us. Each was separately invited into his office where perhaps 20 other individuals, mainly scientists and a minister, were seated."[90] Riehl did not find anything special about the meeting with Beria except that it was his first encounter with Igor Kurchatov.

Von Ardenne, however, described that meeting as a watershed in his work in Russia.[91] In his recollections, among the attendees were Kurchatov, Alikhanov, Galperin, Kikoin, Artsimovich, and Col. Generals Zavenyagin and Makhnjov.[92] Beria told von Ardenne that as the director of a new atomic institute, von Ardenne must build an atomic bomb for the Soviet Union. Von Ardenne realized that if he made the actual bomb, he would never see his homeland again. Thus, von Ardenne suggested to Beria that his institute should work on uranium enrichment, while the Russians build the actual bomb. After half an hour internal discussion, the commission agreed to von Ardenne's proposal and suggested that he select and hire the people he needed for the task.[93]

The meeting with Beria was indeed a watershed for all the German groups. Soon after it, they departed to their new locations where they would spend the next five years. The most significant sites were Institutes "A" and "G" near Sukhumi, NII-9 in Moscow, Laboratory "V" in Obninsk, Plant 12 in Elektrostal, and Laboratory "B" in Sungul.

Von Ardenne and Institute "A"

According to von Ardenne, in late August 1945, Hertz, Vollmer, and he boarded the train that carried them south to Sukhumi, where von Ardenne was to set up his new institute. From the very beginning, von Ardenne asked that Hertz be provided a separate location. Such a location was found seven kilometers from Sukhumi—a sanatorium named Agudzery where an independent Institute "G" was founded for Hertz. Von Ardenne stayed in a place called Sinop, also in a building of a former sanatorium.

Von Ardenne's group arrived at Sukhumi with approximately 20 co-workers, but by the late 1940s, there were almost 300 Germans working at his institute (the total staff size is unknown).[94] Von Ardenne's group was the most active among the German groups in Russia in engaging prisoners of war (POWs) in its work. For instance, Gernot Zippe, who became the head of all centrifuge experimental work in Steenbeck's group at Institute "A," came from the Krasnogorsk camp (the main camp for German POWs who had scientific degrees) near Moscow. After major programs in Institute "A" had ended, however, most of the POWs were transferred back to camps where they received fairly rough treatment.[95]

Soon after the initial unloading and settling, A.P. Zavenyagin paid an inspection visit to Institutes "A" and "G." He saw German teams in disarray, as much of their original equipment never arrived (it went instead to the Kharkov Physical-Technical Institute), and confused about their roles in the new institutes. To improve the morale of the teams, Zavenyagin dispatched to Sukhumi a group of prominent Soviet physicists: Abram Ioffe, Lev Artsimovich, and Sergei Sobolev, who were full members of the Soviet Academy of Sciences, and Isaak Kikoin, who was a corresponding member at the time. Heinz Barwich got the impression that the visit was a sign of goodwill and desire to cooperate with the German groups.[96]

Soon the academicians were followed by Georgy Flerov. The meeting with Flerov was the closest that German teams came to the specifics of atomic bomb design. Von Ardenne recalled that Flerov clearly was looking for new ideas as he described the problem of plutonium predetonation and the requirements for fissile material purity and enrichment.[97] Barwich, in turn, remarked that von Ardenne used the seminar to complain about the quality of the lab equipment.[98]

Serious scientific work began only at the end of 1945. After the organizational period, the topics assigned to Institute "A" (Sinop sanatorium) were:[99]

- electromagnetic separation of uranium isotopes (leader—Manfred von Ardenne);
- techniques for manufacturing porous barriers (leader—Peter Adolf Thiessen); and
- molecular techniques for separation of uranium isotopes (leader—Max Steenbeck).

Based on Heinz Barwich's account, Thiessen must have arrived at Sukhumi some time in November 1945.[100] Thiessen's son Klaus stated that Soviet representatives promised his father they would create a new institute of physical chemistry near Moscow. However, contrary to his expectations, they took him to Sukhumi instead.[101]

Max Steenbeck probably arrived at Sukhumi at the same time as Thiessen. Steenbeck had been a director at Siemens works and in charge of the *Volkssturm*[102] militia at his plant. After his arrest, he was put into a concentration camp in Posnan.[103] After some time, Steenbeck wrote a letter to NKVD headquarters explaining his scientific background, and he was soon taken to Moscow, presumably by Artsimovich.[104] Barwich recalled that Steenbeck was recuperating at the dacha "Opalicha" in November 1945, where he was receiving a cream diet to make him fit again. In Sukhumi, Steenbeck had double duty: he worked with Artsimovich on electromagnetic methods and also led independent research on new isotope separation techniques (using centrifuges).

Artsimovich was a staff member of the Kurchatov Institute in Moscow. Demonstrating Steenbeck's dual role, the personnel records of that institute show that on December 29, 1947, Max Wilhelm Steenbeck was appointed the head of sector 6 in scientific division "A," which was headed by Artsimovich. From April 16, 1949, to February 1, 1950, Steenbeck was listed as the head of Sector 26 of the Thermal Control Instruments Department—OPTK. The OPTK department was headed by Isaak Kikoin, the leader of the Russian uranium enrichment programs, and this transfer meant that during the late 1940s, Steenbeck's work on centrifuges was a higher priority than any other activity.[105] At its largest, Steenbeck's group included from 60 to 100 people, both Germans and Russians.

Gernot Zippe, who was put in charge of experiments in Steenbeck's group, arrived at Sukhumi in the summer of 1946 after his liberation from the Krasnogorsk camp. Zippe had a scientific degree from the Radium Institute in Vienna, thus his selection was natural. At the end of the war, Zippe was conscripted, took part in radar and airplane research, then was captured and put into a camp next to Stalingrad. Later he was transferred to Krasnogorsk.

Von Ardenne noted that his institute also had a radiobiology laboratory that studied the effects of radioactivity on different environments.[106] The laboratory was probably headed by Wilhelm Menke, a biologist who had accompanied von Ardenne at the very beginning.[107]

Von Ardenne drove away some of his personnel. First he demoted his deputy Dr. Stuedel in a conflict over what material to use in an installation for electromagnetic separation of isotopes: Stuedel insisted on glass, while von Ardenne believed it must be metal. This happened in the initial period when von Ardenne was busy with organizational matters and had put Stuedel fully in charge of technical matters. Later Dr. Stuedel worked in Steenbeck's group on fully magnetic suspension of a centrifuge rotor.[108] Another "loss" was Dr. Bernhard, who went with von Ardenne to Leningrad and did not agree with von Ardenne regarding the reasons for their failures there. Bernhard had to transfer to Hertz's group because von Ardenne accused him of "breaking the unity of the German group."[109]

In the late 1940s, when the major work on uranium separation was completed, the number of staff at Institute "A" was reduced. In 1949, von Ardenne with a small group of co-workers went for a year to the Elektrosila plant in Leningrad to implement his ideas. The centrifuge research work was transferred to Leningrad in 1952. In 1949, Thiessen's group moved to Elekrostal to continue at Plant 12 their work on diffusion membranes. Institute "A" later served as the foundation for the Sukhumi Physical-Technical Institute.

Gustav Ludwig Hertz and Institute "G"

Gustav Hertz was probably the most eminent scientist among all the Germans who went to work in the Soviet Union. He received the Nobel Prize in physics in 1925 for his work with James Franck demonstrating the quantized nature of atomic excitation potentials.[110] In 1932, he conducted the first experiments into separation of neon isotopes by the diffusion method. At the time of his transfer to the Soviet Union, he was the head of Siemens Research Laboratory. According to Kikoin, he used Hertz as his model: in 1943, Kikoin went to Sverdlovsk where he tried to repeat Hertz's experiments with a slightly different set-up.[111]

Hertz arrived at Sukhumi together with von Ardenne and was given a separate institute—Institute "G" at Agudzery. Soon after this institute was established, the NKVD organized a trip to Berlin to hire new people for Institute "G." The trip occurred in November 1945.[112] The physical chemist Max Vollmer originally was included in Institute "G," but he soon left for Moscow to work on heavy water production at NII-9 (VNIINM).[113] To Hertz's surprise, the equipment that had been taken from his laboratory in Berlin never arrived in Sukhumi. The Russians explained that Soviet institutes, like the Kharkov Physical-Technical Institute, had a higher priority. Hertz became angry and threatened that the quality of research in his institute would correspond to the equipment provided and thus would be the physics of 1900. The situation soon improved.

The topics assigned to Institute "G" were:[114]

- separation of isotopes by diffusion in a flow of inert gas (leader—Gustav Hertz);
- development of a condensation pump (leader—Muellenpford); and
- development of a theory of stability and control of a diffusion cascade (leader—Heinz Barwich).

By the end of 1945, Hertz and Barwich were given one new team member—a former convict, theoretical physicist Krutkov. Barwich and Krutkov then participated in the NKVD-announced competition for development of a diffusion cascade control theory.

Hertz's position was important enough to the Russians that he could request needed information from Soviet colleagues in other locations. For instance, D.L. Simonenko (who after 1945 was working in Kikoin's department) recalled that:

> at the request of director of Institute "G" Gustav Hertz, the encrypted cable from PGU ordered D.L. Simonenko to inform scientists at Institute "G" on the research into diffusion in the vapor counterflow environments. This information was delivered in the format of a seminar. In his turn, D.L. Simonenko was shown the work of G. Hertz on the cascade of molecular pumps, and the experimental installation of M. Steenbeck used to investigate the issues of stability of a long thin-walled rotor.[115]

Despite von Ardenne's attempts to avoid direct competition with Hertz, in some subject areas, groups from Institute "G" achieved the results that were expected from and assigned to Institute "A." For instance, Werner Schuetze developed an operational mass-spectrometer that was put into production and used at the gaseous diffusion plant in Sverdlovsk-44. Another success was the work of Reinhold Reichmann who, parallel to Peter Thiessen, designed a technique for production of tubular ceramic filters. Reichmann died in 1948 and was posthumously awarded the Stalin Prize. In 1949, Reichmann's group was moved to the Moscow Combine of Hard Alloys (MKTS) to continue its work on diffusion membranes.

A member of Hertz team, Dr. Hans Gerhard Krueger, came to Institute "G" as a POW; he was found in the Krasnogorsk camp.[116] Originally Krueger was a member of Reichmann's team where he worked on the production aspects of "mouthpiece" tubular filters. In 1949, Krueger moved to Laboratory "V" in Obninsk, where he developed techniques for quantitative spectral analysis of reactor materials like beryllium oxide, sodium, boron, lead, and bismuth. In an exception to the usual prohibition, Krueger was allowed to publish papers in Soviet journals during his "stint" in Russia.

After 1950, Hertz moved to Moscow where, together with Werner Schuetze, he started to work on analysis of lithium and purification of tritium.

According to the recollections of a former security escort at Agudzery, before Dr. Muellenpford arrived there for a final cooling-off period, he was the chief of a design bureau in Leningrad.[117] Evidently, this meant that the work of Muellenpford at Institute "G" was successful, and at the end of an initial period in 1949, it was considered important enough to be continued, probably at the Elektrosila plant in Leningrad.

Max Vollmer in NII-9

Max Vollmer came from the Technical Institute in Berlin-Scharlottenburg and spent eight years in the Soviet Union. Originally assigned to Hertz's Institute "G," together with Gustav Richter (a former employee of Hertz in Siemens Research Laboratory), he moved to NII-9 in Moscow to work on the design of an installation for production of heavy water. Vollmer worked with Dr. Victor Bayerl, who earlier had been engaged in oil distillation, and Paul Heulandt, a pioneer Luftwaffe research engineer. The original heavy water assignment came in late January 1946. In March 1946, Vollmer's group was put under the direction of Alexander Mikhailovich Rosen.

In 1946, Vollmer was given a design bureau in NII-9 created specially for the task of heavy water production.[118] Ministry of Atomic Energy (Minatom) archives have a record of Max Vollmer presenting his ideas to the PGU Scientific Council on August 22, 1946.[119]

Vollmer's group designed an installation for heavy water extraction based on the counterflow of ammonia. The installation was constructed at Norilsk. The design work was completed in 1948, and Vollmer and his group were transferred to Zinaida Yershova's group, which worked on plutonium extraction from fission products. Being a physicist, Gustav Richter proposed the idea of using mechanical separation techniques (centrifuges) for extraction of plutonium. Another institute tested the idea, but Richter was never told the results.

The heavy water installation appeared to be inefficient and had no immediate application to atomic bomb production because a decision had already been made to use reactors with graphite as the moderator rather than heavy water. Moreover, the plutonium extraction work came too late. Consequently, Vollmer's group did not produce any significant results, and he did not receive any awards.

Laboratory "V" (Obninsk)

Heinz Pose from Dresden had actually participated in the German uranium project. He accomplished the measurement of a neutron multiplication coefficient in an uranium-moderator system. Soviet officials somehow found him in Germany, and he accepted their invitation to work in the USSR, arriving with his family in February 1946. His future laboratory's location was close to Malojaroslavets, a small city in the Moscow region, which prior to 1945 had been used as a camp for Spanish children.[120] The site was given the code-name "Malojaroslavets-10." After initial discussions, it probably became clear that the future laboratory would be unable to recruit the necessary personnel in Russia. On March 5, 1946, Pose together with NKVD General Kravchenko and two other officers, returned to Germany to hire scientists for his laboratory. He spent six months in Germany procuring equipment and selecting new personnel. Pose signed contracts with his new employees that obligated them to work for him for two years.[121]

Records in Pose's diary[122] indicate that he procured equipment from Siemens, AEG, Zeiss, Schott Jena, and Mansfeld for his laboratory in Obninsk. Pose envisaged a large and extensive structure for his laboratory. He planned to have 16 laboratories in his institute. Originally the plans were to have the following eight laboratories and a nuclear chemistry laboratory:

1. Heinz Pose's lab for nuclear processes;
2. Werner Czulius's lab for uranium machines;
3. Walter Herrmann's lab for special issues of nuclear disintegration;
4. Westmayer's lab for systemic nuclear reactions;
5. Prof. Carl Friedrich Weiss's lab to study natural and artificial radioactivity;
6. Schmidt's lab to study methodologies for nuclear measurements;
7. Prof. Ernst Rexer's lab for applied nuclear physics; and
8. Hans Juergen von Oertzen's lab to study cyclotrons and high voltage.[123]

In 1947, Alexander Leipunski, an Ukrainian academician and scientific liaison of the 9th Chief Directorate of the NKVD since 1946, was given a position in Laboratory "V." (Eventually Leipunski became the scientific director of the Institute of Power and Power Engineering [IPPE] that was founded on the basis of Laboratory "V" in Obninsk.)

Records of the Reactor Section of the Scientific Council of PGU from May 1947 identify the goals for Laboratory "V": "Assign to comrade A.I. Leipunski and Laboratory 'V,' together with Laboratory No. 2, development of reactors with beryllium as a moderator, and submit their practical proposals on this subject in the first half of 1948."[124]

This large-scale work was performed mainly by German scientists. It included research in the following areas:

- physical, mechanical, chemical, and nuclear-physical properties of beryllium and beryllium oxide;
- analysis of chemical contaminants and methods for reducing their amount;
- calculations of the [neutron] multiplying systems with a beryllium moderator;
- preparation and performance of experiments on the transport of neutrons in beryllium environments; and
- development of various instrumentation and techniques needed in research.[125]

Later Heinz Pose's Laboratory "V" was put in charge of "development of a nuclear reactor with gas coolant, 500-MW[126] power, using enriched uranium as its fuel, and beryllium oxide as the neutron moderator."[127] Kruglov also reports that Laboratory "V" was engaged in studies of radiation biology and separation of radioisotopes similar to Laboratory "B" in Sungul.[128]

Until 1948, the site was open, and there were no restrictions on outside trips. But, in 1948, the site was surrounded by a fence, and thereafter members of the colony could leave only with escorts.[129] At this time, two scientists in Pose's group, Dr. Karl-Heinrich Riewe and Dr. Renger, declared a "strike"; they apparently hoped that the NKVD would find nothing else for them to do and send them back to Germany. It is not clear whether their protest was caused by the introduction of the fence or the fact that the two-year contracts they had signed in 1946 had expired and they still were not allowed to return home. Their protest, however, had very grave consequences. Riewe and Renger were imprisoned, and accused of being the ring-leaders of a sabotage.[130] Riewe received a sentence of 25 years in labor camps and essentially disappeared.[131]

In 1952, most of the Germans left Obninsk for Sukhumi where they lived until their return to Germany in 1955. Heinz Pose continued his employment at Laboratory "V" until 1955, when he moved to the Laboratory of Nuclear Problems (now the Joint Institute of Atomic Research) in Dubna. In 1959, Pose returned to Eastern Germany.

Plant 12 (Elektrostal)

Nikolaus Riehl described[132] how, after his arrival in the Soviet Union, he and Zavenyagin spent some time surveying different sites for the future uranium plant. The news of the Hiroshima bombing sped up their search, and the decision was made to place the uranium plant in Elektrostal (near Noginsk, formerly Bogorodsk) using the facilities of a former munitions plant that had been decommissioned at the end of World War II. Ironically, the Bogorodsk factory had been used by the Germans as a munitions factory prior to World War I; in the 1930s, the Germans built steel works at the same place.

All the equipment originally installed at the plant came from Riehl's home company, Auer Gesellschaft:

> All that we had were the materials that we had stripped from our company and other places and brought to the Soviet Union. Even then, much was missing as a result of having been lost or damaged in transport. Missing for example, was a large vacuum oven. I went to Zavenyagin, the Atomic Minister mentioned earlier, and wailed. He determined from a telephone conversation that it had inadvertently been shipped to Krasnoyarsk in mid-Siberia by mistake. A cargo plane was sent, and we retrieved it two days later. On one occasion Zavenyagin visited us in the tiny munitions laboratory where we were first located. He asked the staff of Russian workmen, who encircled him respectfully, from where the various pieces of equipment had come. The response was uniform. Each had been liberated as war tribute from Germany. Just as this exercise was finished, a rat suddenly ran by. He said harshly, "That clearly is ours."[133]

Riehl's group in Elektrostal was relatively small, and only two POWs later joined it. There were 14 German "specialists" in Elektrostal, or, counting all dependents, a total of 31 Germans in town.[134] On one occasion, Riehl tried to improve the living conditions of some of his former colleagues from Berlin-Buch. For example, after Riehl had learned that radiochemist Hans Born and chemist Karl Gunther Zimmer were in the Krasnogorsk camp, he told Zavenyagin that he needed them. The Soviet authorities brought them to Elektrostal, but there was almost no work for them there. To everybody's benefit, Zimmer and Born left Elektrostal for Laboratory "B" in Sungul in December 1947.[135]

Although some sources call it unprecedented,[136] Riehl routinely attended scientific councils of the First Chief Directorate, PGU. Riehl was a member of the "uranium mining and production" section of the PGU council and took part in such decisions as:

- the annual plan for NII-9 for 1949 (on February 22, 1946, i.e., three years in advance, as was typical in the Soviet planned economy);
- conclusions about the technological scheme of Plant 12 (jointly with Academician V.N. Khlopin and Gunther Wirths, on March 14, 1946); and
- briefings on the requirements for purity of chemicals used at Plant 12 (also on March 14, 1946). [137]

As there was no experience with uranium production in the Soviet Union in 1945, Riehl and his group used a technology they had used in Germany. Gunther Wirths took the lead in wet-chemistry processes (i.e., extraction of uranium from the ore), while Dr. Ortmann was in charge of melting and casting operations. There were three important upgrades in the technology. The first involved the replacement of the low-throughput fractional crystallization method with a superior ether technology; this resulted in a substantial increase of the uranium oxide available for the reduction operation and final casting. Riehl learned information about this technology from a Russian translation of Henry D. Smyth's *Atomic Energy for Military Purposes*, published in the United States in August 1945. Two members of Riehl's team, Gunther Wirths and Herbert Thieme, quickly worked out the technology—"we can do anything Americans can."[138] They procured all the equipment for the ether process from the Hermsdorf ceramic factory in Thuringia. The ether process was ready to run by June 1946.[139]

The second improvement involved changes in the reduction process used to make metallic uranium out of powdered uranium oxide. At the suggestion of a scientist from NII-9,[140] Riehl agreed to use uranium tetrafluoride instead of uranium oxide. Because the scientist did not describe the source of his information, Riehl believed that the data were obtained by intelligence. There are, however, dissenting opinions,[141] which state that the first experiments with uranium tetrafluoride were carried out in the laboratory of the State Institute of Rare Metals

(GIREDMET) in 1944 and that the technology was completely ready for implementation in 1946. Gunther Wirths and the chief engineer of the plant, Golovanov, jointly worked out the application of tetrafluoride technology. Their first experiments were conducted in 1946, and the technology was accepted as the main one in 1947.[142]

Both the oxide and tetrafluoride technology used metallic calcium for chemical reduction. For some time, the USSR lacked a plant to produce metallic calcium, and therefore from November 1945 until September 1946,[143] this important metal was carried by planes from the I.G. Farbenindustrie "Nord" factory in the German city of Bitterfeld. During that period, a group of scientists and workers from Plant 12 traveled to the Nord factory to learn the process and to dismantle equipment. In November 1946, the first experimental shop at Elektrostal produced the first portion of calcium.[144] However, local production could not support all the needs of Soviet industry, and the Soviets continued to import German calcium until a large facility was commissioned in 1950.[145]

The third upgrade in technology involved the vacuum oven used for melting and casting uranium. Initially, the group used the vacuum oven brought from Germany. Very soon, however, the Russians provided a much better, high-frequency, induction-type vacuum oven AJaKS from Plant 627 (that plant specialized in the casting of ferrous metals and magnets).[146]

In 1950, the German team was no longer needed in Elektrostal. Production was going smoothly, and Riehl wanted to leave. At first, the PGU leadership offered him the new task of extracting uranium from Estonian shales.[147] This "earth-processing" job did not appeal to Riehl, and he opted to go elsewhere. A.P. Zavenyagin offered Riehl a position in Laboratory "B" at Sungul to work on the problems of radiobiology and the extraction of radioisotopes. After initial inspection of this site, Riehl, along with Ortmann and two POWs on their team—Baroni and Schmidt—left for Sungul in 1950. Herbert Thieme moved to Obninsk.[148]

Laboratory "B" (Sungul/Snezhinsk)

The smallest among all the laboratories in the 9th Directorate of the NKVD, Laboratory "B" in the Urals, received probably the most publicity in the Soviet Union because of Daniil Granin's book *Zubr* published on the wave of *perestroika* in 1987.[149] This book described the life of Nikolai Timofeyev-Resovsky. He had spent nearly 20 years working in the Kaiser Wilhelm Institute in Berlin-Buch, before being arrested in Berlin by Soviet troops sometime in September 1945,[150] put into a labor camp in Kazakhstan, and then taken to Sungul. The book mentioned his work in Sungul with German scientists brought from Berlin-Buch. Laboratory "B" never dealt with production or high-priority technologies. Instead, it appears to have been a place to provide some useful employment for the people who, for various reasons, ended up in the NKVD system. This was true for Nikolaus Riehl, Karl Zimmer, and Hans Born, who elected to leave Elektrostal[151] for Sungul.

Advocates for the leading role of Timofeyev-Resovsky tend to believe that the whole Sungul facility was created for him and his genetics research. This theory is supported by the fact that Timofeyev-Resovsky was among the first "NKVD" scientists brought to Sungul. But given the NKVD's relative neglect of this facility, a more plausible hypothesis is that Karl Zimmer (or someone else) in Germany suggested to the leaders of the Russian atomic project that they set up the radiobiology laboratory.[152] Possibly, Soviet leaders saw a role for the laboratory researching the effects of and protection from the radiological weapons that were under active development until 1954 in the USSR.[153]

Whatever the reasons for establishing this laboratory, work there focused on two areas: radiobiology and radiochemistry. The radiobiology department was headed by Timofeyev-Resovsky, and the radiochemistry department by S.A. Voznesenky, who had come from the Glazov, Udmurtia uranium plant. Owing to their proximity to the Mayak radiochemical (plutonium) plant, scientists in Sungul could work with very high doses of radiation. Veterans of the laboratory also recall large quantities of uranium ore stored in the basement of the laboratory and allegedly brought from Germany.

At its busiest time, Laboratory "B" had nearly 300 employees (that is why Zavenyagin and Riehl referred to it as an "institute"). According to the archives of the city of Snezhinsk (formerly Chelyabinsk-70), which inherited the Sungul laboratory's property, in the early 1950s there were 15 German employees in the laboratory.[154]

Laboratory "B" did not produce any results that won Stalin Prizes or other awards for its scientists. After the

German contingent left the laboratory in 1953, it continued its operations at a much slower pace until it was assimilated into a new nuclear weapons design institute NII-1011 (now known as the Institute of Technical Physics). While the actual products of the lab's radiobiology research are unclear, Kruglov in his account of Minatom history, described the accomplishments of the radiochemistry group: they developed the first technology in the USSR for the isolation of such fission by-products as strontium-90, cesium-137, zirconium-65, and the technology to remove these isotopes from chemical compounds.

ACCOMPLISHMENTS OF THE GERMAN GROUPS

The indicators of "success" for intellectual work depend on the type of society in question. In societies governed by meritocracy, scientific success is measured by the number of publications, the number of citations to those publications, and the awards a scientist receives from peers. In an authoritarian society, accomplishments are often measured by the level of administrative position reached and the government awards received.

Due to security restrictions imposed on their work, German scientists could hardly expect peer review of their progress. Following traditional practices, they requested permission (which was denied) to be published in Soviet journals: the Kurchatov Institute archives contain a Ministry of Interior (MVD) memorandum to Beria asking if German physicists could publish their work under pseudonyms.[155] In such circumstances, the only available measures for success are the government awards received by the scientists.

The most prestigious award in the 1940s and 1950s was the Stalin Prize (later renamed the "State Prize"). It was conferred in three degrees and was associated with a very large financial bonus: the first degree prize carried with it 150,000 rubles, the second degree prize conferred 100,000 rubles, and the third merited 50,000 rubles. The prize was given to honor a prominent technological achievement. Frequently when a certain technology was recognized, the financial bonus had to be split among its several co-creators. With a few exceptions, Stalin Prizes were awarded after a prominent event, such as a successful nuclear test in the case of the atomic program. Thus, the shower of Stalin Prizes in 1949 (after the first atomic test) fell mostly on people who participated in weapons design and plutonium production (including uranium fuel), while the prizes for 1951 (after the second and third tests) included scientists from the enriched uranium program (because the third test used parts made of uranium-235).

The case of Gustav Hertz, Heinz Barwich, and their Russian colleague Prof. Krutkow exemplifies the process. The three worked mostly on uranium diffusion cascades control theory. In late 1951, after the successful test of a uranium-containing bomb, their contribution (the control theory) was awarded a Stalin Prize of the second degree. The 100,000 ruble bonus was split among them as follows: Hertz and Barwich received 40,000 rubles each, while Krutkow received only 20,000 rubles.[156]

The list of Stalin Prize recipients in the atomic program was classified. The full list of recipients of the 1949 Stalin Prize was first published in the HISAP-96 proceedings.[157] The following descriptions of the accomplishments of German scientists rely on the authoritarian society model: they cover the cases where either German scientists occupied leading positions in various projects, or where their work received recognition in the form of the Stalin Prize.

Reactor Design

In the late 1940s, the Soviets considered the development of a beryllium-moderated reactor, the project assigned to Heinz Pose's group in Obninsk, to be very important. They hoped that the neutron multiplication reaction that takes place in beryllium could substantially improve the neutron balance in a reactor and even support an expanding chain reaction. However, the original idea did not live up to expectations. In the course of research at Laboratory "V," it was discovered that the neutron capture in beryllium matches the multiplication of neutrons, meaning the net outcome is zero.[158]

After the initial goal of the atomic project—a successful test in August 1949—was accomplished, the First Chief Directorate (PGU) initiated a review of the feasibility of building nuclear power installations for large ships, submarines, and civilian power production. Laboratory "V" proposed a concept that included a beryllium moderator, helium gas cooling, and a fuel made of enriched uranium. The Scientific Council of PGU, by its decree of November 29, 1949, instructed Laboratory "B" to continue development of helium-cooled reactors.[159]

Because the majority of the German employees left Obninsk in 1952, they were not able to see the results of their original work. Only Heinz Pose continued his work in Obninsk until 1955.

Electromagnetic Installations (Electronic Microscope, Mass Spectrometer, Calutron)

Manfred von Ardenne, before he became involved in atomic physics, was famous in Germany for his development of vacuum tubes for radars and other electromagnetic devices.[160] At the time of Makhnjov's and Kikoin's inspection on May 10, 1945, von Ardenne already had an electronic microscope in his laboratory. Therefore, he was not surprised when in 1946 he was asked to design a new, table-top electronic microscope. He was able to quickly deliver the drawings. In January 1947, the Chief of the Site[161] presented von Ardenne with the State Prize (a purse full of money) for his microscope work.[162]

As mentioned above, sometimes Institute "G," headed by Gustav Hertz, was more successful than von Ardenne in designing instruments. This was the case with the mass spectrometer. Dr. Werner Schuetze from Institute "G" designed a mass spectrometer that received unanimous approval from the Government Commission[163] and was immediately installed at the future gaseous diffusion plant at Sverdlovsk-44. In 1949, Schuetze was awarded a Stalin Prize of the second class for his work.[164]

Ironically, it was Schuetze's mass spectroscope that continued to prove that von Ardenne's efforts in electromagnetic separation (calutron) did not deliver the expected results.[165] While in 1950 von Ardenne was still continuing his research into separation of isotopes at the Elektrosila plant in Leningrad, the SU-20 installation designed by Lev Artsimovich (commissioned in 1948) was successfully enriching uranium. Ultimately, von Ardenne managed to resolve the problems, which had to do with the ion source and confinement of plasma.

At the end of his career in the Soviet Union, von Ardenne received one more award—a Stalin Prize of the first class. He used this money to buy land for his future private institute in East Germany.[166] According to the agreement that von Ardenne had reached with the Soviet authorities soon after his arrival in the Soviet Union, the equipment brought from his laboratory in Berlin-Lichterfelds was not considered a reparation to the USSR and he could take it back (which he successfully did in 1954).

Heavy Water Installations

The story of heavy water production in the USSR is one of the few in the atomic project where agency rivalry was especially visible and counterproductive. The clash between the NKVD and the Ministry of Chemical Industry is reflected even in Minatom's official history. According to Kruglov and Rosen, German involvement in the heavy water projects began in 1946, when Max Vollmer proposed a new method of heavy water production and was transferred from Institute "G" to NII-9 in Moscow. By then, the USSR already had a few facilities doing the job. One, situated in Central Asia, in Chirchik, Uzbekistan, produced heavy water by means of electrolysis in cascades; the other, in Tula, used hydrosulfates (e.g., H_2S). The Chirchik facility had existed prior to 1945 and was totally indigenous. The facility in Tula, with a high degree of certainty, can be attributed to the Germans' work. A 1955 US Central Intelligence Agency (CIA) report gave the following account:

> 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 H_2S-H_2O 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 H_2S-H_2O exchange plant is unknown.[167]

The CIA's statement that the evacuation on October 21, 1946, followed the successful completion of the design was probably inaccurate. That day was the date of the largest enforced deportation of scientists, mostly working on the Soviet-funded rocket projects, from East Germany to the USSR.[168]

Vollmer's involvement followed a parallel track. He happened to propose deuterium separation using ammonia rectification. The same process had been independently proposed by Adrian Rosen approximately half a year earlier in the State Institute of Nitrogen Industry—GIAP.[169] Through the efforts of Zavenyagin, Max Vollmer and Victor Karl Bayerl were transferred to Moscow to work with Rosen. Because few people were available to work, the progress was slow. Finally, Zavenyagin prepared a governmental order, approved on March 18, 1946,[170] which transferred the heavy water project to NII-9—an NKVD institute with more chemists. This move angered Mikhail Pervukhin, the minister of chemical industry, who forbade construction of the heavy water plant at any site belonging to the Ministry of Chemical Industry. This put a stop to plans to erect the plant in the Moscow region, at the Novomoskovsk nitrogen combine.

Forced to identify another location, the only suitable site that Zavenyagin could find for the heavy water facility was in Norilsk, at a nickel mining combine where he once worked. The single advantage of this remote location was the availability of cold water even in summer. Because carrying clean liquid ammonia by trains was prohibitively costly, the facility's designers decided to use the locally generated ammonia that was a by-product of coke production. This decision proved to be fatal.

When, in the fall of 1952, the ammonia rectification unit was finally phased in after delays,[171] it was discovered that contaminated ammonia resulted in a massive generation of foam. This foam obstructed the normal flow of liquids in the isotope exchange unit. A group of consultants was flown in to solve the problem. The group included Igor Petrjanov-Sokolov, the leading Soviet chemist on heavy water issues, and Max Vollmer, among others. After several months, the group was able to improve the performance of the facility and return home. However, the installation in Norilsk turned out to be a worthless investment: its operation was irregular and expensive. In 1962, seven years after the Germans departed, an order was made to shut down and disassemble the facility.[172]

Membranes for Gaseous Diffusion Machines

The Soviet Union's research into isotope separation methods experienced some abrupt shifts, in part due to information gained through foreign intelligence. In the late 1930s and early 1940s, Soviet scientists seemed to support the use of centrifuge separation. Fritz Lange, a German émigré, worked at the Kharkov Physical-Technical Institute on centrifuge separation in 1940. Yuli Khariton also was among the advocates of the centrifuge approach.[173]

However, in 1942, after the Soviet government had asked Igor Kurchatov to write a review of intelligence materials on the US atomic project, the Soviets began to emphasize gaseous diffusion technology. They trusted the technology because it worked in the United States. In addition, they had very detailed information (including blueprints of the Oak Ridge plant) on gaseous diffusion technology acquired by Soviet intelligence.[174]

In gaseous diffusion, uranium in the form of a gas (uranium hexaflouride, UF_6) is passed through a series of porous membrane barriers. Because the fissile isotope uranium-235 is slightly lighter than uranium-238, it passes more rapidly through the membrane. After a sufficiently large number of passes, the uranium can be enriched to a high enough percentage of uranium-235 to be used in a weapon. One of the important problems in the design of a gaseous diffusion machine is the membrane. Gaseous diffusion will work only in a set-up where the size of a membrane pore is commensurate to (or is only a fraction of) the mean free path (the average distance a molecule moves without hitting another molecule) of the isotope of interest. The mean free path depends on the gas pressure and increases as the pressure grows smaller. Thus, to make diffusion work when membranes cannot be made with small enough pores, a machine must be designed that will operate at lower gas pressures. This requires the compressors to work harder to pump the same amount of material (gas volume is inversely proportional to pressure). Therefore, the smaller the pore size is, the higher the gas pressure is, and the more efficient is the gaseous diffusion plant.

German scientists substantially contributed to the Soviet's efforts to design a membrane for gaseous diffusion technology. In early 1946, Laboratory No. 2 (now the Kurchatov Institute) issued a classified request for a proposal to design a *flat* membrane.[175] Fifteen organizations submitted their designs. The Moscow Combine of Hard Alloys (MKTS) won the competition. In their design, nickel powder was poured into a mold atop a vibrating table. After some vibration to compact the powder and level its surface, the tray was baked in an oven until the powder was partially melted and formed a ceramic-like porous plate. After the addition of some strengthening elements, the plate was turned into a membrane ready for use. After tests, however, it was found that nearly 10 percent of all pores in such a membrane would let any molecule go through (i.e., were too big to perform the separation function), and that the operating pressure of such membranes was 20 to 30 millimeters (mm) of mercury (Hg) column, a feature that would lead to large losses of electric power, a waste of compressor power, and extremely high requirements on the air-tightness of the machinery.

German groups in Institutes "A" and "G" joined the competition some time in 1947 and started to work on designs for tubular membranes that were expected to be more efficient. Peter Thiessen's group in Institute "A" focused on a lattice-type filter: a nickel lattice with 10,000 holes per square centimeter was covered by fine-grain nickel carbonyl and baked in an oven. Afterwards, the mesh was bent and welded into tubes. It was discovered that Soviet industry at the time was unable to duct nickel wire finely enough to make the required lattice. For some time the necessary wire and the lattice were ordered from Berlin.[176] Although Peter Thiessen later received a Stalin Prize for his work in the area of gaseous diffusion, it is unlikely that he personally invented the membrane. Rudenko and Kruglov mention that a Dr. Schtuze received a Stalin Prize in 1948 for design of a diffusion membrane.[177]

Both German and Russian sources state that Thiessen's design had an unpredictable nature and was more appropriate for a lab bench than mass production; Zavenyagin derided his process as "artisanship."[178] Nickel carbonyl powder was manually sprayed on flat lattices and then these were pressed by rolls. Given the huge surface area of diffusion membranes, manual spraying was a real drawback. The need to do it manually disappeared only in 1952 when a way to automate this tedious process was found.[179]

The German group in Institute "G" was headed by a former pharmacist, Reinhold Reichmann. He was working on a mouthpiece type of membrane that could be extruded and would require no welding. Reichmann first experimented with copper and silver, then with nickel. Reichmann's solution clearly had its roots in his previous occupation—he mixed nickel with dimethylgloxin and then with a mild pain killer, clove pinks oil.[180] The mixture was then extruded and baked. Reichmann died soon after his discovery, and a Stalin Prize was awarded to him posthumously in 1948.[181]

Both types of tubular filters developed by the German teams, after tests in Laboratory No. 2, were approved for use in second-generation diffusion machines.[182] It was decided to send Thiessen's group to Plant No. 12 in Elektrostal, and Reichmann's group (headed then by V.N. Yeremin and his wife) to the MKTS. Beginning in 1949, these two plants started to manufacture all filters for diffusion machines.

The new filters could be used at pressures up to 50 mm of Hg column. This meant that—without any changes in the gaseous diffusion plant's design—its capacity could be increased by a factor of 2 or 2.5, provided its compressors could work at higher pressures. Tubular filters were first used in the second-generation diffusion machines that formed the basis of the second diffusion plant, the D-3 plant at Sverdlovsk-44.[183] In 1953, Zavenyagin decided that the production of diffusion filters should be transferred to the Sverdlovsk-44 site in the Urals.[184]

Activating the Diffusion Plant

At the NKVD's instruction, in late 1945 Hertz and his colleagues in Institute "G" started development of a control theory for diffusion cascades. Cascades connect a large number of individual diffusion stages in which the isotope of interest is gradually separated from the initial feed gas. Hertz and Barwich were calculating requirements for pumps in the diffusion cascades, and also acceptable losses of uranium hexaflouride due to corrosion in the cascades. Also, from theoretical calculations they determined percolation (i.e., a statistical description of a particle's path through a filter) in a membrane and the diameter of pores in a filter. In 1946, Barwich worked out a theory of natural stability of separation cascades that led to a reduction in the number of compressors in the design of the enrichment plant and a reduction in the time the material stayed inside the plant.

In a diffusion plant, because the depleted gas still contains some uranium-235, it is not discarded but is rather fed back into the previous cascade. The enrichment level and gas pressure of the depleted material must be the same as that of the incoming gas in the previous enrichment cascade. If the pressure differentials between cascades are set wrong, the whole flow may invert its direction and no enriched product will reach the output. The process control problem had to be solved theoretically first. The Soviets had engaged their best mathematicians and theoreticians to solve this problem (among them was Academician S.L. Sobolev).

In 1948, the first gaseous diffusion plant in the USSR, D-1, was put into operation. It contained 6,200 diffusion machines installed in 56 enrichment cascades.[185] The D-1 plant had problems. [186] Ball-bearings in compressors were made too precisely, without proper tolerances for thermal expansion, and quickly failed. Infusions of uranium hexafluoride into the plant were not leading to any product at the output. The situation was catastrophic. Among the luminaries brought in to help solve the problem in October 1948 were Gustav Hertz, Heinz Barwich, and Peter Thiessen.[187] Because they did not know the official name of the secret facility, the trio christened it “Kefirstadt” (now Sverdlovsk-44 or Novouralsk) after the “kefir” milk drink that they were given there every day for more than a month.[188]

The D-1 plant’s greatest problem was corrosion. In the presence of water, uranium hexafluoride turned into tetrafluoride and stuck to the surfaces of the cascades as a powder. To fix this, all workshops were put under air hoods where they were supplied with dehumidified air. Also, nearly 5,000 leaky compressors were replaced in the plant. Peter Thiessen, with his co-worker from Sukhumi Prof. Karzhavin, proposed using a heated fluorine-air mixture to passivate (i.e., give a protective coating to) all internal surfaces of the cascades to reduce future corrosion by tetrafluoride.[189]

Even after these problems were solved, the plant was unable to deliver the expected product, 90-percent enriched uranium-235. The maximum enrichment that could be reached even after two full runs through the cascades was 75 percent. The further enrichment to 90 percent could only be reached by using an SU-20 calutron developed by Artsimovich.[190]

The first awards for uranium enrichment technologies were presented in 1951 after the successful tests of a nuclear bomb containing uranium (the earlier Soviet test in 1949 involved a plutonium bomb).[191] Thiessen was awarded a first class Stalin Prize, while Hertz, Barwich, and their Russian colleague Krutkow received a second class award.[192]

Production of Metallic Uranium

As noted earlier, the real boost to the Soviet atomic project came from German uranium stocks and the scientists who could work with them. According to Kruglov, almost two years after Elektrostal began its operations, it was still using the uranium brought in 1945 from Germany by the ALSOS search teams:

> The raw uranium—unprocessed uranium powder—that the first uranium blocks were made of was the trophy one. In the first half of 1947, a workshop for processing of imported rich uranium ores was put into operation at Plant No. 12. The lower-content national ores starting from 1947 were processed at Plant No. 906 in Dneprodzerdzhinsk.[193]

Another indicator of how long Riehl’s group used German uranium is the case of boron contamination[194] discovered in uranium blocks in November 1946. Contamination of uranium at Plant No. 12 happened all the time: uranium attracted boron from the enamel coatings of process vessels as well as from the graphite cladding of the molds where it was cast. In November 1946, the boron concentration exceeded the limits by a factor of nearly 100. Everything was under investigation: German calcium, graphite crucibles for uranium melting, and graphite molds for casting. It appeared that the culprit was the Moscow Graphite Plant, which had shipped a batch of cladding made of non-chlorinated graphite to Plant No. 12.[195] Riehl, however, knowing that German uranium was being processed, saw a different solution:

> A possible solution to the excess boron finally occurred to me and eased the mood. I remembered that the uranium oxide that we had produced at Auer Company had been stored in a shed that previously contained boric acid, which was required in the production of luminescent materials. Back in Germany, the zealously active service officers of the NKVD had scraped together all the uranium oxide on the floor of the shed along with some dirt.[196]

The work of Nikolaus Riehl and his colleagues at Elektrostal, especially in 1945 and 1946, had a direct impact on the production of the first plutonium bomb.

Therefore, it is not surprising that he received one of the first batch of Stalin Prizes granted in November 1949. The only two employees of Plant No. 12 who were awarded the title "Hero of the Socialist Labor" were Nikolaus Riehl and the director of the plant, Anatoly N. Kallistov.[197] Both also received first class Stalin Prizes. Gunther Wirths, Herbert Thieme, and Yuri Golovanov, the chief engineer of the plant, received second class Stalin Prizes.[198] Wirths and Thieme might have received their awards for their work in implementation of the ether process.[199] Overall, the German scientists at Elektrostal acted primarily as scientific advisors. The plant grew quickly and by 1950 had nearly 10,000 workers, so there was no need for Germans to actually handle the bomb material. Instead they developed ideas to improve the technological process.

The Centrifuge Story

Soviet scientists had originally sought to develop centrifuge technology for enrichment but then abandoned it in favor of gaseous diffusion. Fritz Lange conducted the first experiments with centrifuges in 1940. According to the records of Daniil Simonenko, a member of Kikoin's group, Lange's centrifuge was a mammoth structure:

> The centrifuge rotor was a steel cylinder 250 mm in diameter, 600-mm long, with walls 5-mm thick…. Along the rotor axis there was a big shaft (70 mm in diameter) which was installed horizontally, in massive columns on special bearings…. When assembled, the centrifuge was a bulky structure with all parts weighing slightly less than a ton.[200]

Because the future applications for Lange's centrifuge were unclear, all centrifuge research was suspended. However, centrifuge work was revived after Max Steenbeck at Sinop demonstrated the feasibility of a light-weight, inexpensive centrifuge. According to Gernot Zippe,[201] who joined Steenbeck's group in the summer of 1946 from the Krasnogorsk POW camp, the first experiments with centrifuges began at the end of 1946. Steenbeck's group had more than 60 staff members. Steenbeck developed all the theoretical background, while Zippe became the head of experimentation.

At first, Steenbeck investigated the feasibility of centrifuge enrichment using rubber hoses instead of foil-wound tubes, and worked on the theory of gas flow inside a rotating cylinder. Based on his findings, Steenbeck proposed to the PGU Scientific Council in Moscow building an apparatus for enriching uranium to weapons grade in one step. He envisaged the apparatus as a 10-meter long, thin-walled centrifuge; this concept was called a "rotating chimney."[202] The Scientific Council agreed to try Steenbeck's approach, probably in early 1947.[203]

Having started with a two-meter-long cylinder, Steenbeck and Zippe eventually reduced the design of the tube down to 25-cm long, 25-mm in diameter, with a wall thickness of only 0.15 mm. Zippe recalled a visit of a professor from Moscow who came to check their progress.[204] Based on other accounts, this professor could have been Daniil Simonenko, Isaak Kikoin's deputy:

> By March 1947 approximately 25 samples of enriched uranium hexafluoride were obtained. Measurement of isotopic composition of samples was performed at Institutes "A" and "G" where D.L. Simonenko was sent on a business trip…. D.L. Simonenko was shown the work of G. Hertz on making a cascade of molecular pumps, and the experimental installation of M. Steenbeck used in investigations of the stability of a long thin-walled rotor. The installation already had needle support[205] at the bottom. The idea to use such support, according to M. Steenbeck, emerged during design of an instrument for measurement of the degree of separation in the electromagnetic enrichment method.[206]

After a successful demonstration, the concept received further support. The expectations rose, as did the pressure on the team, and "on March 1, 1948, Steenbeck came back from Moscow with the message: if we cannot show a successful experiment on uranium separation before April 1, the centrifuge development would be finished."[207]

To meet this stringent deadline, the group pursued two solutions. The first, suggested by Zippe, consisted of making the centrifuge as simple as possible; the second, pursued by Dr. Steudel, was a technique for magnetic suspension of the spinning rotor. The operation of both designs was successfully demonstrated on March 21, 1948.[208] The project was saved.

When, in 1950, Steenbeck heard from Lev Artsimovich about the problems with the gaseous diffusion plant and its inability to reach the required 90-percent enrichment, "Steenbeck decided to write directly to the boss of the Soviet nuclear enterprise, Marshal Beria. He proposed to build a centrifuge enrichment factory on top of a diffusion plant to get the necessary enrichment."[209] The letter remained unanswered, so Steenbeck wrote a second one. Then he "was summoned to an audience." His meeting with Beria must have taken place in the middle of 1950, as Steenbeck requested that his people be given contracts identifying the end date for their work. In the case of Gernot Zippe, his contract was signed on November 29, 1950.[210]

In 1952, the centrifuge technology was developed enough to be transferred to Elektrosila, the serial production plant in Leningrad. This plant and its design bureau were already involved in manufacturing gaseous diffusion machines. According to Sinjov,[211] the German design appeared to be impractical. The centrifuge was supercritical, measured three meters in length, consisted of nine sections, and used the thermal mechanism of counterflow (evaporation/condensation). Sinjov says that his team made all the remaining design refinements. However, Zippe reports that he was ordered to Leningrad in the second half of 1952.[212] With his Soviet colleagues, Zippe experimented for two more years with new short centrifuges until his transfer to a transition camp in Kiev for a two-year stay.[213] The first prototype centrifuge plant was built in Sverdlovsk-44 in 1957, while the full-scale facility was commissioned in the 1960s.

The sequel of this story was a nightmare for Sinjov because Zippe allegedly stole the credit for his work on the centrifuge. In 1956, after his return to Germany, Zippe continued his work on the mechanics of high-speed rotations (he worked on spindles for the textile industry that, to a certain extent, also were fast spinning rotors). After attending a conference on centrifuge enrichment in 1957, he realized the advanced nature of the results that Steenbeck's group had reached in Russia, and filed for a patent covering the short-bowl centrifuge technology. He acted with the consent of the Soviet representative to the International Atomic Energy Agency in Vienna, V.S. Yemeljanov.[214] Having received the news from Europe, American scientists mounted a campaign to get the funds to invite Zippe to repeat his Soviet short-bowl experiments at the University of Virginia.[215] For various reasons, on August 1, 1960, at the request of the United States, all centrifuge research in Germany became classified.[216] In his 1991 book, Sinjov angrily accused Zippe of borrowing the ideas and explained that the Soviets did not protest the centrifuge patent in order to "preserve in secrecy for 30 years the existence in the USSR of a technology superior to anything else."[217]

THE CADRE OR THE MATERIAL?

Speaking to graduates of the Military Academy in 1938, Joseph Stalin coined a phrase "Cadres decide everything." This phrase epitomized the epoch when the Soviets believed that through an act of will, the Soviet people could overcome any technological obstacles or lack of resources. Reflecting this bias, when evaluating the contribution of German scientists to the Soviet atomic project, Soviet officials claimed that the USSR used only a few, mostly second-rate scientists and, therefore, the overall German contribution was insignificant.[218]

The above descriptions, however, indicate that those officials, intentionally or not, ignored the importance of material confiscated from satellite states. As discussed above, the uranium the USSR acquired from Germany in 1945 alone was enough to power its first experimental reactor F-1 (which had an uranium fuel load of 50 tons and went critical on December 25, 1946) and the first plutonium-generating reactor "A" (which had an uranium fuel load of 150 tons and went critical on June 10, 1948). German uranium alone was extremely important to the Soviet project.

There were other benefits to the Soviet bomb project, smaller in size but still very important. In 1945, the USSR lacked the technologies and materials crucial for developing an atomic bomb:

> The previous two years [prior to 1945] the experimentalists were literally living as paupers. Even the simplest milli-ammeter was moved from one laboratory to another, and had to be borrowed for a day or two; a vacuum pump was a rare treasure; due to the absence of furniture, people were sitting on tarp-covered boxes left over from the rare deliveries of equipment at the makeshift nailed tables they made themselves. The war trophies allowed us to begin full-fledged experiments. The library received complete sets of much-needed scientific magazines, compendiums, and books.[219]

The Soviet atomic project rested not only on steel and uranium. Instruments and electronics also were essential. Practically every electronic component that the Soviet Union used for nearly five years after 1945 came from Germany. A physicist from the Institute of Physical Chemistry who led the development of instrumentation for atomic tests recalled:

> In 1947-1949 there were very few indigenous radio components existing in the country. Therefore, the instruments manufactured for the first test of the atomic bomb were mainly assembled from the trophy radio components: resistors, capacitors, relays, motors, transformer iron; some vacuum tubes were manufactured in Germany. Even wires, vinyl tubes, and assembly fixtures that we used were German. [The voltage converter] for the ISV instrument, "Exacta" cameras for photographing images from oscilloscopes were also of German production. …
>
> With time the lab started to receive instrumentation, mostly of non-Russian make. Thus, the measurement bridges ("Brown "), vacuum tube-based voltmeters ("Jackson"), and high-voltage electrostatic voltmeters were American, the voltammeters ("multizets")—German, the electrostatic voltmeters ("Zierold")—Czech. The group of P.V. Kevlishvili received the high-end, according to standards of the time, cathode ray tube oscilloscope "Dumont-248." The Russian-made instruments started to arrive in the 1950s.[220]

According to the officers at the Semipalatinsk test site, even the programmable control board at the site was built entirely of German components and "had two hundred relays manufactured at a V-2 missile factory."[221]

The Soviet Union even lacked electro-mechanical calculators (i.e., primitive computers) before it imported them in large numbers from Germany as a replacement for mechanical calculators and slide rules. The two most popular models were "Mercedes" and "Rheinmetall Borsig." Their names can be found almost in every description of the atomic calculations of the late 1940s and early 1950s.[222] Table 1 summarizes some of the most visible German material contributions.

In addition to the clearly identifiable foreign "endowments," there were several cases of indirect German influence. Because the involvement of German scientists and industry in projects in the USSR was so widespread, oftentimes managers of the atomic program probably did not recognize the origin of the contributions. Aviation, electronics, optics, shipbuilding, all benefited from German contacts and, in turn, worked for the overall benefit of the Soviet Union.

The transfer of German technology certainly accelerated the progress of the Soviet atomic bomb program. However, even without the input of German material the Soviet Union would have become a nuclear power. It would have continued its practice of buying turn-key technologies from the West (not only from Germany, but also from the United States) as it had done in the 1930s. Even after May 1945, when the Soviet push for global dominance became particularly clear, Laboratory No. 2 managed to buy different instrumentation from the United States for a total of $250,000.[223] Using such a procurement path, the Soviets would have taken longer to develop a bomb (probably within the US intelligence community's estimate of 10 years), but they would have been successful.

The Limits on German Scientific Contributions

While the Germans aided the Soviet bomb program, they did not design the Soviet bomb. Instead, the Soviets followed US blueprints. Even Petr Kapitsa, who in 1945 advocated an indigenous approach in weapons development, was not able to win over the government.[224] The Soviets had US drawings for technologies that were known to have worked, and their goal was to duplicate those, potentially inefficient, designs. Therefore, it is safe to conclude that the first Soviet atom bomb never could have been the "German bomb," because it already was the "American bomb."

German participation in the Russian bomb program in the 1940s was also limited by security considerations and domestic politics. During the late 1940s, the Soviets curtailed the pro-Western attitudes fostered by alliances during World War II and began a new governmental campaign targeted against contacts with the Western world. This campaign of trials and "purges" was championed by Andrei Zhdanov, a leading Soviet government official and Stalin's son-in-law at the time, and was targeted against "ideological servility towards the bourgeois West."

Prior to the campaign, German science and technology had been widely recognized and respected. In the

Table 1: German Materials Used in the Soviet Atomic Project

RAW URANIUM MINING	
Mills for uranium mines	Were acquired in competition with other ministries, specifically, the Ministry of Construction which wanted to use the mills for cement production.
URANIUM FUEL PRODUCTION	
Uranium ore	For nearly two years German and Czech ores were the only sources Russians had; the imported uranium was enough to jump-start the reactor industry and defy US assessments that the USSR would need 10 years to make its first bomb.
Ceramic equipment for ether-based extraction	Was bought from a plant in Thuringia; no Russian manufacturing capability existed.
Equipment for fractional extraction	Copied and dismantled equipment taken from Nord Works of I.G. Farbenindustrie.
Metallic calcium for reduction melting	Was bought from I.G. Farbenindustrie plant at Bitterfeld.
URANIUM ENRICHMENT BY DIFFUSION	
Nickel wire for filters	Until 1950, this wire was entirely German-made.
INSTRUMENTATION FOR WEAPONS DESIGN	
Oscilloscopes	In the three years after 1945, German oscilloscopes were dominant in Soviet laboratories.
Cameras	The high-speed cameras for imaging of atomic explosion evolution were replicas of US “Fortax” cameras and Zeiss cameras.
Electronic components	The Russians inherited and ran at full capacity the V-2 components factories.

early 1940s, Georgy Flerov, a co-worker of Kurchatov, thought Germany would be the first country to develop an atomic bomb:

> At that time it seemed that if anybody would succeed in making a nuclear bomb, it would not be the Americans, not the British, not the French, but the Germans. They had excellent chemistry and technology for production of metallic uranium; they were doing experiments on separating isotopes by centrifuges and had brilliant physicists. Moreover, the Germans had heavy water and stocks of uranium. And the predominant feeling was that the Germans could build this thing.[225]

Things started to change after 1947. Although German scientists did not directly experience the new attitudes, they were able to see some signs of them. Riehl described a visit Beria paid to Elektrostal in 1948 that was prompted by a perceived preference being given to the German scientists:

> The Soviet scientists, particularly those in the Institutes of the Academy of Sciences, were accusing Zavenyagin of preferring to obtain advice from the Germans instead of from them. This reaction was not unreasonable, for there were excellent scientists in their organizations. This complaint made it possible for Zavenyagin to arrange to show Beria that he had a very productive German group under his control and this justified his actions.[226]

Under the new political guidelines, what started as "an attitude of admiration for German technological achievements coupled with a desire to learn, which is the expression of one of the basic themes of Russian history" was followed by "a rejection of Western influence and an insistence on Russian self-sufficiency and even pre-eminence which is, unfortunately, an equally basic historic theme."[227]

In such a situation, even if the German scientists could, through their knowledge and skills, have made the bomb, they were not allowed to build it. Their role always remained "on tap, not on top."

CONCLUSION

It is hard to fully explore the German contributions to the Soviet atomic project without performing a detailed examination of the whole Soviet atom bomb effort. What is clear from the available evidence is that German involvement had several very important implications for the Soviet Union and the world:

- German resources jump-started the Soviet program and saved up to five years of time. If not for this time, the USSR could hardly have been as aggressive as it was in seeking global dominance. Very likely, the USSR could not have wielded its influence in Asia, and the whole course of regional history (e.g., the Korean War) would have been different.
- German scientists, although not always of the highest caliber, were diligent in doing their jobs and provided important on-site training for their Soviet colleagues. Many former workers of Laboratory "V" (Obninsk) and Laboratory "B" recalled the educational benefits of working hand-in-hand with the more experienced and knowledgeable German scientists.
- Participation of German scientists in the development of new uranium enrichment methods revolutionized the whole uranium fuel industry. The work of Max Steenbeck and Gernot Zippe shaped the European and Japanese enrichment plants, and was used by several later proliferators (e.g., Pakistan and Iraq) as well.

In sum, although the Soviets would have eventually developed nuclear weapons on their own, they benefited considerably from German technology, expertise, and raw materials. The German contributions undoubtedly accelerated the program by several years and enhanced the Soviets' stature on the world stage. An accurate and complete history of the Soviet bomb program must acknowledge the importance of the Germans' contribution.

[1] I wish to express my gratitude to Professor Wolf Haefele for opening the whole subject and guiding me through it; Dr. William Potter for encouraging me to persevere; Dr. Gernot Zippe for providing documents and personal accounts; Dr. Mark Walker for offering the generous opportunity to familiarize myself with his unpublished interviews; Dr. Klaus Thiessen for candid discussions and patience; Dr. Eberhard Born for personal exposure to the history; Dr. Frederick Seitz for generous support; and many others in the United States who lent their friendly assistance.

[2] See Clarence G. Lasby, *Project Paperclip. German Scientists and the Cold War* (New York: Atheneum Press, 1971); and Ulrich Albrecht, Andreas Heinemann-Gruder, and Arend Wellmann, *Die Spezialisten: Deutsche Naturwissenschaftler und Techniker in der Sowjetunion nach 1945 (Specialists: German Scientists and Technicians in the Soviet Union after 1945)*, (Berlin: Dietz Verlag, 1992).

[3] Lasby, *Project Paperclip*, p. 6.

[4] During his work in the USSR in 1945-1954, Max Steenbeck also worked on electromagnetic enrichment of uranium, but his ideas and designs of centrifuges proved to be particularly groundbreaking.

[5] A. K. Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR* (*How the Atomic Industry of the USSR Was Created*) (Moscow: TsNIIAtominform, 1994), p. 192.

[6] Information about the US intelligence assessment only recently became available. See Gregory W. Pedlow and Donald E. Welzenbach, *The CIA and the U-2 Program, 1954-1974* (US Central Intelligence Agency, Center for the Study of Intelligence, 1998), p. 2; and *Section 73 (Atomic Energy) NIS 26 (USSR)* (CIA document, published March 20, 1955, declassified and released May 19, 1998), available by a title search at <www.foia.ucia.gov>.

[7] Samuel Goudsmit, *ALSOS* (Woodbury, New York: American Institute of Physics, 1996), p. 34.

[8] V. Khapayev and E. Gudkov state that Soviet intelligence knew of the atomic developments in Germany, and also knew these developments (like manufacturing of uranium separation centrifuges) were thwarted by bombings and the rapid advance of the Red Army. See V. Khapayev and E. Gudkov, "Secrets of the Caucasus Gem: German Specialists—Participants of the Build-up of the National Atomic Industry," *Atompressa* 12 (1993).

[9] Full text of the letter published in Raisa V. Kuznetsova and Natalya Seleznjova, "Trevozhny Kolokol Georgija Flerov" ("The Alarm Bell of Georgy Flerov"), *History of Atomic Project* 13 (Moscow: Kurchatov Institute, 1998), p. 82.

[10] Ibid., pp. 85-86.

[11] *Alsos* is the Greek word for "grove"; though this was probably coincidental, the mission's name came to be seen as a reference to General Leslie Groves, head of the Manhattan Project.

[12] Goudsmit, *ALSOS*, p. 15.

[13] Vassily Yershov, "Confiscation and Plunder by the Army of Occupation," in Robert Slusser, ed., *Soviet Economic Policy in Postwar Germany: A Collection of Papers by Former Soviet Officials* (New York: Research Program on the USSR, 1953), p. 1.

[14] In 1945, Nikolai Dollezhal was the director at the Chemical Machine Building Institute. In early 1946, he was put in charge of designing the first plutonium production reactor.

[15] Nikolai Dollezhal, *U istokov rukotvornogo mira* (*At the Origin of a Manmade World*) (Moscow: GUP NIKIET, 1999), p. 112.

[16] GOKO is a Russian abbreviation for Gosudarstvenny Komitet Oborony (State Defense Committee), the chief governing body during the Great Patriotic War.

[17] Translated from a photographic copy of the identification published as an illustration in Dollezhal, *U istokov rukotvornogo mira*, p. 229.

[18] Boris Chertok, *Rakety I Ljudi* (*Rockets and People*) (Moscow: Mashinostrojenie, 1999), p. 47.

[19] Until 1943, the NKVD (Peoples' Commissariat of Interior) performed the functions of both the modern Russian Ministries of the Interior and State Security, including foreign intelligence. In 1943, a separate Peoples' Commissariat of State Security (NKGB) was founded.

[20] A. K. Kruglov, *Shtab Atomproma* (*Headquarters of Atomic Industry*) (Moscow: TsniiAtominform, 1998), p. 70.

[21] Evidently, GULGMP had the function of providing a cheap labor force for mining and metallurgy.

[22] For a historical account of Laboratory No. 2, a reader should turn to the published proceedings of the conference on the History of the Soviet Atomic Project (HISAP-96), held in Dubna in 1996 and sponsored by Kurchatov Institute. The two-volume proceedings extensively cover the organizational and scientific evolution of the early Soviet atomic project and its braincenter—Laboratory No. 2 headed by I.V. Kurchatov. See *HISAP-96 Proceedings* (Moscow: IzdAt, 1999).

[23] In 1946, in order to be able to knowledgably communicate with the scientists it tried to manage, the NKVD invited a prominent Soviet scientist, Alexander I. Leipunski (an academician from the Ukrainian Academy of Sciences known for his experiments on neutrino detection), to be the deputy head of the 9th Directorate and perform the functions of scientific liaison. See Kruglov, *Shtab Atomproma*, p. 72.

[24] Zavenyagin was promoted to his position within the NKVD after delivering results by managing huge scale "conventional" mining operations conducted by convicts at Norilsk. See Viktor N. Mikhailov and Andranik M. Petrosjants, eds., *Sozdanije pervoi sovetskoi atomnoi bomby* (*Creation of the First Soviet Atomic Bomb*) (Moscow: Energoatomizdat, 1995), p. 404.

[25] Mikhail Rudenko, "Yaderny Plagiat" ("Nuclear Plagiarism"), *Moskovsky Komsomolets*, June 10, 1996, p. 10. Probably, this was only one of several tasks assigned to this trophy recovery team. Statements near the end of this article tend to support the conjecture that the decision to create specialized search teams was made in March 1945.

[26] Kruglov, *Shtab Atomproma*, p. 16.

[27] Mikhailov and Petrosjants, *Sozdanije pervoi sovetskoi atomnoi bomby*, p. 435.

[28] Rudenko, "Yaderny Plagiat," p. 10.

[29] This service operated as part of the armed forces and took the motto "Death to Spies" (*Smert' Shpionam*) as its title.

[30] Artsimovich later took charge of the Soviet effort to develop electromagnetic isotope separation technology. Khariton moved to the weapons design center Arzamas-16 where he became chief scientist.

[31] Rudenko, "Yaderny Plagiat."

[32] Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p. 291.

[33] Raisa V. Kuznetsova and Natalya V. Seleznjova, "Documents of the Personal Archive of Academician I.V. Kurchatov," *HISAP-96 Proceedings* 2, p. 94.

[34] Golovin and Shevchenko were assisted by the 337th Border Guard Regiment. Traditionally, border guard troops belonged to the NKVD/KGB system.

[35] Igor N. Golovin, "Problema urana v Germanii za gody voiny" ("Uranium Problem in Germany During the War"), *History of the Atomic Project* 16 (Moscow: Kurchatov Institute, 1998), pp. 46-52.

[36] Out of five cyclotrons that existed in Germany in 1945, the Soviet atomic program "inherited" four. See A.A. Ogloblin, "Tsyklotrony v atomnykh projektakh" ("Cyclotrons in Atomic Projects"), *History of the Atomic Project* 12 (Moscow: Kurchatov Institute, 1997), p. 13.

[37] Norman M. Naimark mentions this fact in the footnotes to his chapter "The Soviet Use of German Science," in *The Russians in Germany* (Cambridge: Belknap Press, 1997), p. 523, footnote 23.

[38] Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 48.

[39] Rudenko, "Yaderny Plagiat."

[40] Isaak Kikoin was in charge of diffusion and centrifuge methods of isotope separation.

[41] Igor S. Drovenikova and Sergei V. Romanov, "K istorii poezdki sovetskikh phyzikov v Germaniju (mai-ijun' 1945)" ("On the History of the Trip of Soviet Physicists to Germany [May-June 1945]"), in *HISAP-96 Proceedings* 2, p. 182.

[42] Manfred von Ardenne, *Erinnerungen, fortgeschrieben: ein Forscherleben in Jahrhundert des Wandels der Wissenschaften und politische Systeme* (*Memoirs: Life of a Scientist in the Century of Changing Science and Political Systems*) (Dusseldorf: Droste Verlag, 1997).

[43] Von Ardenne explained his preference for Russia by an almost unbelievable decision made as early as in 1944 to work for the Russians after the war. A reader may suspect that von Ardenne's memoirs could have been strongly influenced by the fact that their first editions were published in the GDR, where anti-Soviet sentiments were censored.

[44] Von Ardenne, *Erinnerungen*, p. 222.

[45] We can only wonder if this major was the head of the chemical laboratory of the first Ukranian Front mentioned earlier.

[46] V.A. Makhnjov had the title "Deputy Member of the State Defense Committee" and performed the functions of assistant and secretary to Lavrenty Beria.

[47] Drovenikov and Romanov, "On the History," p. 181.

[48] Kuznetsova and Seleznjova "Documents of I.V. Kurchatov," p. 94.

[49] Following the tradition of secrecy, when dictating his memoirs Kikoin did not name the atomic problem directly, but referred to it as a "problem of interest."

[50] Drovenikov and Romanov, "On the History," p. 182.

[51] Nikolaus Riehl, head of research of Auer Company, was in charge of uranium production for the erman "Uranium Club." He recalled staying at

Berlin-Friedrichschagen for a week. See Nikolaus Riehl and Frederick Seitz, *Stalin's Captive* (Washington, DC: American Chemical Society, Chemical Heritage Foundation, 1996), p. 72.
[52] Goudsmit, *ALSOS*, p. 70.
[53] Laboratory No. 3 was tasked with the development of heavy water reactors, and became what is now known as the Institute of Theoretical and Experimental Physics (ITEF) in Moscow.
[54] B.L. Ioffe, "Truba, pochemu ona ne proshla. Tjazhelovodnye reaktory v ITEF" ("Pipe, Why It Did Not Go Through. Heavy Water Reactors in ITEF"), in *HISAP-96 Proceedings* 2, p. 223.
[55] Drovenikov and Romanov, "On the History," p. 183.
[56] Anna G. Plotkina and Evgeny M. Voinov, "Academician Isaak Konstantinovich Kikoin—Scientific Leader of the Problem of Uranium Isotopes Separation in the USSR (1908-1984)," in *HISAP-96 Proceedings* 2, p. 198.
[57] Goudsmit, *ALSOS*, pp. 125-126.
[58] Von Ardenne, *Erinnerungen*, p. 226.
[59] Ibid., pp. 227-228.
[60] Ibid., p. 228.
[61] Ibid., pp. 234-235
[62] At least, von Ardenne claims this in his memoirs.
[63] Heinz and Elfi Barwich, *Das rote Atom* (*The Red Atom*) (Munich and Bern: Scherz Verlag, 1967), p. 20.
[64] For a detailed account of Riehl's life, see Riehl and Seitz, *Stalin's Captive*. Riehl was engaged in research into luminescence, and extraction of thorium. At the suggestion of K.G. Zimmer, Riehl talked to Otto Hahn regarding interest of the latter in production of uranium and construction of the German "uranium machine." Hahn agreed, although he was more interested in chemistry of fission products than in the new energy source.
[65] Riehl and Seitz, *Stalin's Captive*, p. 71.
[66] Ibid., p. 72.
[67] Ibid., p. 79
[68] Drovenikov and Romanov, "On the History," p. 183.
[69] David Holloway, *Stalin and the Bomb: the Soviet Union and Atomic Energy, 1939-1956* (New Haven: Yale University Press, 1994), p. 110.
[70] Lasby, *Project Paperclip*, p. 273.
[71] Ibid, p. 278
[72] Scientists going to Laboratory "V" in Obninsk expected to stay there only for two years, and Thiessen's group thought they would be allowed to go back in a year.
[73] Klaus Thiessen, son of Peter A. Thiessen, telephone conversation with author, July 9, 1999.
[74] Natalya V. Knjaz'kaja, "I.V. Kurchatov on the Main Directions of Work in the First Stage of Solving the Atomic Problem," in *HISAP-96 Proceedings* 2, p. 103.
[75] Andreas Heinemann-Grueder, "Soviet Atomic Project and Shortage of Uranium. Production of Uranium in Eastern Germany and Czechoslovakia after 1945," in *HISAP-96 Proceedings* 2, p. 332.
[76] Charles A. Ziegler and David Jacobson, *Spying Without Spies: Origins of America's Secret Nuclear Surveillance System* (Westport, CT: Praeger Publishers, 1995), p. 10.
[77] Heinemann-Grueder, "Soviet Atomic Project and Shortage of Uranium," p. 334.
[78] Drovenikov and Romanov, "On the History," pp. 179-188.
[79] Ibid.
[80] Knjaz'kaja, "I.V. Kurchatov on the Main Directions of Work," p. 103.
[81] Heinemann-Grueder, "Soviet Atomic Project and Shortage of Uranium," p. 331. Although the subject of uranium mines lies somewhat outside the activities of the Russian ALSOS groups in Germany, it should be noted that the Soviet Union benefited greatly from uranium mines in Czechoslovakia (Joachimstal) and Germany (Saxony). The Eastern European mines had much richer uranium ores than those in the Soviet Union and production of uranium in Eastern Europe far exceeded the Russian amounts.
[82] Drovenikov and Romanov "On the History," p. 188.
[83] Riehl and Seitz, *Stalin's Captive*, p. 82.
[84] This fact is reflected in the memoirs of both von Ardenne and Riehl, the only difference is that Riehl says they were attending "Prince Igor," while von Ardenne says "Swan Lake." Von Ardenne also mentions attending a similar performance in August celebrating victory in a short Soviet-Japanese war. Von Ardenne, *Erinnerungen*, p. 233, and Riehl and Seitz, *Stalin's Captive*, p. 82.
[85] Von Ardenne, *Erinnerungen*, p. 237.
[86] Rudenko, "Yaderny Plagiat"
[87] Riehl and Seitz, *Stalin's Captive*, p. 83.
[88] Kruglov, *Shtab Atomproma*, p. 18.
[89] Von Ardenne recalls the date as mid-August in von Ardenne, *Erinnerungen*, p. 241.
[90] Riehl and Seitz, *Stalin's Captive*, p. 111.
[91] Von Ardenne, *Erinnerungen*, p. 241.
[92] Gernot Zippe, who joined von Ardenne's institute in the summer of 1946 and must have heard the story of the meeting with Beria from von Ardenne, stated that Nikita Khrushchev was also present at the meeting. See Gernot Zippe, "Historical Review On the Development of Gas Centrifuges for Uranium Enrichment," presentation at the University of Nagoya, 1998, p. 2.
[93] Von Ardenne, *Erinnerungen*, p. 241, and Zippe, "Historical Review," p. 3.
[94] Klaus Thiessen, telephone conversation with author, July 9, 1999.
[95] Max Steenbeck, *Impulse und Wirkungen: Schritte auf meinem Lebensweg* (Berlin: Verlag der Nation, 1977), p. 278.
[96] Barwich, *Das rote Atom*, p. 63.
[97] Von Ardenne, *Erinnerungen*, p. 253.
[98] Barwich, *Das rote Atom*, p. 64.
[99] Kruglov, *Kak sozdavalas atomnaja promyshlennost*, p. 165
[100] Barwich, *Das rote Atom*, p. 40.
[101] Klaus Thiessen, telephone conversation with author, July 9, 1999.
[102] *Volkssturm* literally means "people's army." It was a last resort measure in which untrained civilians were armed and put to defend the territory where they lived or, in case of the Siemens plant, worked. Thus, Steenbeck was the head of "organized resistance" at his plant.
[103] Zippe, "Historical Review," p. 4.
[104] Artsimovich assumed leadership in the area of electromagnetic isotope separation, and must have known about an original design of a betatrone invented by Steenbeck; Zippe, "Historical Review," p. 4.
[105] "Rukovodjaschi Sostav Instituta Atomnoi Energii 1943-1965" ("Leadership of the Institute of Atomic Energy, 1943-1965"), in *History of Atomic Project 9-10* (Moscow: Kurchatov Institute, 1997), pp. 51-52, 57.
[106] Von Ardenne, *Erinnerungen*, p. 255.
[107] In 1950, when the main work at Sukhumi ended, Wilhelm Menke and von Ardenne's sister Rinata von Ardenne moved to another MVD laboratory for German specialists—Laboratory "B" at Sungul in the Urals.
[108] Zippe, "Historical Review," p. 7.
[109] Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 72.
[110] Riehl and Seitz, *Stalin's Captive*, p. 24.
[111] Vladimir N. Prusakov and Alexander A. Sazykin, "On the History of Uranium Enrichment Problem in the USSR," in *HISAP-96 Proceedings* 1, p. 159.
[112] Barwich, *Das rote Atom*, p. 38.
[113] See Riehl and Seitz, *Stalin's Captive*, p. 142.
[114] Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, pp. 165-166
[115] Oksana D. Simonenko, "Experimental Research for Creation of Industrial Methods of Uranium Isotope Separation in the USSR in 1943-1950," in *HISAP-96 Proceedings* 2, p. 442.
[116] Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 67.
[117] Tamara Andrjuschenko, interview by author, Snezhinsk, July 14, 1999.
[118] Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p. 293.
[119] Mikhailov and Petrosjants, *Sozdanije pervoi sovetskoi atomnoi bomby*, p. 296.
[120] The Soviet Union was involved on a large scale in the civil war in Spain in the late 1930s; taking care of Spanish children was just another form of assistance to Spanish communists.
[121] A German documentary "Forschen hinter Stacheldraht" describes the history of Wolfgang Burkhardt and mentions this fact. Wolfgang Burkhardt signed a contract in Leipzig on July 29, 1946, for a laboratory assistant position with a salary of 2,500 rubles a month.

[122] Rudolph H. Pose, "Vospominanija ob Obninske" ("Reminiscences of Obninsk"), in *HISAP-96 Proceedings* 2, p. 286.
[123] The German team in Obninsk also included Wolfgang Burkhardt, Dr. Baroni, Dr. Ernst Busse, Dr. Hans Keppel, Dr. Willi Haupt, Dr. Karl-Heinz Riewe, Dr. Ing. Herbert Thieme, Dr. Krueger, Dr. Helene Kuelz, Dr. Hellmut Scheffers, and Dr. Renger. See Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, pp. 61, 67.
[124] Boris F. Gromov, Oleg D. Kazachkovsky, and Mikhail F. Trojanov "Sozdanije laboratorii "V" i pervy etap eje dejatel'nosti" ("Establishment of Laboratory "V" and First Phase of Its Activities"), in *HISAP-96 Proceedings* 1, p. 177.
[125] Ibid.
[126] This number appears to be unbelievably high and probably is a typo in the original, as the largest design conceived in Obninsk in the early 1950s was for a five MW nuclear power plant. See Gromov "Sozdanije Laboratorii "V"…" p. 180.
[127] Kruglov, *Shtab Atomproma*, p. 73.
[128] Ibid., p. 71.
[129] Pose, "Vospominanija ob Obninske," p. 288.
[130] Disruption of a defense projects in times of war can easily be considered sabotage.
[131] Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 67. His wife later moved to Sukhumi where she married a German draftsman Lange. In 1950, Lange and his daughter Hannelora, along with Frau Riewe and her children, arrived at Laboratory "B" in Sungul. After 1953, they all served their "stint" in the Agudzery transition camp. T. Andrjuschenko recalls that NKVD escorts had heard that Karl Riewe had been executed for sabotage. Tamara Andrjuschenko, interview by author, Snezhinsk, July 14, 1999.
[132] Riehl and Seitz, *Stalin's Captive*, p. 87.
[133] Ibid., p. 92
[134] Albrecht, Heinemann-Grueder, and Wellmann, *Der Spezialisten*, p. 57.
[135] Eberhard Born, son of H.J. Born, correspondence with author, June 7, 1999.
[136] Rudenko, "Yaderny Plagiat."
[137] Kruglov, *Shtab Atomproma*, p. 40.
[138] Riehl and Seitz, *Stalin's Captive*, p. 95.
[139] Ibid.
[140] Riehl mentions this man in his book twice and calls him the "platinum colonel." It is very likely that this was Ilja Chernjaev who, indeed, became famous for his studies of platinum and its refinement. See Kruglov, *Shtab Atomproma*, p. 37.
[141] Fyodor G. Reshetnikov, "Stanovlenije i razvitije promyshlennogo proizvodstva urana i transuranovykh elementov dlja oboronnoi otrasli v Sovetskom Sojuze," ("Maturing and Evolution of Industrial Production of Uranium and Transuranium Elements for the Defense Sector in the Soviet Union"), in *HISAP-96 Proceedings* 1, p. 147.
[142] Ibid., p. 147.
[143] Rudenko, "Yaderni Plagiat"; Kruglov, *Kak sozdavalas atomnaya promyshlennost*, p. 297.
[144] Mikhailov and Petrosjants, *Sozdanije pervoi sovetskoi atomnoi bomby*, pp. 319, 325.
[145] *Section 73 (Atomic Energy) NIS 26 (USSR)*, p. 69.
[146] Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p. 301.
[147] Riehl and Seitz, *Stalin's Captive*, p. 165.
[148] Albrecht, Heinemann-Grueder, and Wellmann list his name among Obninsk scientists. See Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 61.
[149] A well-known Soviet comedy "A Little Giant of Big Sex" is another example of a mass media product briefly covering a German group's location. The plot takes place in Sukhumi and contains an episode inside a "secret institute" that must have been Institute "A" or its successor organization.
[150] "Professor Timofeev-Ressovsky, former director of Kaiser Wilhelm Institute for Genetics and Biophyisics … was summoned to Soviet Headquarters in early September, and left for Russia the same day." See Lasby, *Project Paperclip*, p. 141.
[151] As Eberhard Born recalls, his father was arrested by the Soviet Military Administration in the fall of 1945, flown to Lubjanka—the NKVD prison in Moscow—where he was intensively interrogated on the subject of V-2 rockets and then transferred to Elektrostal. Born's family arrived at Elektrostal on August 20, 1946. In December 1947, Born and Zimmer left for Sungul. Eberhard Born, e-mail to author, May 21, 1999.
[152] Judging by Nikolaus Riehl's interview with Mark Walker in 1985, Zimmer and Born moved to Laboratory "B" merely because it provided a more interesting job for them, not because they were badly needed there.
[153] V.N. Mikhailov, ed., *Chastitsy Otdannoi Zhizni* (*Parts of a Dedicated Life*) (Moscow: Izdat, 1999), p. 432. This book is a collection of memoirs of Novaya Zemlya test site veterans.
[154] Among them: Nikolaus Riehl, Rinata von Ardenne (sister of Manfred von Ardenne), Wilhelm Menke (head of radiobiology lab at Institute "A"), W. Lange (who married widow Riewe), H.E. Ortmann, A. Baroni, Schmidt, Karl Guenther Zimmer, Aleksander Sergejevich Katsch, Hans J. Born, Joachim Pani, and K.K. Rintelen. Including dependents, there must have been nearly 50 Germans at Sungul.
[155] Kuznetsova and Seleznjova "Documents of I.V. Kurchatov," p. 97.
[156] Barwich, *Das rote Atom*, p. 156.
[157] Arkadi Kruglov, "Kto uchastvoval v realizatsii sovetskogo atomnogo proekta," in *HISAP-96 Proceedings* 1, p. 62.
[158] Gromov, Kazachkovsky, and Trojanov, "Sozdanije Laboratorii V…" p. 177.
[159] Ibid., p. 179.
[160] As Boris Chertok observed in May 1945 when inspecting aviation research facilities: "In answer to my question, who is the most distinguished expert in vacuum tubes, Wilki said, 'Germany is proud of professor Manfred von Ardenne. He was a great engineer and visionary.' 'Why?' 'For the last two years he has been working on some new idea. A new secret weapon...'" Chertok, *Rakety I Ljudi*, p. 60.
[161] This must have been NKVD Major A. Zhdanov who was in charge of the Sinop and Agudzery sites. Tamara Andrjuschenko, interview by author, Snezhinsk, July 14, 1999.
[162] Von Ardenne, *Erinnerungen*, p. 268
[163] Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 68.
[164] Shuetze was number 110 in the list of second class Stalin Prize winners. See Kruglov, "Kto uchastvoval," p. 69.
[165] Ibid., p. 72.
[166] There was an agreement that allowed Germans in the USSR to get two eastern deutschmarks for every ruble they were paid. As von Ardenne writes, not long before their departure Eastern Germany reduced the exchange rate by 25 percent, thus putting in danger his plans of buying the land. After a special request from the Soviet Union, the GDR restored the previous exchange rate for the scientists. See von Ardenne, *Erinnerungen*, p. 297.
[167] *Section 73 (Atomic Energy) NIS 26 (USSR)*, pp. 70-71.
[168] Some accounts put the number of deported scientists as high as 5,000. See Michel Bar-Zohar, *The Hunt for German Scientists* (New York: Hawthorn Books, 1967), p. 153.
[169] A.M. Rozen "Yasnye mysli ne tolko v Poljarnuyu noch" (Clear thoughts not only in the Polar night), in B.I. Ogorodnikov, ed., *I.V. Petrjanov-Sokolov* (Moscow: Izdat, 1999), p. 416.
[170] Mikhailov and Petrosjants, *Sozdanije pervoi sovetskoi atomnoi bomby*, p. 293.
[171] Rozen, "Yasnye mysli," p. 417.
[172] Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 70.
[173] Simonenko, "Experimental Research for Creation of Industrial Methods of Uranium Isotope Separation in the USSR," p. 439.
[174] Recollections of L.R. Kvasnikov (KGB resident in New York), as quoted in Kruglov, *Shtab Atomproma*, p. 80.
[175] N.M. Sinjov, *Obogaschjonny uran dlja atomnogo oruzhija i energetiki (Enriched Uranium for Atomic Weapons and Energy Production)* (Moscow: TsNIIAtominform, 1991), pp. 39-40.
[176] Russian respect for Germany and its industry was well-founded. Even in times of war Germany was able to produce products much superior to anything in the Soviet Union. See, for example, B. Chertok, *Rakety I Ljudi*,

where he mentions that the Germans had used nearly 80 metals and alloys in their V-2 rocket, while Soviet industry was capable of producing less than 40.

177 Rudenko, "Yaderny Plagiat," p.10; Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p.167.

178 Barwich, *Das rote Atom*, p. 147.

179 Mikhailov and Petrosjants, *Sozdanije pervoi sovetskoi atomnoi bomby*, p. 331.

180 Clove pinks oil was used as a mild pain killer by dentists. It relieves pain when it evaporates.

181 Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 67.

182 Amazingly, there was strong opposition to this decision. The Gorkiy machine plant that won the contract to manufacture the first-generation machines with flat filters was against the idea, while the design bureau from the Elektrosila plant in Leningrad, which was still trying to promote its designs, wanted to adopt the new technology. In his book, Sinjov openly speaks of "revenge by Gorkiy people." Even huge projects do not kill envy in people! See Sinjov, *Obogaschjonny uran dlja atomnogo oruzhija i energetiki*, p. 42.

183 Sverdlovsk-44 is now also known as Novouralsk. Ibid., pp. 43-44.

184 Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p. 175.

185 Ibid., p. 185.

186 Ibid.

187 Barwich, *Das rote Atom*, p. 103

188 Klaus Thiessen, telephone conversation with author, July 9, 1999.

189 Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p. 186.

190 Sinjov, *Obogaschjonny uran dlja atomnogo oruzhija i energetiki*, p. 45.

191 V. Zhuchikhin, *Vtoraja atomnaja* (*The Second Atomic Bomb*) (Snezhinsk, Russia: RFNC-VNIIEF, 1995), p. 110.

192 Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, pp. 74-75.

193 Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p. 298.

194 Boron has very large neutron capture cross-section and is considered an enemy of a nuclear chain reaction.

195 Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p. 297.

196 Riehl and Seitz, *Stalin's Captive*, pp. 108-109.

197 Kruglov, "Kto uchastvoval," p. 65.

198 They were numbers 16 and 99 on the list. Ibid., pp. 66-68.

199 Riehl and Seitz, *Stalin's Captive*, p. 95.

200 Simonenko, "Experimental Research for Creation of Industrial Methods of Uranium Isotope Separation in the USSR in 1943-1950," p. 440.

201 Gernot Zippe was a graduate of the Radium Institute in Vienna and had a degree in physics. He was put on a list of POWs available for research in the Soviet Union and was picked by von Ardenne in his campaign to strengthen his institute through integration of a new workforce. For a full account of centrifuge development in the Soviet Union until 1953, see Gernot Zippe, "Historical Review of the Development of Gas Centrifuges for Uranium Enrichment," presentation at University of Nagoya, Japan, June 1998.

202 Ibid., p. 5.

203 This surmise is based on the fact that Steenbeck, Thiessen, and von Ardenne travelled to Moscow to attend the annual Scientific Council in December every year. Von Ardenne, *Erinnerungen*, p. 270.

204 Zippe, "Historical Review," p. 5.

205 Using a needle-bearing instead of a ball-bearing to support the cylinder was the breakthrough that made supercritical centrifuges possible. Because of high rotational speeds, no ball-bearing could withstand the load.

206 Simonenko, "Experimental Research for Creation of Industrial Methods of Uranium Isotope Separation in the USSR in 1943-1950," p. 441.

207 Zippe, "Historical Review," p. 6.

208 Ibid., p. 7.

209 Ibid., p. 9. According to the popular version of the Soviet atomic bomb project, progress was spurred by the letters Georgy Flerov was writing to Stalin. One may conclude that, at least on the surface, Steenbeck's letters might have played a similar role for the centrifuge enrichment project.

210 Ibid., p. 10.

211 Sinjov, *Obogaschjonny uran dlja atomnogo oruzhija i energetiki*, p. 125.

212 Zippe, "Historical Review," p. 10.

213 The Semiconductor Institute in Kiev where Zippe and Steenbeck were kept must have been the location of another trophy German group that worked on electronics. See Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 168.

214 At least, Dr. Zippe keeps a tape recording of his conversation with Yemeljanov, who agreed to his plan to get a patent. Zippe, "Historical Review," p. 13.

215 "Dr. Kuhlthau and his colleagues undertook to evaluate the gas centrifuge reports coming out of Europe on a continuing basis. In connection with this latter work they became interested in the Russian work described in an interview with Dr. G. Zippe who had been allowed to return to Germany from Russia. The interview had been carried out by Dr. M. Schutte who reported to Dr. K. Brewer at the Navy. … Through the most effective efforts of Dr. Kuhlthau, Dr. McDaniel and Dr. Kolstad of the AEC, and Dr. Brewer and Dr. Schutte, Dr. Zippe was invited to come to Virginia and substantially repeat the short bowl experiments which he had carried out in Russia. This work was started in August 1958 and completed in June 1960." See Jesse W. Beams, "Early History of the Gas Centrifuge Work in the U.S.A." (Charlottesville, VA: Department of Physics and School of Engineering and Applied Science, University of Virginia. May 1975), p. 31.

216 Zippe, "Historical Review," p. 14.

217 See Sinjov, *Obogaschjonny uran dlja atomnogo oruzhija i energetiki*, p. 110.

218 Khapayev and Gudkov, "Secrets of the Caucasus Gem."

219 I.N. Golovin, "Ot laboratorii 2 do Kurchatovskogo instituta" ("From Laboratory 2 to Kurchatov Institute"), *History of Atomic Project* 1 (Moscow: Kurchatov Institute, 1995), p. 9.

220 Ye.E. Goller, "Laboratorija G.L. Shnirmana. Nachalo" ("Laboratory of G.L. Shnirman: The Beginnings") *History of Atomic Project* 11 (Moscow: Kurchatov Institute, 1997), p. 168.

221 S.L. Davydov, "Zadacha, stavshaja delom zhizni" ("The Task That Became a Whole Life"), *History of Atomic Project* 2 (Moscow: Kurchatov Institute, 1997), p. 173.

222 P.E. Nemirovski, "Na zare teorii reaktorov: idei I ljudi" ("The Dawn of Reactor Theory: Ideas and People"), *History of Atomic Project* 1 (Moscow: Kurchatov Institute, 1995), p. 86.

223 A copy of the decree on measures to support the construction of a new cyclotron at Laboratory No. 2 can be found in *History of Atomic Project* 12 (Moscow: Kurchatov Institute, 1997), p. 52.

224 Pavel E. Rubinin, "Kapitza, Beria i bomba" ("Kapitsa, Beria and the Bomb"), in *HISAP-96 Proceedings* 2, p. 273.

225 Yury N. Smirnov, "G.N. Flerov i stanovlenije sovetskogo atomnogo projekta" ("G.N.Flerov and Establishment of the Soviet Atomic Project"), in *HISAP-96 Proceedings* 2, p. 145.

226 Riehl and Seitz, *Stalin's Captive*, p. 116.

227 Slusser, ed., *Soviet Economic Policy in Postwar Germany*, p. 15.