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The development of the first Soviet atomic bomb

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Contents

Abstract. In the late 1930s and early 1940s, two remarkable physical phenomena — the fission of heavy nuclei and the chain fission reaction — were discovered, implying that a new powerful source of energy (nuclear fission energy) might become a practical possibility for mankind. At that time, however, the political situation in the world made the development of the atomic bomb the main objective of nuclear energy research in the countries involved. The first atomic bombs, notoriously used in the war against Japan, were produced by the United States of America only six and a half years after the discovery of fission. Four years later, the first Soviet atomic bomb was tested. This was a major step toward the establishment of nuclear parity which led to stability and global peace and thus greatly influenced the destiny of human kind. Based on documentary materials covering the period from 1939 to 1949, this paper traces the origin and evolution of the physical ideas behind the first Soviet atomic bomb and discusses the most important events associated with the project.

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1. Research on the use of atomic energy in prewar USSR

As soon as the epochal discoveries in nuclear physics were made in 1938 and 1939, Soviet academics realized that nuclear energy could in principle be put to practical use and began to research this possibility. In 1939, the feasibility of accomplishing nuclear chain reactions was discussed in the USSR at the 4th All-soviet Meeting on the Atomic Nucleus held in Khar'kov from 15 – 20 November. In his report summing up the meeting dispute, I M Frank stated that calculations of the feasibility of chain reactions "*were made by a number of researchers; some of them, in particular, the French — Joliot, Perrin and others — came to the conclusion that such reactions are possible, and we are, therefore, on the verge of learning to use nuclear energy for practical purposes*" [1, p. 80]. In June 1940, V I Vernadsky and V G Khlopin wrote: "*The 1939 discovery of nuclear fission of uranium bombarded by neutrons, leading to huge energy releases, and especially the fact that it*

produces new neutrons in quantities surpassing those which are required to initiate this process, has for the first time brought us close to the issue of putting intraatomic energy to practical use''[1, p. 113]. In a draft letter written on July 12, 1940 and addressed to N A Bulganin, Vice Chairman of the USSR Council of People's Commissars (CPC), V I Vernadsky, A E Fersman and V G Khlopin wrote that in developing technical use of nuclear energy ''*there are still a whole range of major difficulties; it will require a great scientific effort but, nevertheless, we believe that the difficulties are not cardinal. It is clear that once there is a positive solution to the problem of using intraatomic energy for practical purposes, the entire field of applied power engineering will be transformed. This is fully understood abroad. According to Western sources, frantic efforts to resolve this problem are now being made in the United States and Germany; the efforts get ample funding... Given the significance of finding ways of putting nuclear energy to technical use, we believe that it is time for the government to take certain steps to enable the Soviet Union to keep abreast with foreign states in this field*'' [1, p. 121].

The scientists' viewpoint, set down in the above document, got support from the Presidium of the USSR Academy of Sciences; in September 1940, it was brought to the attention of the Central Committee of the Communist Party. In early 1941, V A Maslov submitted a proposal, stating the necessity to organize research into military uses of atomic energy, to the USSR People's Commissar of Defense, S K Timoshenko [1, pp. 141 – 142, 224 – 225]. However, the USSR Government made no decisions in 1940 – 1941 concerning the use of atomic energy based on nuclear chain reactions. This particular avenue of research was coordinated by rulings of the Presidium of the USSR Academy of Sciences and by the Uranium Commission, established by the Presidium on July 30, 1940 with V G Khlopin as its Chairman [1, pp. 127 – 128].

An interesting remark on who could head the uranium research project was made as early as 1940 by A F Ioffe who was on the Uranium Commission. Reacting to a query made by P A Svetlov, Secretary of the Presidium of the USSR Academy of Sciences, concerning the status of research into practical uses of nuclear energy, A F Ioffe wrote in a note dated August 24, 1940: ''*Our present understanding being what it is, we cannot rule out the possibility that the energy of uranium can be put to practical use,*'' adding that ''*the top men who should be consulted on this matter are I V Kurchatov* (*of the Leningrad Physicotechnical Institute*) *and his colleagues, Flerov and Petrzhak, Zel'dovich and Khariton* (*of the Leningrad Institute of Chemical Physics*)... *I V Kurchatov should be entrusted with managing the whole project since he is the number one man in this field, and the construction of the cyclotron has proved him to be an outstanding manager*'' [1, p. 135].

Although before the war neither A F Ioffe himself nor the majority of other Soviet academics expected ways to use atomic energy for practical purposes to be found in the near future, quite a few were aware from the very start that a positive solution would enable both peaceful and military, i.e. explosive, uses of nuclear fission.

Ya B Zel'dovich and Yu B Khariton in a paper they co-authored in 1940, ''The kinetics of uranium chain decay'' [2], gave the following description of the conditions necessary for a nuclear explosion: ''*Explosion-oriented uses of nuclear chain decay require special-purpose devices that would both enable an extremely rapid and profound transition to the supercritical region and reduce natural thermal regulation*''. They put forward a suggestion that certain measures [1] could make it possible to ''*create the right conditions for uranium chain decay through branching chains; bombardment by neutrons, however as weak as is exerted, would then induce a violent chain reaction and macroscopic effects*''. They mentioned the extremely rapid (increasing by a factor of e in 10^{-7} s) exponential growth of neutron concentration in such a system at high supercritical levels, and the problems they believed would ensue from it: ''*Considering the violent progress of chain decay, we cannot any longer ignore the establishment of supercritical conditions themselves at which the chain decay is only possible. There is little hope that the time required for processes enabling the transition to critical conditions, such as the time for approaching two uranium masses both of which are in a subcritical region with respect to chain decay, can be reduced to values if only comparable with the time of the reaction speed-up*''. Ya B Zel'dovich and Yu B Khariton emphasized the fact that ''*the kinetics of chain decay is the final argument for judging one or the other of ways of putting uranium decay to practical use, whether in power engineering or explosion-oriented*''.

The fact that Ya B Zel'dovich and Yu B Khariton described the essential conditions for a nuclear explosion, i.e. those that would enable '*an extremely rapid and profound transition to the supercritical region*', stimulated further research into practical ways to provide those conditions, although, as can be seen from the paper, the authors themselves viewed the prospect of possible efficient solutions to this problem with great caution, expecting serious obstacles to arise along the way.

In October 1940, V A Maslov and V S Shpinel' filed a classified application to the Inventions Bureau of the USSR People's Commissariat of Defense. Their invention was entitled ''The use of uranium as an explosive and toxic substance'' [1, p. 193]. Quoting the paper by Zel'dovich and Khariton [2], they wrote in their application that ''*the problem of initiating an explosion in uranium consists in creating a considerably supercritical mass of uranium within a short time interval. We propose to do this by placing the uranium in a container with isolated sections, each containing a subcritical amount of uranium, with walls that are impermeable to neutrons. As soon as the container is filled, the inner walls are destroyed by an explosion, and, consequently, we get a mass of uranium that is much larger than critical. This will instantly start a nuclear explosion*''. As the material for walls, the inventor's application proposed explosives. The authors presumed that the conditions could be established then to prevent the uranium throwing off prior to the chain reaction occurrence. Although obviously irrelevant, the application by Maslov and Shpinel' is interesting insofar as it is the first pretension to the invention of an atomic bomb design made in the USSR. This is probably the reason why the Inventions Department at the USSR Ministry of Defense decided on December 7, 1946 to issue an author's certificate to Maslov and Shpinel' despite the negative reviews of their application that were made as early as 1941 [1, pp. 195 – 196].

The final report made at the Chemical Research Institute of the USSR People's Commissariat of Defense read that ''*The authors suggest exploding the walls between sections filled with uranium in order to promptly obtain a supercritical mass of uranium. Meanwhile, the paper by Khariton and Zel'dovich* [2], *quoted by the authors of the application, lists a whole range of*

[1] One of the measures mentioned by Ya B Zel'dovich and Yu B Khariton was the uranium enrichment by the isotope 235.

factors that slow down the explosion of the entire mass and are extremely important when conditions are close to the critical level (*the consumption of uranium, the emergence of new nuclei, the delay in the production of some of the neutrons, heat expansion, etc*.) *It is essential that some of the slowing-down factors progress at the same pace as the uranium explosion. Therefore, the entire block will not explode instantaneously. If the released heat does not have time to propagate and breaks the bomb into fragments, the isolated fragments will be already subcritical and will not explode...*" [1, pp. 220–221]. It is remarkable that the findings contained doubts as to the possibility of a nuclear explosion, not just with respect to the particular design suggested by Maslov and Shpinel' but rather, of a more general nature; they reflected the authors' understanding of the paper itself issued by Zel'dovich and Khariton [2].

Neither did another review of the inventor's application by Maslov and Shpinel', made on April 17, 1941 by V G Khlopin, focus on the proposed design; it, too, stated the above described attitude to the problem shared by many Soviet academics in prewar time. In his inference, V G Khlopin wrote: "*The current situation with uranium research is such that any practical use of the intraatomic energy which is released during the fission of uranium bombarded by neutrons, is a more or less distant goal of our efforts, and not the matter in hand... Concerning the application ... it should be said that at present it is unsubstantiated*" [1, p. 228]. At the same time, V G Khlopin noted that "*To date, in no part of the world have experiments ... producing a uranium chain decay reaction been at all successful; however, according to our sources, great efforts in this direction are now being made in the US and Germany. We do our own research in this field, and it is greatly desirable to boost it further...*" [1, p. 228]. V G Khlopin went on to say that even if a chain reaction of uranium fission was produced, the large energy released in the process "*would be more appropriately used to start engines, for instance, aircraft engines, or for other purposes, than as a substitute for explosives. This is especially true since the total amount of uranium mined worldwide is fairly small, around 250 to 275 tons per annum. In the Soviet Union, it is now mined in the tiniest quantities: in 1941, it is only planned to mine around half a ton of uranium salts* " [1, p. 229].

Concern for the fate of uranium research in the USSR fills the entries in V I Vernadsky's diary made in 1941 [1, pp. 229–232]. He was very critical of the decision to suspend excavation at the Taboshary uranium mines, and took extensive care to have that decision cancelled. V I Vernadsky wrote that physicists "*are making every effort to study the atomic nucleus and the relevant theory, and quite a few important things are being done* (*by Kapitza and Landau, for example*) — *but life demands the development of chemical mining*" (entries made on May 16 and June 18). On June 1, 1941, V I Vernadsky made the following entry: "*We now face the problem of uranium as a source of energy — real, technical energy, and the problem may reform the entire technical capacity of mankind... Still, we have ongoing arguments: physicists focus on the nuclear theory, not on the particular goal set before physical chemists and geochemists, i.e. extracting the 235-isotope of uranium. Here we have to follow the theory, testing it at once by experience...*"

To Vernadsky's description of prewar nuclear physics in the USSR, it should be added that Soviet physicists had at that time done some brilliant experimental work that yielded results of fundamental merit.

One of the greatest accomplishments made by Soviet scientists in the field of nuclear physics in prewar times that was directly related to the problem of producing nuclear chain fission reactions of explosive type, had been the discovery by K A Petrzhak and G N Flerov of spontaneous uranium fission accompanied by neutrons escaping [3, 4].

2. The beginning of Great Patriotic War. Soviet scientists' views on the feasibility of making an atomic bomb

The attack of fascist Germany on the Soviet Union on June 22, 1941 suspended all the nuclear studies in the USSR, including the investigation of the feasibility of chain fission reactions. Meanwhile, this avenue of research was actively pursued in the United Kingdom and the USA.

However, as the Soviet leadership was fully aware, it was essential that research serving a military cause should continue and its results be implemented as promptly as possible. The extraordinary party and state body named the State Defense Committee (GKO in Russ. abbr.), established on June 30, 1941 to be the commanding authority for the duration of the war, acted promptly by passing Resolution No. 34ts (ts stands for top secret) on July 6, 1941, which appointed S V Kaftanov, then Chairman of the Committee on High School Affairs at the USSR Committee of People's Commissars, to the post of GKO representative responsible for coordinating and advancing chemical research for military needs [5]. GKO Resolution No. 88ts, passed on July 10, 1941, required S V Kaftanov to compile proposals on the manufacture and military use of new scientific and technical achievements and inventions such as explosives, chemical weapons and defense technologies, and to bring those proposals for GKO approval. As GKO representative, S V Kaftanov was appointed head of a Scientific and Technical Council composed of leading scientists and professionals, including A N Bakh, N D Zelinskiĭ, P L Kapitza, S S Nametkin, and A P Frumkin. The council was responsible for promoting and organizing research in new fields which could serve the cause of defense [6]. A physicists' committee under Kaftanov was soon appointed, headed by P L Kapitza. In a letter to O Yu Shmidt, dated September 4, 1941, Kapitza wrote: "*We are doing our best to help defend our country... The State Defense Committee's representative on science has established a physicists' commission which I chair. On the commission, we have the Members of the Academy: Vavilov, Semenov and Sobolev; the Corresponding Members of the Academy: Alikhanov and Khristianovich; Professor Khaĭkin... The purpose of the commission is to start organizing defense research in physics...*" [1, pp. 237–238].

P L Kapitza was probably the first Soviet scientist to believe it necessary to give public warning of the existing threat of the creation of atomic weapons. Speaking at a meeting in Moscow on October 12, 1941, held in the Hall of Columns of the Union House on the initiative of the Anti-Fascist Committee of Soviet Scientists, P L Kapitza said: "*Explosives are an important weapon in modern war. Science points to the possibility of increasing their power by a factor of 1.5 to 2. However, we have recently gained new possibilities of extracting intraatomic power that used to be no more than a topic of science fiction stories... Theoretical calculations show that while a modern powerful bomb can, for example, destroy a whole city district, even a small atomic bomb, if it is ever produced, could easily destroy a large capital with several*

million people in it... My own opinion is that the technical obstacles in the way of extracting intraatomic energy are still great. It remains a very questionable enterprise, but it is highly probable that great opportunities will open up. We are raising the issue of employing atomic bombs of enormous destructive power. I believe I have said enough to show that scientists' work can be used for the purpose of helping the defense of our country in the most efficient way. Wars shall become more merciless as time goes by. This is why scientists must warn people of that danger right now in order that public leaders worldwide do their best to prevent future wars from happening..." [1, pp. 245–246], [7, p. 64].

1941 – 1942 was also the time when G N Flerov launched his valuable initiatives. A lot has been written about them (see Ref. [8]); we can understand them even more accurately and in greater detail now that copies of Flerov's letters have been discovered in the Archive of the President, Russian Federation (APRF). These are copies of draft letters, either original or restored by Flerov in Kurchatov's lifetime, addressed to Kurchatov (with Flerov's comments), Kaftanov, I V Stalin and to Stalin's secretary. On February 1, 1946, Kurchatov, acting on Flerov's request, sent all the copies to the Special Committee [9, pp. 11 – 14], [10, sheets 422 – 439] [2].

In late 1941, G N Flerov was doing military service in Ioshkar-Ola after graduating from a course at the Air Force Academy, which had moved to Ioshkar-Ola during the war. He persuaded his commander to send him to Kazan' where the Leningrad Physicotechnical Institute was based at the time. As Flerov wrote later, he gave a talk at a seminar in LPTI in November 1941 [10, sheets 430 – 431]. In his talk, Flerov pictured the situation with a possible use of atomic energy and suggested to start working on the atomic bomb. He remembers that the suggestion was not accepted [10, p. 431]. By the end of November 1941, immediately after the seminar, Flerov wrote a letter to Kurchatov who had not been present at the seminar. The original of the letter has been lost but the Kurchatov Institute has a typewritten copy of the draft (either original or restored by Flerov); however, a number of important data which had to be filled in by hand are missing from it [8, pp. 23 – 31]. Meanwhile, the President's Archive was found to possess the first copy of the same typewritten material of Flerov's letter to Kurchatov with the missing data filled in by Flerov [10, pp. 422 – 430], and with his comments. The letter, which Flerov dated November 1941, with an appendix he made on December 21, 1941, contains the following passage: "*I and all of us must continue to study uranium, because, in my view, this matter has been treated with surprising improvidence*". He emphasized the fact that he "*has a profound conviction that sooner or later we shall have to study uranium*". Flerov expressed the notion that "*further research should be aimed both at keeping up with the solution of the problem, if positive, and at estimating the potential danger of our opponents producing such a bomb* (i.e. atomic bomb — Auths.)".

In a letter to Kurchatov, Flerov drew his sketch of an atomic bomb (the sketch was reproduced by Flerov on the copy which is now stored in the President's Archive). The bomb consisted of a 5 to 10-meter long iron shaft and a spherical, initially subcritical assembly of uranium-235 embedded in a shell, which had to be shoved into the shaft at high speed (Fig. 1) to effect the atomic explosion.

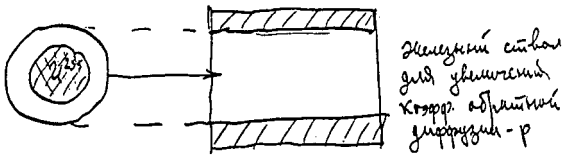

Figure 1. "Iron shaft to increase the outward diffusion coefficient p".

Flerov wrote: "*To start the reaction, the uranium bomb must be rapidly pushed into the shaft. The 'p'* coefficient (defined by Flerov as the coefficient of neutron reflection back into the uranium) *will increase, and the first stray neutron* (*from space or earth*) *which penetrates the uranium will produce an avalanche effect, causing the bomb to explode. For certain reasons it is essential that at the moment of contact with the first 'stray' space neutron, 'q'* (the coefficient characterizing supercriticality) *should be sufficiently larger than unity:* $q \approx 1.05$. *Larger values are hard to obtain by this method; smaller ones are undesirable for a number of reasons...*" Listing those reasons, Flerov noticed that "*for small values of 'q' the reaction will proceed too slowly, the meanwhile shell bursting and scattering together with unreacted uranium*". Flerov also mentioned the fact that at small $q = 1.01$, even a slight elevation of the radius of the sphere due to released heat and increased pressure can reduce q to values below unity and interrupt the chain reaction.

In the bomb design proposed by Flerov, the rapidly moving uranium assembly could fly right through the shaft if the neutrons, produced by spontaneous fission or originating from space, did not induce a chain reaction while the assembly was still in the shaft. What Flerov was especially concerned about, however, was the option of a premature chain reaction at the moment when the assembly entering the shaft was already at a supercritical level ($q > 1$) but had not reached the maximum supercriticality. To this end, the design included a special appliance for accelerating the assembly to sufficiently high speeds, from 50 to 3000 m/s. The lower limit applied when the background consisted of neutrons of space origin; the upper, when neutrons produced by spontaneous fission prevailed. The rate at which neutrons are born by spontaneous fission of uranium-235 was then unknown in the USSR, so it was assumed to be the same as that of uranium-238 (in 1940, K A Petrzhak and G N Flerov discovered spontaneous fission of uranium of natural isotope composition but as the uranium-235 and uranium-238 isotopes were not separated at the time, they could not estimate the rate of spontaneous fission of uranium-235). Mentioning the fact that he had placed the upper estimate of the required speed at 3 000 m/s, and admitting how difficult this speed was to attain, Flerov wrote: "*It is clear from the estimate just how important it is to find out whether uranium-235 does or does not emit spontaneous neutrons. If it does, it is questionable whether we shall ever be able to use uranium-235 in atomic bombs??!!*"

[2] Kurchatov's letter to the Special Committee, copies of Flerov's draft letters to Kurchatov (with the author's comments), Kaftanov, Stalin and to Stalin's secretary, stored in the Archive of the President, Russian Federation, were published in Ref. [11]. As mentioned in Section 3 of this paper (see also Ref. [12]), one of Flerov's letters, probably the one addressed to Kaftanov, fell into the hands of the State Defense Committee in 1942 and was given to Kaftanov. The latter wrote in his memoirs that it had played an important part in stimulating himself and Ioffe to approach the State Defense Committee with a proposal to resume research on atomic energy. As to Flerov's letters to Stalin and Stalin's secretary, there are reasons to believe that Flerov never finished writing them and did not mail them [12].

It is now clear to physicists that although the probability of spontaneous fission of uranium-235 is more than an order of magnitude smaller than that of uranium-238, the chances of producing a nuclear explosion with a large energy release using Flerov's device are slight (first of all, because of the relatively small practically attainable supercriticality). Flerov himself was probably aware of this fact, and in his subsequent work on the atomic bomb he focused on 'gun type' designs in which the active material is divided into two parts which are brought together by the detonation of an explosive.[3]

In a note addressed to the Vice Chairman of the Council of People's Commissars and the People's Commissar of the Chemical Industry at a time M G Pervukhin on March 7, 1943, containing a reference to the next in turn intelligence material from England concerning the use of atomic energy (as will be related in more detail below, such materials were supplied to the USSR from September 1941), Kurchatov wrote that the intelligence data "*are of enormous, inestimable value to our State and science. On the one hand, the material pointed out how serious and active scientific research on uranium was in England, on the other, it provided very important landmarks for our science research, enabled us to skip certain extremely labor-consuming phases of investigation and to learn about new scientific and technical approaches to the problem...". "The entire bulk of data contained in the material points to the technical feasibility of solving the problem of uranium in shorter terms than our academics presume, being unaware of the research done abroad..."* Touching on Section III of the intelligence titled "The physics of fission", Kurchatov observed that "*...this section does not contain any new data which are of principal importance to Soviet physicists but some of the data still deserve careful consideration*". First of all, Kurchatov stressed the point that "*it was very important for us to learn that Frisch has confirmed the phenomenon discovered by Soviet physicists G N Flerov and K A Petrzhak, i.e. spontaneous fission of uranium that can produce initial neutrons in a mass of uranium, leading to the development of the avalanche process. On account of this phenomenon, the entire uranium charge may not be kept in one place before the explosion happens. The uranium must be divided into two parts which must be brought together at high relative speed at the moment of detonation. This method of activating a uranium bomb is described in the material and is not new to Soviet physicists as well. A similar approach was proposed by our physicist G N Flerov: he calculated the required speed of approach of both halves of the bomb, and his results agree well with those contained in the intelligence...*" [1, p. 318], [13, pp. 114–115].

Quoting Flerov's suggestion, Kurchatov probably meant the manuscript of Flerov's paper "On the issue of employing intraatomic energy", a copy of which has been discovered in the private archive of I N Golovin [14] (see also Ref. [1, pp. 253–258]). In that manuscript, written between March 7 and June 6, 1942 [12], Flerov drew a schematic diagram of one of the atomic bomb versions related to those known as a gun type bomb (Fig. 2).

He also estimated the time that it would take to attain the supercriticality level needed to provide a sufficiently large energy release. The estimate for uranium-235 (Flerov also considered using protactinium-231) was inevitably very rough since, as has been said earlier, Flerov had no data on the parameters of neutron emission during spontaneous fission of uranium-235. It should be observed that reviewing a list of 286 American papers in this field, which was supplied on July 4, 1943 by the intelligence service, Kurchatov wrote: "*Finally, it would be very interesting to find out which results Kennedy and Segre have got on the spontaneous fission of uranium isotopes and the decay constant... Spontaneous fission of uranium was discovered in 1940 in the Soviet Union in my laboratory, by C[omra]des Flerov and Petrzhak. The paper was printed but had, to our surprise, received no noticeable response abroad. Since the investigation had involved the use of very complex methods, we felt slightly uncertain about the reality of our discovery.*

The material from England tells us that spontaneous fission was observed in England by the famous Danish scientist Frisch, one of Bohr's pupils; just like Flerov and Petrzhak, he was unable to find out which particular isotope was responsible for the spontaneous fission, as the isotopes were not separated. Kennedy and Segre, as can be seen from the table of contents, have solved this problem. Laboratory No. 2 will be able to carry out the necessary investigations as soon as we get separated isotopes; even small quantities will suffice. Understanding spontaneous fission in detail is essential for estimating the speed at which uranium masses must be brought together in order to produce a sufficiently powerful explosion" [1, p. 356], [15, p. 282].

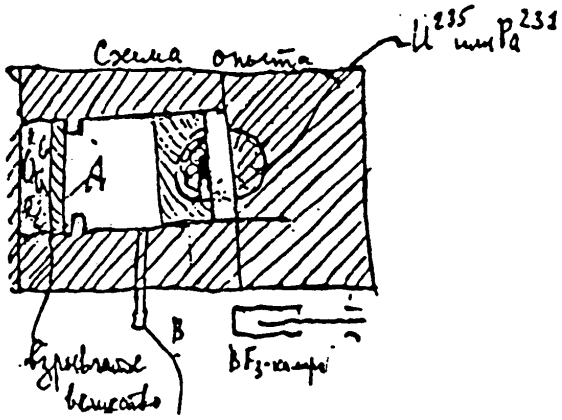

Figure 2. "Experimental scheme — U^{235} or Pa^{231} — BF_3-chamber — explosive" (clockwise from top).

3. The USSR Government decides to resume research on the use of atomic energy

Kurchatov's references quoted above were written at a time when the USSR Government had already decided to resume research on the release and practical use of atomic energy, interrupted by the war. The decision was finally made on September 28, 1942 when Stalin approved Order No. 2352ts of the State Defense Committee: "On Organizing Uranium Research" [1, pp. 269–271], [15, p. 277], [16, p. 28, 30], [17].

The decision was made just six weeks after the launch of the US Manhattan project. The Order of the State Defense Committee directed: "*To bind the Academy of Sciences of the USSR (Academician Ioffe) to resume research of the possibility of using atomic energy from nuclear fission of uranium and to report back to the State Defense Committee by April 1, 1943 on*

[3] Such a construction of an atomic bomb had previously been discussed by Zel'dovich and Khariton in paper [2]; compared to Flerov's 1941 design, a gun-type scheme makes it possible to attain greater supercriticality and, consequently, larger energy releases.

the possible creation of a uranium bomb or uranium fuel...'' The order established the special Atomic Nucleus Laboratory at the USSR Academy of Sciences, and ordained the building of laboratory facilities for separating isotopes of uranium and the launch of experimental research. According to the order, the Council of People's Commissars (CPC) of the Tatar Autonomous Soviet Socialist Republic was bound to provide to the USSR Academy of Sciences premises in Kazan' with an area of 500 sq m for the nuclear laboratory, and lodgings for ten researchers.

It is very interesting to look at the circumstances under which this historical decision was made while the war was raging at its worst.

A covering letter with appropriate elucidations was submitted to Stalin, asking him to approve the order of the State Defense Committee ''On Organizing Uranium Research''. The letter was signed on September 27, 1942 by V M Molotov, the Vice Chairman of the State Defense Committee and of the USSR CPC; it described the project as a joint initiative of the USSR Academy of Sciences (A F Ioffe) and the Committee on High School Affairs at the USSR CPC (S V Kaftanov) [1, pp. 268 – 269]. The available war-time documents are not sufficient to generate a clear picture of the events which occurred while the order in question was being prepared and accepted. The memoirs of the people who took part in those events are, of course, invaluable; however, human memory is not always perfect, so we must leave room for inevitable mistakes and discrepancies. The memoirs of S V Kaftanov are of special interest (the above observation is valid in this case too, so we have to select data which do not disagree with documentary sources). After many years, Kaftanov told the story of the events that brought about the SDC Order of September 28, 1942 to resume Soviet research on possible uses of atomic energy; he recalled: ''*In the autumn of nineteen-forty two, I was forwarded a letter sent to the State Defense Committee by Lieutenant Flerov. He was an aviation officer who had worked at FizTekh before the war. He had already made a first-rate discovery. Together with Petrzhak, they had discovered spontaneous fission of uranium. In his letter, Flerov spoke of the abrupt interruption of Western scientific publications on nuclear research. Flerov believed this meant that the research had become classified and, therefore, that the West is working on atomic weapons... This means that we, too, should start developing atomic weapons right away...*'' [18, p. 6]. Going back to Flerov's letter in a later passage, S V Kaftanov wrote: ''*The autumn of nineteen-forty two. The Germans are approaching the Volga river and the Caucasus. Everyone is working hard on things of utmost importance: tank armour, explosives, fuel for tanks and aircraft... People, natural resources, materials, everything is mobilized to capacity. And then someone suggests that we start working in an absolutely different field, totally new, something from science fiction...*'' [18, p. 7].

S V Kaftanov stressed the point that to him personally, Flerov's proposal did not sound like science fiction, not only because Kaftanov was an excellent professional and his official status gave him more access to information, but for two other reasons as well. The first was that his office had received in April 1942 notes on the use of atomic energy made by a killed German officer and found by guerrillas on territory previously occupied by the Germans. The second reason Kaftanov put as follows: ''*Roughly at the time when we were studying the German officer's notes and Flerov's letter, Hitler started making a fuss about the Germans inventing 'super-weapons'. And what if this were not mere propaganda? What if the fiend meant atomic weapons?*

I started asking physicists' advice. The person whose opinion I valued highest was Abram Fedorovich Ioffe. He believed there was proof that a nuclear chain reaction or, plainly, a nuclear explosion was principally possible, and that we should tackle it. My war-time experience proved that scientific and technical ideas are implemented at much higher speeds in an emergency. What would have taken 15 to 20 years before the war, could now be done several times quicker.

I asked Ioffe to add his signature to my first brief letter to the State Defense Committee, telling them about the need to open a scientific center on atomic weapons. He agreed. The letter was thus signed by the two of us and then sent...'' [18, p. 8]. As can be concluded from Kaftanov's story, after various departments drew their decisions about the letter, not all of them positive, the GKO charged Kaftanov and Ioffe with preparing a draft of the GKO order, which was approved by Stalin on September 28, 1942. Kaftanov and Ioffe also composed a draft GKO order ''On Uranium Mining'', accepted on November 27, 1942 (GKO Order No. 2542ts) [1, pp. 275 – 276].

The description of circumstances entailing the approval of the GKO order on uranium research resumption of September 28, 1942 would not be complete without another important detail.

Since September 1941, the USSR began to receive intelligence reports on conducting in Britain joint British – American intensive (classified) research on methods of using atomic energy for military purposes and creating enormously destructive atomic bombs. One of the most important documents obtained by the Soviet secret service in 1941 was the report of the British 'M.A.U.D. Committee'. The materials of the report obtained by the USSR People's Commissariat of Internal Affairs (NKVD in Russ. abbr.) pointed to the fact that the creation of atomic bombs was realistic, and there were chances it would happen before the war was over and therefore influence its course [19, p. 79 – 80].

L P Beriya (Vice Chairman of the USSR Council of People's Commissars and a member of State Defense Committee) sent an official letter to I V Stalin, informing him of Western research on atomic energy use for military purposes, mentioning proposals to organize similar research in the USSR and recounting the reactions of leading Soviet specialists to the NKVD intelligence. The first drafts of Beria's letter were composed by NKVD officers in late 1941 — early 1942 but the letter was dispatched as late as October 1942, after the GKO had accepted the order to resume uranium research in the USSR [1, pp. 244 – 245, 271 – 272], [13, pp. 99, 104 – 105, 109 – 111], [16, p. 27].

Meanwhile, at the time it was decided to resume uranium research, intelligence on atomic energy research done abroad arrived in the USSR from two sources: the NKVD and the GRU — the Main Intelligence Directorate of the Red Army General Staff.

For obvious reasons, Kaftanov did not mention the part played in the events he described by one major source of information, i.e. the materials that the GRU had sent him in August and early September 1942 [1, p. 266].

Before that, in May 1942, the GRU leadership informed the USSR Academy of Sciences of reports on Western research on military uses of atomic energy, and wanted to be

told whether the problem had any practical grounds at the moment [1, pp. 262 – 263].

The answer to the query was supplied by V G Khlopin in June 1942; he observed that for the previous year, there had been almost no publications of scientific papers concerned with the problems of using atomic energy. Khlopin wrote: "*The fact itself, I presume, is a cogent reason to believe that such papers are rated as highly important and are therefore classified. As to the institutes of the USSR Academy of Sciences, the research that was being done in that field has been interrupted, both because the institutes were moved away from Leningrad for the war, leaving behind their basic equipment* (*RIAN's cyclotron*), *and because, as we assume, the feasibility of using nuclear energy for military purposes in the near future* (*during the present war*) *is very questionable*" [1, p. 265 – 266], [16, pp. 27 – 28].

Against the cautious estimates of the prospects of extracting nuclear energy contained in Khlopin's letter, the vast importance of Kaftanov's actions looks even more convincing. It was what Kaftanov did that finally led to the government's decision to resume research on atomic energy problem in the USSR. Of course, when stressing Kaftanov's contribution we must keep in mind that the decisive role was undoubtedly played by the intelligence materials on contemporary Western research in the field of atomic energy. The intelligence had in all probability been Kaftanov's main motive as well.

Nevertheless, according to S V Kaftanov, the letter by Flerov was an important factor that encouraged Kaftanov and Ioffe to write their joint letter to the State Defense Committee.

Which one of Flerov's letters did Kaftanov allude to? Most probably, the letter addressed to Kaftanov, written, judging by its contents, in December 1941 but not mailed until March 17, 1942 [8, pp. 45, 50]. As was mentioned above, the original of this letter has not been found, but the Archive of the President, Russian Federation possesses a typewritten copy of its draft, the copy that Kurchatov forwarded to the Special Committee in February 1946 [10, pp. 432 – 434]. The archive of the Kurchatov Institute has a hand-written draft, either the original or the one restored by Flerov, of the same letter [8, pp. 53 – 60].

It was in this letter that Flerov emphasized the fact that Western journals had stopped publishing papers on uranium problem. Unlike Khlopin, Flerov quotes this fact as proof of the need to resume research in this field in the USSR:

"*The bottom line is that in all foreign journals we find a total absence of papers on this matter. The silence does not mean that work has stopped: papers which logically follow from previously published ones are not printed either, and announced papers fail to appear. In other words, there is a pledge of silence on this matter, and that is the best indication of the intensive work now being done.*

The Soviet Union must resume appropriate research; small as the chances of solving this problem in the near future may be, doing nothing will not certainly lead us to success, whereas new additional data that appears in the course of research may bring us closer to the solution..." [8, pp. 51, 56 – 57], [10, p. 433].

Flerov's letter to Kaftanov had a remarkable ending: "*History is now being made on battlefields but we must not forget that the science that pushes technology ahead is done in scientific laboratories. We must bear in mind for all time that the state which makes the first atomic bomb will be able to dictate its will to the whole world. And the only thing that we can do now to make good the mistake of staying idle for six months is to resume work and to launch it on a scale even greater than before the war*" [8, pp. 52, 60], [10, p. 432].

The order of the State Defense Committee, accepted on September 28, 1942, made A F Ioffe responsible for resuming research on the use of atomic energy. However, probably as soon as the order was approved, A F Ioffe started making steps in order to accomplish what he proposed in August 1940 [1, p. 135], i.e. to have I V Kurchatov appointed head of the entire uranium project (see Ref. [1, pp. 280 – 283, 297 – 299]).

By Molotov's direction, in October – November 1942 Kurchatov was given access to intelligence reports supplied by the NKVD and GRU that concerned nuclear research abroad, including the report of the 'M.A.U.D Committee'. Having studied those materials, Kurchatov filed a report to Molotov. In the Conclusions to this report, Kurchatov wrote:

"(1) *In the field of uranium research, Soviet science has fallen considerably behind English and American science and now commands incomparably smaller material resources for experimental research.*

(2) *In the USSR, uranium investigations are now less active, and in England and America more active than before the war.*

(3) *The scale of research done in England and America in 1941 was greater than that planned for 1943 by the USSR State Defense Committee's Order.*

(4) *The materials at our disposal are insufficient to judge the practical feasibility or infeasibility of producing uranium bombs, although there is almost no doubt that Western scientists have come to a very definite conclusion on this matter.*

(5) *However, in view of the fact that obtaining definite information on that conclusion would meet with huge, perhaps insurmountable obstacles, and also of the fact that we cannot rule out the possibility that such a terrible weapon as a uranium bomb may be used in the war, there is a clear need to place the uranium work on a broad footing in the USSR, involving the most qualified scientists and technical professionals of the Soviet Union. Apart from the scientists who are already working on uranium, it would be desirable to engage the following people:*

Professor A I Alikhanov and his group,
Professors Yu B Khariton and Zel'dovich,
Professor I K Kikoin,
Professor A P Aleksandrov and his group,
Professor A I Shal'nikov.

(6) *To manage this complicated and extremely strenuous effort, it will be expedient to establish an ad hoc committee, reporting to the USSR State Defense Committee, with you as Chairman, and with Academy Members A F Ioffe, P L Kapitza and N N Semenov as science officers.*

Professor I Kurchatov
27.11.42" [1, p. 279], [15, pp. 278 – 279].

Molotov's resolution is written on the report:

"*To Cde Stalin. Please read Kurchatov's report. V Molotov, 28.11*" [1, p. 279], [15, p. 279].

It should be noted that the proposal "*to consider the matter of establishing a scientific advisory board of experts answerable to the USSR State Defense Committee that would coordinate, analyze and direct the efforts of all academics and research agencies of the USSR working on the problem of uranium atomic energy*" was contained in a letter dispatched to Stalin by Beriya on October 6, 1942 (as well as in the drafts of the same letter that were composed by USSR NKVD officers in late 1941 – early 1942) [1, pp. 271 – 272].

4. Kurchatov is appointed Science Supervisor of uranium research. The creation of Laboratory No. 2 at the USSR Academy of Sciences

The above-quoted report reveals Kurchatov's deep concern about the situation with uranium research in the USSR in late 1942, and with what was planned for 1943. Increasing both the scale and the efficiency of research cried for new logistical measures. Such measures were suggested in letters sent to Kaftanov and Ioffe in December 1942 and January 1943 by Alikhanov and Khlopin [1, pp. 285 – 286, 293 – 297].

Having analyzed the outcomes of the first stage of the organization and activities of the special atomic nucleus laboratory, Kaftanov and Ioffe filed a note to Molotov on January 23, 1943, reporting the accomplished results and proposing new steps to improve the organization of research [1, pp. 297 – 299]. The proposals included creation of a material base for a Moscow-based special atomic nucleus laboratory, moving most of the research to Moscow and appointing I V Kurchatov head of the entire uranium project. The choice of Kurchatov as head of the uranium project, suggested long since by Ioffe, was doubtless due to Kurchatov's apparently unrestrained and infectious commitment to active work, his youthful ardour undiminished by years, his ability to find the right people and bring them together for a particular scientific or technical effort, his utmost lucidity of mind, and his ability to subject emerging problems as well as scientific and technical data to the most profound analysis. Seeking the maximum accuracy in both the setting up the scientific problems and the choice of methods for solving them, he demanded the same of everyone who worked with him [15, pp. 279 – 280].

The note written by Kaftanov and Ioffe, to which a draft for a new State Defense Committee's order was appended, ended with the words: "*For the enhancement and further development of uranium research, we ask you to peruse and accept the attached draft order of the State Defense Committee*" [1, p. 299]. By the time the draft order was submitted for approval, S V Kaftanov and the CPC Secretariat filed two more notes to Molotov, explaining and justifying the proposed measures [1, pp. 307 – 309].

On February 11, 1943, the draft State Defense Committee's order was signed by V M Molotov with a few amendments made to it [1, pp. 306 – 308].

The final text of the USSR State Defense Committee's Order No. 2872ts read, in particular:

"*With the purpose of promoting the progress of uranium research:*

(1) *Cdes M G Pervukhin and S V Kaftanov are made responsible for everyday management of uranium research and systematic assistance to the special atomic nucleus laboratory at the USSR Academy of Sciences.*

Professor I V Kurchatov is appointed scientific supervisor of the uranium project.

(2) *The Presidium of the Academy of Sciences is given permission to bring a group of scientists from the Kazan' special atomic nucleus laboratory to Moscow to carry out the most responsible part of the uranium project...*

(11) *The Head of the special atomic nucleus laboratory, Professor I V Kurchatov, is bound to carry out all necessary investigations by July 1, 1943, and to report back to the State Defense Committee by July 5, 1943 on the feasibility of creating a uranium bomb or uranium fuel*" [1, pp. 306 – 307], [15, p. 280], [17].

Notice the careful wording of the objective stated in the State Defense Committee's Order of February 11, 1943 (similar to that of September 28, 1942): it requests a report on the feasibility of creating "*a uranium bomb or uranium fuel*", which probably reflected the lack of faith in the prospects of designing an atomic bomb.

Soon after releasing the GKO Order of February 11, 1943, the governing body of the USSR Academy of Sciences made the decision to establish a special laboratory at the Academy for conducting the uranium research provided by the order outlined. The Academy passed Order No. 121, which read: "*In accordance with the Order of the State Defense Committee, to organize Laboratory No. 2 at the USSR Academy of Sciences*". The order was signed by the Vice President of the Academy, A A Baikov, and the Secretary of its Presidium, N G Bruevich, on April 12, 1943. At an earlier date, March 10, 1943, the same two officials had signed USSR Academy of Sciences' Order No. 122, appointing I V Kurchatov Head of Laboratory No. 2 [1, p. 321].

Judging by Kurchatov's reports on the uranium project (for instance, the report filed to Molotov on July 30, 1943), Laboratory No. 2 started functioning in March 1943, although it took a few months in 1943 and even the first weeks of 1944 before the laboratory acquired the administrative status of a fully fledged scientific institution, later to become the Laboratory of Measurement Tools at the USSR Academy of Sciences (LIPAN in Russ. abbr.), then the I V Kurchatov Institute of Atomic Energy, and now the Russian Research Centre 'Kurchatov Institute' [1, pp. 321, 368 – 373, 382 – 283], [15, p. 280].

There is the question of how the Kurchatov Institute got its original name, 'Laboratory No. 2'. Why did the leading institute of applied research into atomic energy get the number 2? The most plausible explanation seems to be the following [20, 21].

The GKO Order of September 28, 1942, laid the responsibility for resuming work on the project on the Vice President of the USSR Academy of Sciences, the Director of the LFTI (Leningrad Physicotechnical Institute) A F Ioffe. Naturally, forming of a special atomic nucleus laboratory that the order committed the Presidium of the USSR Academy of Sciences to accomplishing within the Academy, was started basing around the LFTI, which was evacuated from Leningrad to Kazan' because of the war. However, until the approval of the new GKO Order of February 11, 1943, which appointed Kurchatov science supervisor of the uranium project effort and head of the special atomic nucleus laboratory and permitted the Presidium of the USSR Academy of Sciences to bring a group of scientists from the Kazan' special nuclear laboratory to Moscow, the USSR Academy of Sciences passed no orders concerning the organization of a special laboratory. The first relevant order was the USSR AN Order No. 122 of March 10, 1943, by which Kurchatov was appointed Head of Laboratory No. 2. According to Ref. [20, pp. 150 – 151], the LFTI had by that time organized ten laboratories. One of those ten, Laboratory No. 2 on acoustics and radiophysics, was being closed down, and its former head, A A Kharkevich, had taken a job with the P N Lebedev Physics Institute (FIAN) of the USSR Academy of Sciences by summer 1943. This is why the Order No. 122 of the USSR Academy of Sciences gave Kurchatov's laboratory at LFTI the number 2, as agreed

with the administration of LFTI. The laboratory kept its number even when the order of the USSR Academy of Sciences accepted on April 12, 1943 made it legally independent from the LFTI and renamed it 'Laboratory No. 2 of the USSR Academy of Sciences'. This story was taken by the authors from Refs [20, 21]; it is corroborated by an order of 14 August 1943 signed by Ioffe in his capacity as LFTI Director; the order concerned the LFTI group in Kazan' and read:

"1. *To organize a laboratory with the following staff:*

1) I V Kurchatov 2) A I Alikhanov 3) M O Kornfel'd 4) L M Nemenov 5) P Ya Glazunov 6) S Ya Nikitin 7) G Ya Shchepkin 8) G N Flerov 9) P E Spivak 10) M S Kozodaev 11) V P Dzhelepov.

2. *To refer to the laboratory in the future as 'Laboratory No. 2'.*

3. *To appoint Professor I V Kurchatov as Head of Laboratory No. 2.*

4. *To consider the entire staff of the laboratory being transferred to Moscow to a regular work.*

5. *To dismiss Professor I V Kurchatov from his present post as Head of Laboratory No. 3...*" [20, p. 150].

By making this order, A F Ioffe both confirmed the earlier decision to organize Laboratory No. 2 at the USSR Academy of Sciences and stressed, quite rightly, that the laboratory had its roots in the LFTI. It should be noted that an LFTI order by which "*I V Kurchatov was taken off the staff and pay-roll of LFTI in connection with his being entered in a separate pay-roll*" was only issued on January 27, 1944, and the fact was entered on Kurchatov's job record [20, p. 151].

5. The uranium bomb and a bomb made of the 'extraterrestrial' material

The urgent goal pursued by the special atomic nucleus laboratory (called Laboratory No. 2 since March 1943) — to carry out all necessary investigations and to report back to the State Defense Committee "*on the feasibility of creating a uranium bomb or uranium fuel*" — was made even more imperative by the fact, mentioned earlier in Kurchatov's letter to Molotov of November 27, 1942, that intelligence reports did not provide a comprehensive answer to the question of whether it was possible to make a uranium bomb.

Meanwhile, the experimental and theoretical bases that Laboratory No. 2 had at its command in the first six months of 1943 and for quite a while afterwards, was insufficient to give a final answer to the question of the feasibility of an atomic bomb while relying solely on its own experimental and theoretical data.

However, regularly supplied intelligence materials, including those that I V Kurchatov already had at his disposal by spring 1943, left him no doubts as to the feasibility of a bomb made from uranium-235. As follows from I V Kurchatov's report of July 4, 1943 regarding the list of American papers on the uranium problem that was supplied through intelligence service channels, it was not the possibility of producing a uranium-235 bomb that he was concerned about, but rather the contradictions between various papers on the fission cross sections of uranium-235 in the medium-energy region of neutrons. I V Kurchatov observed: "*The issue is of critical importance, since the fission cross section in this region dramatically affects the size of the uranium-235 bomb and the very possibility of making a pile from metallic uranium*" [1, p. 356], [15, p. 281].

In spring 1943, I V Kurchatov understood a principally new option for designing an atomic bomb. In a note to M G Pervukhin, dated March 22, 1943, I V Kurchatov wrote: "*The materials that I have been studying recently... show that waste from the burning of nuclear fuel in a 'uranium pile' can probably be used to replace uranium-235 as the bomb material*[4]. *Bearing this in mind, I have studied with care the last papers on transuranium elements (eka-rhenium-239 and eka-osmium-239) that the Americans published in 'Physical Review', and have found a new direction for solving the entire uranium problem...*". I V Kurchatov meant the use of plutonium-239, called eka-osmium-239 in the letter, for the atomic bomb. He wrote that "*the prospects of this approach are extremely exciting... According to all the currently existing theoretical ideas, a neutron penetration into eka-osmium nucleus must lead to the large energy release and the emission of secondary neutrons, so that in this respect it should be equivalent to uranium-235... If eka-osmium does indeed have the same properties as uranium-235, it can be extracted from a 'uranium pile' and used as material for an 'eka-osmium' bomb. The bomb will thus be made from an 'extraterrestrial' material which is no longer to be found on our planet.*

It is clear that such a solution to the whole problem eliminates the need to separate the isotopes of uranium which is used both as fuel and explosive...

Of course, many of the amazing options analyzed above are not yet fully substantiated. Their implementation is only realistic if eka-osmium-239 is truly analogous to uranium-235 and if, moreover, we can operate some kind of the 'uranium pile'. Besides, the proposed scheme still requires quantitative consideration of every detail of the process. I shall assign Professor Ya B Zel'dovich to do this without delay" [1, pp. 326–327], [13, pp. 116–117], [15, pp. 281–282].

In July 1943, Kurchatov was acquainted with the recently obtained intelligence that the first uranium pile had been started in the USA, thus opening up prospects for large-scale use of atomic energy and enabling the creation of a new fissionable material with an atomic mass 239 that could be used in an atomic bomb (the pile in question was Enrico Fermi's nuclear reactor, launched in Chicago on December 2, 1942).

I V Kurchatov recognized the launch of the world's first nuclear reactor as an extraordinary event. In his review of the intelligence material, he wrote: "*The reviewed material contains the extremely important news that the first uranium–graphite reactor has been launched in America: this news can only be described as a major event in science and technology worldwide*" [1, pp. 375–376], [15, p. 281], [16, p. 33].

6. Research on the atomic bomb begins at Laboratory No. 2 of the USSR Academy of Sciences

I V Kurchatov was perfectly aware that the Soviet atomic project would not be a success unless profound research and development efforts covered every aspect of the project. Ever

[4] It should be observed that the above-mentioned report of the 'M.A.U.D. Committee', supplied through the secret service channels in 1941 and shown to I V Kurchatov in late 1942, mentioned the fact that an element with mass 239 would probably possess fission properties similar to those of uranium-235, and could be used as the explosive in an atomic bomb (see Ref. [19, p. 80]).

since the project started, an important place in Kurchatov's plans had been given to organizing theoretical justification along with computation supply and eventually the design and manufacture of an atomic bomb. I V Kurchatov had been actively working on this since 1943. He realized that the success of the atomic bomb project depended on the effort of the highest-class professionals.

On March 20, 1943, just over a month after being appointed science supervisor of the uranium project, I V Kurchatov wrote a letter to M G Pervukhin, which read:

"*At the first stage of the explosion of a uranium bomb, a large amount of matter that is not yet involved in the reaction will reside in a very peculiar state of almost complete ionization of all the atoms. This state of matter will dictate the future development of the process and the destructive capacity of the bomb.*

Nothing like this state of matter has ever been observed in experiments, even on the minutest scale, nor can it be observed until the bomb is created. Such a state of matter is only assumed to exist in stars. I believe it is possible to examine this particular stage of the explosion theoretically in general terms. This difficult task can be assigned to Professor L D Landau, a well-known theoretical physicist who is a specialist and brilliant expert on similar matters" [1, p. 325], [15, pp. 282 – 283].

In the letter, I V Kurchatov asks M G Pervukhin to consider his proposal to give L D Landau the job of calculating the development of an explosion in a uranium bomb (he also raised the issue of employing P L Kapitza as a consultant on isotope separation).

The available documents prove that theoretical work on the atomic bomb at Laboratory No. 2 of the USSR Academy of Sciences began in 1944. The plan of scientific research at Laboratory No. 2 for 1945 was passed on May 15, 1945 and signed by Stalin as the GKO Order No. 8579ts/sd (sd stands for special dossier). The plan emphasized the fact that all planned calculations of energy release in a uranium bomb followed from research done in 1944, developing it further [22, pp. 6 – 14]. Calculations in 1944 were being made disregarding the fact that the official 1944 plan for Laboratory No. 2, authorized by GKO Order No. 5582ts on April 8, 1944, signed by Molotov, did not include research on the atomic bomb [23, pp. 135 – 136]. The story behind this is as follows. In the first wording of the 1944 plan for Laboratory No. 2, signed by I V Kurchatov on January 7, 1944, there was an item "Theoretical elaboration of the problems involving making of a bomb and a reactor (01.01.44 – 01.01.45) — Zel'dovich, Pomeranchuk, Gurevich" [15, p. 283], [24, sheets 12 – 13]. However, M G Pervukhin wrote on the manuscript of the plan: "*Widen the plan of experimental research. Add experimental work, the construction of pilot plants, participation in design and construction*". The project was revised, with an accent on experiment and methodology as well as the manufacture of physical facilities (elaborating methods for industrial production of heavy water, completing construction and launching of the cyclotron, making a prototype uranium-graphite reactor, creating a neutron generator, and conducting physical experiments including those on plutonium production and methods for studying it); meanwhile, direct mention of the atomic bomb was deleted.

It should be observed that the GKO Order No. 5582ts which commanded I V Kurchatov to ensure that Laboratory No. 2 fulfilled its plan for 1944, also bound the People's Commissariat of Chemical Industry (M G Pervukhin) to engineer in 1944 a workshop that would manufacture heavy water and a factory that would produce uranium hexafluoride (the raw material for uranium isotope separation facilities). Coincident with these directions, the People's Commissariat of Nonferrous Metallurgy (P F Lomako) was bound to ensure that the pilot plant produced 500 kg of metallic uranium in 1944, that metallic uranium workshop was built by January 1, 1945, and that Laboratory No. 2 was supplied with tens of tons of high-quality graphite blocks in 1944.

Approved simultaneously with GKO Order No. 5582ts, the GKO Order No. 5585ts planned a boost of geological prospecting for radioactive elements in 1944.

7. "To entrust Cde L P Beriya with supervising the advance of the uranium project"

In spite of the approval of GKO orders quoted above, and a whole range of other GKO orders accepted earlier and aimed at encouraging progress in the nuclear energy release (they concerned geological prospecting, mining and processing of uranium ores, the production of metallic uranium, the construction and staffing of Laboratory No. 2, the design of facilities for separating uranium isotopes by diffusion, and, in particular, the establishment in Leningrad of an affiliate of Laboratory No. 2 with a special design bureau of its own), I V Kurchatov and M G Pervukhin, after analyzing the progress of research in the USSR and new intelligence reports on the work being done abroad, soon realized the need for additional organization measures that would provide further development of uranium research in the USSR. In May 1944, I V Kurchatov and M G Pervukhin composed several documents in which they proposed measures towards this end.

The first of these documents was Kurchatov's report to Pervukhin in which he quoted data on technical approaches to making the atomic bomb and atomic reactors, and described the relevant situation in the USSR and abroad [24, sheets 19 – 22].

In that report, dated May 18, 1944, Kurchatov made a drawing of a gun type atomic bomb and described its design and the way it was supposed to work: "*An atomic aerial bomb consists of cylindrical shell with the atomic explosive, uranium-235 or plutonium-239, placed at both ends. The detonation of initiation powder charges located underneath the active explosive sets the bomb off. The A-bomb explosion happens when the (a) and (b) halves of the uranium-235 or plutonium-239 charge are brought together.*

Calculations show that a bomb charge equivalent to 1000 tons of TNT can be produced using 2 to 5 kg of uranium-235 or plutonium-239.

At present, we do not have any absolutely unequivocal data to prove that a bomb built this way will work, but the more experiments we do, the more certain we are that we have the right scheme.

The main difficulty in making the bomb is to produce uranium-235 and plutonium-239...

After reading through some very important documents that were handed over to us, and conducting certain experiments, we now have no doubts that diffusion machines can be used to produce uranium-235..."

I V Kurchatov wrote that according to interim estimates, the design of a diffusion plant for producing uranium-235 would be finished by mid-1945. "*It is now difficult to predict*

exactly when the plant shall be built and put into operation.'' Touching upon problems with making atomic piles of 'uranium – graphite' and 'uranium and heavy water' type, and mentioning existing difficulties[5], I V Kurchatov observed, nevertheless: ''*The difficulty of building a diffusion plant may hold back the production of uranium-235 for many years, so that it will be quicker to make a bomb using the plutonium produced in the operating reactor*.''

For the Soviet atomic project, this Kurchatov's observation proved to be a prophecy.

I V Kurchatov's report ended with the words: ''*The major leap forward in uranium research that has been made in our country in 1943 – 1944 is still not enough. I think we continue to lag behind Western countries. It is absolutely necessary to invite new scientists to work at Laboratory No. 2 (Professors Khariton and Artsimovich, and researcher Meshcheryakov) and to further improve the material and technical basis of the laboratory*.''

The proposal to invite Yu B Khariton to work at Laboratory No. 2 was probably motivated by I V Kurchatov's plans to take the first practical steps towards designing the atomic bomb.

The next day, on May 19, 1944, I V Kurchatov wrote a memorandum entitled ''On the situation in uranium research as of May 20, 1944'' and addressed to Stalin. He wrote:

''*The successes of 20th century science in studying the properties of the atom reached a climax in 1939 when the fission of uranium atoms was discovered. Due to this phenomenon, it is now possible, for the first time in human history, to find a way to make practical use of the enormous stores of energy that are concentrated at the center of an atom, in its nucleus, to make superdestructive bombs and superpowerful reactors.*

However, the technical solution to the problem has, since the very start, met with huge difficulties that most Soviet scientists believed were impossible to overcome.

Naturally, due to this attitude, only a small group of academics carried out uranium research in our country before the war, and with the start of the war that work was suspended.

Abroad, things were very different indeed...

In late 1942, the USSR Government became familiar with both the scope of uranium research done abroad and some of its results.

Accordingly, on February 11, 1943, the State Defense Committee ordered to organize a special laboratory (Laboratory No. 2) at the USSR Academy of Sciences to do classified research on uranium.

The new laboratory was organized from scratch, having no staff, premises or equipment, and suffered from war-time hardships. The laboratory did not also enjoy the support of the scientific community, because most scientists were not familiar with the course of classified research and were very sceptical about its prospects. However, the unfailing attention and help of Cde V M Molotov, the direct everyday management by Cde M G Pervukhin, and the support of Cde S V Kaftanov helped Laboratory No. 2 to get past its problems, to get up on its feet, to start work and obtain a number of important results''.

The next section of the memorandum was entitled ''The atomic bomb''. It read:

''*Study of intelligence data on the research of foreign scientists together with the theoretical calculations and experiments done at Laboratory No. 2 refute the opinion, widespread in our country, that there is no feasible technical solution to the uranium problem.*

At the moment, we have found definite ways of using intraatomic energy both to make atomic bombs and to make atomic piles.

As the explosive in the atomic bomb, we can use either uranium-235, a special kind (isotope) of uranium which in nature is always mixed with common uranium, or plutonium-239, a new chemical element which has been obtained using a cyclotron. Plutonium-239 has long been nonexistent on Earth; it shall be produced in atomic piles as a result of violent processes of transformation of matter.

To set off the explosion, two pieces of uranium-235 or plutonium-239 should be rapidly brought together; this can be accomplished through their counter motion by the action of the pressure of gunpowder gasses in a tubular shaft sealed at both ends.

Calculations show that the atomic bomb needs at least 2 – 5 kg of uranium-235 to make it work. American research reveals that the same amounts will be required if we use plutonium, since its properties are very similar to those of uranium-235. The destructive effect of such a bomb is equivalent to that of an ordinary bomb charged with 1000 tons of TNT...''

Further down in his memorandum, I V Kurchatov dwelt in detail upon the problems and difficulties in producing uranium-235 and plutonium-239. Let us quote the final words of the report: ''*It can be seen from the above that although the use of uranium energy involves the solution of immensely complicated problems, the threat of atomic warfare and the prospects that atomic piles open up for power engineering are of such importance to the state that there is an imminent need to advance uranium research to the greatest possible extent. I ask you to place the issue of further progress of this research for thorough consideration*'' [25, sheets 4 – 9].

M G Pervukhin appended I V Kurchatov's memorandum to his own letter entitled ''On the uranium problem'', also written on May 19, 1944 and addressed to Stalin. In this letter, M G Pervukhin stressed the following point: ''*At present, the status of theoretical research on uranium problem in the USSR makes it possible to begin the construction of a number of production units, and to design plants that will produce uranium-235 and the new chemical element, plutonium. In order to catch up with foreign countries, we must give the uranium project the status of an affair of national importance, no less large-scaled and significant than, for example, radar design*[6]. *It is necessary to make decisions on the following issues:*

(1) *To have more physicists working at Laboratory No. 2.*

(2) *To create an experimental base at Laboratory No. 2 and to increase the staff of designers at its newly organized special design office in order to expedite the design of machines for producing uranium-235.*

(3) *To begin the construction of the unit for industrial production of heavy water...*

[5] Shortage of uranium and the fact that large amounts of it were needed for a uranium – graphite pile; the lack of a plant producing the heavy water needed in a 'uranium and heavy water' pile, which would require smaller amounts of uranium compared to the uranium – graphite pile.

[6] GKO Order No. 3686ts of July 4, 1943 ruled the establishment under the GKO of a Radar Council chaired by G M Malenkov.

(4) *To develop extensive geological prospecting of uranium deposits in the USSR, since all known deposits are very small and have low uranium content...*

(5) *To establish under the GOKO a Uranium Council that will execute everyday control and support of uranium research; the Council could consist of the following: 1) Cde L P Beriya (Chairman), 2) Cde V M Molotov, 3) Cde M G Pervukhin (Vice Chairman), 4) Academician I V Kurchatov.*

The last item is especially important since Laboratory No. 2 belongs to the USSR Academy of Sciences only on paper, whereas in fact it reports to the USSR Council of People's Commissars. As authorized by the State Defense Committee, I supervise the activities of Laboratory No. 2 on a daily basis and handle all current matters on behalf of the USSR Council of People's Commissars".

The letter ended with the words: "*I append herewith a more detailed memorandum on the uranium problem made by Academician I V Kurchatov, asking you to read it and, if possible, to give me an appointment in order that I may report on this matter*" [25, sheets 1 – 3].

M G Pervukhin had thus approached I V Stalin with a proposal to raise the status of the management of the Soviet atomic project and, simultaneously, to charge L P Beriya with managing the project on the part of the state (so far, this function was de-facto exercised by V M Molotov). Pervukhin's proposal suggested a boost of his own status in the management of the project: he was proposed as the Vice Chairman of the Council, i.e. Beriya's deputy, whereas Molotov was reduced to a member of the Council. S V Kaftanov was not listed at all on the Uranium Council (as mentioned before, under the GKO Order of February 11, 1943, both M G Pervukhin and S V Kaftanov were entrusted with responsibility to manage the uranium project on a daily basis and to give systematic assistance to Laboratory No. 2).

It must not be ruled out that Pervukhin's direct approach to Stalin was qualified as a breach of subordination, so that the next day, on May 20, 1944, M G Pervukhin sent letters of the same contents to V M Molotov and L P Beriya. The two letters only differed from the original letter to Stalin in the final words: "*I ask you to give consideration to this matter and to give myself and Academician Kurchatov an appointment for a more detailed report. I have sent Comrade Stalin a similar note with the detailed report of Academician Kurchatov*" [24, sheets 23 – 25].

The following comment, probably in V M Molotov's hand, was written over this letter: "*Important. — Report to Cde Stalin. — Talk to Cde Pervukhin. — Collect all we have on uranium. 25/V.44*".

Apparently, M G Pervukhin and I V Kurchatov were received by V M Molotov in June 1944, and it was around those dates that Molotov reported to Stalin. The latter accepted Pervukhin's suggestion to entrust L P Beriya with managing the uranium project. We have the following facts to corroborate this. Already on June 21, 1944, V M Molotov forwarded L P Beriya next draft orders on the atomic project that he had received, and a letter which read: "*Cde Beriya. I am sending you draft orders (of the GOKO and the CPC) on the uranium project that I received from Cde Pervukhin. V Molotov. 21.06.44*" [24, sheet 47]. On July 10, 1944, M G Pervukhin and I V Kurchatov sent L P Beriya a letter entitled "On developing efforts on the uranium problem in the USSR"; appended to it was a draft GKO Order of the same title [24, sheets 53 – 61].

The letter read, in particular:

"(1) *Available theoretical materials make it possible to begin the technical design of a uranium – graphite pile and a uranium and heavy water pile right away... Parallel to the design, it is necessary to prepare materials to be used in the construction of the piles...*

(2) *As the explosive in the atomic bomb, either uranium-235 or plutonium can be used... To obtain plutonium, we need a working atomic pile which requires large amounts of rare materials. Uranium-235 can be produced from smaller amounts of uranium by the diffusion technique...*

The immediate task is to build a pilot diffusion installation and to design a diffusion plant for the production of uranium-235.

Solving this complex problem requires the trial development of special compressors and a special porous partition with small orifices, which demands the creation of a well-equipped pilot plant at the Leningrad affiliate of Laboratory No. 2 at the USSR Academy of Sciences.

Uranium-235 is obtained by the diffusion technique from uranium hexafluoride, which requires the building of a special workshop for its commercial production.

Moreover, it is possible and necessary to immediately start working on the design of the atomic bomb.

(3) *The uranium project requires, besides addressing the practical matters mentioned above, further profound research of theoretical issues of nuclear physics.*

The first in that range is the magnetic method of producing uranium-235. This method is not fully understood but is known to have a number of advantages over the diffusion technique...

An urgent task is to finish the construction, started in pre-war time, of the cyclotron at the Leningrad Physicotechnical Institute of the USSR Academy of Sciences (with an electro-magnet weighing 70 tons) and to build one or two powerful state-of-the-art cyclotrons with 1000-ton electromagnets.

The steadily growing rate at which the project is progressing requires more professional staff than we have; it is therefore necessary to launch a major project for training qualified professionals in this field.

We submit to your attention a draft order of the State Defense Committee, commanding the development of uranium efforts in the USSR".

Here are a few extracts from the order:

"*Considering the progress of Soviet efforts to solve the uranium problem to be a task of utmost importance to the state, the State Defense Committee orders:*

(1) *To hold it necessary to place the work on the uranium – graphite pile, the uranium and heavy water pile, on diffusion and magnetic methods of producing uranium-235, and on the use of uranium-235 and plutonium in the atomic bomb on a wide footing.*

(2) *To reorganize Laboratory No. 2 of the USSR Academy of Sciences as the Scientific Research Institute No. 2 of the USSR Council of People's Commissars. To appoint Academician I V Kurchatov Director of the Institute.*

(3) *To bind the Scientific Research Institute No. 2 of the USSR Council of People's Commissars (Academician I V Kurchatov): ... e) in collaboration with the Scientific Research Institute No. 6 of the People's Commissariat of Ammunition, to complete the design of an aerial uranium bomb by September 1, 1945...*

(15) *To establish the Uranium Council, subordinate to the State Defense Committee; the Council will supervise and*

support the uranium effort on a daily basis, and will have the following members: Cde L P Beriya (Chairman), Cde M G Pervukhin (Vice Chairman), Cde I V Kurchatov".

The above-quoted draft GKO order contains a few points deserving special attention. This was the first draft government's order which dealt directly with designing the atomic bomb. One can only wonder at I V Kurchatov's readiness to have Laboratory No. 2 leave the umbrella of the USSR Academy of Sciences. Although the lab's subordination to the Academy of Sciences had in fact been formal in many respects, it had still mattered a great deal and its significance even at that time had doubtless been much more than formal. Finally, the draft order reflected the decision, already taken at that time, to dismiss V M Molotov from the command of the atomic project.

The draft GKO order did not get L P Beriya's support; on July 14, 1944, Beriya ordered his office staff to collaborate with M G Pervukhin in composing a new draft order within five days.

The new draft was submitted to L P Beriya for examination in early August 1944 [24, sheets 119 – 123]. It lacked the items mentioning the reorganization of Laboratory No. 2 and the establishment of a Uranium Council. However, L P Beriya did not approbate this draft either, and commissioned the executors with its revising once again.

While the new draft order was being re-written, the cyclotron at Laboratory No. 2 was fully built and put into operation. I V Kurchatov deemed it necessary to inform V M Molotov about this. The fact that I V Kurchatov wrote to V M Molotov to tell him about the cyclotron start-up, and not to L P Beriya, merits notice:

"*Secret*
To Cde V M Molotov

Deeply respected Vyacheslav Mikhaĭlovich,

I am glad to inform you that our laboratory has completed the construction of the cyclotron and put it into operation in late August this year. The creation of this unit is but a minor achievement in view of the goals that you set before us; still, the laboratory body is inspired by the first success on its laborious path.

The launching of the cyclotron makes me want to express here my warmest gratitude for your help in the construction of the unit.

I would be very glad if you could afford some time, however short, to visit and examine the new unit.

Academician I Kurchatov
Moscow, September 8, 1944" [26, sheet 55].

To show the kind of atmosphere that surrounded the preparation of a new draft GKO order [7] on the development of work on uranium, we can look at the information that an executive at L P Beriya's office, the future Secretary of the Special Committee, V A Makhnev [9, p. 17], wrote on November 1, 1944. Below are a few extracts from the material.

"*To Cde L P Beriya*
Information

While preparing, on your instructions, the draft GOKO order "On developing efforts on the uranium problem", we looked into the current situation with respect to the prospecting, mining and processing of uranium ores and the organization of scientific research in this field. We consider it necessary to inform you of the following:

Prospecting of uranium deposits.

Over the last two years, owing to the lack of attention to this matter and the poor material and technical equipment of geological prospecting teams, the survey of uranium deposits has made almost no headway".

The next section of the information dealt with "Mining and processing of ore".

The figures given in this section show that the actual quantities of uranium ore mined and processed in 1944 proved many times smaller than what the GKO Order No. 3937ts of August 16, 1943 had targeted for the USSR Committee on Geology and the USSR People's Commissariat of Nonferrous Metallurgy. "*The unsatisfactory situation in mining uranium ores and producing uranium salts is explained by the fact that the People's Commissariat of Nonferrous Metallurgy did not encourage the relevant activities and allotted meagre funds and efforts to them... The technology for producing metallic uranium of such standards that meet the conditions of Academician Kurchatov's experiments, has not been devised at all; the metal was not and is not being produced...*

Organizing scientific research.

At this moment, Laboratory No. 2 is located in a single three-storey building which houses all experimental units, the laboratory, the library, the mechanical workshop, the lodgings of the staff and the guards, and a one-storey building intended to be used as a kitchen for dog food by an experienced dog-breeder working for the VIÉM [8].

The laboratory does not have sufficient premises to bring its staff from Leningrad and the Ural; it suffers from a shortage of lodgings, equipment and materials and therefore fails to fulfil its plans.

Having no suitable depository, the laboratory keeps its invaluable store of radium (4 grams) in a potato cellar.

Proposals.

In view of the fact that the USSR Academy of Sciences and the People's Commissariat of Nonferrous Metallurgy have failed to lead the mining and processing of uranium ores and scientific research into uranium nature and extraction out of a primitive state in two years, we ask you to accept the proposed draft GOKO order which stipulates the following:

(a) the transfer of scientific research on uranium, the mining and processing of principal uranium deposits to the control of the USSR NKVD;

(b) the allotment to the USSR NKVD of equipment and materials needed for developing the uranium project.

V Makhnev" [24, sheets 133 – 136].

The new draft GKO order "On developing the uranium problem" submitted by L P Beriya was coherent with V A Makhnev's information. The draft read:

"*The State Defense Committee holds that extensive development of uranium mining, ample progress of scientific research on the uses of uranium for military and industrial purposes, and prompt practical application of scientific discoveries in the domain of uranium research in the USSR are of utmost importance to the state.*

[7] In some of the documents written in those years, the State Defense Committee was also abbreviated in Russian as GOKO.

[8] All-Soviet Institute of Experimental Medicine.

In this connection the State Defense Committee orders:

(1) *To reorganize Laboratory No. 2 of the USSR Academy of Sciences as the State Scientific Research Institute No. 100 and to subordinate it to the USSR NKVD (Cde Beriya).*

To appoint Academician I V Kurchatov Director, and Corresponding Member of the Academy, Professor I K Kikoin, Vice Director of the State Scientific Research Institute No. 100. To establish a Technical Council at Institute No. 100. To charge Cdes Beriya and Malenkov with selecting and approving the staff of the Technical Council within 15 days.... To entrust the USSR NKVD with: (a) prospecting and mining uranium deposits; (b) processing ores; (c) devising technology for producing metallic uranium" [24, sheets 124 – 132].

The plan to turn Laboratory No. 2 at the USSR Academy of Sciences into an NKVD institute was doomed. However, the proposals to give the NKVD control over mining of uranium deposits, processing of uranium ores and devising the technology for producing metallic uranium were accepted by the government.

On December 3, 1944, I V Stalin approved the GKO Order No. 7069ts "On urgent measures to enable the development of efforts undertaken by Laboratory No. 2 at the USSR Academy of Sciences". It became a landmark in the history of the Soviet atomic project. The order gave details of future measures to construct Laboratory No. 2 and supply its needs; in particular, the USSR NKVD was committed to conduct all the construction and roadwork required for the laboratory. The order stipulated a transfer to Moscow of the Affiliate of Laboratory No. 2 from Leningrad, and I K Kikoin's laboratory from Sverdlovsk. A design office with its own pilot mechanical plant was to be established at Laboratory No. 2. The order bound I V Kurchatov within one month to compose a plan of scientific research and experimental activities on the use of intraatomic energy of uranium for 1945 and to submit it for the GKO's approval. The final item of the order read: "*To entrust Cde L P Beriya with supervising the advance of the uranium project*". This item made L P Beriya legally responsible for the further fate of the Soviet atomic project [15, p. 285], [16, p. 36], [25, pp. 12 – 47].

On December 8, 1944, I V Stalin approved the GKO Order No. 7102ts/sd "On measures to enable the progress of mining and processing of uranium ores", which regulated the procedure of transferring the activities related to mining and processing of uranium ores to USSR NKVD' control. The order also ordained the establishment of a uranium research institute subordinate to the USSR NKVD, to be referred to as the 'NKVD Institute of Special Metals' (the 'NKVD Inspetsmet'), which was to be based in Moscow on the territory and premises that used to belong to the VIÉM. The institute would later become NII-9, now called the A A Bochvar All-Russian Scientific Research Institute of Inorganic Materials.

It should be noted that on November 24, 1944, when the preparation of the above-mentioned draft GKO orders was nearing completion, I V Kurchatov filed the information to L P Beriya, raising the issue of inviting a number of prominent Soviet scientists to participate in the uranium project. With a view to the making of the atomic bomb, he spoke once again in this information of the need to have L D Landau join the project. He wrote: "*Professor L D Landau, D.Sc. in Physics and Mathematics, Head of the Theoretical Department of the Institute for Physical Problems at the USSR Academy of Sciences, is one of the most profound, talented and knowledgeable theoretical physicists in the Soviet Union. While reporting to Cde V M Molotov* (apparently, in June 1944 — Auths.), *I raised the issue of having him join our work. His participation in the uranium project would be very useful when it comes to solving profound physical problems concerning the basic processes that occur in an atom of uranium*" [15, pp. 283 – 284], [16, p. 35], [24, sheets 141 – 143].

8. Yu B Khariton becomes Scientific Supervisor of the atomic bomb effort

The plan of activities at Laboratory No. 2 for 1945, composed by I V Kurchatov to execute the GKO Order No. 7069ts/sd, was approved by the GKO Order No. 8579ts/sd, passed on May 15, 1945 [22, pp. 6 – 14].

The draft plan was sent to Stalin together with a letter dated May 15, 1945 and written by L P Beriya and I V Kurchatov. It read:

"*As we submit to your examination the plan of activities of the USSR Academy of Sciences' Laboratory No. 2, we would like to report to you on the state of this work, which consists in researching the intraatomic energy of uranium and finding ways to put it to practical use.*

In 1944, the activities of Laboratory No. 2 consisted in analyzing intelligence materials on the work done by scientists abroad in the field of uranium, and in conducting our own theoretical research.

The research lead us to the conclusion that it is possible to use the intraatomic energy:

(a) manufacturing a powerful explosive from a particular kind (isotope) of uranium, namely, uranium-235, which makes up about 1 per cent of the composition of ordinary uranium, and plutonium-239, which can be obtained from ordinary uranium to the extent of 50 per cent while the atomic pile is operating.

(b) using ordinary uranium as a source of thermal energy or, together with heavy water or graphite in an atomic pile, as a raw material for plutonium-239.

In order to obtain uranium-235 and plutonium-239 and prove the accuracy of these calculations by experiment, it is necessary to build special, highly complicated new diffusion plants, atomic piles and new designs of an atomic missile — a bomb.

At present, the activities of Laboratory No. 2 are at a stage which makes it possible to start conceptional designing of the devices listed above. Therefore, unlike last year's plan, the plan for 1945 includes, alongside continued research, the following design and engineering activities:

(a) to develop a scheme design of a pilot plant in 1945 that should produce 75 grams of uranium-235 a day by diffusion method, and to draw up the technical design of one section of this plant;

(b) to develop both the draft and the technical designs of a 'uranium and heavy water' atomic reactor in 1945;

(c) to develop a draft of a 'uranium – graphite' reactor in 1945 and to work out its technical project by May 1, 1946;

(d) to compile a technical assignment in 1945 for the project statement of an atomic missile — a bomb, relying on the assistance of design and research institutions of the People's Commissariats of Armaments and Ammunition.

Outline descriptions of the units are to be found in the appended reference by Academician I V Kurchatov. [9]

[9] Reference of March 28, 1945 [22, sheets 20 – 27].

The immediate target is to design a plant for manufacturing uranium-235 by the diffusion technique in 1945, with the prospect of building it in 1946 and producing uranium-235 in 1947 and testing it in pilot constructions of an atomic missile — a bomb..." [22, sheets 36 – 38].

At the same time, two more documents were submitted for Stalin's examination: a draft GKO order to build the world's second largest cyclotron at Laboratory No. 2 "*for investigations permitting determination of the uranium destructive power and for obtaining small amounts of plutonium-239*", and a draft GKO order that stipulated the expansion of uranium mining and processing enterprises that had been turned over from the People's Commissariat of Nonferrous Metallurgy to the USSR NKVD. As followed from the figures quoted in the letter, the per annum level of uranium mining and uranium concentrate production targeted for July 1, 1946 was greater than that reached by January 1, 1945 by a factor of 20 to 25. The draft order stipulated the building of enterprises that would produce standard-quality metallic uranium (previously not manufactured in the USSR) at the rate of 50 tons per annum. The target amount for 1945 was set at 500 tons. Orders to this effect (No. 8581ts/sd and No. 8582ts/sd) were approved simultaneously with Order No. 8579ts/sd, on May 15, 1945.

In the plan for Laboratory No. 2, approved by GKO Order No. 8579ts/sd, the section relating to the atomic bomb effort was entitled "VI. Research on the atomic uranium bomb (Scientific Supervisor Professor Yu B Khariton)". The GKO order thus appointed Yu B Khariton Scientific Supervisor of the atomic project [15, p. 286], [22, pp. 6 – 14].

The section in question contained the following items which dealt directly with the making of the atomic bomb:

"(1) *Experimental research of the conditions for synchronizing two simultaneous shots from special barrel systems of 10, 15 and 25-mm calibre (by October 1, 1945).*

(2) *Experimental research of the consequences of a collision between two bodies moving towards one another at high speed (by December 31, 1945).*

(3) *Development of a technical assignment for an aerial uranium bomb (by December 31, 1945).*

(6) *Calculation of the heat release in a uranium bomb for different quantities of the explosive (extending and developing the work done in 1944) (by October 1, 1945).*

(7) *The inclusion of the medium (insulation) surrounding the explosives in an atomic bomb and making an intelligent choice of this medium (by September 1, 1945)*".

9. The implosion method. "This method should be preferred to the 'shot method'"

The "Work on the atomic uranium bomb" section of the 1945 plan for Laboratory No. 2 had thus included research on a version of 'gun type' devices in which two simultaneous shots were made from counter directions. Apparently, attention to this scheme was dictated by the need to increase the relative velocity at which the two bulks of active material moved towards one another. Research in this direction was the focus of that section of the 1945 plan for Laboratory No. 2.

However, the main body of the text of the GKO Order No. 8579ts/sd mentioned research on two construction schemes of the atomic bomb, not one. Let us quote the relevant items in the order:

"*The State Defense Committee orders:*

(1) *To pass the plan of research for Laboratory No. 2 at the USSR Academy of Sciences for 1945 in accordance with Annex No. 1, and to bind Academician I V Kurchatov to conduct the following design and engineering work:*

... (d) to develop the design assignment for devices BS-1 and BS-2 in 1945.

(1) *To entrust Cdes Vannikov (convocation), Ustinov, Makhnev with examination, with the participation of Cdes Kurchatov and Khariton, of the ideas existing at Laboratory No. 2 about organizing the design and manufacture of the BS-1 and BS-2 devices in the design institutions of the People's Commissariats of Armaments and Ammunition, and to submit to the GKO in one month's time their own proposals on how to proceed with these activities*" [22, sheets 1 – 5].

It is not explained in the body text of the order what the abbreviations 'BS-1' and 'BS-2' stand for. However, if we look at the above-cited reference that I V Kurchatov drew up on March 28, 1945, the one that concerned the 1945 plan for Laboratory No. 2 and was attached to L P Beriya and I V Kurchatov's joint letter to Stalin [22, sheets 20 – 27], we can see that the abbreviations stood for two types of atomic bomb, the gun-type bomb and the implosive device ('BS' probably stood for 'bomb, special').

Indeed, the section "Uranium-235 and plutonium-239 atomic bomb constructions" of the reference read:

"*The atomic bomb can be set off by two different methods:*

(1) *rapidly bringing together two halves of the uranium-235 or plutonium-239 charge which are initially placed at a distance of 0.5 to 1 meter from one another;*

(2) *densifying the uranium-235 or plutonium-239 charges by a powerful explosion of TNT which coats the charges.*

Both the coming together and the densification would need to happen in a very short time, no greater than several thousandths of a second.

The larger the uranium-235 or plutonium-239 charge, the greater the destructive effect would be; however, unlike ordinary bombs, the atomic bomb can only set off if its amount of charge is above a certain critical value. The value cannot now be calculated with reliable accuracy; according to various estimates, it is between 1 and 10 kg.

Preliminary calculations place the total weight of the atomic bomb, charged with 5 to 10 kg of uranium or plutonium and having a destructive power equivalent to that of 10,000 to 50,000 tons of TNT, at 3 to 5 tons.

Designing the atomic bomb will require serious artillery and explosive work, involving specialized institutions subordinate to the Narkomats [People's Commissariats] of Armaments and Ammunition".

It should be observed that only one of the two types of atomic bomb listed in I V Kurchatov's reference, i.e. the gun type bomb, was known in the USSR until early 1945. However, from February 1945, the USSR began receiving intelligence data that US scientists were working on a new construction of the atomic bomb based on implosion. On 28 February 1945, V N Merkulov, the People's Commissar of State Security, sent Beriya a letter telling him that in the USA "*they are working on two methods of setting off the atomic bomb: (1) the ballistic method, and (2) the method of 'inward-directed explosion'*" (i.e. implosion) [13, pp. 120 – 122]. On March 16, 1945, I V Kurchatov signed his inference from the intelligence reports (the accompanying letter was dated March 5, 1945), stressing the point that the implosion method "*should be preferred over the shot method. It is now*

difficult to pass a final assessment of the correctness of such conclusion, but there is no doubt that the 'inward-directed explosion' method deserves serious attention; it is correct in principle and must be subjected to serious theoretical and experimental examination" [13, p. 123].

Finally, in an inference that he made on April 7, 1945 (after making his reference to the 1945 plan for Laboratory No. 2) concerning intelligence materials with the accompanying letter dated April 6, 1945, I V Kurchatov while characterizing one of the sections in the material wrote: "*This is the largest section of the material; it describes how the 'inward-directed explosion' method (implosion method) can be used to set off the bomb. We have only recently learned about this method and are only beginning to work on it, but we are already aware of its advantages compared to the counter shot method*" [13, p. 124].

In this inference, I V Kurchatov raised a question that Yu B Khariton should be allowed to examine a part of the secret files. To settle this matter, on April 30, 1945 Kurchatov wrote to one of the leaders of the Soviet intelligence service, G B Ovakimyan: "*The material attached to the covering letter of April 6, 1945 is of crucial importance: it deals with the implosion method. The material being very specific, I hereby ask your permission to allow Prof. Yu B Khariton to participate in translating it (from the second half of page 2 until the end, excluding page 22). Prof. Yu B Khariton is working at our laboratory on the construction of the uranium bomb; he is one of the best specialists on explosion phenomena in our country. To date, he has not been allowed to read the materials even in the Russian translation. I told him myself about the chances of spontaneous fission of uranium-235 and uranium-233 and the general principles underlying the implosion method*" [27, annex No. 6].

Looking at the foreign intelligence supplied to the USSR in early 1945 that dealt with the implosion method, one must point out an important fact.

On March 30, 1945, I V Kurchatov signed a review on the intelligence "On the German atomic bomb" which read:

"*The material is extremely interesting. It describes the construction of a German atomic bomb intended to be carried on a 'V' missile.*

The transfer to a critical mass of uranium-235 that is essential for the atomic chain process to start, is effected in this construction by the detonation of a mixture which coats the uranium-235 and consists of porous TNT and liquid oxygen.

The chain initiation in uranium is conducted by fast neutrons generated in a high-voltage tube fed by special generators. To ensure protection from thermal neutrons, the container with uranium is surrounded by a layer of cadmium. All details of the construction are quite plausible and coincide with those on which our construction of the atomic bomb is based[10].

It should be pointed out that the material did not leave me fully convinced of the fact that the Germans did indeed experiments with an atomic bomb..." [28, sheets 24 – 25].

I V Kurchatov continued by emphasizing the extreme importance of receiving more detailed and accurate intelligence on the matters discussed in the material, involving those methods that Germans intended to apply when producing uranium-235.

A number of German scientists were thus familiar with the implosion principle; at least they were in 1945. In their bank of ideas, there was the idea of initiating a nuclear chain reaction in an atomic bomb using a flow of fast neutrons generated by a high-voltage tube. It is known that in the first implosion type atomic bombs designed in the USA and the USSR, the chain reaction was initiated by an internal Po – Be source of neutrons, whose utilization was extremely inconvenient due to operating conditions. The more advanced idea of using an external source of neutrons generated by a high-voltage tube was only implemented afterwards in more elaborated constructions of atomic bombs (in the USSR, in 1954 [29, pp. 196 – 197]).

Despite I V Kurchatov's profound interest in the implosive construction of the atomic bomb, experimental work done at Laboratory No. 2 in 1945 concerned, as has been mentioned above, the gun type bomb. In June 1945, V A Makhnev forwarded a letter to L P Beriya, asking him to postpone the deadline for proposals on organizing the work on BS-1 and BS-2 atomic bombs that Laboratory No. 2 was bound to draw up under GKO Order No. 8579ts/sd [30, sheet 103]. Experimental research on the implosive type atomic bomb was only organized after the establishment of the Special Committee and the First Main Directorate.

10. The establishment of the Special Committee and the First Main Directorate

August 1945 brought dramatic changes in the organization of work on the USSR atomic project. It is well known that on July 16, 1945, the USA made the world's first test of the atomic bomb, followed on August 6 and 9 by the atomic bombings of the Japanese cities Hiroshima and Nagasaki, respectively. The world had to face the USA's monopoly on a new weapon, unprecedented in its dissipated power and unsurpassed in its defeating factors. By dropping atomic bombs on the two Japanese cities, the US government really demonstrated its readiness to use the weapon.

On August 20, 1945, I V Stalin signed the USSR GKO Order No. 9887ts/sd which actually gave the Soviet atomic project a top national priority status [9, pp. 11 – 14]. The order stipulated the establishment of two new state agencies: the Special Committee, subordinate to the State Defense Committee (later under the Council of People's Commissars, subsequently the USSR Council of Ministers), and the First Main Directorate (PGU in Russ. abbr.) at the Council of People's Commissars (Council of Ministers after March 1946) of the USSR. Both served the purpose of governing all the efforts related to atomic energy problem, and were given vast authority. Special Committee orders were binding to all ministries and government agencies. The establishment of the Special Committee and the First Main Directorate was the Soviet government's reaction to the ominous events of August 1945.

L P Beriya headed the Special Committee; its members were G M Malenkov, N A Voznesenskiĭ, B L Vannikov, A P Zavenyagin, I V Kurchatov, P L Kapitza, V A Makhnev, M G Pervukhin. B L Vannikov was appointed Head of the PGU.

The Special Committee was made responsible for organizing all the activities related to the use of atomic energy in the USSR: scientific research, prospecting uranium deposits and mining uranium in the USSR and abroad, building an atomic industry and atomic energy plants, and devising and making atomic bombs. The latter was the key objective: during the first years of the Soviet atomic project, all other efforts were subordinate to it.

[10] The underlined text had been crossed out in I V Kurchatov's original manuscript.

The Special Committee became the genuine headquarters of the Soviet atomic project. It handled all matters of vital importance that arose in the course of development of the Soviet atomic project.

Meetings of the Special Committee discussed, amended and approved draft resolutions and orders of the USSR GKO and the USSR Council of People's Commissars (CPC) [subsequently the Council of Ministers (CM)] that concerned the Soviet atomic project. The resolutions and orders were then either submitted for Stalin's approval or signed by Beriya. By the time the first Soviet atomic bomb was tested, the Special Committee had met 84 times. Between 1945–1949, the GKO, the CPC and the CM of the USSR accepted over 1000 orders and resolutions.

The First Main Directorate was responsible for direct leadership in the research and designing organizations and industrial enterprises that were engaged in the use of atomic energy and making atomic bombs.

The Special Committee had its own Technical Council chaired by B L Vannikov; I V Kurchatov was soon appointed its Vice Chairman. On December 10, 1945, the CPC Resolution No. 3061-915ts established the additional Engineering and Technical Council, also subordinated to the Special Committee and chaired by M G Pervukhin [9, pp. 415–419].

The first meeting of the Special Committee was held on August 24, 1945; I V Kurchatov made the progress report [9, pp. 15, 612].

A meeting of the Special Committee held on September 28, 1945 approved a resolution of its Technical Council concerning additional attraction of a number of research institutions, scientists and professionals to the atomic project effort. The resolution listed specific research that was to be conducted at 20 scientific research institutions. Amongst these was NII-6 at the People's Commissariat of Ammunition; its was committed to "*conduct experiments on a metal sphere compression with the detonation wave produced by a spherical layer of TNT*" [9, pp. 27–35].

11. I V Kurchatov continues fighting to have L D Landau join in the calculations on atomic bombs

I V Kurchatov remained the virtual scientific supervisor of the Soviet atomic project even after being appointed to the Special Committee. Although engaged in the complex job of building an atomic industry, I V Kurchatov continued to pay a lot of attention to the theoretical substantiation, the calculations and the design of atomic bombs.

One can only wonder at I V Kurchatov's stubborn insistence that L D Landau should be recruited for doing calculations for the atomic bombs. Such perseverance was doubtless part of his character when he was convinced that a certain measure or decision that he proposed was a must.

On December 18, 1945, I V Kurchatov wrote to L P Beriya: "*The progress in doing a number of works at the laboratory, especially those which deal with factory products*[11]*, would be considerably improved by the collaboration of Professor Lev Davidovich Landau, D.Sc. in Physics and Mathematics, Head of the Theoretical Department at the Institute of Physical Problems of the USSR Academy of Sciences.*

Prof. L D Landau is the most prominent theoretical physicist in our country.

I hereby ask you to allow Laboratory No. 2 to invite Prof. L D Landau to participate in the theoretical research on the issues mentioned above and in the meetings of the laboratory seminar" [15, p. 284], [31, sheet 190].

Due to I V Kurchatov's perseverance, the decision to put L D Landau on the team that made calculations for atomic bombs was finally made in 1946. At a meeting of the Technical Council attached to the Special Committee, held on February 11, 1946 and chaired by I V Kurchatov, Yu B Khariton gave a talk on atomic bombs, and the Technical Council passed a decision which included the following items:

"(1) *To take the talk into consideration.*

(2) *To charge a group of theoretical physicists led by L D Landau with preparing all the materials needed for doing quantitative calculations for testing samples of industrial products*[12].

To hold it necessary to create a calculation group, equipped with state-of-the-art computing machine, that will make numerical calculations on the materials of the theoretical group.

(3) *To charge Cdes Sobolev and Khariton to make a plan of necessary activities for establishing the calculation group and equipping it with the required modern equipment (calculating machines), and to submit the plan to the approval of the Technical Council by February 25 this year*" [32, sheets 57–59].

Most of the work done by L D Landau and his group that had to calculate the energy release of atomic bombs — finding a way to calculate the atomic bomb efficiency[13] — was based at the Institute of Physical Problems of the USSR Academy of Sciences at the time when A P Aleksandrov replaced P L Kapitza[14] as its Director, and the institute was committed to work on a number of problems associated with the Soviet atomic project[15].

The result achieved by L D Landau and his group that worked on calculating the energy release of atomic bombs was the elaboration of the 'theory of efficiency' that was in reasonable agreement with experimental data obtained in the testing of the first American atomic bombs, and later of Soviet ones, despite the fact that the mathematical modeling of physical processes that follow during an explosion was performed using the set of ordinary differential equations. For a number of years, while working on atomic bombs, theoretical physicists continued to rely on Landau's efficiency formula tested by approximate calculations.

Subsequently, scientists got around to direct numerical calculations of the energy release in an atomic explosion using the method of finite differences. This approach was based on models of the basic physical processes (the neutron propagation and transfer of thermal energy, nuclear combustion and gas dynamics) described by a system of nonlinear partial differential equations. Pioneering research in this direction was started in the USSR in 1948 by A N Tikhonov and his group [34].

[11] A code phrase for atomic bombs.

[12] A code phrase for atomic bombs.

[13] A phrase which was popular with the Soviet professionals.

[14] P L Kapitza was relieved from the post of member of the Special Committee and its Technical Council by the USSR CM Order accepted on December 21, 1945 [9, p. 419].

[15] USSR CM Orders No.1815-782ts "On the production of oxygen by the method of Academician Kapitza" taken on August 17, 1946 and No. 2557-1069ts "On the plan of activities of the Institute of Physical Problems of the USSR Academy of Sciences and measures of assistance to the Institute" [15, p. 284], [33].

The need to create an atomic industry and to start producing atomic bombs in the USSR in the shortest possible time dictated the use of strong measures to involve material and human resources in the effort. Individuals were often recruited to the project by what amounted to mobilization. At the same time, early in the Soviet atomic project its leadership created a system of awards for its participants. On March 21, 1946, the USSR CM approved Resolution No. 627-258ts "On awards for scientific discoveries and technical achievements in the field of the use of atomic energy and for work in the field of cosmic radiation that assists the solution of this problem" [9, pp. 421 – 428]. The preamble of the resolution stressed the point that all possible development of research and engineering directed at practical use of atomic energy for national-economic purposes and defensive capacity is a goal of primary importance to the country.

12. Design Bureau No. 11 (KB-11) is established under Laboratory No. 2 of the USSR Academy of Sciences. The immediate tasks of KB-11: development of the implosive type RDS-1 atomic bomb with plutonium, and the gun type RDS-2 atomic bomb with uranium-235

On April 9, 1946, the USSR Council of Ministers made several important decisions concerning the arrangement of works on the Soviet atomic project.

USSR CM Resolution No. 803-325ts "On the First Main Directorate (PGU) at the USSR CM" stipulated changes in the structure of the PGU and the merging of the Technical and the Engineering and Technical Councils attached to the Special Committee into single Scientific and Technical Council under the PGU. B L Vannikov was appointed Chairman of the new Council; I V Kurchatov and M G Pervukhin became Vice Chairmen [33]. From December 1, 1949, the Scientific and Technical Council was chaired by I V Kurchatov [9, pp. 606 – 609].

USSR CM Resolution No. 805-327ts "On Laboratory No. 2" [9, pp. 429 – 430] reorganized sector No. 6 of the laboratory into Design Bureau No. 11 at Laboratory No. 2 of the USSR Academy of Sciences. The design bureau was assigned the task of designing and manufacturing prototypes of 'jet engines' (a code phrase for atomic bombs).

Under the resolution, KB-11 was to be based near the village of Sarov on the border between Gorky oblast' (region) and the Autonomous Soviet Socialist Republic of Mordovia (currently the city of Sarov is in the Nizhniĭ Novgorod region, also known as Arzamas-16). P M Zernov was appointed Chief of KB-11; its Chief Designer, responsible for the design and manufacture of 'jet engine' prototypes, was Yu B Khariton. This was to be the Soviet analogue of the Los Alamos Laboratory in the USA.

By USSR CM Resolution No. 1286-525ts "On the plan of activities of KB-11 of the USSR Academy of Sciences Laboratory No. 2" [9, pp. 434 – 456], the first goals of KB-11 were set as follows: under the scientific supervision of Laboratory No. 2 (Academician I V Kurchatov), to develop atomic bombs, conditionally referred to in the resolution as 'jet engines S', in two versions: RDS-1 and RDS-2 (in Russ. abbr.). (The abbreviation 'BS' used in the GKO Order of May 15, 1945 was now replaced by 'RDS'). RDS-1 was to be an analogue of the first American implosive type atomic bomb that used plutonium-239 (the type of bomb that was exploded over Nagasaki), while RDS-2 signified an analogue of the gun type atomic bomb using uranium-235 that was exploded over Hiroshima.

Notice the extremely tight deadlines for the activities that were set in the resolution. The tactical and technical assignments for RDS-1 and RDS-2 designs had to be developed by July 1, 1946, the designs of the main RDS units, by July 1, 1947. A completed RDS-1 bomb had to be ready for official testing of its explosion on the ground by January 1, 1948, in the air, by March 1, 1948; for RDS-2, the respective deadlines were set at June 1, 1948 and January 1, 1949. In parallel to designing the bombs, KB-11 had to establish specialized laboratories and launch their activities. Meeting the tight deadlines and organizing parallel efforts was made easier by the fact that the USSR received intelligence materials on the construction of the two American atomic bombs, 'Fat Man' and 'Little Boy', the prototypes of RDS-1 and RDS-2. The Soviet atomic bombs, according to a decision that the leadership of the Soviet atomic project made in 1946, were to be identical to their American prototypes to the greatest possible extent. The decision was primarily political: it was expected to minimize the time it would take to develop the bombs and to guarantee success, which was essential in view of the need to override the US monopoly on the atomic bomb.

Meanwhile, the intelligence materials could not replace own theoretical and experimental research and work on the design of the Soviet atomic bombs as they were prepared for testing. Given the extreme responsibility that the leaders of and participants in the Soviet atomic project bore for the results of the first test, the RDS-1 bomb was only tested after all the data were thoroughly verified and a full cycle of comprehensive studies whose level corresponded to maximum capabilities of that time was completed.

An important peculiarity of the demands put on RDS-1 and RDS-2 designs was that they were to be developed as real aerial bombs suitable for dropping off an aircraft. Consequently, the plan of activities included ballistic tests of models of the bombs and the design of devices that would set off the explosion at a given altitude.

USSR CM Resolution No. 1286-525ts commanded a number of research and design institutions to join in the making of RDS-1 and RDS-2 bombs; they had to fulfil tasks set before them by KB-11. In their number were research institutes NII-6 and NII-504, design offices KB-47 of the Ministry of Agricultural Machine Building, KB-88 of the Ministry of Armaments, and the design office of the Kirov plant of the Ministry of Transport Machine Building, based in the city of Chelyabinsk.

In order to enable the development of atomic weapons in the USSR, despite the difficult post-war conditions and shortages of resources, a large quantity of materials and essential equipment was directed at constructing new buildings and promoting the works of KB-11 and other enterprises of the atomic industry.

13. The F-1 nuclear reactor: the first in the USSR, the first in Europe and Asia. I V Stalin receives participants in the Soviet atomic project

Now the immediate tasks were to set up industrial production of plutonium-239 and uranium-235.

The first task required initially the building of a pilot nuclear reactor and then an industrial one, and the construction of a radiochemical and a specialized metallurgical shop. For the second, the building of a plant for separating uranium isotopes by the diffusion technique was begun.

To fulfil the two tasks, the USSR had to create industrial technologies, organize production and accumulation of the necessary large amounts of pure metallic uranium, uranium oxide, uranium hexafluoride and other uranium compounds, high-purity graphite and a variety of other special materials; it also had to manufacture new industrial apparatus and devices. The fact that the USSR at that time did not mine sufficient quantities of uranium ore or produce enough uranium concentrate was compensated by captured raw materials and products supplied by uranium factories of Eastern Europe under agreements made with the USSR.

The first pilot nuclear reactor in the USSR (the first in Europe and Asia as well), the F-1, built in Laboratory No. 2 of the USSR Academy of Sciences, was successfully launched on December 25, 1946. The historical merit of this event is beautifully summed up in the report filed to Stalin by L P Beriya, I V Kurchatov, B L Vannikov and M G Pervukhin on December 28, 1946 [9, pp. 631 – 632]:

"*To Comrade Stalin I V.*

We report:

On December 25, 1946, I V Kurchatov's laboratory completed the construction of a pilot physical (research) uranium – graphite pile and put it into operation.

In the first days of work of the uranium – graphite pile (December 25 – 26 – 27), we have already obtained the first nuclear chain reaction to be launched in the USSR on a semi-industrial scale. It is now possible to regulate the functioning of the pile in the necessary range and to control the run of the nuclear chain reaction.

The newly built pilot physical uranium – graphite pile contains 34,800 kg of absolutely pure metallic uranium, 12,900 kg of pure uranium dioxide and 420,000 kg of pure graphite.

Having built the physical uranium – graphite pile, we can now address the vital issues of industrial atomic power generation and putting it to use that to date have been treated hypothetically, based on theoretical calculations".

I V Stalin greatly appreciated the completion and launch of the first nuclear reactor in the USSR and other successes that the Soviet atomic project had in that period. On January 9, 1947, a fortnight after the launch of F-1, members of the Special Committee and leading scientists and professionals who took part in the Soviet atomic project were received by Stalin in the Kremlin and submitted the progress reports in relation to the project. The session lasted around three hours; among those present were V M Molotov, L P Beriya, G M Malenkov, N A Voznesenskiĭ, M G Pervukhin, V A Malyshev, V A Makhnev, B L Vannikov, A S Elyan, I K Kikoin, Yu B Khariton, D V Efremov, A P Zavenyagin, P M Zernov, I V Kurchatov, L A Artsimovich, N A Borisov and A N Komarovskiĭ [9, p. 631]. The next day, I V Stalin approved the USSR CM resolution to give I V Kurchatov and L A Artsimovich bonuses (respectively, for creating and launching the F-1 reactor and for making a unit that separated uranium isotopes by the electromagnetic technique and had by that time produced macroscopic amounts of uranium-235). In March 1947, bonuses were given to members of I V Kurchatov's and L A Artsimovich's teams who took part in these activities, and to German scientists and specialists who participated in the Soviet atomic project, to their Soviet colleagues and other Soviet specialists.

According to available documents, the session on January 9, 1947 was the only occasion during the entire Soviet atomic project when Stalin received scientists and professionals from the USSR atomic industry. This had been I V Kurchatov's *second* (and last) personal encounter with Stalin. The first, at which Beriya and Molotov were also present, took place on January 25, 1946 [9, p. 634], [36].

14. The first Soviet industrial nuclear reactor

It was now time to complete construction and launch an industrial nuclear reactor. USSR CM Resolution No. 2145-567ts, passed on June 19, 1947, appointed I V Kurchatov scientific supervisor of Plant No. 817 (subsequently Enterprise No. 817, now the 'Mayak' enterprise) and of its Central Laboratory [35]. The enterprise built the first industrial nuclear reactor in the USSR and radiochemical plutonium isolation plant; later on, it built metallurgical complex that produced metallic plutonium and machined plutonium parts. Earlier, almost a year before the F-1 reactor was launched, USSR CPC Resolution No. 229-100ts/sd of January 28, 1946 appointed I V Kurchatov scientific supervisor of the building project for the first industrial reactor [33].

The physical launch of the first industrial reactor with its technological channels empty of water took place on June 8, 1948; with water, two days later on June 10 [9, pp. 634 – 636]. The reactor was set to work at its rated capacity for the first time on June 19, 1948 [9, p. 662]. I V Kurchatov was personally involved in the activities prior to the launch, and supervised them. It should be observed that both at the stage of launching and during the functioning of the reactor there were a number of emergencies when radioactivity transgressed the active zone. During repairs, I V Kurchatov ignored the health hazards and frequently visited high-level radioactivity areas. The USSR CM representative at Enterprise No. 817, I M Tkachenko, had to report to Beriya on I V Kurchatov's breaches of personal safety measures [37, sheet 68].

By their selfless labor, I V Kurchatov and the entire personnel of the reactor and of other units of the enterprise overcame all the frequent obstacles and succeeded in producing and isolating the amount of plutonium that was needed for the first bomb in the first six months of 1949.

15. The making of RDS-1 and RDS-2. The start of work on advanced atomic bombs

During 1947 – 1949, the USSR Council of Ministers passed a number of new resolutions expanding and supplementing the USSR CM Resolution No. 1286-525ts of June 21, 1946. The new resolutions provided for the efficient work of KB-11 on making the RDS-1 and RDS-2 atomic bombs and researching options for developing other types of atomic weapons.

The USSR CM Resolution No. 234-98ts/sd "On the plan of activities of the USSR Academy of Sciences Laboratory No. 2 KB-11" approved on February 8, 1948 [9, pp. 481 – 489] postponed the deadline for the manufacture of the first RDS-1 by KB-11 from January 1, 1948 to March 1, 1949, and the one for RDS-2, from June 1, 1948 to December 1, 1949. The deadlines for designing, manufacturing and testing separate RDS units were changed accordingly. As L P Beriya wrote in a letter to Stalin, commenting on the draft resolution submitted for Stalin's approval: "*the delay is caused by the*

fact that due to the novel character of the work and many scientific and technical difficulties that could not have been predicted at the time, the bulk of research and design efforts required for making the RDS proved to be much larger than was presumed in 1946. By the new deadlines, Design Bureau No. 11 is to manufacture the RDS in two months' time after the production of appropriate amounts of plutonium and uranium-235''. In the body text of the resolution, a delay in the selection of staff for KB-11, belated development of its activities and delayed construction of its essential facilities and buildings are listed as some of the reasons why KB-11 failed to meet the deadlines for manufacturing the main RDS-1 and RDS-2 units that were set by the USSR CM Resolution No. 1286-525ts of June 21, 1946.

It should be noted that on the eve of the day on which Stalin approved the CM Order in hand, L P Beriya (acting on the decision of the Special Committee, made on January 23, 1948 [9, p. 241]) wrote Stalin a letter, saying: ''*I hereby ask you to hear out, in the presence of members of the Special Committee and leading researchers, a report on work done in 1947 and on plans made for 1948 in the field of the use of atomic energy (speaker Acad. Kurchatov)*'' [7, pp. 633 – 634]. Stalin turned down Beriya's offer. As has been observed earlier, the available data show that after January 9, 1947, Stalin did not have a single meeting with scientists who worked on the problems of the use of atomic energy and making atomic weapons in the USSR.

USSR CM Resolution No. 234-98ts/sd bound I V Kurchatov and Yu B Khariton to organize inside KB-11 theoretical research of problems relevant to the tasks set before it; to this end, N N Semenov was to send a group of researchers from the Theoretical Department of the Institute of Chemical Physics of the USSR Academy of Sciences to work at KB-11 for one year starting February 10, 1948. The group was to be headed by Ya B Zel'dovich [16]. The theoretical brain center of KB-11 was thus originated.

On June 10, 1948, Stalin approved the USSR CM Resolution No. 1989-773ts/sd ''On additions to the plan for KB-11''. By the new order, by January 1, 1949 KB-11 had to complete the theoretical and experimental verification of new data concerning the prospects of making several new versions of atomic bombs, referred to in the resolution as RDS-3, RDS-4 and RDS-5; by June 1, 1949, it had to verify new data on the prospect of making a hydrogen bomb, referred to as RDS-6 [9, pp. 494 – 495]. Resolution No. 1989-773ts/sd made it clear that the extra research it prescribed to KB-11 should not interfere with its work on RDS-1 and RDS-2. On the same day, the USSR CM accepted another resolution No. 1990-774ts/sd ''On additional tasks under the plan of specialized research'', which listed measures aimed at providing the implementation of the Resolution No. 1989-773ts/sd [9, pp. 495 – 498]. In particular, the resolution bound the Institute of Physical Problems of the USSR Academy of Sciences (A P Aleksandrov and L D Landau) to calculate the efficiency of RDS-1, RDS-2, RDS-3, RDS-4 and RDS-5 atomic bombs.

[16] As prescribed by the USSR CM Resolution No. 805-327ts of April 9, 1946, the Institute of Chemical Physics of the USSR Academy of Sciences had to fulfil the tasks set to it by Laboratory No. 2. They consisted in doing calculations needed for the design of atomic bombs, measuring necessary reaction rate constants and preparing for tests of atomic bombs. The same resolution required the Institute of Chemical Physics to work on theoretical aspects and technical applications of nuclear explosion and combustion [9, pp. 429 – 430].

The same resolution instructed the Institute of Geophysics of the USSR Academy of Sciences to establish a Mathematical Bureau, headed by A N Tikhonov, that would make calculations commissioned by the Institute of Physical Problems. It also commanded the Mathematical Institute of the USSR Academy of Sciences to build up its Calculation Group, headed by I G Petrovskiĭ, and to start a Calculation Group, led by L V Kantorovich, at the Leningrad affiliate of the Mathematical Institute. Both groups were to do calculations commissioned by Laboratory No. 2 of the USSR Academy of Sciences (Yu B Khariton and Ya B Zel'dovich).

The abbreviation RDS-3 used in the above two resolutions stood for an implosive type atomic bomb of 'solid' design that used both plutonium-239 and uranium-235. RDS-4 and RDS-5 stood for implosive type atomic bombs of 'shell – nucleus' design (with the nucleus suspended in a hollow space) using, respectively, plutonium-239 and a combination of plutonium-239 and uranium-235 [9, p. 287].

Both resolutions were passed in response to intelligence supplied to the USSR in March 1948 by Klaus Fuchs via Soviet intelligence service agents in London [38 – 40]. The materials delivered by Fuchs together with the management measures prescribed by the new resolutions stimulated Soviet research on more advanced constructions of implosive type atomic bombs than RDS-1; they had a decisive impact on the development of the Soviet hydrogen bomb.

The foreign intelligence on the atomic and hydrogen bombs that arrived at the USSR in 1948 was a valuable addition to previously obtained intelligence materials. The most important piece of information was that received in 1945, dealing with atomic bombs. As far as can be judged from publications, the sources of data on atomic bombs had been Theodore Hall, Klaus Fuchs and David Greenglass. In 1948, at early stages of making the hydrogen bomb, valuable data is known to have been supplied by K Fuchs [38 – 41].

Going back to Soviet scientists' work on atomic bombs, we must mention that the gun type RDS-2 bomb using uranium-235 that the USSR CM Resolution No. 1286-525ts of June 21, 1946 instructed Soviet scientists to produce, was in fact never tested. After the tests of a gun type RDS-2 bomb were cancelled, the codes were changed, and RDS-2, RDS-3, RDS-4 and RDS-5 were used to refer to more advanced implosive type atomic bombs, successfully tested in 1951 and 1953. RDS-2, RDS-4 and RDS-5 bombs used plutonium-239 as the active fissile material, the same as in RDS-1. The RDS-3 bomb, tested in 1951, used a combination of plutonium-239 and uranium-235. By that time, the USSR had started to produce uranium-235 on an industrial scale; industrial production of plutonium-239 had begun earlier. By using uranium-235 in the RDS-3 bomb, it was possible to use less amounts of the deficient plutonium-239. The amounts of uranium-235 used in RDS-3 were much smaller than those required for a gun type bomb. This was why it was decided not to test gun type RDS-2 bombs. Ignoring the chronological order of events for a moment, let us mention that the TNT equivalent of RDS-2 and RDS-3 bombs was almost twice that of the first Soviet RDS-1 atomic bomb, whereas the former were considerably smaller in size and weight [29, pp. 186 – 192].

New atomic bombs were based on proposals and constructive decisions put forth by Soviet scientists and designers as well as on ideas found in intelligence data from abroad.

16. The completion of the development and testing of the first Soviet RDS-1 atomic bomb

Due to the delay in producing the necessary amount of plutonium, the deadline set by the USSR CM Resolution No. 234-98ts of February 8, 1948 for making the first RDS-1 specimen — March 1, 1949 — was not met. By August 1949, however, all the components of RDS-1 were finally produced, the bomb was prepared for testing, and the testing area near Semipalatinsk was ready for conducting the tests and for research and measurement of the bomb's efficiency. The plan of the test prescribed that the bomb should be fully assembled directly on the testing ground (minus its ballistic housing and the devices needed for dropping the bomb off an aircraft) and set off on top of a tower 33 meters tall.

On August 18, 1949, Beriya submitted a draft USSR CM Resolution "On conducting the atomic bomb test" for Stalin's approval. However, Stalin did not sign it. The Secretary of the Special Committee, V A Makhnev, wrote on the first copy of the draft that Beriya had returned both copies and said that "*the matter was discussed at the Central Committee of the Communist Party and there will be no decision*" (i.e. the resolution will not be approved) [9, pp. 636–638].

On August 26, 1949, before leaving for the testing grounds, L P Beriya signed the minutes of a meeting of the Special Committee; the agenda of the meeting was "On the test of the first atomic bomb specimen". The decision was worded in the minutes as follows: "*To accept the draft Resolution of the USSR Council of Ministers "On the test of the atomic bomb", proposed by Cdes Vannikov, Kurchatov and Pervukhin, and to submit it for the approval of the Chairman of the USSR Council of Ministers, Comrade I V Stalin (the draft is attached)*" [9, p. 388].

The draft resolution appointed I V Kurchatov Science Supervisor of the test, Yu B Khariton, P M Zernov and P Ya Meshik were made Vice Science Supervisors in charge of various matters. The draft resolution prescribed: "*a test of the atomic bomb carry out on August 29–30, 1949, at Testing Area No. 2 (170 km to the west of the city of Semipalatinsk) built and equipped according to the USSR CM Resolution No. 2142-564ts/sd of 19 June 1947*".

The second draft resolution, only slightly different from that of August 18, 1949, was not signed by Stalin either [9, pp. 388–390].

The test of the first Soviet RDS-1 atomic bomb was conducted on the basis of a draft USSR CM Resolution accepted by the Special Committee.

There are no documents which explain why Stalin refused to approve the draft USSR CM Resolution on the test of the first Soviet atomic bomb.

It should be noted that although the American prototypes of RDS-1 worked, it still could not be ruled out that the test of RDS-1 would fail, perhaps for purely physical reasons (the relatively high probability of a pre-term nuclear explosion with low energy release due to its constructive features).

RDS-1 was tested on August 29, 1949.

The next day, on August 30, 1949, L P Beriya and I V Kurchatov signed a hand-written report to I V Stalin that contained the results of preliminary processing of the test data.

The report read:

"*We hereby report to you, Comrade Stalin, that a large team of Soviet scientists, designers, engineers, managers and industrial workers has succeeded, after four years of hard work, in fulfilling the task that you set before them and has made the Soviet atomic bomb.*

Our country owes its atomic bomb to your day-to-day attention, care and help in fulfilling this task.

We hereby report to you the following preliminary data on the results of testing the first atomic bomb specimen with a plutonium charge, designed and manufactured by the First Main Directorate at the USSR Council of Ministers under the scientific supervision of Academician Kurchatov and the Chief Designer of the atomic bomb, Corresponding Member of the USSR Academy of Sciences Prof. Khariton.

On August 29, 1949, at 4 o'clock in the morning Moscow time and at 7 o'clock in the morning local time, in a remote steppe area of the Kazakh SSR, 170 km west of the city of Semipalatinsk, on a specially built and equipped testing area, for the first time in the USSR, we have exploded an atomic bomb of exceptional destructive and affecting and affecting power.

The atomic explosion was monitored by specialized devices and witnessed by a large group of scientists, military and civilian specialists, and a group of members of the Special Committee who were present at the test: Cdes Beriya, Kurchatov, Pervukhin, Zavenyagin and Makhnev.

Amongst experts present at the test was the physicist Meshcheryakov, who had been our observer at the tests of atomic bombs in Bikini..." [9, pp. 639–643].

On October 28, 1949, Beriya (alone this time) signed the final report on the results of the RDS-1 tests and submitted it for Stalin [9, pp. 646–658]. The report read, in particular: "*Based on the data of physical measurements and research of the explosion results, specialists have concluded that the atomic bomb efficiency (i.e. the percentage of the mass of plutonium that became involved in fission during the nuclear chain reaction initiated by atomic bomb explosion) extracted from the test on August 29, 1949, equals (...)* [17]*, i.e. it is 50 percent greater than was expected from calculations and was said in our preliminary report of August 30*".

The next day, Stalin approved the USSR CM Resolution No. 5070-1944ts/sd "On awards and rewards for outstanding scientific discoveries and technical achievements in the use of atomic energy" [9, pp. 530–562]. The resolution provided recommendations for awarding the title of Hero of Socialist Labour to the participants in the efforts to make and to provide with making the first Soviet atomic bomb, whose contribution had been especially valuable; persons who already had that title were recommended for awarding a second "Hammer and Sickle" gold medal; other participants who made important contributions to the effort were recommended for awarding USSR Orders, making Stalin prize winners, and giving rewards and certain privileges.

The order began with the words:

"*The USSR Council of Ministers declares that as a result of a joint effort of a large team of Soviet scientists, designers, engineers, managers, builders and industrial workers, the government mission of solving the problem of the use of atomic energy for practical purposes in the USSR has been successfully fulfilled.*

Considering the great services they have rendered to their Soviet Homeland by solving the problem of the use of atomic energy, and in accord with the USSR CM Resolution No. 627-258 of March 21, 1946, the USSR Council of Ministers RULES:

[17] In the document quoted here, published in Ref. [9, pp. 645–648], the value of the atomic bomb efficiency is omitted.

I.

1. KURCHATOV Igor' Vasil'evich, Member of the Academy, Scientific Supervisor of the project of making the atomic reactors and the atomic bomb:

— is recommended for awarding a Hero of Socialist Labour;

— is rewarded with the sum of 500,000 roubles (in addition to the first instalment (50%) of the reward in the sum of 500,000 roubles and a ZIS-110 car) [18].

Acad. I V Kurchatov is awarded the title of 'Stalin prize winner' of the first degree.

A townhouse and a holiday cottage (dacha) shall be built and furnished at the expense of the government and made the property of Acad. I V Kurchatov.

Acad. I V Kurchatov's wages shall be doubled for the whole duration of his work in the field of the use of atomic energy.

Acad. I V Kurchatov will enjoy the right (for life, for himself and his wife) to free travel by railway, sea and air within the borders of the USSR".

Let us quote here the section which referred to Yu B Khariton's awards and prizes:

"**XVII.**

60. KHARITON Yuliĭ Borisovich, Corresponding Member of the USSR Academy of Sciences, Chief Designer of the atomic bomb:

— is recommended for awarding a Hero of Socialist Labour;

— is rewarded with the sum of 1,000,000 roubles (the first prize, as set down in the USSR Council of Ministers Order No. 627-258 of March 21, 1946) and a ZIS-110 car.

Corresponding Member of the USSR Academy of Sciences Yu B Khariton is awarded the title of 'Stalin prize winner' of the first degree.

A townhouse and a holiday cottage (dacha) shall be built and furnished at the expense of the government and made the property of Corresponding Member of the USSR Academy of Sciences, Yu B Khariton.

Corresponding Member of the USSR Academy of Sciences Yu B Khariton's wages shall be doubled for the whole duration of his work in this field.

Corresponding Member of the USSR Academy of Sciences Yu B Khariton is given

— the right to educate his children at any educational institution of the USSR at the expense of the state;

— the right (for life, for himself, for his wife and for his children until they come of age) to free travel by railway, sea and air within the borders of the USSR".

On the same day, October 29, 1949, the Presidium of the USSR Supreme Council made a number of Edicts on awards to Soviet atomic project participants, in accord with the CM Order No. 5070-1944ts/sd [9, pp. 563 – 605]. By one of the Edicts, I V Kurchatov and Yu B Khariton, amongst 33 scientists, specialists and managers, were made Heroes of Socialist Labour. Amongst other holders of this title were A A Bochvar, A P Vinogradov, N A Dollezhal', A P Zavenyagin, Ya B Zel'dovich, P M Zernov, M G Pervukhin, the German scientist N V Riehl, M A Sadovskiĭ, E P Slavskiĭ, G N Flerov, V G Khlopin, and K I Shchelkin. The Head of PGU, B L Vannikov, the Director of Plant No. 817, B G Muzrukov, and the Vice Chief Designer of KB-11, N L Dukhov, were awarded the second "Hammer and Sickle" gold medal. A total of 800 people received USSR orders. Amongst other recipients, the Lenin Order was given to A P Aleksandrov, L V Al'tshuler, E I Zababakhin, E K Zavoĭskiĭ, S B Kormer, S G Kocharyants, L D Landau, G P Lominskiĭ, M G Meshcheryakov, K A Semendyaev, N N Semenov, S L Sobolev, D A Frank-Kamenetskiĭ, and V A Tsukerman. USSR orders were also given to officers of the Soviet intelligence service: L R Kvasnikov, V B Barkovskiĭ, S M Semenov, A S Feklisov, and A A Yatskov.

Speaking of the events of 1949, we should note the complicated political situation in the USSR at that time. After the test on August 29, 1949, the USSR did not possess a single atomic bomb for several months, because an amount of plutonium sufficient for another bomb had not yet been produced. It was planned to manufacture plutonium parts for the first reserve bomb by November 1, 1949, for the second, by December 28, 1949. Other parts and assembly units were to be ready by December 1, 1949 [9, p. 392]. Meanwhile, in 1949, by some estimates, the USA had around 200 atomic bombs. This was probably the reason behind the TASS statement made on September 25, 1949 as a reaction to US President Harry S Truman having said on September 23, 1949 that the US government had been informed of an atomic explosion taking place in the USSR in the last few weeks. Although the TASS statement did not confirm the fact that the USSR had tested its atomic bomb, it said that "*the Soviet Union had mastered the secret of atomic weapons as early as 1947*" and *"has these weapons at its disposal... As to the concern that some circles abroad are spreading in connection with this fact, it is groundless. It must be said that although the Soviet government possesses atomic weapons, it has kept and shall keep to its former standpoint that atomic weapons should be undoubtedly abolished*" [9, p. 645].

17. Conclusions

The creation and successful testing of the first Soviet atomic bomb in troublesome post-war times, in a period which was very short by historical standards, was a triumph of Soviet science, technology and industry. It had been the result of an unprecedented effort on the part of the State to concentrate all intellectual, material and spiritual resources for the sake of solving a problem of vital importance to the country. It became a turning point in world history: no longer did a single country have a monopoly on nuclear weapons. From that time onwards, the USSR and the USA began their progress towards a strategic balance; despite the creation of thermonuclear weapons in both countries and the arms race (only abating in the last few years), it contributed to global stability and prevented the occurrence of a new world war.

Yu B Khariton put his signature under the following passionate words: "*It is with wonder and reverence that I look upon what our people accomplished during 1946 – 1949. Times were hard afterwards, too. But the tension, the heroism, the creative urge and the commitment of those days is beyond words... Four years after the mortal combat with Nazism was over, my country eliminated the US monopoly on the atomic bomb. Eight years after the war, it made and tested the world's first hydrogen bomb, twelve years after the war, it launched the first artificial Earth satellite, and another four years later it sent the first man into space... You can see that those are landmarks of eternal merit in the history of civilization...*

The making of nuclear missiles had required extreme human effort and maximum intellectual strain. Perhaps this can be

[18] Given in 1947 for the creation and launch of F-1, the first experimental nuclear reactor in the USSR.

excused by the fact that for almost fifty years nuclear weapons with their incredible destructive power, threatening life on Earth if they are used, have deterred world powers from war, from an irreparable step leading to total devastation. Probably the greatest irony of our time is that the most terrible weapon of mass destruction has remained a safeguard of peace on Earth, a powerful deterrent of war..." [42, p.165].

In August 1999, Russia celebrated the 50th anniversary of testing RDS-1. The motto of the celebration was: 50 years since the tests of the first Soviet atomic bomb — 50 years of peace.

In the present international context, which remains fairly complicated, nuclear weapons still serve as a deterrent and ensure a strategic balance of world powers.

The strategic balance of power would never have been reached had it not been for the phenomenal breakthrough of the Soviet Union: in hard post-war times, in a time span which now looks unbelievably short, it created its atomic industry and produced its first atomic bomb, followed by highly evolved nuclear and thermonuclear weapons. The fact that intelligence from abroad was used in the process in no way diminishes the creative quality of Soviet efforts that brought forth new technologies, new laboratory and industrial equipment, new inventions in physics and design, new methods for computing, theory and experiment, and the organization of an efficiently working complex of atomic research and production.

The bottom line of the efforts was the creation of the first Soviet atomic bomb.

This paper is devoted to both well-known and only recently discovered pages in the history of its creation.

Note that a number of documents dating back to 1944 – 1945 that were quoted here have been published in Ref. [43].

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