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ON 80th ANNIVERSARY OF VICTORY IN GREAT PATRIOTIC WAR

Role of Academy of Sciences in Atomic Project *

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Contents

Abstract. The review is an expanded version of a report presented at a session of the Physical Sciences Division of the Russian Academy of Sciences dedicated to the 80th anniversary of Victory in the Great Patriotic War and the 80th anniversary of the nuclear industry. The author hopes that the article will be useful to a wide range of readers, especially the younger generation, as it illustrates how, under the most difficult political and economic conditions of complete isolation from the outside world and without any assistance, our country, despite losing 27 million of its citizens in the Great Patriotic War and suffering enormous losses, managed to solve modernization problems and become a leader in global development in an astonishingly short time. In 1957, our country launched Sputnik, and, in 1961, Yury Gagarin flew into space. The achievements of our Atomic Project during those years are a clear example of the scientific and technological heights that can be reached in Russia when three key conditions are met: a vital super-task, the creative work of specialists from various fields united in a unique final product, and, finally, powerful government support. These were major advances in high technology — technologies based on completely new scientific knowledge. The country's leaders and the leaders of the Atomic Project managed to organize the work, creating multidisciplinary teams of specialists and closely linking scientific, engineering, design, experimental, and technological work into a unified system aimed at creating an atomic bomb in two to three years. The rapid implementation of fundamental scientific advances through the careful selection of priorities and the concentration of resources on them, the selection and training of talented personnel, and the utmost responsibility and enthusiasm of all nuclear weapons specialists have allowed, and continue to allow, despite our country's significantly smaller financial and economic resources compared to those of the USA, effectively maintaining strategic balance in the world and thereby ensuring peace for many decades.

Keywords: USSR Atomic Project, role of Academy of Sciences, development of first nuclear and thermonuclear weapons

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Great deeds — great people
Ya.B. Zel'dovich

1. Greatness of spirit of Russia

The 20th century has gone down in the history of civilization as the century of the development of nuclear energy. This was the golden age of physics. And, as always, *war* and *peace* vied for the right to be the first to exploit the results of scientific and technological progress.

World civilization in recent centuries has never known such a history, such disasters, such losses as those that befell Russia.

Having lost 27 million people during the Great Patriotic War, our people in the late 1940s and early 1950s made breakthroughs in new knowledge, technology, and education, created new industries, and rebuilt the country.

The atomic project is a striking example of the country's breakthrough to new horizons, which made it one of the most developed countries in the world in just ten years — the era of Sputnik, the era of Gagarin. The Sputnik era revealed to the world, on the one hand, proof of the triumph of the socialist system and, on the other, the limitless possibilities of applying modern science.

The development of thermonuclear weapons in the USSR in the early 1950s was a turning point that made World War III impossible and transformed our country into a leading world power.

Consciousness of the enormous potential for using nuclear energy in the 20th and 21st centuries led to a significant number of publications on the role and significance of nuclear weapons (NWs), as well as specific memoirs of actual NW developers. A real breakthrough in this field was achieved by the team at Minatom (Rosatom), under the leadership and editorship of L.D. Ryabev. From 1998 to 2010, a vast number of archival documents were declassified and published, summarized in a unique publication, *The USSR Atomic Project* (*1930–1955*) in three volumes and 12 books. No other nuclear country had ever accomplished anything similar. A review of these materials clearly reveals the heroism of our people, their unleashed creative energy, thanks to which our country became a great world power.

1.1 Responsibility of scientists in nuclear age

The emergence of nuclear weapons is unique in that nothing similar has ever arisen in world politics, and, apparently, never will. It will remain in world history as an island of the extraordinary influence of scientists directly on politics and directly on the political decision-making of leaders of various states.

Because of the specific nature of nuclear weapons and their enormous destructive power, all the political consequences of their existence became clear to scientists before they were to politicians. The fundamental ideas and public impulses associated with this originated first with scientists and were only later interpreted by politicians (Albert Einstein's letter of August 2, 1939 to US President Franklin Roosevelt — the beginning of the US atomic energy project).

We must always remember that the primary material component of ensuring strategic stability in the world, in the past and in the foreseeable future, has been and will continue to be Russia's nuclear weapons system, which defines real, not proclaimed, doctrine.

Ensuring national security means ensuring there is no gap between the actual state of affairs in nuclear weapons and the proclaimed doctrine — this has been and remains the mission and responsibility of specialists in the nuclear weapons complex and the Russian Academy of Sciences.

1.2 On brink of nuclear war

In 1949, even before the first Soviet atomic bomb test, the United States had four industrial nuclear reactors producing weapons-grade plutonium, two of which were launched in late 1944 and one in early 1945. By the end of 1949, these reactors had produced approximately 950 kg of weapons-grade plutonium [1].

By the end of 1949, the USSR possessed 19 kg of plutonium [5].

In 1949, the US nuclear arsenal consisted of 235 nuclear charges with a total energy release of 4.2 megatons [2].

In the fall of 1945, the United States had a plan to nuclear bomb 20 cities in our country, so the Cold War began long before Winston Churchill's Fulton speech in 1946.

Number of US nuclear warheads.

Year	Total number of charges	Total energy release, Mt of TNT equivalent
1945	6	0.12
1946	11	0.22
1947	32	0.64
1948	110	3.6
1949	235	4.2

City of Hiroshima after atomic bombing, August 6, 1945.

These facts clearly demonstrate the vital need to dismantle the US atomic monopoly.

Let the US nuclear explosions serve as a reminder to humanity of the consequences of nuclear war, when, ‘instantly,’ with two atomic bombs with yields of 15 and 21 kilotons of TNT equivalent, the US annihilated approximately 200,000 people, mostly civilians, in the cities of Hiroshima and Nagasaki! The exact death toll remains unknown. It is worth noting that long-term radiation exposure has killed approximately 250,000–400,000 people as of 2014 (https://news.un.org).

2. Beginning of work. Fate of Atomic Project decided along with fate of Stalingrad

2.1 Pre-War foundations of USSR Atomic Project

Academician A.P. Aleksandrov wrote of that time: “The scientific level of the work carried out here was approximately the same as in the leading laboratories of the West.”

Between 1922 and 1934, in just 12 years, more than six institutes were created in our country to study modern physics, and here a special role belongs to Academician A.F. Ioffe and his school — the school of the Leningrad Physical-Technical Institute (PTI) of the USSR Academy of Sciences.

In 1940, the Commission on Uranium Problems was formed under the Presidium of the USSR Academy of Sciences, consisting of N.N. Semenov, I.V. Kurchatov, and Yu.B. Khariton.

On August 29, 1940, I.V. Kurchatov, Yu.B. Khariton, L.I. Rusinov, and G.N. Flerov submitted proposals, “On the Use of Uranium in a Chain Reaction,” for discussion to the Presidium of the USSR Academy of Sciences [3].

The high level of Soviet research is evidenced by the tangible results of world-class work:

— the development of the theory of the atomic nucleus (Ya.I. Frenkel, D.D. Ivanenko, et al.);

— the discovery of nuclear isomers and spontaneous fission of uranium in 1935–1940 (PTI, Radium Institute of the USSR Academy of Sciences (RIAS)), I.V. Kurchatov, G.N. Flerov, K.A. Petrzhak, and G.N. Petrov;

— the creation of Europe’s first 4-MeV cyclotron (RIAS, 1939), L.V. Mysovskii, I.V. Kurchatov;

— holding five All-Union and international conferences on nuclear physics;

— development of the physics of explosive detonation processes;

— calculation of the fission chain reaction (1939), Yu.B. Khariton, Ya.B. Zel’dovich (Institute of Chemical Physics (ICP) of the USSR Academy of Sciences);

— the atomic bomb project (1940, ICP), F.F. Lange;

— launch of Europe’s first reactor, F-1, on December 25, 1946, I.V. Kurchatov (Laboratory No. 2).

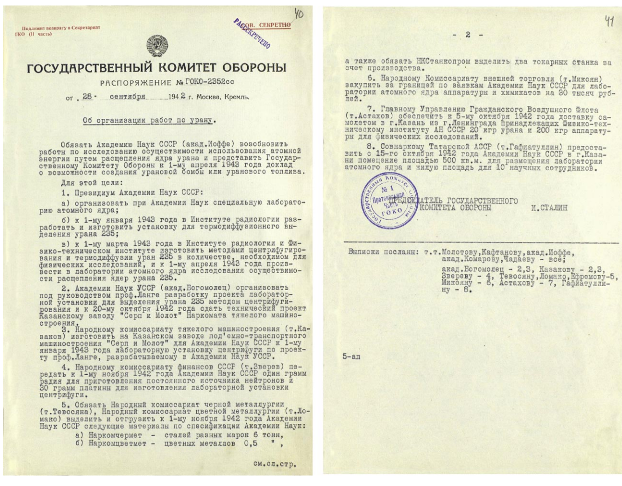
In 1939, Zel’dovich and Khariton performed a number of difficult and important theoretical calculations on the nuclear chain reaction, which were the first serious attempts in world science to analyze phenomena in moderating media and control problems.

2.2 Founders and leaders of USSR Atomic Project

Abram Fedorovich Ioffe was the founder and director of the Leningrad Physical-Technical Institute — which became the base organization for developing work in various fields of physics (ICP, Kharkov Physical-Technical Institute) — an academician since 1920, an active participant in the early stages of the Atomic Project, a member of the Technical Council of the Special Committee, and a Hero of Socialist Labor. A number of outstanding scientific and technical leaders of the Atomic Project belonged to his school: I.V. Kurchatov, Yu.B. Khariton, N.N. Semenov, I.K. Kikoin, A.P. Aleksandrov, A.I. Alikhanov, L.A. Artsimovich, and A.I. Leipunsky.

An organizer of physics research in the USSR, A.F. Ioffe, with his students, A.I. Alikhanov and I.V. Kurchatov, in Leningrad PTI laboratory (1935).

In a note to the Presidium of the USSR Academy of Sciences dated August 24, 1940, A.F. Ioffe wrote that “the possibility of the technical use of uranium energy cannot be considered excluded in the present state of our knowledge.... The main specialists to be addressed, first of all, are: I.V. Kurchatov (Leningrad PTI) and his colleagues G.N. Flerov and K.A. Petrzhak, Ya.B. Zel’dovich and Yu.B. Khariton (Leningrad ICP).... General management of the entire problem as a whole should be entrusted to I.V. Kurchatov as the best expert on the issue, who demonstrated outstanding organizational skills during the construction of the cyclotron.”



Подлежит возврату в Секретариат ГКО (II часть)

СОВ. СЕКРЕТНО

РАССЕКРЕЧЕНО

40

ГОСУДАРСТВЕННЫЙ КОМИТЕТ ОБОРОНЫ

РАСПОРЯЖЕНИЕ № ГОКО-2352сс

от „28" сентября 1942 г. Москва, Кремль.

Об организации работ по урану.

Обязать Академию Наук СССР (акад.Иоффе) возобновить работы по исследованию осуществимости использования атомной энергии путем расщепления ядра урана и представить Государственному Комитету Обороны к 1-му апреля 1943 года доклад о возможности создания урановой бомбы или уранового топлива.

Для этой цели:

1. Президиум Академии Наук СССР:

а) организовать при Академии Наук специальную лабораторию атомного ядра;

б) к 1-му января 1943 года в Институте радиологии разработать и изготовить установку для термодиффузионного выделения урана 235;

в) к 1-му марта 1943 года в Институте радиологии и Физико-техническом институте изготовить методами центрифугирования и термодиффузии уран 235 в количестве, необходимом для физических исследований, и к 1-му апреля 1943 года произвести в лаборатории атомного ядра исследования осуществимости расщепления ядер урана 235.

2. Академии Наук УССР (акад.Богомолец) организовать под руководством проф.Ланге разработку проекта лабораторной установки для выделения урана 235 методом центрифугирования и к 20-му октября 1942 года сдать технический проект Казанскому заводу "Серп и Молот" Наркомата тяжелого машиностроения.

3. Народному комиссариату тяжелого машиностроения (т.Казаков) изготовить на Казанском заводе под'емно-транспортного машиностроения "Серп и Молот" для Академии Наук СССР к 1-му января 1943 года лабораторную установку центрифуги по проекту проф.Ланге, разрабатываемому в Академии Наук УССР.

4. Народному комиссариату финансов СССР (т.Зверев) передать к 1-му ноября 1942 года Академии Наук СССР один грамм радия для приготовления постоянного источника нейтронов и 30 грамм платины для изготовления лабораторной установки центрифуги.

5. Обязать Народный комиссариат черной металлургии (т.Тевосяна), Народный комиссариат цветной металлургии (т.Ломако) выделить и отгрузить к 1-му ноября 1942 года Академии Наук СССР следующие материалы по спецификации Академии Наук:

а) Наркомчермет - сталей разных марок 6 тонн,

б) Наркомцветмет - цветных металлов 0,5 " ,

см.сл.стр.

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\- 2 -

а также обязать НКСтанкопром выделить два токарных станка за счет производства.

6. Народному Комиссариату внешней торговли (т.Микоян) закупить за границей по заявкам Академии Наук СССР для лаборатории атомного ядра аппаратуры и химикатов на 30 тысяч рублей.

7. Главному Управлению Гражданского Воздушного Флота (т.Астахов) обеспечить к 5-му октября 1942 года доставку самолетом в г.Казань из г.Ленинграда принадлежащих Физико-техническому институту АН СССР 20 кгр урана и 200 кгр аппаратуры для физических исследований.

8. Совнаркому Татарской АССР (т.Гафиатуллин) предоставить с 15-го октября 1942 года Академии Наук СССР в г.Казани помещение площадью 500 кв.м. для размещения лаборатории атомного ядра и жилую площадь для 10 научных сотрудников.

ПРЕДСЕДАТЕЛЬ ГОСУДАРСТВЕННОГО КОМИТЕТА ОБОРОНЫ И.СТАЛИН

Государственный Комитет Обороны № 1 Протокольная часть ГОКО

Выписки посланы: т.т.Молотову,Кафтанову,акад.Иоффе, акад.Комарову,Чадаеву - все; акад.Богомолец - 2,3, Казакову - 2,3, Звереву - 4, Тевосяну,Ломако,Ефремову-5, Микояну - 6, Астахову - 7, Гафиатуллину - 8.

5-ап

First official government document ordering ‘resumption’ of uranium work (September 28, 1942).

The fate of the Atomic Project was decided along with the fate of Stalingrad. While the Germans stood at Stalingrad and the outcome of the Great Patriotic War was still uncertain, on September 28, 1942, the State Defense Committee (GKO) issued Order No. 2352, "On the Organization of Uranium Work," signed by Joseph Stalin.

2.3 Role of Soviet intelligence

Soviet intelligence played a prominent role in creating the scientific and technical basis for the USSR's nuclear weapons development, obtaining and transmitting a variety of valuable information regarding both the fundamental ideas and specific data on the atomic project.

Intelligence materials received from Great Britain and a report by L.P. Beria noted that, beginning in 1939, work on the use of uranium for military purposes had been underway in France, England, the USA, and Germany, under conditions of secrecy. A technical analysis of intelligence data for the purposes of the Atomic Project is given in Ref. [27].

From 1941 to 1945, the role of intelligence information in the development of the Soviet Atomic Project was paramount, while, from 1946 to 1949, the primary significance lay in the Soviet Union's own efforts and achievements. The boundary between these two periods is 1945, defined by the USSR's victory in the Great Patriotic War and the opportunity to concentrate the state's efforts on a practical solution to the atomic problem.

At the same time, even during this first stage, it is necessary to note the outstanding role of our specialists, primarily I.V. Kurchatov, in analyzing intelligence data, comparing it with our own data, verifying and evaluating it, and defining the main conceptual directions of our atomic project.

On the other hand, if fundamental government decisions to accelerate work on the atomic project had been made before August 1945, this would hardly have significantly shortened the timeframe for creating the atomic bomb. The fact is that at that time the USSR simply lacked the basic raw material — natural uranium.

Kurchatov's words, written in 1943 to M.G. Pervukhin, Deputy Chairman of the Council of People's Commissars (Sovnarkom), were very accurate: "...intelligence materials are of enormous, invaluable importance for our state and science."

In V.P. Vizgin's article, "At the origins of the Atomic Project: The role of intelligence 1941–1946 (Based on materials from the Russian Foreign Intelligence Archives)," published in the Russian journal *Voprosy istorii yestestvoznaniya i tekhniki* (*VIET*), No. 3, pp. 97–134, 1992 (in English at https://nuclearweaponarchive.org/News/Voprosy2.html?utm_source=chatgpt.com), a number of intelligence materials were apparently published openly for the first time, including those of our intelligence officer, Hero of Russia Anatolii Antonovich Yatsky. A book by GRU Colonel V.I. Lot presents the work of intelligence from the inside. Thanks in large part to Vladimir Ivanovich's research and initiative, four illegals who provided us with information about the US atomic project were awarded the title Hero of Russia at the beginning of the 21st century. We hope that the time will come when the outstanding anti-fascist physicist Klaus Fuchs, who provided information about the atomic projects of Germany, England, and the US beginning in 1941, will be awarded the same high title.

3. Creation of first atomic bomb, RDS-1, dispelled myth of Russia's technological backwardness

3.1 Strategic decision to implement Atomic Project

You must work with Russian magnitude
Joseph Stalin

As early as 1942, Igor' Vasil'evich Kurchatov proposed "the formation of a special committee chaired by V.M. Molotov to manage this complex and enormous task, with Academician Ioffe, Academician P.L. Kapitza, and Academician N.N. Semenov representing science."

On August 20, 1945 (two weeks after the atomic bombing of Hiroshima), the State Defense Committee of the USSR decided to create a Special Committee headed by L.P. Beria to manage all atomic energy work.

On August 30, 1945, the Council of People's Commissars of the USSR issued a decree establishing the First Main Directorate (FMD) for the operational and day-to-day management of work on the Atomic Project, headed by B.L. Vannikov.

It is instructive for our time that the decisions of the Special Committee, in essence, had no legal force, but its members included the highest party and government officials and outstanding scientists. This means that this body, without legal red tape, prepared decisions of the USSR Council of Ministers, which Stalin approved as Chairman of the Council of Ministers. A week later, they were sent for implementation to the USSR ministries and enterprises; all this took place in complete secrecy.

Within the framework of the Special Committee, special technical (scientific, technical, engineering) councils were formed, consisting of leading specialists in various aspects of the atomic issue.

On November 27, 1942, the State Defense Committee adopted the resolution "On Uranium Mining."

On April 12, 1943, Laboratory No. 2 of the USSR Academy of Sciences was established, headed by I.V. Kurchatov.

These resolutions were the first example of a comprehensive approach aimed at implementing the Soviet Atomic Project.

3.2 Education

The training of specialists for the atomic industry was considered a critical and top-priority state task.

At the end of 1945, just over 340 physicists worked in the country's main physics institutes, and approximately 140 physicists were working on nuclear physics issues. These physicists worked in six research institutes that lacked the necessary scientific and technical base for conducting work on the practical use of nuclear energy.

In the field of radiochemistry, at the end of 1945, just over 100 people worked in four institutes involved in the study of radioactive materials [5]. In the United States, when the atomic issue was being resolved, specialists from all over the world (numbering 1200) were brought in.

Outstanding scientists from all over the world were among the physicists who participated in the US work on the Atomic Project: Einstein, Fermi, Teller, Szilard, Neumann, Chadwick, Cockcroft, Oliphant, Niels Bohr, Bethe, Peierls, Wigner, Frisch, Kistiakowsky, Richtmyer....

There can be no doubt that the names of Kurchatov and Khariton stand alongside those of Tchaikovsky, Tsiolkovsky, and Tolstoy, who belong to Russia — a nation that produces geniuses.
(A. Kramish and T. Reed, participants in the US Manhattan Project.)

Igor' Vasil'evich Kurchatov (1903–1960).
Outstanding physicist and science organizer, academician (1943); scientific director of Atomic Energy Project; three-time Hero of Socialist Labor (1949, 1951, 1954); laureate of four Stalin Prizes (1942, 1949, 1951, 1953); Lenin Prize laureate (1956); Head of Laboratory No. 2 of USSR Academy of Sciences (1943–1960) — Institute of Atomic Energy — now National Research Center Kurchatov Institute; participant in and director of nuclear tests of first nuclear and thermonuclear weapons. I.V. Kurchatov's name is mentioned more than 2000 times in governing documents of our country from 1940 to 1954.

Yulii Borisovich Khariton (1904–1996).
Outstanding figure in USSR Atomic Project, outstanding researcher in physics of explosions, author of pioneering work on nuclear chain reactions jointly with Ya.B. Zel'dovich, academician (1953); three-time Hero of Socialist Labor (1949, 1951, 1954); laureate of three Stalin Prizes (1949, 1951, 1953); Lenin Prize laureate (1956): participant and director of more than 100 nuclear tests; chief designer of KB-11 (1946–1952); chief designer and scientific director (1952–1959); scientific director of VNIIEF (1959–1992); honorary scientific director of RFNC–VNIIEF (1992–1996). In governing documents of our country in period of 1943–1954, Yu.B. Khariton's name is mentioned more than 1100 times.

In December 1945, on the initiative of scientists from the USSR Academy of Sciences (I.V. Kurchatov, A.I. Alikhanov, P.L. Kapitza), the Council of People's Commissars issued a series of decrees on the training of specialists in the 'physics of the atomic nucleus.'

Special faculties were created at leading universities, which quickly evolved into new institutes (Moscow Engineering Physics Institute (MEPhI), Moscow Institute of Physics and Technology (MIPT), etc.).

By 1949, 760 and in 1950 1200 specialists were graduating for the First Main Directorate.

The famous Resolution of the Council of Ministers (CM) of the USSR of March 21, 1946, "On Prizes for Scientific Discoveries and Technical Achievements in the Use of Atomic Energy and for Work in the Field of Cosmic Radiation Contributing to the Solution to This Problem," signed by Stalin [3], was issued.

The achievements for which awards were given were clearly spelled out. For example, "For the development of a proven method for producing plutonium, accepted for industrial production, the leader is awarded the Stalin Prize, first degree; receives a cash prize of one million rubles; is nominated for the title of Hero of Socialist Labor; and receives the title of Stalin Prize Laureate, first degree." Furthermore, they received significant rights for their family and relatives. From 1949 to 1953, this was indeed the case!

It should be noted that G.D. Smith's book, "Atomic Energy for Military Purposes," was published in a mass print run of 30,000 (!) copies at a price of 5 rubles (1946).

The difficulties of preparing students are described in detail in G.V. Kiselev's article in *Physics–Uspekhi* [24].

3.3 Creation of first domestic atomic bomb, RDS-1

The main elements of the Atomic Project were:

- solving the most complex scientific and technical problems in developing RDS-1, creating technologies for producing key nuclear materials;
- creating a new nuclear industry;
- creating a nuclear weapons center;
- creating a nuclear testing site;
- creating a system of cooperation among enterprises, organizations, and institutes of the Academy of Sciences aimed at achieving a common goal — implementing the Atomic Project;
- developing fundamental and applied research in new fields;

• accelerated training of a new generation of specialists in universities and developing scientific schools.

The fundamental features of the USSR Atomic Project were research in fields of completely new knowledge and technologies, such as

— nuclear physics;
— explosion physics and high-energy-density hydrodynamics;
— radiochemistry;
— specialized materials science;
— new technologies;
— nuclear reactors;
— plutonium extraction from irradiated nuclear fuel;
— gaseous diffusion and electromagnetic isotope separation;
— new production facilities:
— uranium mining and processing plants;
— plutonium production plants;
— highly enriched uranium production plants.

The Atomic Project encompasses dozens of the USSR's most important pre-war achievements, which culminated in the successful testing of the first atomic bomb, RDS-1 (August 29, 1949), and the first thermonuclear weapons, RDS-6 (August 12, 1953) and RDS-37 (November 22, 1955). Hundreds of organizations and industries worked on the Atomic Project.

3.4 New style of scientific and engineering work

The unique organization of the Atomic Project, which brought together not only outstanding scientists but also outstanding designers, engineers, technologists, and production managers who had been through the school of industrialization and the Great Patriotic War, quickly led to the creation of not just prototype nuclear charges but mass-produced weapons.

The achievements of our Atomic Project during those years are a clear example of the scientific and technical heights that can be achieved in Russia when three key conditions are met: a crucial super-task, the creative work of specialists from various professions united in a unique final product, and, finally, strong government support.

These were first-rate advances in high technology — technology based on completely new scientific knowledge.

The country's leaders and the heads of the Atomic Project managed to organize the work by creating multidisciplinary teams of specialists, closely linking scientific, engineering, design, experimental, and technological work into a unified system of activities aimed at creating an atomic bomb in 2–3 years.

Undoubtedly, the basic factor of the project was the participation of outstanding scientists of the 20th century: N.N. Bogoliubov, I.M. Gelfand, V.L. Ginzburg, Ya.B. Zeldovich, L.V. Kantorovich, M.V. Keldysh, I.V. Kurchatov, L.D. Landau, S.A. Lebedev, A.D. Sakharov, A.N. Samarskii, N.N. Semenov, I.E. Tamm, A.N. Tikhonov, G.N. Flerov, I.M. Frank, D.A. Frank-Kamenetsky, and Yu.B. Khariton and hundreds of other specialists in various fields: technology, medicine, geology, etc., whose work within the framework of a unified approach led our country to outstanding results.

Scientists needed to change their traditional methodological scientific approach of 'investigation' to the creation of a military-reliable 'device' in a given time.

Simultaneously with the creation of the bomb, new experimental nuclear physics, computational mathematics, instrumentation, and precision engineering were being developed.

The scale of the transition from the results of fundamental research at the 'micro level' to the design and construction of new gigantic factories is impressive. For example, the scale of laboratory (cyclotron) plutonium research differed from the scale of the Mayak plutonium factory by a factor of 10^{10}.

For today, the work style was surprising (especially during the period of work on the first thermonuclear weapons): the majority of the institute staff were young people aged 25–35.

The fusion of young specialists with world-class scientists, a clear understanding of the project's goals, and the administration's ability to concentrate resources on the right areas, abandoning secondary projects or projects that could not be completed within one to five years — all of that led to such outstanding results in such a short time.

We should also note the close collaboration between scientists and managers during the work on the atomic bomb. It was the scientists who shaped the programs, plans, and deadlines.

The allocation of significant resources in many cases made it possible, through trial and error, to compensate for incomplete knowledge of phenomena and processes.

3.5 Scientists from Academy of Sciences in key positions in Atomic Project

In 1945–1946, the following institutions were involved in the project by relevant decrees of the USSR Council of Ministers:

(1) Laboratory No. 2 (Director — Academician I.V. Kurchatov).

(2) Physical-Technical Institute of the USSR Academy of Sciences (Director — Academician A.F. Ioffe) — A.P. Aleksandrov.

(3) Physical Institute of the USSR Academy of Sciences (Director — Academician S.I. Vavilov) — G.M. Frank, E.L. Feinberg, L.V. Groshev, D.V. Skobeltsyn, V.I. Veksler, et al.

(4) Radium Institute of the USSR Academy of Sciences (Director — Academician V.G. Khlopin) — B.A. Nikitin, A.P. Ratner, K.A. Petrzhak, M.P. Meshcheryakov et al.

(5) Institute of Physical Chemistry of the USSR Academy of Sciences (Director — Academician A.N. Frumkin) — S.Z. Roginsky.

(6) Institute of Inorganic Chemistry of the USSR Academy of Sciences (Director — Academician I.I. Chernyaev).

(7) Institute of Chemical Physics of the USSR Academy of Sciences (Director — Academician N.N. Semenov).

(8). Ural Branch of the USSR Academy of Sciences (Branch Director — Academician I.P. Bardin) — F.F. Lange et al.

(9) Institute of Geochemistry and Analytical Chemistry of the USSR Academy of Sciences (Director — Academician A.P. Vinogradov).

(10) Physics Institute of the Ukrainian Academy of Sciences (Director — Full Member of the Ukrainian Academy of Sciences A.N. Leypunsky).

(11) Physical-Technical Institute of the Ukrainian Academy of Sciences (Director — Professor K.D. Sinel'nikov) — A.K. Walter, M.I. Korsunsky et al.

Boris L'vovich Vannikov (1897–1962).
Three-time Hero of Socialist Labor (1942, 1949, 1954), Stalin Prize (1951, 1953), outstanding organizer of the USSR defense industry, People's Commissar of Armaments (1939–1941), people's commissar of ammunition (1942–1946), head of first Main Directorate (FMD) at Council of People's Commissars of USSR (1946–1953), first deputy minister of Ministry of Medium Machine Building (1953–1958).

How decisions were made

Mutual expert reviews were mandatory. Widely practiced were

— appointments of scientists to leadership positions at industrial enterprises (during the start-up period) — for example, I.V. Kurchatov was the scientific director of Combine No. 817 and spent six months in the Urals;

— part-time employment (L.D. Landau worked at Laboratory No. 3, the Institute for Physical Problems (IPP), Moscow State University, etc.).

Scientific and Technical Councils (STCs) played an important role. On June 19, 1947, a resolution of the Council of Ministers established the STC at Laboratory No. 2 with I.V. Kurchatov as chairman, Yu.B. Khariton as deputy chairman, N.N. Semenov, K.I. Shchelkin, A.S. Aleksandrov, and P.M. Zernov as council members, and A.P. Aleksandrov, I.K. Kikoin, Ya.B. Zel'dovich, A.A. Bochvar, A.S. Zaimovskii, B.A. Nikitin, and K.V. Selikhov as council experts.

Just a week (!) after the decision of the Special Committee (an extradepartmental body), resolutions of the USSR Council of Ministers were adopted, then signed by Chairman of the USSR Council of Ministers Joseph Stalin, with the decisions of the Special Committee translated into legal form.

It should be especially noted that, in many cases, construction of commercial plants began before reliable data had been obtained from experimental facilities. The commercial plant in Sarov, Combine No. 816 in Tomsk-7, the first F-1 reactor, and the Annushka industrial reactor at Combine No. 817 in 1945 in Chelyabinsk-40 (now Ozersk) are examples.

3.6 Obtaining uranium feedstock a key issue in creating atomic bomb

Igor' Vasil'evich Kurchatov, in his report to Stalin on February 12, 1946, noted that "1946 was a turning point in uranium work: we moved from theoretical calculations to the practical construction of nuclear facilities." By early 1946, the Special Committee had recruited 20 research institutes from the Academy of Sciences and People's Commissariats for atomic energy research.

In 1951, 63,208 people (5863 with a higher education) worked on the Atomic Project. The number of research institutes involved had increased more than fivefold (112 research institutes and 200 scientists).

In the United States, metallic uranium was not produced until the fall of 1942. In December 1942, Fermi launched the first reactor, using 6 tons of pure uranium and 40 tons of uranium dioxide and uranium oxide.

In 1944, only 2 tons of uranium ore in concentrates were mined in our country, and 7 tons in 1945. Therefore, large-scale exploration for finding uranium deposits was organized in the country.

By 1949, the USSR's resources of mined and accumulated natural uranium amounted to 25% of those of the United States. Approximately 73% of this natural uranium came from abroad (Germany and Czechoslovakia). In 1949, the USSR's natural uranium supply already accounted for 86% of the US's supply that year [5].

In the USSR and Eastern European countries, more than 50 uranium deposits with total reserves of 84,000 tons were discovered, explored, and commissioned. A stable foundation for the development of the Atomic Project was successfully established. In the early years, even mountain climbers were recruited to search for uranium deposits (!).

Of significant importance was the receipt of 100 tons of uranium from East Germany in May 1945 (Yu.B. Khariton), which made it possible to "reduce the reactor startup time by several years" (these words were spoken by I.V. Kurchatov to Yu.B. Khariton) [6]. A total of 35 tons of metallic uranium and 300 tons of its compounds were exported from Germany, from which 150–200 tons of metallic uranium could be extracted.

It was necessary to develop a technology for producing pure metallic uranium. The German scientist of Russian origin N. Riehl made an outstanding contribution to the solution to this problem. The technology was mastered and significantly improved on an industrial scale at Plant No. 12 (Elektrostal) in 1945–1946. Two hundred fifty German specialists participated in the USSR Atomic Project.

The second most complex technological challenge in reactor development was the production of large quantities of ultra-high-purity graphite (500 tons). Research was initiated by I.V. Kurchatov at Laboratory No. 2. Production was mastered at the Neftegaz plant (according to specifications, the boron content in a 500-ton mass should not have exceeded 5×10^{-6}; using the developed technology, it amounted to $(1.2-1.7) \times 10^{-6}$).

The decision to build Gaseous Diffusion Plant No. 813 was made on December 1, 1945. In 1942, uranium-235 (70–

90% enriched) was considered the primary material for making atomic bombs in the United States. Several methods were proposed for its enrichment (in natural uranium, uranium-235 constituted only 0.71%): gaseous, electromagnetic, centrifugal, and thermal diffusion. These methods were the primary ones in the United States.

In 1943, Laboratory No. 2 began research on the possibility of separating uranium isotopes in the gas phase. In 1944, the same laboratory began studying the electromagnetic method of separating uranium isotopes. That same year, the Laboratory of Electrical Phenomena (headed by I.K. Kikoin, Institute of Metal Physics, USSR Academy of Sciences) was brought in to develop uranium separation methods.

Igor' Vasil'evich Kurchatov was well aware of the difficulties of moving from laboratory research (micrograms) to kilogram quantities.

Therefore, in 1943, after receiving information about the launch of the first American Fermi reactor (in late 1942), Kurchatov decided to focus on the use of plutonium, although this was an extremely risky decision. In the United States, work continued simultaneously on producing enriched uranium using three methods.

Igor' Vasil'evich entrusted the development of gaseous diffusion technology to his outstanding associate I.K. Kikoin and electromagnetic technology to the outstanding scientist A.A. Artsimovich. Academician S.L. Sobolev provided the computational and theoretical justification for the gaseous diffusion method.

The technological challenges were enormous, and it appeared possible to create practical uranium enrichment technologies only in 1949 using electromagnetic enrichment and in 1950 using gaseous diffusion.

The developers of the first diffusion plant technology were staff members of Laboratory No. 2 and German scientists working at the Sukhumi Institute of Physics and Technology. Construction of the commercial plant began in 1946, and, in May 1948, a government decree was issued authorizing the launch of the first stage of Combine No. 813 — the D-1 diffusion plant.

In November 1949, the D-1 plant produced its first finished product, UF_6, containing 75% of the U-235 isotope. After a series of measures completed by 1950, diffusion technology was fully mastered, enabling the production of tens of kilograms of 90%-enriched U-235.

I.V. Kurchatov selected gaseous diffusion uranium enrichment technology as the primary method for producing highly enriched uranium-235. On October 8, 1946, Beria sent a letter to Stalin regarding the design of a uranium electromagnetic separation plant. The letter noted that Laboratory No. 2 (headed by L.A. Artsimovich), together with the Electrosila Plant Design Bureau and the Central Vacuum Laboratory, had created a pilot plant with a 60-ton magnet for the electromagnetic separation of uranium isotopes. Its capacity was 4 to 5 μg of uranium-235 per hour with a purity level of at least 80%. Based on these achievements, the Special Committee considered it necessary to begin construction of an industrial plant with a capacity of 150 g of uranium-235 per day.

On June 6, 1947, a government decree established the construction of the first stage of a plant for the electromagnetic separation of uranium isotopes (now the EKhP Combine in Lesnoy, Sverdlovsk Region), which was commissioned in late 1950.

The first RDS-3 charge using enriched uranium was tested in 1951. This outstanding achievement allowed us to increase our country's nuclear arsenal severalfold in those years, and, in 1953, to test the first RDS-6s thermonuclear charge using uranium-235 as a fuse.

Unlike the US, our specialists continued complex technological work to develop centrifuge technology, and it was launched in 1958. This allowed our country to vigorously develop nuclear energy and take a leading position in the world in the sale of enriched uranium (its production cost is fractions of that of the gaseous diffusion method, and its energy consumption is 10–20 times lower).

Interesting facts about the 'Ural trace' in the development of gaseous diffusion technology under the leadership of I.K. Kikoin are presented in *Physics–Uspekhi* in a review by S.A. Gudin [25].

3.7 First nuclear reactor, F-1. 1946

In 1944, Laboratory No. 2 developed a theory of neutron transport in a heterogeneous medium consisting of uranium and a moderator (I.I. Gurevich, I.Ya. Pomeranchuk, Ya.B. Zel'dovich), the conclusions of which were confirmed by model experiments (G.N. Flerov, V.A. Davidenko) in a medium consisting of tungsten blocks with paraffin and neutron sources.

The reactor launch was a remarkable achievement which became the cornerstone for solving the problem of creating an atomic bomb and, subsequently, nuclear power.

The F-1 reactor contained 34,800 kg of metallic uranium, 12,900 kg of uranium dioxide, and 420 tons of pure graphite. The peak power of the reactor was 3.9 MW.

The absence of a special heat sink in the reactor determined its 'quasi-pulse' nature; the average pulse power over 30 minutes was 1 MW.

The launch of the first F-1 nuclear reactor on December 25, 1946 significantly expanded the possibilities for obtaining plutonium samples for nuclear physics and chemical research and, of course, confirmed Kurchatov's choice to use plutonium for the first domestic atomic bomb based on implosion.

3.8 Creation of weapons-grade plutonium production infrastructure main technological stage in implementation of USSR's nuclear weapons program

On December 1, 1945, the Council of People's Commissars of the USSR issued a decree establishing Combine No. 817 in the Urals (PO Mayak, Chelyabinsk-40, now Ozersk); the scientific director for the creation of reactor 'A' was I.V. Kurchatov, and the chief designer was N.A. Dollezhal. The decision to build it was made before the launch of the RDS-1 reactor.

On January 9, 1947, Stalin received members of the Special Committee and leading scientists of the Atomic Project in the Kremlin and heard a status report (although the original 1945 plan called for the first atomic bomb test in 1947, the deadlines had to be adjusted. No harsh punishments followed).

At the end of November 1947, I.V. Kurchatov was appointed deputy director of Combine No. 817, retaining his responsibilities as scientific director of the industrial reactor project. The Mayak plant's construction employed 45,000 people and utilized minimal equipment, yet it was completed in the same amount of time as in the United States.

Under the direction of I.V. Kurchatov, reactor 'A' began operation on June 19, 1948, and, on June 22, it reached its design capacity of 100 MW. The reactor contained 150 tons of uranium and over 1000 tons of high-purity graphite. On December 22, 1948, Plant 'B' for the radiochemical separation of plutonium was commissioned. The radiochemical processes for Plant 'B' were developed at the Radium Institute under the direction of V.G. Khlopin. In August 1949, plutonium metal hemispheres for the RDS-1 reactor were manufactured at Plant 'V.' The technology for producing pure plutonium metal was developed at Research Institute-9 under the supervision of A.A. Bochvar, the scientific director of Plant 'V.'

The first batch of irradiated uranium slabs was transferred to Radiochemical Plant 'B' (scientific director V.G. Khlopin), which was part of the combine, on December 22, 1948. The first products were transferred to Metallurgical Plant 'V' in February 1949 (scientific director A.A. Bochvar). In 2003, a remarkable book on this topic, *Plutonium in Girls' Hands* [7], was published by Plant 'B' workers.

We must especially remember that the production of plutonium came at a very high price. Hundreds of people received high doses of radiation ($\sim$ 1000 R). Half of them were girls and young women.

3.9 RFNC–VNIIEF — national treasure and pride of Russia

The work of specialists at KB-11, the Russian Federal Nuclear Center — VNIIEF, played a decisive role in the creation of the first nuclear and thermonuclear weapons and ensuring strategic balance with the United States.

The unique organization of work at KB-11, which, in addition to outstanding scientists, brought together outstanding designers, engineers, technologists, and production managers trained in industrialization and the Great Patriotic War, quickly led to the creation of not just prototype nuclear warheads, but weapons for mass production.

It is important to note that the concentration of outstanding individuals of the victorious generation within KB-11 created a special atmosphere of intellectual freedom, while work on the 'bomb' and the foreign policy environment engendered a special sense of responsibility. Participation in nuclear testing completed the formation of a worldview: if humanity is to survive, a new level of thinking is necessary.

Superimposed on these circumstances was the special mission of the Russian state and the spirit of the Russian people, which had developed over more than a thousand years of history; a unique type of civilization with its own culture had emerged. For Russia, nuclear weapons and nuclear deterrence are not a means of war, but a way to build and protect what has been built.

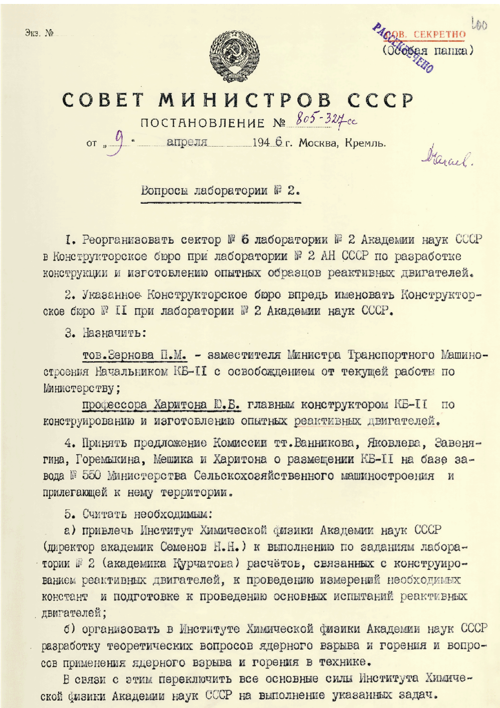
On November 13, 1945, the decree "On the Organization of Research on the Use of Atomic Energy for Peaceful Purposes" was issued (Vavilov, Semenov, Frank). The Academy of Sciences (Vavilov) was tasked with leading this work.

From 1945 to 1948, research on the creation of a hydrogen bomb began (Zel'dovich, Landau, Tamm, Sakharov, Blokhintsev, Romanov, et al.).

During these same years, at Semenov's initiative, work on anti-nuclear defenses was underway, which gave impetus to the development of accelerator technology.

At the suggestion of N.N. Semenov, construction of the Semipalatinsk test site began in 1947. It was completed in just two years. Essentially, it was to support measurements within the walls of the ICP that nuclear instrumentation was born during that period [26].

As early as 1948, in addition to the first atomic bomb, the RDS-1, KB-11 was to begin designing four new bombs with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СОВ. СЕКРЕТНО
(Особая папка)

РАССЕКРЕЧЕНО

100

СОВЕТ МИНИСТРОВ СССР

ПОСТАНОВЛЕНИЕ № 805-327сс

от „9" апреля 1946 г. Москва, Кремль.

Вопросы лаборатории № 2.

1. Реорганизовать сектор № 6 лаборатории № 2 Академии наук СССР в Конструкторское бюро при лаборатории № 2 АН СССР по разработке конструкции и изготовлению опытных образцов реактивных двигателей.

2. Указанное Конструкторское бюро впредь именовать Конструкторское бюро № 11 при лаборатории № 2 Академии наук СССР.

3. Назначить:

тов.Зернова П.М. - заместителя Министра Транспортного Машиностроения Начальником КБ-11 с освобождением от текущей работы по Министерству;

профессора Харитона Ю.Б. главным конструктором КБ-11 по конструированию и изготовлению опытных реактивных двигателей.

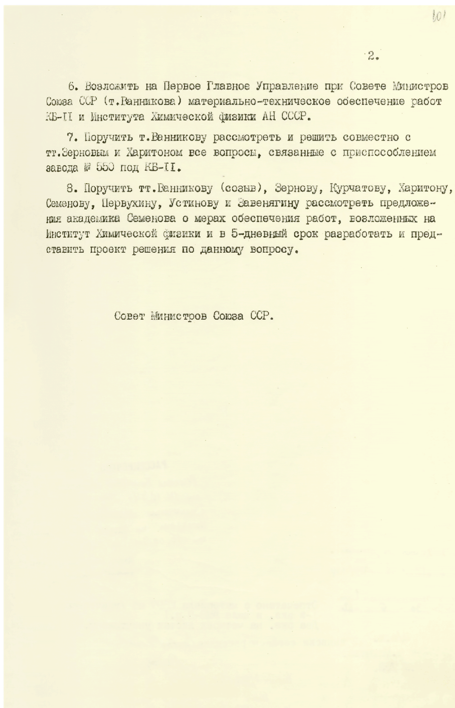
4. Принять предложение Комиссии тт.Ванникова, Яковлева, Завенягина, Горемыкина, Мешика и Харитона о размещении КБ-11 на базе завода № 550 Министерства Сельскохозяйственного машиностроения и прилегающей к нему территории.

5. Считать необходимым:

а) привлечь Институт Химической физики Академии наук СССР (директор академик Семенов Н.Н.) к выполнению по заданиям лаборатории № 2 (академика Курчатова) расчётов, связанных с конструированием реактивных двигателей, к проведению измерений необходимых констант и подготовке к проведению основных испытаний реактивных двигателей;

б) организовать в Институте Химической физики Академии наук СССР разработку теоретических вопросов ядерного взрыва и горения и вопросов применения ядерного взрыва и горения в технике.

В связи с этим переключить все основные силы Института Химической физики Академии наук СССР на выполнение указанных задач.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2.

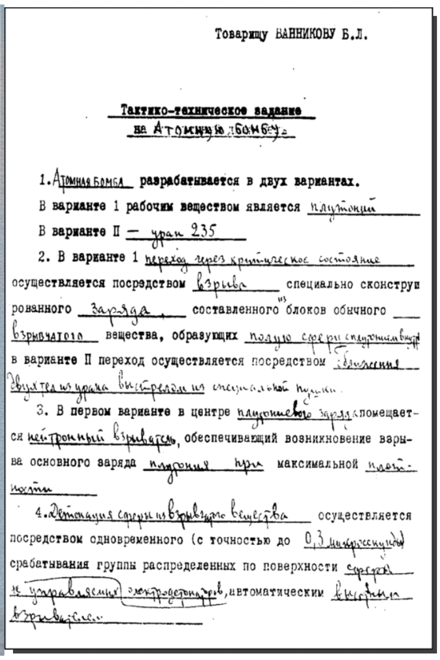
6. Возложить на Первое Главное Управление при Совете Министров Союза ССР (т.Ванникова) материально-техническое обеспечение работ КБ-11 и Института Химической физики АН СССР.

7. Поручить т.Ванникову рассмотреть и решить совместно с тт.Зерновым и Харитоном все вопросы, связанные с приспособлением завода № 550 под КБ-11.

8. Поручить тт.Ванникову (созыв), Зернову, Курчатову, Харитону, Семенову, Первухину, Устинову и Завенягину рассмотреть предложения академика Семенова о мерах обеспечения работ, возложенных на Институт Химической физики и в 5-дневный срок разработать и представить проект решения по данному вопросу.

Совет Министров Союза ССР.

Resolution of Council of Ministers of USSR No. 805-327ss of April 9, 1946, on establishment of Design Bureau (KB) No. 11 at Laboratory No. 2 of USSR Academy of Sciences.


Товарищу ВАННИКОВУ Б.Л.

Тактико-техническое задание
на Атомную бомбу.

1. Атомная бомба разрабатывается в двух вариантах.
В варианте 1 рабочим веществом является плутоний
В варианте II — уран 235
2. В варианте 1 переход через критическое состояние осуществляется посредством взрыва специально сконструированного заряда, составленного из блоков обычного взрывчатого вещества, образующих полую сферу, сходящимися внутрь; в варианте II переход осуществляется посредством сближения двух тел из урана выстрелом из специальной пушки.
3. В первом варианте в центре плутониевого заряда помещается нейтронный взрыватель, обеспечивающий возникновение взрыва основного заряда плутония при максимальной плотности.
4. Детонация сферы из взрывчатого вещества осуществляется посредством одновременного (с точностью до 0,3 микросекунды) срабатывания группы распределенных по поверхности сферы управляемых электродетонаторов, автоматически включенных взрывателем.

Tactical and technical assignment (TTA), prepared by Yu.B. Khariton, for first domestic atomic bomb, 1946.

different physical designs, including a hydrogen bomb. It is hard for us to even imagine the stress and responsibility that fell on the shoulders of the participants in the Atomic Project. In 1947, KB-11 employed only 36 research staff and 86 engineering and technical workers; its total headcount was 1285 (!).

On July 1, 1946, Chief Designer Yu.B. Khariton signed the "Tactical and Technical Specifications for the Atomic Bomb" in very general terms.

Yulii Borisovich Khariton combined theoretical research, design, engineering, and experimental work on a nationwide scale.

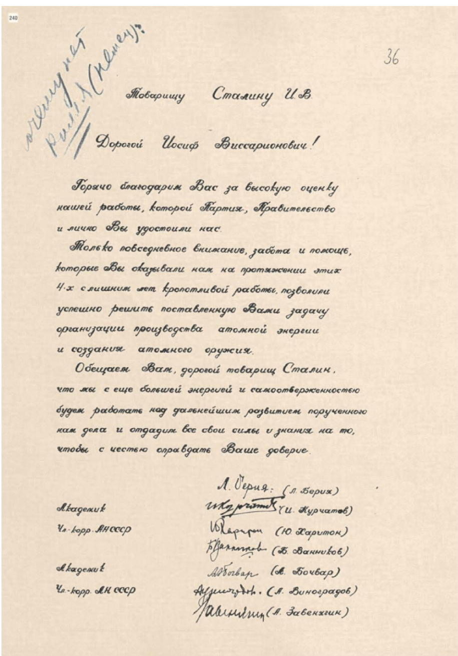
The key areas of RDS-1's development had to be as follows:

— issues of explosive detonation;

— transmission of detonation processes in heterogeneous media;

— theory of the converging detonation wave;

First domestic atomic bomb exists — "When will Russia make an atomic bomb?... Never!"
US President Harry Truman, summer 1949.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Товарищу Сталину И.В.

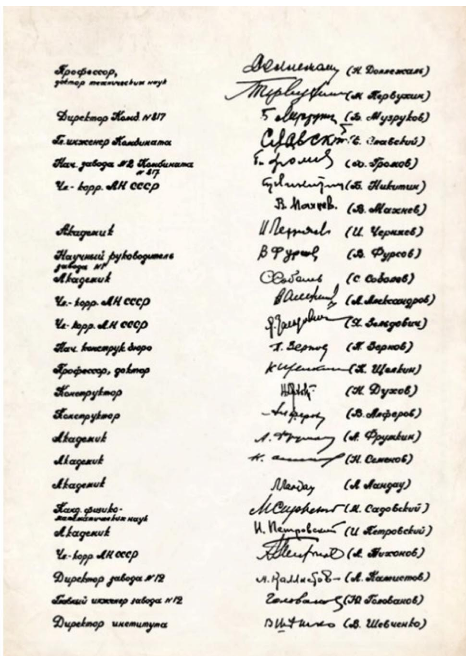
Дорогой Иосиф Виссарионович!

Горячо благодарим Вас за высокую оценку нашей работы, которой Партия, Правительство и лично Вы удостоили нас.

Только повседневное внимание, забота и помощь, которые Вы оказывали нам на протяжении этих 4-х с лишним лет кропотливой работы, позволили успешно решить поставленную Вами задачу организации производства атомной энергии и создания атомного оружия.

Обещаем Вам, дорогой товарищ Сталин, что мы с еще большей энергией и самоотверженностью будем работать над дальнейшим развитием порученного нам дела и отдадим все свои силы и знания на то, чтобы с честью оправдать Ваше доверие.

(Л. Берия)
Академик (И. Курчатов)
Чл.-корр. АН СССР (Ю. Харитон)
(Б. Ванников)
Академик (А. Бочвар)
Чл.-корр. АН СССР (А. Виноградов)
(А. Завенягин)


Профессор, доктор технических наук (Н. Доллежаль)
(М. Первухин)
Директор Комб. №817 (Б. Музруков)
Гл. инженер Комбината (Е. Славский)
Нач. завода №2 Комбината №817 (Ф. Громов)
Чл.-корр. АН СССР (Б. Никитин)
(В. Махнев)
Академик (И. Черняев)
Научный руководитель завода №1 (В. Фурсов)
Академик (С. Соболев)
Чл.-корр. АН СССР (А. Александров)
Чл.-корр. АН СССР (Я. Зельдович)
Нач. конструк. бюро (П. Зернов)
Профессор, доктор (К. Щелкин)
Конструктор (Н. Духов)
Конструктор (В. Алферов)
Академик (А. Фрумкин)
Академик (Н. Семенов)
Академик (Л. Ландау)
Канд. физико-математических наук (М. Садовский)
Академик (И. Петровский)
Чл.-корр. АН СССР (А. Тихонов)
Директор завода №12 (А. Каллистов)
Главный инженер завода №12 (Ю. Голованов)
Директор института (В. Шевченко)

Letter to Stalin about creation of first atomic bomb.

— compressibility of metals at high pressures;

— laboratory methods for studying gas-dynamic processes;

— applied gas-dynamic experiments on RDS-1 models and full-scale mock-ups to reproduce all stages of charge operation: from the operation of the explosive initiation systems and the detonation initiation process to recording the compression of the active substance simulator;

— determination of critical mass;

— development of the theory of atomic bomb energy release;

— research on neutron initiation of nuclear explosions;

— creation of a neutron 'initiator.'

During the development of RDS-1, more than 100 tons of explosives were detonated at the KB-11 facilities (dozens of experiments with 1 ton of explosives, hundreds of scalable experiments); a new instrumentation base was created in collaboration with the ICP [6].

More than 3500 people were awarded government awards for the development and testing of the RDS-1. Thirty-six specialists were awarded the title of Hero of Socialist Labor (including seven specialists from KB-11).

B.L. Vannikov, N.L. Dukhov, and B.G. Muzrukov became the first two-time Heroes of Socialist Labor in our country.

3.10 Main results of creation of RDS-1. Beginning of country's modernization

The 1949 explosion blew away the illusions about Russia's technological backwardness. We knew everything in 1945, but we completed it in 1952.

H. Tizard — Director of the United Kingdom Atomic Energy Project

The influence on scientific and technological progress included

- Creation of precision engineering technologies;
- Development of computational mathematics;
- Creation of a foundation for the development of nuclear energy and nuclear power plants;
- Creation of the foundations of high-energy-density physics, including diagnostic tools for explosive processes;
- Development of accelerator technology and nuclear physics;
- Development of radiochemistry and the physical chemistry of the production of high-purity and special materials;
- Development of radiation biology;
- Creation of a new instrument-making base;
- Creation of RDS-1 not only was a demonstration of the outstanding capabilities of Soviet science, technology, and industry, but also served as a benchmark for the industrial production of nuclear weapons.

On March 3, 1949, i.e., before the RDS-1 test, a Decree of the USSR Council of Ministers ordered the assembly plant established at KB-11 to produce 20 RDS-1 bombs per year.

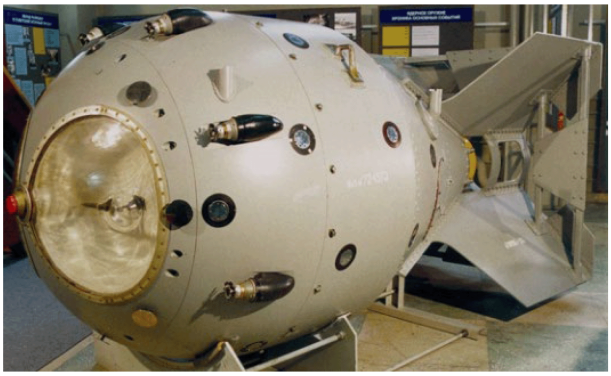
The rapid implementation of fundamental scientific advances through the correct selection of priorities and the concentration of resources on them, the selection and training of talented personnel, and the utmost responsibility and enthusiasm of all nuclear weapons specialists allowed, for many decades, and continue to allow, despite our country's significantly smaller financial and economic resources compared to the United States, effectively maintaining strategic balance in the world, thereby ensuring peace.

The best intellectual talent in the country participated in the creation of the first nuclear and thermonuclear weapons. Yulii Borisovich Khariton attracted outstanding specialists to work on atomic weapons, who, together with their disciples, founded a number of scientific schools that still define the scientific and technical work at RFNC–VNIIEF today. The combination of free scientific and technical creativity with the unconditional fulfillment of plans at the highest level, strong organizational support for new ideas and large-scale projects, and a conscious risk in innovation — all these fundamental principles of work were supported by the country's top leadership and at RFNC–VNIIEF. They were established, developed, and vigorously supported by Yulii Borisovich Khariton.

Yu.B. Khariton's principle: "We must know ten times more than we need to today" — while requiring greater resources, ensuring creative freedom, and, as time has shown, guaranteeing greater reliability of the final product.

In the early 1950s, KB-11 became, without a doubt, the intellectual center of Russia. During that period, scientific schools were formed at KB-11, whose students still hold leading positions in our science today. The leaders of the KB-11 (VNIIEF) scientific schools in the early 1950s included Yu.B. Khariton, Ya.B. Zel'dovich, I.E. Tamm, A.D. Sakharov, N.N. Bogoliubov, M.A. Lavrent'ev, G.N. Flerov, and D.A. Frank-Kamenetskii.

Milestones in practical implementation of fundamental research at RFNC–VNIIEF.



First atomic bomb — RDS-1. Tested on August 29, 1949, yield: 22 kt of TNT [8] (Semipalatinsk test site).

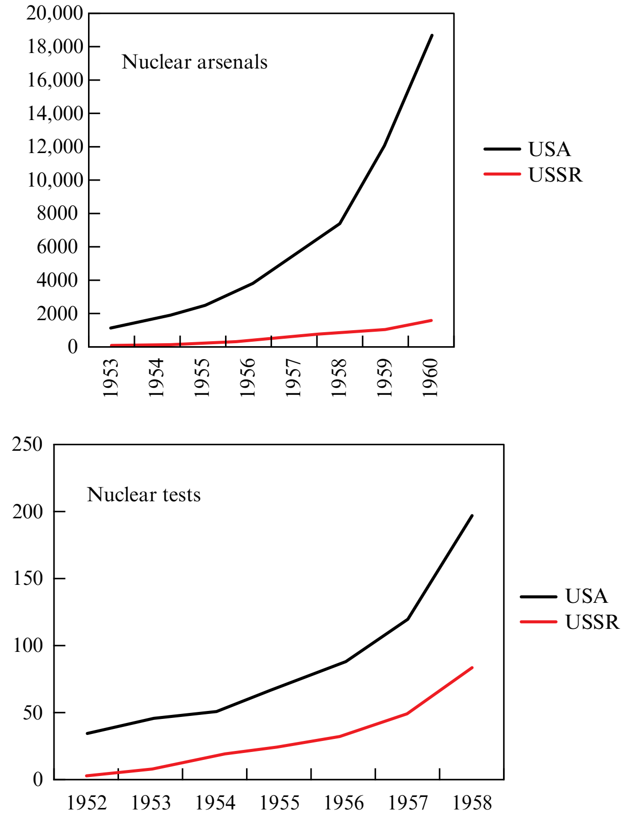
First hydrogen bomb — RDS-6s. Tested on August 12, 1953, yield: 400 kt of TNT [8] (Semipalatinsk test site).

First thermonuclear bomb, RDS-37, based on principle of radiation implosion. Tested on November 22, 1955, with yield of 1.6 megatons [8] (Semipalatinsk Test Site).

These outstanding scientists integrated entire scientific fields on the scale of the whole country.

Project 49 laid the foundation for the modern nuclear arsenal. The device was tested on February 23, 1958 (Novaya Zemlya Test Site).

World's most powerful hydrogen bomb. Yield of 100 megatons, tested on October 30, 1961 at half yield of 50 megatons [8] (Novaya Zemlya Test Site).



Nuclear arsenals of USA and USSR in post-war years.

4. Development of first domestic thermonuclear charges — decisive step toward peace

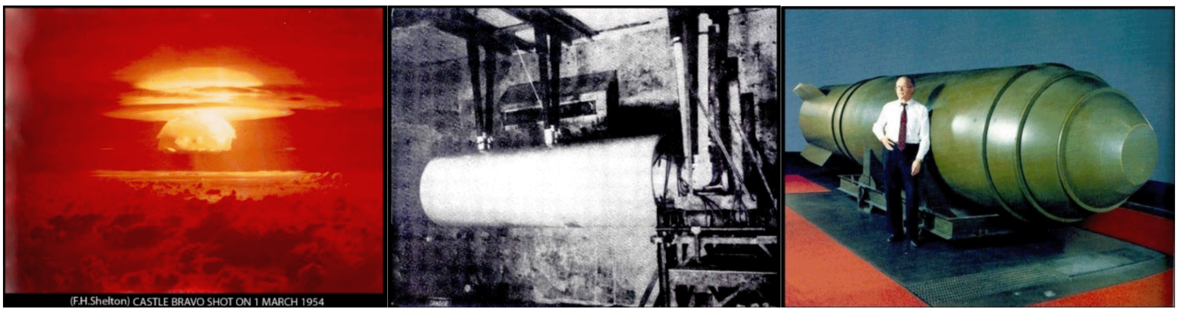
4.1 Threat of US thermonuclear monopoly

In the mid-1950s, the US nuclear arsenal passed the threshold of 'total annihilation.' The total megatonnage of US nuclear weapons in 1956 reached approximately 9 Mt (!). During World War II, 4.5 Mt of explosive weapons were expended. The USSR had nothing comparable at that time. Essentially, our country did not yet have thermonuclear charges, and most importantly, it had no delivery vehicles for these warheads [2] that could reach US territory.

4.2 Beginning of USSR thermonuclear program

Work on the development of thermonuclear weapons began in 1945 and was initiated by intelligence data. I.I. Gurevich, Ya.B. Zel'dovich, I.Ya. Pomeranchuk, and Yu.B. Khariton prepared a paper entitled "Use of Nuclear Energy from Light Elements," which was presented at a meeting of the Technical Council of the Special Committee on December 17, 1945. This was the first proposal by our scientists concerning the thermonuclear question [24].

Beginning in June 1946, theoretical research on the possibility of using the nuclear energy of light elements began in Moscow at the Institute of Chemical Physics by a group consisting of S.P. D'yakov and A.S. Kompaneets,



Powerful US thermonuclear charges: US thermonuclear charge for Bravo tests, yield, 15 Mt, bomb mass, ~ 19 tons, length, 7.5 m, diameter, 1.6 m. Adopted into service (Mark-17) in 1954 (March 1, 1954) [9].

under the direction of Ya.B. Zel'dovich, and at the Institute of Physical Problems (since 1948) by L.D. Landau's group.

The thermonuclear project arose from the very beginning as a project for a superbomb, i.e., a bomb with a multi-megaton energy release. Such was the original project, based on the detonation of 'Super' liquid deuterium in the USA. The original version of A.D. Sakharov's 'Big Layer Cake (Sloika),' which did not utilize implosion, was also similar.

It was quickly realized that the detonation of liquid deuterium in an infinite medium was impossible (due to the enormous reaction zone and the decomptonization regime, as calculated by the groups of Ya.B. Zel'dovich and L.D. Landau).

The main problem that all groups of theoreticians and mathematicians worked on was the study of the physical processes of energy balance. To achieve a self-sustaining thermonuclear reaction ($D+D$), the energy released during fusion must be greater than the energy leaving the system ('truba' (the Russian for 'tube')).

Calculations performed under the supervision of Ya.B. Zel'dovich and L.D. Landau showed that, to ignite such a tube, it is necessary to maintain a temperature at the combustion wave front more than 10 times higher than that obtained in optimistic calculations.

To concentrate all resources, a decree of the USSR Council of Ministers stipulated that the calculation and theoretical work should be carried out according to the assignments and under the supervision of Khariton and Zel'dovich at KB-11, the Mathematical Institute, and Leningrad branch from the Mathematical Institute (Kantorovich's group).

The Institute of Geophysics of the USSR Academy of Sciences (Tikhonov) was to perform calculations based on instructions from the Institute of Physical Problems (Landau).

After receiving new intelligence data on US hydrogen bomb projects in 1948, the Lebedev Physical Institute (FIAN) was brought in to develop a theory of tritium and deuterium combustion based on Khariton's and Zel'dovich's instructions. To address this problem, a group was organized at FIAN under the leadership of I.E. Tamm and consisting of S.Z. Belen'kii, V.A. Fock, A.D. Sakharov, and Yu.A. Romanov.

Just a few months later, on November 18, 1948, FIAN Director S.I. Vavilov informed the FMD leadership that A.D. Sakharov had proposed a fundamentally different physical design for a hydrogen bomb. Moreover, Sergei Ivanovich insisted on ceasing his group's work on the 'truba' to focus on A.D. Sakharov's 'sloika.'

Participating in the analysis of the calculation results of Ya.B. Zel'dovich's group, in September–October 1948, A.D. Sakharov, independently of Edward Teller, came up with the idea of a heterogeneous design with alternating layers of deuterium and uranium-238.

In the fall of 1948, A.D. Sakharov formulated a new principle for a thermonuclear reaction, which became a crucial contribution to the development of our country's thermonuclear weapons. Here is how he wrote about it later: "After two months, I made a sharp turn in my work. Specifically, I proposed an alternative design for a thermonuclear charge, completely different... in the physical processes occurring during the explosion and even in the main source of energy release. I called this proposal 'the first idea.'' [10, 11]. Our materials are supplemented by articles in *Physics–Uspekhi* by the actual developers of nuclear weapons: Yu.B. Khariton, Yu.A. Romanov, G.A. Goncharov, V.I. Ritus, R.I. Il'kaev [13, 18–21, 25].

From Yu. B. Khariton's expert opinion on A.D. Sakharov's 'sloika': "The idea is extremely ingenious and physically clear."

The design proposed by A.D. Sakharov was called sloika. The developers called the principle of ionization compression of thermonuclear fuel underlying it 'sakharification.' It is surprising that A.D. Sakharov came up with the idea of the sloika only 4 months after starting his work.

He characterized the physical principles of his proposal ('ionization implosion') as follows:

(1) In the sloika, a local temperature equilibrium between matter and radiation is achieved. The question of the existence of such a regime does not arise (it undoubtedly exists). The width of the detonation wave zone is not very large. In adjacent phases, the temperature is equalized by thermal conductivity due to radiation; the equality of pressures in adjacent phases implies an equality in the number of particles per unit volume; ionized uranium 'swells,' compressing deuterium with its electron pressure.

(2) As a result of thermal reactions in deuterium, fast neutrons are produced, capable of causing fission of U^{238} nuclei, which significantly increases the calorific value.

(3) The low transparency of uranium with respect to photons ensures a moderate width of the shock wave zone, which runs ahead of the combustion zone.

Initially, A.D. Sakharov envisioned the creation of a large, spherical, uncompressed sloika with an initiating atomic bomb at its center. After visiting KB-11 in June 1949 and learning about the development of RDS-1, and, most importantly, discussing the design with Yu.B. Khariton and Ya.B. Zel'dovich, a more efficient sloika design was developed based on the principle of combining ionization implosion and gas-dynamic 'implosion.' An atomic detonator was located at the center of the sloika, surrounded by layers of thermonuclear fuel and uranium. The entire system was compressed by an explosive placed outside the multilayer system, and the sloika was initiated by implosion and explosion of the atomic detonator [11, 12].

This was a perfectly fruitful and pragmatic unification of the fundamental sloika and implosion physical ideas.

The fundamental features of the sloika allowed a wide variation in its design and the materials it contained. Here is how A.D. Sakharov wrote about this [10]: "Soon, my proposal was significantly supplemented by V.L. Ginzburg, who put forward a 'second idea.'" In his report of March 3, 1949, "Use of Lithium-6 Deuteride in the Sloika," V.L. Ginzburg noted "the advantages associated with the use of Li^6D in the 'sloika'" [11]. In this case, the reaction $Li^6 + n = He^4 + T$ produces tritium, which, as a result of the reaction $D + T = He^4 + n$, produces neutrons that fission uranium [11, 12]. It is worth noting the detailed review of the essence of the 'first and second' ideas in the article in the *Physics–Uspekhi* journal by the direct developer of RDS-6s, Vladimir Ivanovich Ritus [12], at that time a young specialist in Tamm's group. Vladimir Ivanovich directly interacted with L.D. Landau's group.

The above principles were fundamental to all thermonuclear weapons, and their practical implementation was determined first by their combination with the principle of gas-dynamic implosion (RDS-6s), and then with the principle of atomic compression (RDS-37), implemented by a team of researchers led by A.D. Sakharov. All this determined the basic features and properties of thermonuclear modules of several generations of the warheads of our nuclear arsenal over the course of decades up to the present day.

The developers understood the physical picture of the RDS-6s's operation, but justifying its performance and design required considerable efforts from many specialists. Reference [11] cites a document by B. Vannikov and I.V. Kurchatov addressed to L.P. Beria on the results of their visit to KB-11 on June 15, 1949 (i.e., before the RDS-1 atomic bomb test). By this time, there had been no serious progress in defining the RDS-6 design:

The state of the work was reviewed with the participation of Comrade A.D. Sakharov. The theoretical studies conducted to date at FIAN have not provided a comprehensive answer to the question of the feasibility of using the energy of transmutation of light nuclei (*deuterium, tritium*) *for practical purposes. Nor did the first theoretical results provide the initial data necessary to begin work on the preliminary design.*

It was decided that, in order to ensure the development of work on RDS-5, the meeting considers it necessary to concentrate on the main research necessary for the creation of an RDS-6-type system in Laboratory No. 2 (*KB-11*).

I.E. Tamm's group, with an expanded staff composition, was transferred to KB-11 (Sarov) in early 1950: Sakharov, S.Z. Belen'kii, Yu.A. Romanov, N.N. Bogoliubov, I.Ya. Pomeranchuk, V.M. Klimov, D.V. Shirkov, and D.N. Zubarev. In modern terms, during the development of RDS-6, KB-11 acted as a systems integrator in the implementation of an innovative project based on breakthrough technologies.

To concentrate resources on the RDS-6 project, by the Government Decree of December 29, 1951, all the country's top scientific experts — Landau, Zel'dovich, Keldysh, Blokhintsev, and Kolmogorov — were required to focus on this project (although it should be noted that they were aware of the sloika idea through their participation in various commissions).

For calculations of the RDS-1, 2, and 3 components, KB-11, the ICP (Ya.B. Zel'dovich), and the IPP (L.D. Landau, I.M. Khalatnikov, and N.N. Meiman) succeeded in creating satisfactory models using only averaged process characteristics: average neutron energy, average uranium shell density, average main charge temperature, etc.

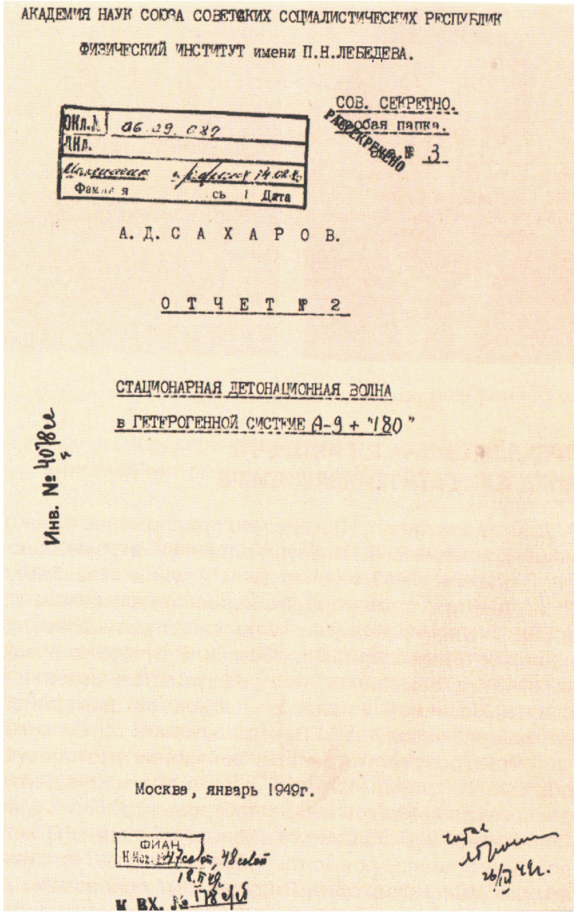
In the case of RDS-6s, such an approach was impossible for two reasons:

(a) neutrons of different energies play qualitatively different roles in an explosion, and it is natural to break their calculations into 'energy groups' (KB-11, Yu.A. Romanov);

(b) the presence of a layered structure in the system precludes the use of averaged values and requires knowledge of the temperature, density of the substance, neutron density of the various 'energy groups,' etc. in each layer.

In the groups of the Division of Applied Mathematics (DAM) (A.N. Tikhonov, A.A. Samarskii) and the Institute of Physical Problems (I.M. Khalatnikov, N.N. Meiman, and L.D. Landau), methods for calculating the explosion process were developed based on the assignments of KB-11 (A.D. Sakharov, Yu.A. Romanov, V.I. Ritus, and Yu.N. Babaev).

In A.D. Sakharov's report of April 20, 1953 on the physical principles of the RDS-6s model, the calculation technology was outlined: using the KB-11 geometry and the assignments of Ya.B. Zel'dovich and E.I. Zababakhin, K.A. Semendyaev's group (Mathematical Institute of the



АКАДЕМИЯ НАУК СОЮЗА СОВЕТСКИХ СОЦИАЛИСТИЧЕСКИХ РЕСПУБЛИК

ФИЗИЧЕСКИЙ ИНСТИТУТ имени П.Н.ЛЕБЕДЕВА.

СОВ. СЕКРЕТНО.
Особая папка.
№ 3

РАССЕКРЕЧЕНО

Экз. № 06.29.082

Фамилия | Подпись | Дата

Инв. № 4078

А. Д. С А Х А Р О В.

О Т Ч Е Т № 2

СТАЦИОНАРНАЯ ДЕТОНАЦИОННАЯ ВОЛНА

в ГЕТЕРОГЕННОЙ СИСТЕМЕ "Д-9 + U-180"

Москва, январь 1949г.

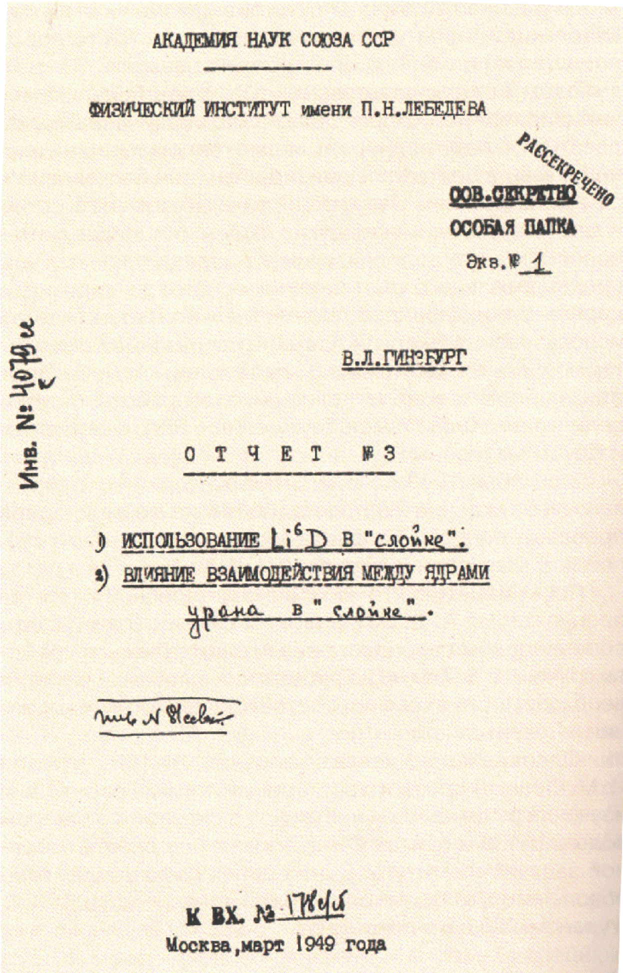
ФИАН

Вх. №

Andrei Dmitrievich Sakharov (1921–1989).

Outstanding theoretical physicist, author of pioneering studies on operating principles of thermonuclear charges, leading developer of first thermonuclear devices, RDS-6s and RDS-37, and most powerful thermonuclear charge, 100 Mt of TNT (product 602, tested on October 30, 1961 at yield of 50 Mt). He developed concepts of magnetic plasma insulation and explosive magnetic generators. Academician from 1953, deputy scientific director and head of theoretical research on development of thermonuclear weapons at KB-11 (1950–1968). Three-time Hero of Socialist Labor (1954, 1956, 1962). Laureate of Stalin Prize (1953). Laureate of Lenin Prize (1956). Nobel Peace Prize laureate (1975). Author of 'first idea': the principle of ionization compression of the thermonuclear fuel.

USSR Academy of Sciences) performed gas dynamics calculations, the results of which were passed on as initial data to the groups of L.D. Landau, A.N. Tikhonov, and I.M. Gelfand.



АКАДЕМИЯ НАУК СОЮЗА ССР

ФИЗИЧЕСКИЙ ИНСТИТУТ имени П.Н.ЛЕБЕДЕВА

РАССЕКРЕЧЕНО

СОВ.СЕКРЕТНО
ОСОБАЯ ПАПКА
Экв.№ 1

Инв. № 4079

В.Л.ГИНЗБУРГ

О Т Ч Е Т № 3

1) ИСПОЛЬЗОВАНИЕ Li^6D В "слойке".
2) ВЛИЯНИЕ ВЗАИМОДЕЙСТВИЯ МЕЖДУ ЯДРАМИ урана в "слойке".

К ВХ. №

Москва, март 1949 года

Vitaly Lazarevich Ginzburg (1916–2009).
Outstanding theoretical physicist and participant in development of first thermonuclear devices. Corresponding member of the USSR Academy of Sciences (1953) and academician (1966). Laureate of the Stalin (1953) and Lenin (1966) prizes, awarded the Order of Lenin (1954). Laureate of the Nobel Prize in Physics (2003). In November 1948, V.L. Ginzburg, a member of I.E. Tamm's group, published a report proposing the use of a new thermonuclear fuel — lithium-6 deuteride, which forms tritium upon neutron capture — in a layered system. The RDS-6s device was successfully tested on August 12, 1953, with a yield of 400 kT of TNT. Author of 'second idea,' using lithium-6 deuteride.

During the development of RDS-6s, an exceptionally large volume of gas dynamics research was conducted at KB-11, led by K.I. Shchelkin and V.K. Bobolev, and nuclear physics research was quickly conducted in Sarov, Moscow, Leningrad, and Kharkov.

During the gas-dynamic development process, 200 gas-dynamic experiments with TNT detonations were conducted on models of the device design and 31 experiments with full-size devices, which confirmed the device design's compliance with the theoretical requirements [12].

The recollections of those directly involved in the work are very important for a comprehensive understanding of the solution to scientific and technical problems. In particular, an excellent review [27] was presented in *Physics–Uspekhi* by V.I. Ritus, who worked in I.E. Tamm's group under the supervision of A.D. Sakharov at the stage of development of RDS-6s and RDS-37 (1951–1955).

4.3 Development of first thermonuclear devices

In connection with the US President's decision (January 31, 1950) to begin large-scale work on the development and production of thermonuclear charges in response to the detonation of the first Soviet atomic bomb on August 29, 1949, the USSR Council of Ministers immediately issued a decree of February 26, 1950,

"On Work on the Creation of RDS," which mandated PSU, Laboratory No. 2 of the USSR Academy of Sciences, and KB-11 to conduct work on creating the RDS-6s (Sloika) and RDS-6t (Truba) devices.

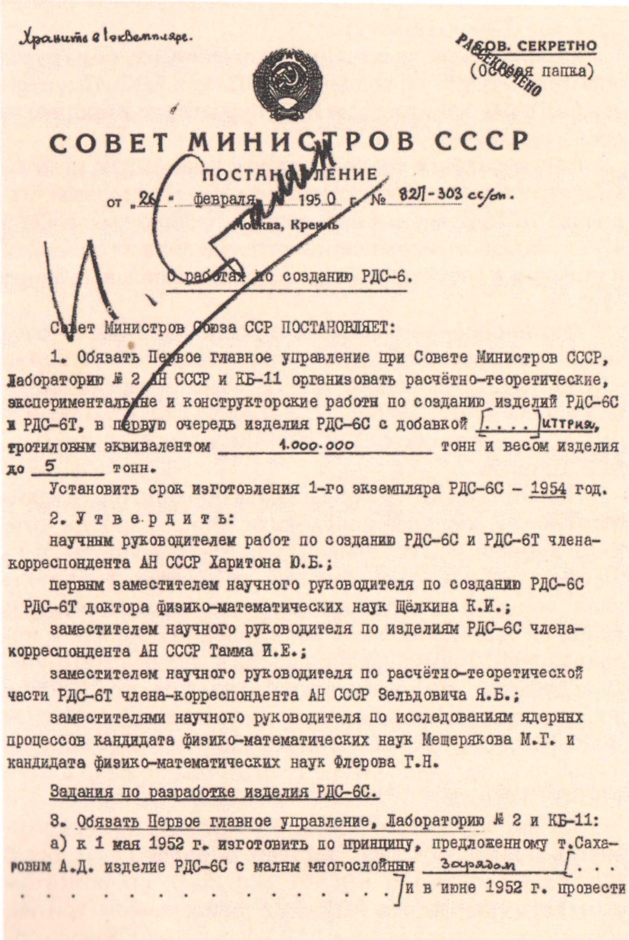
Yu.B. Khariton was appointed scientific director of the RDS-6s and RDS-6t devices, with I.E. Tamm and Ya.B. Zel'dovich as deputies.

The full drama of the current situation can be sensed from L.P. Beria's letter to I.V. Kurchatov, a month after the US tested a 10.4-megaton thermonuclear bomb at Enewetak Atoll in the Pacific Ocean [8, 27].

Calculations of energy release based on the initial data of A.D. Sakharov, Ya.B. Ze'ldovich, Yu.A. Romanov, V.I. Ritus, and Yu.N. Babaev were performed by the groups of L.D. Landau, A.N. Tikhonov, K.I. Semendyaev, and I.M. Gelfand (in Moscow). Calculations of the RDS-6s compression were performed at the Mathematical Institute of the Academy of Sciences by K.A. Semendyaev's group by order of E.I. Zababakhin, Ya.B. Zel'dovich, and E.A. Negin.

The purpose of a nuclear explosion is to initiate a thermonuclear reaction, and here 'sakharification' (the first idea) plays a key role.

Ground test (H = 30 m) of RDS-6s on August 12, 1953, E = 400 kt of TNT.



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РАССЕКРЕЧЕНО

СОВ. СЕКРЕТНО
(Особая папка)

СОВЕТ МИНИСТРОВ СССР

ПОСТАНОВЛЕНИЕ

от „26" февраля 1950 г. № 827-303 сс/оп.

Москва, Кремль

О работах по созданию РДС-6.

Совет Министров Союза ССР ПОСТАНОВЛЯЕТ:

1. Обязать Первое главное управление при Совете Министров СССР, Лабораторию № 2 АН СССР и КБ-11 организовать расчётно-теоретические, экспериментальные и конструкторские работы по созданию изделий РДС-6С и РДС-6Т, в первую очередь изделия РДС-6С с добавкой [. . . .]иттрия, тротиловым эквивалентом 1.000.000 тонн и весом изделия до 5 тонн.

Установить срок изготовления 1-го экземпляра РДС-6С – 1954 год.

2. Утвердить:

научным руководителем работ по созданию РДС-6С и РДС-6Т члена-корреспондента АН СССР Харитона Ю.Б.;

первым заместителем научного руководителя по созданию РДС-6С РДС-6Т доктора физико-математических наук Щёлкина К.И.;

заместителем научного руководителя по изделиям РДС-6С члена-корреспондента АН СССР Тамма И.Е.;

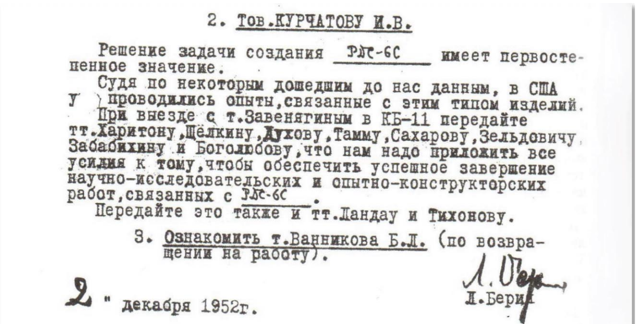
заместителем научного руководителя по расчётно-теоретической части РДС-6Т члена-корреспондента АН СССР Зельдовича Я.Б.;

заместителями научного руководителя по исследованиям ядерных процессов кандидата физико-математических наук Мещерякова М.Г. и кандидата физико-математических наук Флерова Г.Н.

Задания по разработке изделия РДС-6С.

3. Обязать Первое главное управление, Лабораторию № 2 и КБ-11:

а) к 1 мая 1952 г. изготовить по принципу, предложенному т.Сахаровым А.Д. изделие РДС-6С с малым многослойным зарядом [. . . . .]и в июне 1952 г. провести



2. Тов.КУРЧАТОВУ И.В.

Решение задачи создания РДС-6С имеет первостепенное значение.

Судя по некоторым дошедшим до нас данным, в США у) проводились опыты, связанные с этим типом изделий.

При выезде с т.Завенягиным в КБ-11 передайте тт.Харитону, Щёлкину, Духову, Тамму, Сахарову, Зельдовичу, Забабихину и Боголюбову, что нам надо приложить все усилия к тому, чтобы обеспечить успешное завершение научно-исследовательских и опытно-конструкторских работ, связанных с РДС-6С.

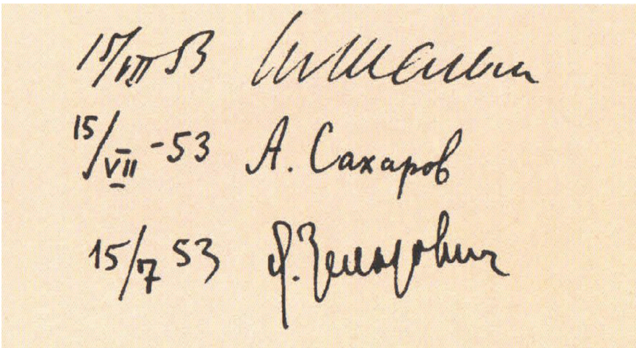
Передайте это также и тт.Ландау и Тихонову.

3. Ознакомить т.Ванникова Б.Л. (по возвращении на работу).

„2" декабря 1952г.

Л.Берия

Cover page of report "Model of RDS-6s device."



A report substantiating the performance of the RDS-6s device was released on July 15, 1953 (I.E. Tamm, Ya.B. Zel'dovich, A.D. Sakharov).

The report was cautiously titled 'RDS-6s Device Model,' although the tested model "is no different from the combat device," except for the greater mass of active materials in the combat device. The developers clearly stated that "the RDS-6s device is a hydrogen atomic bomb." The estimated yield was 300 ± 100 kt of TNT equivalent.

A.D. Sakharov based the nominal energy release (450 kt of TNT equivalent) on the calculations of L.D. Landau's group. In the test report, he included an accounting for the mixing effect, which reduces the energy release.

The nuclear physics research program necessary for the creation of a thermonuclear charge largely served as the basis for the subsequent development of nuclear physics in the USSR.

To create a thermonuclear device, a program of theoretical and experimental research for 1949–1951 was adopted at the state level. All the country's best scientific centers were involved: Laboratory No. 2 (LIPAN), FIAN, ICP, IPP, Leningrad PTI (LPTI), KB-11, Ukrainian PTI (UPTI), RIAS, and Central Scientific Research Institute No. 12 (Ministry of Defense)).

M.G. Meshcheryakov, Yu.B. Khariton, Ya.B. Zel'dovich, K.I. Shchelkin, and A.D. Sakharov issued a work plan for nuclear physics research for RDS-6s (1949–1950).

The project envisaged measuring the reaction constants of DD, DT, TT, and D ^{3}He and studying the spectra of the neutrons produced in these reactions (performed by LIPAN, ICP, UPTI). The deadline was 01.01.1951. The initial work program included measuring more than 120 constants (RIAS + KB-11 + Lab. No. 2).

A special program was devoted to radiochemical research: Yu.A. Zysin, A.A. Lbov, I.E .Starik, V.N. Ushatskii, I.V. Kurchatov, A.I. Pavlovskii, et al.

The following nuclear reactions played a decisive role in the RDS-6s device:

(a) thermonuclear reaction D + T;

(b) fission of uranium 235 and 238 nuclei by fast neutrons with an energy of 14 MeV and neutrons of lower energies;

(c) formation of tritium from lithium-6 in the reaction $n + Li^6$.

The use of new materials containing tritium required the KB-11 designers to solve the problem of heat removal (handling materials containing tritium). In the first quarter of 1951 alone, six RDS-6s charge configurations were completed. In February–March 1953, drawings for the final version of the RDS-6s were developed. Tritium production and the manufacture of deuteride (lithium-6 tritide) were carried out at Combine No. 817 (Mayak), for which a new enriched uranium reactor was built.

Today, we can only marvel and be proud. Using the electromagnetic method (L.A. Artsimovich), the first 3 grams of lithium-6 were obtained on June 5, 1950, and by January 1953, its industrial production (B.P. Konstantinov's method) had already begun. Four institutes participated in perfecting lithium-6 production methods: LPTI, the State Institute of Applied Chemistry (GIPH), Scientific Research Institute-10 of the Ministry of Medium Machine Building or Minsredmash, and the Institute of Organoelement Compounds.

All this in 1953 made it possible not only to test RDS-6s but also to obtain the necessary amount of lithium-6 for the

Explosion phases of RDS-6s.

entire thermonuclear program and quickly expand the nuclear arsenal.

The initiative of Yu.B. Khariton, A.D. Sakharov, and Ya.B. Zel'dovich to launch industrial production of lithium-6 in the early 1950s proved prophetic. Here, too, our country was ahead of the United States, although Teller had proposed using lithium-6 as early as 1946 (V.L. Ginzburg's proposal in late 1948 was made independently).

The RDS-6s test at the Semipalatinsk test site was the fourth. By that time, the United States had conducted 34 nuclear tests [8].

Today it is difficult to imagine that four nuclear tests with new device configurations were conducted during the 1953 session.

The test was conducted on a steel tower and at the same location as in 1949 (RDS-1 test) and 1951 (RDS-2 test). For this purpose, the area within a radius of several hundred meters was cleared of radioactive materials.

As in previous years, the tests were supervised by I.V. Kurchatov. The best scientists and specialists of our country were involved in the work at the test site: Minister of Medium Machine Building V.A. Malyshev, Deputy Minister of Defense Marshal of the Soviet Union A.M. Vasilevsky, Deputy Minister of Medium Machine Building A.P. Zavenyagin, Director of the Institute of Applied Mathematics Academician M.V. Keldysh, Academician of the Ukrainian SSR N.N. Bogoliubov, Academician M.A. Lavrent'ev, Director of the Institute of Chemical Physics of the Russian Academy of Sciences Academician N.N. Semenov, Corresponding Member of the Russian Academy of Sciences I.E. Tamm, B.S. Dzhelepov, V.P. Dzhelepov, A.D. Sakharov, Corresponding Member of the Russian Academy of Sciences Ya.B. Zel'dovich, Head of the 6th Civil Defense Department of the Ministry of Defense V.A. Bolyatko, Test Site Commander A.V. En'ko, B.M. Malyutov, Deputy Minister of Health A.I. Burnazyan, S.L. Davydov, Head of the 5th State Department V.I. Alferov, and Chief Designer, Scientific Director, Corresponding Member of the Academy of Sciences Yu.B. Khariton.

4.4 Results of research during RDS-6s test

The US Atomic Energy Commission submitted a report to the president noting that the Soviet Union had produced a "high-tech hydrogen explosion" and was in some respects ahead. "The USSR had already accomplished some of what the United States had hoped to achieve as a result of the experiments scheduled for the spring of 1954" [12].

Nobel Prize winner and head of the first theoretical division at Los Alamos, H. Bethe, wrote quite sincerely: "I don't know how they did it. What's astonishing is that they were able to do it."

Based on an analysis of radiochemical data from air samples, H. Bethe estimated the yield of the RDS-6s at 500 kt and determined that it was a thermonuclear-boosted atomic bomb, i.e., he defined it as was done by the RDS-6s developers themselves.

It should be noted that, in the first US 'hydrogen' bomb (1952, Mike), 77% of the explosive energy came from fission (!). For comparison with the accuracy of US calculations at that time, we present data from the six Castle Bravo thermonuclear tests (1954). The range in yield estimates ranged from 2.5 to 8 times (for the Bravo explosion, 15 Mt were obtained instead of 6 Mt), which led to the radiation exposure of Japanese fishermen on the fishing boat *Lucky Dragon*.

The creation of the RDS-6s had a profound impact on the design of Soviet thermonuclear weapons:

— the RDS-6s layered core became the prototype for thermonuclear assemblies;

— the scientific and practical groundwork was laid for the next step — increasing the compression of the thermonuclear assembly under radiation implosion conditions, implemented two years later in RDS-37;

— technologies and production of new materials, primarily tritium and lithium-6, were developed. The use of lithium-6 deuteride as a thermonuclear material was implemented for the first time in the world.

The creation of the RDS-6s became a powerful stimulus for the development of nuclear research and nuclear physics in the USSR.

KB-11 became the core organization and integrator of thermonuclear weapons development in the USSR. Cooperation of leading research centers was established.

The successful testing of the RDS-6s determined the development of applied mathematics and computational methods:

— gas-dynamic testing played a leading role in the creation of nuclear charges. During the development of RDS-6s, the operating characteristics of a multilayer charge could only be studied numerically, which defined a new role for physical models and mathematical work;

— with RDS-6s, a new scientific field — computational mathematics — was born;

— the challenges of thermonuclear weapons predetermined the development of computers in the USSR.

4.5 They determined the greatness of our country

Academician S.L. Sobolev's group, at the very initial stage of the Atomic Project, developed a theory of isotope separation (diffusion separation units).

L.D. Landau's and A.N. Tikhonov's groups (beginning in 1946) were engaged in calculating the energy release of atomic bombs and developing numerical difference methods for calculating nonlinear partial differential equations and the energy release of RDS-6s and RDS-37 thermonuclear charges.

A revolution in numerical methods occurred during the development of the first domestic hydrogen bomb — Sakharov's RDS-6s sloika.

When integrating partial differential equations using difference methods, L.D. Landau at the IPP and A.N. Tikhonov and A.A. Samarskii at the Division of Applied Mathematics (DAM) posed and solved the problem of the stability of difference methods (von Neumann independently did the same in the USA).

Particular difficulties in calculating RDS-6s (overcome only in 1952 by L.D. Landau's group and A.N. Tikhonov's and A.A. Samarskii's group) were due to the presence of shock waves in the product, arising from the compression of light layers during a nuclear explosion and caused by the layered structure of the product. M.V. Keldysh's seminar proved particularly effective in resolving this problem.

In 1953, the mathematical teams were united into the Division of Applied Mathematics of the Mathematical Institute of the Academy of Sciences (MIAN), headed by the outstanding mathematician M.V. Keldysh (the first chief mathematician of the Ministry of Medium Machine Building (MMMB)) [12, 14].

These teams included young mathematicians who later became outstanding scientists known throughout the world.

A.D. Sakharov particularly emphasized the role of the computational justification of L.D. Landau's group (E.M. Lifshitz, I.M. Khalatnikov, N.S. Meiman, A.S. Kompaneets, S.P. D'yakov) in the development of the first thermonuclear charges. The results of their calculations were used as the basis for justifying the operability of the RDS-6s device, as well as the strategy for ensuring the safety of the population living near the test site perimeter. The experimentally measured yield was 400 kt of TNT equivalent. According to modern calculation methods of 2003, a similar result of $\sim$ 400 kt of TNT equivalent was obtained.

From declassified documents on the Atomic Industry project [3, 12, 14], it follows that L.D. Landau received unconditional support from I.V. Kurchatov, Yu.B. Khariton, and N.I. Shchelkin, as well as from the administrative leaders of the Atomic Industry project; moreover, L.D. Landau's awards speak for themselves (Order of Lenin, Hero of Socialist Labor, Stalin Prize).

Despite the ideological attacks on cybernetics in the late 1940s and early 1950s, intensive computer development was underway in our country as part of the Atomic Energy Project.

It should be noted that, during those years, mathematical groups were formed at institutes of the USSR Academy of Sciences. As the mathematical programs of the 1950s were transferred to nuclear centers, the role of mathematics departments at these centers increased: VNIIEF (started by N.N. Bogoliubov) and the All-Union Scientific Research Institute of Technical Physics (VNIITF) (N.N. Yanenko).

In the late 1940s and early 1950s, it was precisely thanks to the active position of the physicists who participated in the atomic and hydrogen projects (I.V. Kurchatov, V.A. Fock, M.A. Leontovich, M.A. Lavrent'ev, I.E. Tamm, L.D. Landau, A.D. Sakharov, et al.) that quantum and nuclear physics, the theory of relativity, cybernetics, and genetics were saved from philosophical and ideological defeat (letter of the 'Three Hundred' to the Presidium of the Central Committee of the CPSU) — the role of V.A. Fock was especially great.

RDS-6s was developed primarily by young specialists (A.D. Sakharov was 29 years old in 1950, Yu.A. Romanov was 24, Yu.A. Trutnev was 23, V.I. Ritus was 23, and V.S. Vladimirov was 27).

The industry and institute's leaders entrusted the most critical areas of work to young people. Interestingly, at the test site, I.V. Kurchatov appointed young specialist N.A. Popov "responsible for fireball power calculations." His group included Academician M.V. Keldysh and Corresponding Member of the Ukrainian SSR D.I. Blokhintsev. The shock wave group, led by E.I. Zababakhin, included academicians M.A. Lavrent'ev and M.V. Keldysh.

The titles of Hero of Socialist Labor were awarded, in particular, to 10 employees of KB-11: Bobolev Vasilii Konstantinovich, Grechishnikov Vladimir Fedorovich, Davidenko Viktor Aleksandrovich, Dukhov Nikolai Leonidovich, Zababakhin Evgenii Ivanovich, Zel'dovich Yakov Borisovich, Sakharov Andrei Dmitrievich, Tamm Igor' Evgenievich, Khariton Yulii Borisovich, and Shchelkin Kirill Ivanovich.

By a decree of the Presidium of the Supreme Soviet of the USSR of January 4, 1954, the KB-11 team was awarded the Order of Lenin.

In the fall of 1953, 22 people were selected at the USSR Academy of Sciences for their outstanding contribution to the development of the first thermonuclear atomic bomb RDS-6s: A.P. Aleksandrov, N.N. Andreev, L.A. Artsimovich, N.N. Bogoliubov, A.P. Vinogradov, I.M. Gelfand, L.A. Galin, V.L. Ginzburg (corresponding member), E.K. Zavoisky (corresponding member), N.V. Dollezhal (corresponding member), N.L. Dukhov (corresponding member), V.E. Emel'yanov (corresponding member), I.K. Kikoin, B.P. Konstantinov (corresponding member), A.B. Migdal (corresponding member), M.G. Meshcheryakov (corresponding member), B.P. Nikol'skii (corresponding member), I.Ya. Pomeranchuk (corresponding member), A.D. Sakharov, I.E. Tamm, G.N. Flerov (corresponding member), Yu.B. Khariton, K.I. Shchelkin (corresponding member).

When awarding the Stalin Prizes, specific achievements of the recipients were noted, for example:

Sakharov and Tamm received 500,000 rubles each for the development of a hydrogen bomb with a multilayer charge and the creation of the theoretical foundations of this bomb (Stalin Prize, first degree);

I.V. Kurchatov, Yu.B. Khariton, K.I. Shchelkin, and N.L. Dukhov received an award for scientific and technical leadership in the creation of the RDS-6s, RDS-4, and RDS-5 devices (Stalin Prize, first degree, 100,000 rubles each);

E.I. Zababakhin, for the creation of the theoretical foundations of nuclear charges (Stalin Prize, first degree, 200,000 rubles);

Ya.B. Zel'dovich, for the development of theoretical issues related to the creation of the RDS-6s, RDS-4, and RDS-5 and their testing at Test Site No. 2 (Stalin Prize, first degree, 100,000 rubles);

V.L. Ginzburg, for the proposal to use lithium-6 in RDS-6s (Stalin Prize, first degree, 100,000 rubles).

4.6 Development of RDS-37 thermonuclear device, based on principle of radiation implosion, formed basis of our country's nuclear arsenal

The dramatic aspect of the situation in 1954 lay in the fact that the Resolution of the USSR Council of Ministers of March 26, 1954 [1, p. 156] clearly stated that the most important task of the MMMB and the KB-11 was to create a new type of hydrogen bomb, proposed by Academician A.D. Sakharov, with a 2-megaton energy release within the dimensions of RDS-6s, and to test a weakened version of

RDS-6SD at the Semipalatinsk test site with a 1-megaton energy release. The test was to be conducted by the end of 1954.

At this time, the United States had already conducted eight thermonuclear explosions at the Bikini and Eniwetok atolls in the Pacific Ocean with an energy release of 10–15 Mt of TNT [8].

Just one day after the publication of the Decree of the USSR Council of Ministers of March 26, 1954, Yu.B. Khariton held a technical council meeting of KB-11, at which, following a report by A.D. Sakharov and his report on the results of the expert commission's work, a decision was made on the lack of power advantages of A.D. Sakharov's gas version (a modification of RDS-6s, but without tritium) jointly with Zel'dovich (at least in the dimensions of RDS-6s). Therefore, the council "considers it necessary to cease development of the gas version and focus on the development of the gasless version of RDS-6SD" [17, p. 170]. It follows from this document that, at the end of March 1954, the principle of radiation implosion had not yet been invented, and A.D. Sakharov's initial proposal was unsuccessful.

By the end of 1953, A.D. Sakharov and his colleagues realized that, even with the use of tritium, it would not be possible to obtain significant power in the sloika: after the explosion of the sloika atomic initiator, a diverging shock wave is formed, with the help of which large quantities of thermonuclear fuel cannot be compressed to the required density. To break this impasse, theorists began to consider other ways to obtain higher yields using the sloika principle.

The development of high-power hydrogen devices began in mid-1954, pursuing several approaches simultaneously: RDS-6SD, a modification of the RDS-6s designed to increase yield; RDS-27, a modification of RDS-6s without the use of tritium; and, finally, the creation of a charge based on a new physical principle conceived at KB-11 in late spring (early summer) — radiation implosion (the 'third idea,' in A.D. Sakharov's terminology). This device was designated RDS-37.

The organization of the work was aimed at ensuring the unconditional development and testing of a powerful hydrogen bomb (1–2 Mt) in 1955 and reflected the extremely complex military and political situations of the time.

Calculations for various options began in 1955, the results of which were sharply criticized by Minister V.A. Malyshev at a technical meeting at KB-11 on July 16–17, 1954 [11, pp. 195–217].

The difficulties encountered in achieving high power with the RDS-6s-based device, coupled with the realization that achieving thermonuclear ignition with the truba design was virtually impossible, forced the MMMB leaders, after several discussions at the Scientific and Technical Council, to cancel the truba project in early 1954. KB-11 theorists from Tamm's and Zel'dovich's departments joined. A powerful intellectual storm ensued. Simultaneously, L.D. Landau's group ceased work on the truba and actively joined the development of RDS-37. The truba project was finally closed only after the successful testing of RDS-37 in 1955.

Apparently, the leaders of the Ministry of Middle Machine-Building (MMMB, currently known as ROSATOM State Corporation) and KB-11 knew about the development and testing in the USA of a multi-megaton charge (10.2 Mt of TNT) at the end of 1952, and especially in the 1954 session. In particular, on March 1, 1954, the American press announced that a hydrogen bomb had been successfully tested in the Marshall Islands, the power of which (> 10 Mt) was more than 500 times greater than the power of the bomb dropped on Hiroshima in 1945. This was the reason for the nervousness of the Minister of the MMMB V.A. Malyshev and his call for the need to seek "new principles for the development of atomic and hydrogen weapons, to make a hydrogen bomb at the level of modern scientific knowledge...." Therefore, in late 1953 and early 1954, KB-11 was tasked with 'catching up with the USA' and developing a thermonuclear charge with a yield of 10–15 Mt. The theoretical calculations carried out at that time showed that the sloika design could not achieve not only 10–15 Mt, but even 2 Mt (within the dimensions of RDS-6s) [17].

A.D. Sakharov describes the emergence of the idea of radiation implosion at KB-11 as follows:

"Apparently, several employees of our theoretical departments simultaneously arrived at the 'third idea.' I was one of them. It seems to me that I already understood the basic physical and mathematical aspects of the 'third idea' at an early stage. Because of this, and also thanks to my previously acquired authority, my role in the acceptance and implementation of the 'third idea' was perhaps one of the decisive ones. But also, undoubtedly, the role of Zel'dovich, Trutnev, and some others was very great, and perhaps they understood and foresaw the prospects and difficulties of the 'third idea' no less than I did" [10].

In December 1954, at the Scientific and Technical Council of KB-11, Ya.B. Zel'dovich and A.D. Sakharov noted [15]:

"To develop the AO[1] device, it is necessary to conduct a model experiment in 1955 to verify the spherical symmetry of compression by radiation. This experiment will also record the course of the neutron reaction and the explosive power of the main product (the one being compressed).

The entire system was not subjected to precise calculations, but individual components were calculated with sufficient accuracy.

Comrades Malyshev and Kurchatov considered it advisable to discuss the AO problem with leading physicists Artsimovich, Leontovich, Landau, and Pomeranchuk.

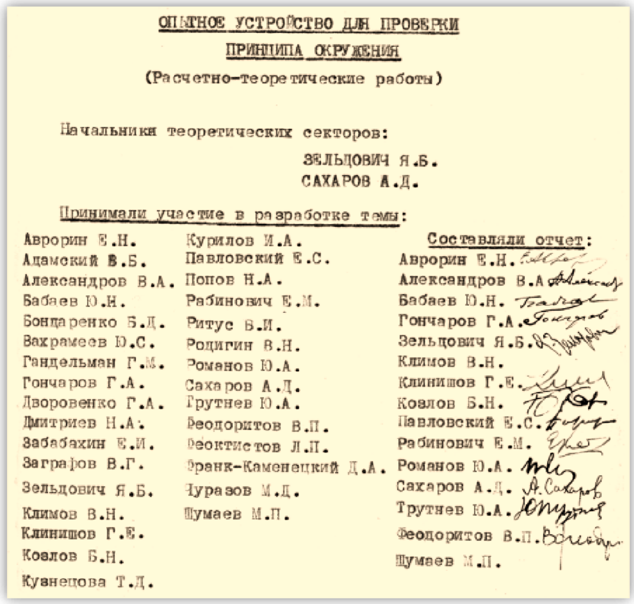
Tamm, Sakharov, Dukhov, and Kurchatov devoted their presentations to the great significance of the AO problem."

The new principle found its way into practice during intensive work in other areas of research and thermonuclear weapon design.

The RDS-37 thermonuclear module was based on the RDS-6s thermonuclear design and the physics of its combustion. This was an entirely original system, which, as we learned decades later, was fundamentally different from the first US thermonuclear charges. It is important to note the fundamental importance of justifying the method of using radiation energy. In particular, the Fuchs–Neumann design transmitted to us by intelligence in 1948 utilized a method of using radiation different from the RDS-37. Therefore, we cannot agree with the point of view of some authors [20, 21] that we were given a radiation implosion design.

In the introduction to the report, A.D. Sakharov [9] wrote: "The development of the encirclement principle is one of the most striking examples of collective creativity. Some contributed ideas (many ideas were needed, and some of them were independently put forward by several authors). Others were more distinguished in developing calculation methods and clarifying the significance of various physical processes."

[1] AO is an abbreviation for the Russian 'atomnoe oruzhie' (atomic weapons). (*V.D.*)

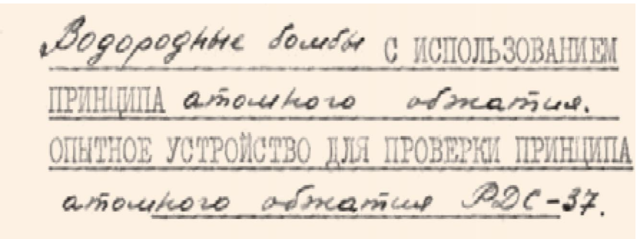

ОПЫТНОЕ УСТРОЙСТВО ДЛЯ ПРОВЕРКИ
ПРИНЦИПА ОКРУЖЕНИЯ
(Расчетно-теоретические работы)

Начальники теоретических секторов:
ЗЕЛЬДОВИЧ Я.Б.
САХАРОВ А.Д.

Принимали участие в разработке темы:

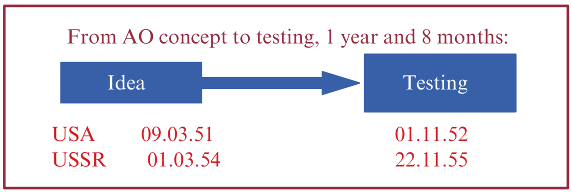
Аврорин Е.Н.	Курилов И.А.	Составляли отчет:
Адамский В.Б.	Павловский Е.С.	Аврорин Е.Н.
Александров В.А.	Попов Н.А.	Александров В.А.
Бабаев Ю.Н.	Рабинович Е.М.	Бабаев Ю.Н.
Бондаренко Б.Д.	Ритус В.И.	Гончаров Г.А.
Вахрамеев Ю.С.	Родигин В.Н.	Зельдович Я.Б.
Гандельман Г.М.	Романов Ю.А.	Климов В.Н.
Гончаров Г.А.	Сахаров А.Д.	Клинишов Г.Е.
Дворовенко Г.А.	Трутнев Ю.А.	Козлов Б.Н.
Дмитриев Н.А.	Феодоритов В.П.	Павловский Е.С.
Забабахин Е.И.	Феоктистов Л.П.	Рабинович Е.М.
Заграфов В.Г.	Франк-Каменецкий Д.А.	Романов Ю.А.
Зельдович Я.Б.	Чуразов М.Д.	Сахаров А.Д.
Климов В.Н.	Шумаев М.П.	Трутнев Ю.А.
Клинишов Г.Е.		Феодоритов В.П.
Козлов Б.Н.		Шумаев М.П.
Кузнецова Т.Д.		

Completion of RDS-37 development.


Водородные бомбы с использованием принципа атомного обжатия.
Опытное устройство для проверки принципа атомного обжатия РДС-37.

On July 8, 1955, report "Experimental Device for Testing Atomic Compression Principle (Calculation and Theoretical Work)" was released, which served as final material.

Igor' Evgenievich Tamm (1895–1971).
Outstanding 20th-century theoretical physicist, academician, and participant in the development of the first thermonuclear devices, he worked at KB-11 (VNIIEF) from 1950 to 1954, serving as KB-11's deputy scientific director. Hero of Socialist Labor, Stalin Prize laureate, and Nobel Prize laureate in Physics.



In the list of participants in the development, the role of each proved significant.

V.A. Davidenko's participation in the discussion of the encirclement problem at an early stage (1952) was very fruitful.

In the development of such a complex system, the role of mathematical calculations was especially significant. The calculations were carried out primarily in the Division of Applied Mathematics (DAM) of the MIAN USSR under the general supervision of M.V. Keldysh and A.N. Tikhonov.

(1) Calculations of the compression of the main device were carried out at the Division of Applied Mathematics in the department of K.A. Semendyaev. A number of calculations were carried out at KB-11 in the department of I.A. Adamskaya. Some calculations were performed in A.A. Samarskii's department.

(2) Heat transfer calculations were performed at DAM, in I.M. Gelfand's department.

(3) Some calculations were performed at KB-11, in A.A. Bunatyan's department.

(4) Primary device efficiency calculations were performed at DAM, in A.A. Samarskii's department.

(5) Heat penetration calculations were performed at DAM, in A.A. Samarskii's department.

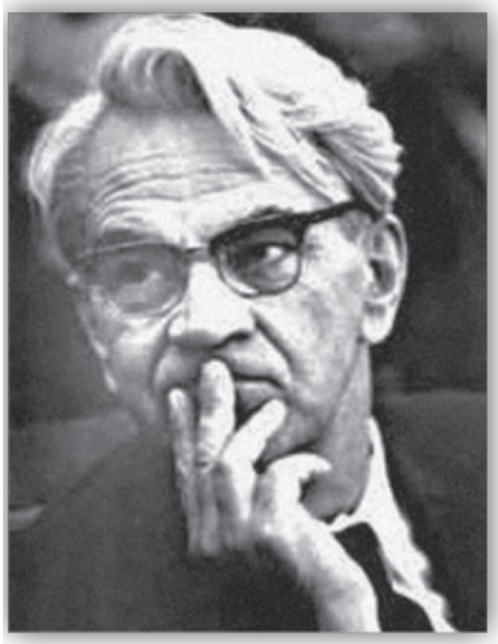
(6) A number of calculations were performed by I.M. Khalatnikov's group (IPP).

Many calculations were performed using the STRELA electronic computer at DAM. Very complex problems of developing calculation, programming, and organizational methods were solved [15].

In accordance with the tradition adopted in the nuclear industry, on July 1, 1955, an expert commission of outstanding scientists was convened, consisting of I.E. Tamm (chair), M.V. Keldysh, M.A. Leontovich, Sakharov, V.L. Ginzburg, Ya.B. Zel'dovich, and I.M. Khalatnikov, which reviewed the theoretical and experimental work on device 37.

"The Commission notes that KB-11 and DAM have done a great deal of work to research the new physical principles underlying the hydrogen bomb with atomic compression" [9].

Computational work

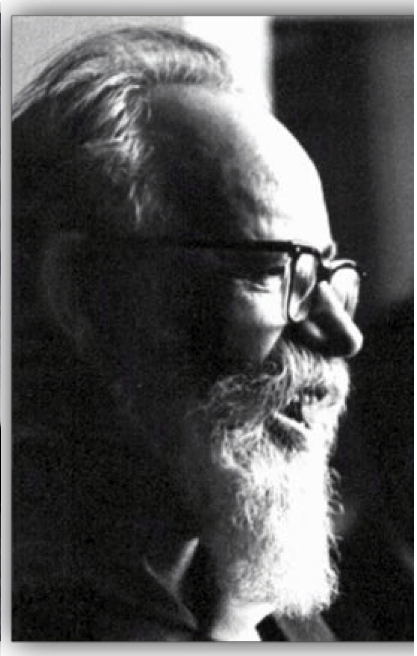


Mstislav Vsevolodovich Keldysh (1911–1978).

Outstanding 20th-century mathematician, active participant and organizer of the USSR's nuclear missile projects, participant in nuclear tests, author of fundamental work in applied mathematics and physics, and significant contributor to development of computational mathematics. He was director and organizer of Institute of Applied Mathematics of USSR Academy of Sciences, president of USSR Academy of Sciences, three-time Hero of Socialist Labor, laureate of Lenin Prize and two Stalin Prizes.

Andrei Nikolaevich Tikhonov (1906–1993).

Outstanding 20th-century mathematician, academician, founder of scientific school, and one of initiators of application of numerical methods to development of atomic and hydrogen bombs. He was director of Institute of Applied Mathematics of USSR Academy of Sciences, twice Hero of Socialist Labor, and laureate of Lenin Prize and two Stalin Prizes.



Konstantin Adol'fovich Semendyaev (1908–1988).

Leading specialist in computational mathematics, he actively participated in development of first atomic and thermonuclear charges. He worked on Atomic and Thermonuclear Projects at Mathematical Institute of USSR Academy of Sciences (1946–1964). He was Stalin Prize laureate three times.

In the interests of public safety, the explosion yield was deliberately reduced by half. This was insisted upon by the leadership of the Ministry of Defense (MD) at the initiative of the test site specialists.

RDS-37 was the first domestic hydrogen bomb with atomic compression. It was tested on November 22, 1955 at the Semipalatinsk test site. The yield was 1.6 Mt of TNT.

The RDS-37 test was supervised by I.V. Kurchatov.

Participants in the test included: Deputy Minister of Defense A.M. Vasilevskii, M.I. Nedelin, V.A. Bolyatko, Deputy Chairman of the USSR Council of Ministers, MMMB Minister A.P. Zavenyagin with a large group of MMMB leaders, and institute directors (N.N. Semenov, E.K. Fedorov, M.A. Sadovsky, A.I. Burnazyan, S.A. Khristianovich), and General A.V. En'ko (Ministry of Defense).

From KB-11, in addition to Yu.B. Khariton, KB-11 Chief B.G. Muzrukov, Chief Engineer N.A. Petrov, Ya.B. Zel'dovich, A.D. Sakharov, experimental physicists, specialists in device assembly and automation, and a large group of young theoretical physicists — the developers of RDS-37 — participated in the tests.

A large group of outstanding mathematicians also attended the tests: M.V. Keldysh, I.M. Gelfand, S.K. Godunov, V.F. D'yachenko, O.V. Lokutsievskii, A.A. Samarskii, and A.N. Tikhonov.

Significant differences between the first US and Soviet thermonuclear warhead designs should be particularly noted. The typical length-to-diameter ratio of the first USSR thermonuclear warheads was $\leqslant 2$, while for the first US thermonuclear warheads it was 3.2–4.8. This points to a fundamental difference in the structure of the secondary modules of the first USSR and US thermonuclear warheads and the originality of our two-stage warhead design. This difference in the US warhead dimensions was significantly reduced only after testing in 1956.

Tu-16A nuclear bomb carrier aircraft. In service since 1954.

In the beginning of 1958, Device 49 was tested at Novaya Zemlya Test Site, which laid the foundation for the nuclear arsenal of Russia.

Of the 23 outstanding citizens of our country who were awarded the title Hero of the Soviet Union or Hero of

Socialist Labor three times, nine were participants in the Atomic Project: B.L. Vannikov, N.L. Dukhov, I.V. Kurchatov, Yu.B. Khariton, K.I. Shchelkin, Ya.B. Zel'dovich, A.D. Sakharov, E.P. Slavsky, and A.P. Aleksandrov. One can rightly include the outstanding mathematician M.V. Keldysh.

Recognition of the world level of Soviet scientists participating in the Atomic Project is the awarding of nine Nobel Prizes to scientists, even during the Cold War. These were I.E. Tamm (1958), N.N. Semenov (1956), I.M. Frank (1958), L.D. Landau (1962), L.V. Kantorovich (Nobel Memorial Prize in Economic Sciences 1975), A.D. Sakharov (Nobel Peace Prize 1975), P.L. Kapitza (1978), V.L. Ginzburg (2003), and A.A. Abrikosov (2003).

4.7 Critical step toward peace

The creation of thermonuclear weapons in the USSR was a turning point in the middle of the 20th century, which made a third world war impossible.

Physicists who participated in the hydrogen project were the first to realize that they had created a weapon of deterrence and conveyed their point of view to the country's leaders. In 1954–1956, politicians transformed this position into the thesis of peaceful coexistence. The first samples of thermonuclear weapons were created in the USSR and the USA almost simultaneously and had fundamentally different configurations of thermonuclear units.

The creation of the RDS-37 thermonuclear bomb, based on the practical implementation of new profound scientific ideas, was the result of a concentration of effort at all technological levels, primarily intellectual.

This was a breakthrough into a new area of knowledge. On November 22, 1955, a sample of a weapon was tested, the physical design of which formed the basis of our country's thermonuclear arsenal, which subsequently ensured nuclear deterrence and national security.

In the mid-1950s the size of the army was reduced from 5,763,000 people in 1955 to 3,623,000 people in 1958.

5. World in 21st century. Struggle for resources as a cause of global conflicts. Russia's nuclear weapons as essential of global stability

The creation of nuclear weapons in the USSR was a historical necessity in conditions of acute political and ideological confrontation with the United States, which grew into a global confrontation.

The test of August 29, 1949 demonstrated to all of humanity that we had mastered one of the fundamental technologies of the 20th century, created new industries and new fields of science, and ultimately eliminated the US atomic monopoly. This event laid the foundation for the creation of our nuclear shield, which became the basis of Russia's national security, ensuring our peace and allowing us to enter the 21st century with confidence in the future. In 1953, 1955, 1958, and 1961, thermonuclear weapons were tested, the development of which laid the foundation for the creation of nuclear deterrent guarantees.

The creation and testing of the first nuclear and thermonuclear weapons was a turning point in world history. The Great Victory of Russia in 1945 and the status of a nuclear power transformed our country into a strong superpower in the world.

Three Ks — founders of nuclear missile shield. Academicians (left to right) Sergei Pavlovich Korolev, Igor' Vasil'evich Kurchatov, and Mstislav Vsevolodovich Keldysh — whose scientific and labor achievements enabled our country to achieve nuclear parity in the 1970s and become a leading world power.

Under these conditions, alongside weapons (and often slightly earlier), a new science was being developed, significantly expanding our understanding of the nature of this 'unusual reality' and enabling us to develop ways to control its processes. It was precisely this approach that allowed us to solve practical problems of enormous national significance, on which the very existence of our country largely depended.

We successfully competed with US nuclear centers. The tests of the first atomic bombs in the US and the USSR were separated by a period of just over four years. However, the period between the tests of the first 'real' thermonuclear charges in the US and the USSR had already shrunk to just eighteen months. Moreover, our RDS-37 thermonuclear device, developed at KB-11 in 1955, was fundamentally different from the first American thermonuclear charges. It was a riskier, but also more promising, system.

Today, Russia remains capable of ensuring nuclear deterrence, which allows us to preserve the sovereignty and territorial integrity of the country and gives our people the opportunity to live in accordance with their historical choice.

The world at the beginning of the 21st century is in a state of unstable equilibrium; a nuclear-free world could now be the bifurcation point toward a third world war — a war to redivide the world in the interests of a struggle of all against all, for people's right to exist.

At the beginning of the 21st century, Russia is once again at a crossroads. A new society, a new statehood, and new relations with the world are being formed. On the one hand, a vaguely perceived Western value system; on the other, a search for a national idea, for Russian roots.

The global problems of civilization are population growth, resource constraints, energy resource problems, national sovereignty and globalization, and the clash of civilizations.

Modern Western capitalism is a source of a profound global crisis.

Global cataclysms of the early 21st century demonstrate the noxious effect of Western 'values' for Russia, and our country's more than 1,000-year history clearly demonstrates that Russia's development strategy is the will to be itself, the will to be and remain in history.

Russia is an alternative to the West, not anti-West!

References

1. "Plutonium: The first 50 years. United States plutonium production, acquisition and utilization from 1944 through 1994," Report DOE/DP-0137, Febrary 1996 (Washington, DC: The United States Department of Energy, 1996)
2. Mikhailov V N (Ed.) *Yadernoe Oruzhie i Natsional'naya Bezopasnost'* (Nuclear Weapons and National Security) (Moscow–Saransk: FGUP Institut Strategicheskoi Stabil'nosti Rosatoma. Krasnyi Oktyabr', 2008)
3. Ryabev L D (Gen. Ed.), Kudinova L I (Exec. Compil.) *Atomnyi Proekt SSSR. Dokumenty i Materialy* (Soviet Atomic Project: Documents and Materials) Vol. 1 *1938–1945* Pt. 1 (Moscow: Nauka, 1998)
4. Ryabev L D (Gen. Ed.), Goncharov G A (Exec. Compil.) *Atomnyi Proekt SSSR. Dokumenty i Materialy* (Soviet Atomic Project: Documents and Materials) Vol. 2 *Atomnaya Bomba. 1945–1954* (Atomic Bomb. 1945–1954) Book 1 (Sarov: RFYaTs– VNIIEF, 1999)
5. Ryabev L D (Gen. Ed.), Goncharov G A (Exec. Compil.) *Atomnyi Proekt SSSR. Dokumenty i Materialy* (Soviet Atomic Project: Documents and Materials) Vol. 2 *Atomnaya Bomba. 1945–1954* (Atomic Bomb. 1945–1954) Book 5 (Sarov: RFYaTs–VNIIEF, 2005)
6. Andryushin I A, Ilkaev R I, Chernyshev A K *Yulii Borisovich Khariton. Stranitsy Tvorcheskoi Biografii* (Yulii Borisovich Khariton. Pages of Creative Biography) (Sarov: RFYaTs–VNIIEF, 2014)
7. Sokhina L P, Kolotinskii Ya I, Khalturin G V *Plutonii v Devich'ikh Rukakh* (Plutonium in Girls' Hands) (Ekaterinburg: LITUR, 2003)
8. Mikhailov V, Andryushin I, Chernyshev A *Catalog of Worldwide Nuclear Testing* (New York: Begell Atom, 1999)
9. Andryushin I A, Ilkaev R I, Chernyshev A K *Reshayushchii Shag k Miru. Vodorodnaya Bomba s Atomnym Obzhatiem RDS-37. K 100-letiyu so Dnya Rozhdeniya A.D. Sakharova* (Decisive Step Toward Peace. The RDS-37 Hydrogen Bomb with Atomic Compression. On the 100th Anniversary of A.D. Sakharov's Birth) (Sarov: RFYaTs–VNIIEF, 2010)
10. Sakharov A D *Vospominaniya* (Memories) (New York: Izd. Imeni Chekhova, 1990)
11. Ryabev L D (Gen. Ed.), Goncharov G A (Exec. Compil.) *Atomnyi Proekt SSSR. Dokumenty i Materialy* (Soviet Atomic Project: Documents and Materials) Vol. 3 *Vodorodnaya Bomba. 1945–1956* (Hydrogen Bomb. 1945–1956) Book 1 (Sarov–Moscow: RFYaTs–VNIIEF. Fizmatlit, 2008)
12. Andryushin I A, Ilkaev R I, Chernyshev A K *'Sloika' Sakharova. Put' Geniya* (The Sakharov's 'Sloika.' The Path of a Genius) (Sarov: RFYaTs–VNIIEF, 2011)
13. Ritus V I "V.L. Ginzburg and the Atomic Project" *Phys. Usp.* **60** 413 (2017); "V.L. Ginzburg i Atomnyi proekt" *Usp. Fiz. Nauk* **178** 444 (2017)
14. Ryabev L D (Gen. Ed.), Goncharov G A (Exec. Compil.) *Atomnyi Proekt SSSR. Dokumenty i Materialy* (Soviet Atomic Project: Documents and Materials) Vol. 2 *Atomnaya Bomba. 1945–1954* (Atomic Bomb. 1945–1954) Book 6 (Sarov–Moscow: RFYaTs–VNIIEF. Fizmatlit, 2006)
15. Kiselev G V "L D Landau in the Soviet Atomic Project: a documentary study" *Phys. Usp.* **51** 911 (2008); "Uchastie L.D. Landau v sovetskom Atomnom proekte (v dokumentakh)" *Usp. Fiz. Nauk* **178** 947 (2008)
16. Samarskii A A "Pryamoi raschet moshchnosti vzryva" ("Direct calculation of the explosion power"), in *Nauka i Obshchestvo. Istoriya Sovetskogo Atomnogo Proekta. Trudy Mezhdunarodnogo Simpoziuma ISAP-96* (Science and Society. History of the Soviet Atomic Project. Proc. of the Intern. Symp. ISAP-96) Vol. 1 (Moscow: IzdAT, 1997) p. 214
17. Ryabev L D (Gen. Ed.), Goncharov G A (Exec. Compil.) *Atomnyi Proekt SSSR. Dokumenty i Materialy* (Soviet Atomic Project: Documents and Materials) Vol. 3 *Vodorodnaya Bomba. 1945–1956* (Hydrogen Bomb. 1945–1956) Book 2 (Sarov–Moscow: RFYaTs–VNIIEF. Fizmatlit, 2009)
18. Andryushin I A, Ilkaev R I, Chernyshev A K *Osnovatel' Atomnoi Otrasli* (Founder of the Nuclear Industry) 2nd ed., rev. and enlarg. (Sarov: RFYaTs–VNIIEF, 2015)
19. Chernyshev A K *Iz Pokoleniya Pobeditelei. Akademik A.D. Sakharov v Atomnom Proekte SSSR* (From the Generation of Winners. Academician A.D. Sakharov in the Soviet Atomic Project) (Sarov: RFYaTs–VNIIEF, 2021)
20. Ilkaev R I "Sakharov at KB-11. The path of a genius" *Phys. Usp.* **55** 183 (2012); "Sakharov v KB-11. Put' geniya" *Usp. Fiz. Nauk* **182** 195 (2012)
21. Ritus V I "A D Sakharov: personality and fate" *Phys. Usp.* **55** 170 (2012); "A.D. Sakharov: lichnost' i sud'ba" *Usp. Fiz. Nauk* **182** 182 (2012)
22. Goncharov G A "American and Soviet H-bomb development programmes: historical background" *Phys. Usp.* **39** 1033 (1996); "Osnovnye sobytiya istorii sozdaniya vodorodnoi bomby v SSSR i SShA" *Usp. Fiz. Nauk* **166** 1095 (1996)
23. Goncharov G A "On the history of creation of the Soviet hydrogen bomb"*Phys. Usp.* **40** 859 (1997); "K istorii sozdaniya sovetskoi vodorodnoi bomby" *Usp. Fiz. Nauk* **167** 903 (1997)
24. Kiselev G V "Moscow State University physics alumni and the Soviet Atomic Project" *Phys. Usp.* **48** 1251 (2005); "Fiziki — vypuskniki Moskovskogo universiteta i sovetskii Atomnyi proekt" *Usp. Fiz. Nauk* **175** 1343 (2005)
25. Gudin S A "Employees of the Institute of Metal Physics of the Ural Branch of the Russian Academy of Sciences and the development of the Soviet Atomic Project" *Phys. Usp.* **67** 717 (2024); "Sotrudniki Instituta fiziki metallov Ural'skogo otdeleniya Rossiiskoi akademii nauk i stanovlenie Atomnogo proekta SSSR" *Usp. Fiz. Nauk* **194** 765 (2024)
26. Khariton Yu B, Adamskii V B, Smirnov Yu N "On the making of the Soviet hydrogen (thermonuclear) bomb" *Phys. Usp.* **39** 185 (1996); "O sozdanii sovetskoi vodorodnoi (termoyadernoi) bomby" *Usp. Fiz. Nauk* **166** 201 (1996)
27. Ritus V I "Tamm–Sakharov group in work on the first hydrogen bomb" *Phys. Usp.* **57** 903 (2014); "Gruppa Tamma–Sakharova v rabote nad pervoi vodorodnoi bomboi" *Usp. Fiz. Nauk* **184** 975 (2014)
28. Mikhailov V N (Head of the Editorial Group), Andryushin I A, Zelentsov S A, Ilkaev R I, Chernyshev A K (Editorial Group) *Yadernye Ispytaniya SSSR* (USSR Nuclear Testing) Vol. 1 *Tseli. Obshchie Kharakteristiki. Organizatsiya Yadernykh Ispytanii SSSR. Pervye Yadernye Ispytaniya* (Objectives. General Characteristics. Organization of Nuclear Testing in the USSR. The First Nuclear Tests) (Sarov: RFYaTs–VNIIEF, 1997)
29. Andryushin I A, Chernyshev A K, Yudin Yu A *Ukroshchenie Yadra: Stranitsy Istorii Yadernogo Oruzhiya i Yadernoi Infrastruktury SSSR* (Taming the Nucleus: Pages in the History of Nuclear Weapons and Nuclear Infrastructure of the USSR) (Sarov–Saransk: Krasnyi Oktyabr' Printing House, 2003)
30. Lota V *Klyuchi ot Bezdny. Bor'ba za Atomnuyu Bombu* (Keys to the Abyss. The Fight for the Atomic Bomb) (Moscow: Izd. Dom Komsomol'skaya Pravda, 2023)