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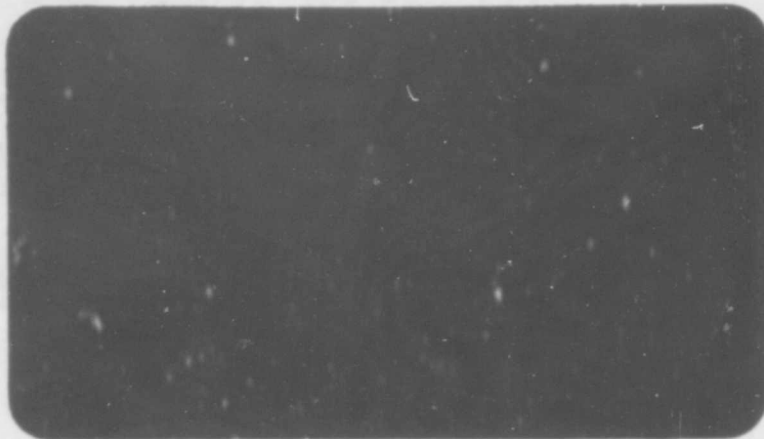
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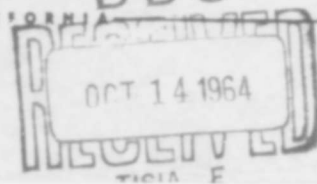


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RESEARCH MEMORANDUM

THE SOVIET UNION AND THE ATOM:
TOWARD NUCLEAR MATURITY

Arnold Kramish

RM-2163 ✓

April 25, 1958

Assigned to _____

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PREFATORY NOTE

The Soviet Union has never issued formal periodic reports as do all western governments on the organization and progress of the atomic energy program. Even though in the west the military aspects of atomic energy are still classified, reports are available which give at least the organizational structure, the institutes, and the sites involved in weapons research and development. It is consequently with the greatest of difficulty that information on the Soviet program can be obtained. That which is presented here must be considered extremely sketchy, and, in the interests of accuracy, no speculative reports have been referenced.

While this paper does not presume to be the Soviet counterpart of the "Smyth Report," it is believed that this final section of "The Soviet Union and the Atom" presents close to the maximum amount of general descriptive information which can be combed from publicly available materials on the USSR atomic energy program.

This study is the third of a series on Soviet atomic policy. The first was issued as RM-1711 on April 2, 1956; the second as RM-1896 on April 11, 1957. Additional information will be included in subsequent research memoranda as it becomes available.

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THE ORGANIZATION AND THE INSTITUTES

The first Chief Directorate of the Council of Ministers under the direction of Boris Lvovich Vannikov⁽¹⁾ continued to exercise overall direction of the Soviet atomic energy program until the day Lavrenty Beria, head of the Secret Police, was arrested on June 26, 1953. As Vannikov's wartime and postwar superior, Beria controlled the atomic energy program within the Politburo. Vannikov, in his munitions post, had been dominated by Beria during World War II. It was a control of terror as graphically illustrated by Victor Kravchenko:

With the outbreak of war, the Armaments and Munitions Commissariats had been placed under control of Beria, Commissar of the N.K.V.D., who was also Assistant Chairman of the Sovnarkom and a member of the State Defense Committee. This amounted to putting them under the control of the secret police. The nominal Commissars, Oustinov and Vannikov, knew what it meant; so did everyone else, down to the lowliest official. They would have preferred a quick death to the righteous anger of Beria and his organization. Everyone in the plants and offices and institutions directly or indirectly connected with armaments and munitions was gripped by dread fear.

Beria was no engineer. He was placed in control for the precise purpose of inspiring deadly fear. I often asked myself--as others assuredly did in their secret hearts--why Stalin had decided to take this step. I could find only one plausible answer. It was that he lacked faith in the patriotism and national honor of the Russian people and was therefore compelled to rely primarily on the whip. Beria was his whip.⁽²⁾

On January 7, 1946, the Peoples' Commissariat of Munitions became a titularly "peaceful" organization as the Peoples' Commissariat of Agricultural Machine Construction, with Vannikov still in charge--and Beria supervising. So it was natural that secret police control should continue after Vannikov relinquished his ministerial duties to assume responsibility for the atomic energy program.

It is a simple matter to trace the beginning of a general lessening of tensions within the Soviet atomic energy program to the very date of Beria's arrest. On that day the atomic energy directorate was elevated to the status of a Ministry, i.e., the "Ministry of Medium Machine Building,"⁽³⁾ and put under the direction of Vyacheslav A Malyshev,⁽³⁾ and Vannikov was given the post of Malyshev's First Deputy. On February 28, 1955,⁽⁴⁾ Malyshev was promoted to the higher post of directing a number of Ministries for the Council of Ministers, and three months later became head of a new Committee for the Council of Ministers for New Technology.⁽⁵⁾ It is believed that this Committee, called Gostekhnika, exercised strong general direction in all major USSR technical problems, including that of the atomic energy program. In May 1957 this Committee was replaced by a Committee called the State Scientific-Technical Committee,⁽⁶⁾ headed by Yu. Ye. Maksarev (appointed July 5, 1957).⁽⁷⁾

With Malyshev's promotion, the Ministry of Medium Machine Building came under the control of Colonel General Avraamij Pavlovich Zavenyagin, a former deputy director of Beria's Ministry of Internal Affairs. Zavenyagin's industrial career had been most impressive; in the 1930's he had developed the Magnitogorsk Steel Combine in the Urals and other installations in Siberia. On New Year's Eve, 1956, Zavenyagin died at the age of 55 of coronary thrombosis.⁽⁸⁾ Vannikov eulogized the departed Minister on behalf of his fellow workers at the Ministry of Medium Machine Building.⁽⁹⁾ Zavenyagin's death marked the beginning of several

³ In Moscow guidebooks the addresses of all Ministries save the Ministry of Medium Machine Building and the Ministry of Defense Industries are given. However, if the reader is moved to make further inquiries of the former, he may request the Moscow operator to ring K5-28-13.

organizational crises within the Soviet atomic energy program, for Malyshev who exercised technical control on a higher level, had been afflicted with leukemia. Although very competent Soviet medical scientists were available a West German specialist was called in to treat Malyshev secretly,⁽¹⁰⁾ perhaps for political reasons. Under these peculiar circumstances Malyshev died on February 20, 1957.

Upon Zavenyagin's death, Mikhail G. Pervukhin, technical and economic expert of the Praesidium, took over the post of Minister of Medium Machine Building. Later, during the period of the "anti-state activities" of Malenkov, Molotov, and Kaganovich, Pervukhin was identified with the dissident group and was removed from most of his official positions, including that of Minister of Medium Machine Building.⁽¹¹⁾

In the meantime, since April 18, 1956, with the increased emphasis on peaceful uses of atomic energy, a sector of the Medium Machine Building Ministry had been split off to form a Chief Directorate attached to the Council of Ministers for the Utilization of Atomic Energy. This Directorate was headed by Yefim P. Slavsky, and when Pervukhin was demoted, Slavsky was elevated to the higher post of Minister of Medium Machine Building.⁽¹¹⁾ Boris Vannikov remains as First Deputy Minister; on December 30, 1957, in honor of his sixtieth birthday and for services to the Soviet State and the Soviet Army for the "development of new techniques," he was awarded the Order of Lenin, the highest state honor.⁽¹²⁾

Vasily Semenovich Yemel'yanov has been promoted to the head of the Chief Directorate for the Utilization of Atomic Energy.⁽¹³⁾ Yemel'yanov has performed competent research in the metallurgy of atomic energy materials at the Moscow Engineering Physics Institute.^(13,14) He is a well-

known figure in the West, since for the past several years he has been the Chief Soviet Delegate to many international atomic energy conferences.⁽¹⁵⁾ Yemel'yanov's Deputy is D. V. Yefremov, who has held a number of important posts in the USSR electrical equipment industry, and, more recently, was Chief Engineer for the construction of the Dubna synchrocyclotron.⁽¹⁶⁾ Thus, the men who administer the Soviet atomic energy program have had technical experience within the program itself.

The actual sites where fissionable materials and nuclear weapons are manufactured must remain unknown until the Soviet leaders deign to tell the world of their location. Meager information is available, however, on some of the installations which have developed the techniques and instrumentation for the secret manufacturing sites. Almost every higher technical institution, which includes the well-known ones such as the Institute of Physical Problems, the Lebedev Physics Institute, the Kurnakov Institute of General and Inorganic Chemistry, the Leningrad Physical-Technical Institute, the Ukrainian Physical-Technical Institute, and particularly the Radium Institute, have contributed to the atomic energy program according to their particular talents. It was also necessary to set up several highly specialized new institutions to attack the atomic energy problem as their primary and sole responsibility. Some of these will be described.

The major research group is that headed by Igor Vasilyevich Kurchatov, and at the end of the war it was simply designated by the name of Laboratory No. 2 of the Academy of Sciences.⁽¹⁷⁾ On Kurchatov's staff at that time were such well-known names as S. L. Sobolev, M. S. Kozodaev, I. K. Kikoin and G. N. Flerov. Kurchatov's Laboratory appears

to have worked on practically every aspect of the Soviet atomic energy program. At an indeterminate date, approximately when the Soviets achieved their first atomic explosion, the title of Kurchatov's Laboratory was changed to the Laboratory for Measuring Instruments (abbreviated LIP),⁽¹⁸⁾ which is obviously a cover name conveying no meaning at all. But the trend toward revealing the Laboratory's true function continued, and in the period after Stalin's death the name was changed again to the Moscow Physical Institute. In official parlance "institute" usually implies broader responsibilities than "laboratory" so that this change indicates a new importance for Kurchatov's Institute. Finally, following the demise of Zavenyagin, Kurchatov's Institute was given its power appellation, The Institute of Atomic Energy (IAE).⁽¹⁹⁾

Located in the western suburbs of Moscow,⁽²⁰⁾ the Institute of Atomic Energy is almost a self-sufficient scientific community, having comfortable apartment accommodations for its staff members.⁽²¹⁾ It is divided into a number of specialized laboratories, including the much publicized Thermonuclear Laboratory of Lev Andreevich Artzimovich.

The research equipment at IAE consists of a 1.5 meter-diameter cyclotron (completed in 1946),⁽²²⁾ electromagnetic isotope separators, and radioactivity "hot lab" facilities. Also on the site are the important 15 to 20-megawatt Reactor for Physical and Technical Research (RPT)⁽²³⁾ and the 3-megawatt shielding reactor⁽²⁴⁾ which are being used for design studies on the large-scale atomic power plants. On November 23, 1957, a "swimming pool" type of reactor (coded "IRT") came into operation at IAE. Similar to a number of reactors in the west, IRT operates at about 2 megawatts and became the prototype for versatile research reactors to be

built at other institutes. (25)

IAE collaborates with the other atomic energy institutes and laboratories. One of the most important joint efforts for the Soviet peaceful power program was a joint enterprise by Kurchatov of IAE with Anatoly Petrovich Aleksandrov, (26) Director of the Institute of Physical Problems during the time when Kapitsa was under arrest. Kurchatov and Aleksandrov are credited with the development, in the USSR, of the water-cooled atomic power reactor (PWR). This type of reactor forms the main basis of the USSR and US (independently developed) peaceful power programs. Now that the Directorship of his Institute has been restored to Kapitsa, Aleksandrov has become the Rector of Leningrad State University, (27) and is concerned with the construction of a large atomic power plant to be built near Leningrad and with the naval propulsion units he reported on at the Geneva Conference of 1958.

Another laboratory established for special purposes was A. I. Alikhanov's Thermotechnical Laboratory (south Moscow), (28) which appears to have had tasks of a nature intermediate to that of Kurchatov's Institute, which was mainly atomic energy engineering, and the Dubna Institute which worked almost entirely on pure research. The word, "thermotechnical," has a slight relationship to the major problems of Alikhanov's Institute which initially were directed toward the development of reactors having highly thermalized neutron spectra, i.e., moderated by heavy water and toward thermalized neutron research. (29) It should be emphasized, however, that this was not the sole function of the Thermotechnical Laboratory. Extensive cosmic ray field work has been sponsored in the past by the Laboratory, although much of this work has been transferred to other

institutes after more specialized equipment relating to the atomic energy program became available. In addition to the neutron spectroscopy equipment, a heavy-water moderated research reactor has been in operation since April 1949.⁽³⁰⁾ Initially operated at a level of 500 kilowatts, it has recently been reconstructed to operate at 2 megawatts. This reactor served as a prototype for the research reactors given to China and Yugoslavia. There is also a small cyclotron (magnet diameter of about 40 inches) on the premises.⁽³¹⁾

As a model for his gigantic 50-Bev nuclear accelerator (see "Attack on the Future"), V. V. Valadimirsky is building at the Thermotechnical Laboratory a 6 to 7-Bev "strong-focusing" synchrophasotron (a most impressive energy for a model), which should be fully operative about 1960.⁽³²⁾

During the war there existed, under the control of Vannikov's Ministry of Munitions and therefore under the control of Beria, a secret training institute called the Moscow Mechanical Institute (MMI)⁽³³⁾ which specialized in training students in the technical arts which are an adjunct to modern warfare. After the war atomic energy was included in the curriculum of the Moscow Mechanical Institute, and many of the prominent scientists from Kurchatov's and Alikhanov's Laboratories and from other institutes became professors at MMI.⁽³⁴⁾ Of course, training in nuclear physics continued at all of the public institutions such as Moscow State University, but it was not the specialized, directed sort of training that was given at MMI. At least until 1949 MMI included in its curricula such subjects as "Construction of Munitions," "Technology and Provision of Munitions," and "Technology and Provision of

Rocket Armaments."⁽³⁵⁾ There is no published information after 1949 which indicates that subjects such as rocket technology are still taught at that Institute, and it is possible that they still are. It can be reported, however, that atomic energy activities have continued to expand. And in addition to its training functions, a large amount of essential atomic energy research has been done at the Institute. After 1953 when so many secret institutes were changing one cryptic title to another, the MMI became known as the Moscow Engineering Physics Institute (MIFI),^{*(36)} and much of the less "sensitive" atomic energy work which is being performed at MIFI today is unclassified and available in the open literature.

A recent education handbook⁽³⁷⁾ lists as the MIFI specialties the following subjects: (1) Theoretical and Experimental Physics; (2) Physico-Energetics; (3) Engineering Physics; and (4) Mathematical Computing Equipment. Soviet authorities still are not completely candid on the function of the Moscow Engineering Physics Institute, obvious as it might be from the scientific literature, and prospective students must have special information to apply. A high-ranking administrator of the USSR Academy of Sciences has claimed that MIFI and the Massachusetts Institute of Technology are comparable institutions.⁽³⁸⁾ This is an impressive comparison for a school so young.

Moscow State University and Leningrad State University are the larger higher educational centers and are well equipped to train nuclear scientists and technicians.

At Moscow State University, the largest educational establishment in the USSR, a research reactor using enriched uranium with ordinary water as moderator and coolant (termed a "swimming pool" reactor) serves

* Main office at 21 Kirova Ulitsa, several blocks northeast of the Kremlin.

as a prototype for research reactors which are being provided to several of the Soviet Bloc nations.⁽³⁹⁾

For Leningrad, which has a number of nuclear research and training institutes, a versatile high power research reactor of the water-moderated type has been provided. The reactor (coded VVR-M) is capable of producing radioisotopes of high specific activity and will be used for a wide range of reactor and irradiation studies.⁽²⁵⁾

Additionally, many of the regional institutes are receiving nuclear equipment. For example, the new Institute of Physics on the outskirts of Kiev⁽²¹⁾ is one of many centers which is being provided with small cyclotrons (which seem to have become stock items), experimental nuclear reactors, and radioisotope laboratories.⁽⁴⁰⁾ Twenty kilometers north-east of Tashkent, at Kibrai, the Uzbek Academy of Sciences has established an Institute of Nuclear Physics⁽⁴¹⁾ having several special laboratories, and a reactor is being provided. Nuclear facilities, including a research reactor, have been installed for the institutes of the City of Sverdlovsk in the Urals.⁽⁴²⁾ These are only a few of the nuclear research and training centers within the vast research complex of the USSR Academy of Sciences.

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THE NEW CITIES

During World War II, three substantial "atomic cities," Hanford, Oak Ridge, and Los Alamos, were created in the United States as secret centers for development and manufacture of the atom bomb. Immediately after the first atomic bomb was dropped on Hiroshima, the existence of the three cities became known, and two or three smaller centers of weapons activity which have since been established in Europe are also known to the rest of the world. Similar communities, "the Atomgrads," which have been established in the Soviet Union for the development and production of bomb materials have remained secret. Consequently, it is not possible to describe their number, location, or function. But several atomic communities for research of a less secret nature have been, or are about to be established in the USSR, and a fair amount of information is available for their description.

One of the intents of the Soviet security system in agreeing to relinquish information on some of the advanced research institutes is to give an impression that the existence of all of the Russian "atomic cities" is being released. There has never been even the vaguest of public references in the Russian press to the huge scientific and industrial complexes which must be in existence to have permitted the Soviet Union to develop and manufacture its atomic and hydrogen bombs.

The most publicized Russian atomic installation is located at the newly-named site of Dubna, north of Moscow, where the Moscow-Volga Canal meets the Volga River. The history of its establishment is as follows.

In early 1946 a Russian physicist, Mikhail G. Meshcheryakov, was in the United States as a Soviet representative in the disarmament

discussions. Following his return from the Pacific where he witnessed the Bikini bomb tests, Meshcheryakov visited the Cyclotron Laboratory of the University of California at Berkeley.⁽⁴³⁾ The accelerator work being conducted at Berkeley seems to have impressed Meshcheryakov, and evidently this was instrumental in a decision to build a similar machine, but of greater power, in the USSR. The site selected was that of the village of Ivankovo,⁽⁴⁴⁾ north of Moscow, and construction was started in 1947 on the cyclotron which is described below in the section, "Attack on the Future." Subsequently, the site name was changed to Bolshaya Volga, and later (about 1956) to Dubna.

Probably this change of name was coincidental with the decision to establish the Dubna site as the Eastern Institute for Nuclear Research,⁽⁴⁵⁾ to be staffed by Soviet personnel and scientists of eleven bloc countries. During March 1956 a meeting was held towards the establishment of this institute.⁽⁴⁶⁾ Evidently, the term "Eastern" was not acceptable to one or more of the delegate nations, and the title of the center emerged at that session several days later as the Joint Institute of Nuclear Research. The agreement establishing⁽⁴⁷⁾ the Institute provides that the laboratory which contained Meshcheryakov's gigantic 680-Mev accelerator, previously known as the Institute of Nuclear Problems of the USSR, should be relegated to the status of the Laboratory of Nuclear Problems of the Joint Institute of Nuclear Research. Similarly, the name of the adjacent Electro-Physical Institute of Vladimir Veksler was to be changed to the High Energy Physics Laboratory, and the 10-Bev accelerator was transferred to Joint Institute use. Evidently, the two large accelerators were the only major pieces of equipment at the Dubna site. The articles of

agreement further resolved that there should be established (a) a Laboratory of Theoretical Physics with a computing department and an electronic computing machine; (b) a Laboratory of Nuclear Problems with an experimental nuclear reactor having high intensity neutron beams; (c) a cyclotron for accelerating multi-charged ions of high atomic weight with helium (this cyclotron to be incorporated as part of the Laboratory of Nuclear Problems); (d) other unspecified laboratories and installations. Professor Dmitry Ivanovich Blokhintsev, who is credited with the direction of the construction of the first Soviet atomic power station, has been named Director of the Joint Institute.

With the establishment of the Joint Institute, Meshcheryakov relinquished his post as Director⁽⁴⁸⁾ of the defunct Institute of Nuclear Problems, and a former deputy director of that Institute, V. P. Dzhelepov, took over as Director of the Laboratory of Nuclear Problems.⁽⁴⁹⁾

Meshcheryakov continued to work as a member of Dzhelepov's group.

Obviously, there is little stability in the leadership of the Laboratory of Nuclear Problems, for in December Bruno Pontecorvo, who had defected from Britain in September 1950, replaced Dzhelepov as Director.⁽⁵⁰⁾

Pontecorvo has been working at the Dubna site ever since his defection, and has published some creditable experimental work in Soviet journals. He is now a Soviet citizen.

Veksler continued as the Director of the new High Energy Physics Laboratory.⁽⁵¹⁾ The Director of the Laboratory of Theoretical Physics is Academician N. N. Bogolyubov, who has recently aroused world-wide interest in his new theory of phenomena which occur at temperatures close to absolute zero. The Director of the Laboratory of Neutron Physics is

Ilya N. Frank, a corresponding member of the USSR Academy of Sciences and a 1958 Nobel Prize winner. It is in his laboratory that a new type of pulsed reactor was to be built. The reactor would operate for extremely short periods at a time (of the order of 15 millionths of a second), but during that time would emit neutrons at an especially impressive rate. A tunnel six-tenths of a mile long would be used for experimentation with the pulsed neutrons from that apparatus, but there has been some difficulty connected with the construction of this reactor and, as of the summer of 1957, the Director of the Joint Institute, Blokhintsev, stated that the reactor was still in an idea stage, that it did not seem at all promising, and probably nothing would be done with it. (52)

On November 21, 1957, the Scientific Council of the Joint Institute recommended that a Nuclear Reactions Laboratory be set up, and Giorgi Flerov who has pioneered in fission research was elected Director of that Laboratory. There is much evidence that the Joint Institute has been afflicted with many organizational difficulties. It is true that the installation possesses two gigantic accelerators, the larger of which had operating difficulties. The equipment which services the smaller accelerator is impressive. However, this seems to be about all that the Institute has, and in the absence of even a small experimental nuclear reactor, it cannot pretend to be a well rounded atomic research center to serve the needs of the Soviet bloc.

Although the articles of incorporation provide that Institute officers be elected by majority vote, the Soviets apparently do not place any trust in the situation where a satellite scientist would be

a director of one of the laboratories, and apparently the other members are forced to accept this situation. As far as the non-privileged members are concerned, Dubna may simply represent a drain on their scientific resources, talents, and the limited amount of funds which they can afford to expend for scientific research. This may be precisely what the Soviets have in mind.

The actual costs of the Institute will be apportioned as follows. The USSR will contribute 47.25 per cent; Communist China 20 per cent; East Germany and Poland 6.75 per cent each; Rumania and Czechoslovakia, 5.75 per cent each; Hungary, 4 per cent; Bulgaria, 3.6 per cent; Albania, North Korea, and Mongolia will each contribute a token sum of .05 per cent. North Vietnam, which is represented on the Scientific Council of the Institute, apparently does not contribute anything. Thus, the USSR is obtaining support for over 50 per cent of its Dubna expenses gratis. The European Organization for Nuclear Research (CERN), which the Joint Institute strives to imitate, has a similar scale of contributions for its western European members, but the situation is such at CERN that no single nation benefits abnormally in respect to the other members.

Overall, the Joint Institute for Nuclear Research probably represents a bonus for the Soviet Union. The Soviet seems to be willing to risk the possibility that the effectiveness of the Dubna work will be sharply reduced by the organizational squabbles which are bound to occur, by the political instabilities, and the transient nature of the workers there. The Soviet can chance this because it is setting up a complex network of similar cities to which the satellite nations will be denied the privilege of making their contributions.

One city to which frequent reference has been made is, of course, Obninsk, which is the site of the 5,000 kilowatt atomic power station which has been operating since the summer of 1954. Since that time Obninsk has become an expanding complex of nuclear laboratories of increasing importance to the USSR program. The scientific complex which has resulted is now known as the Institute of Physics of the Chief Directorate for the Utilization of Atomic Energy of the Council of Ministers (Glavatom). A number of experimental nuclear reactors has since been constructed at this Institute, among them being a beryllium moderated reactor and four or five plutonium-fueled fast reactors. An experimental mobile 2,000 kilowatt atomic power station is also being tested at this site. Certainly, the associated experimental apparatus, chemical and metallurgical facilities required to support the long-range reactor development program of the Institute of Physics of Glavatom must be extensive, and so the new city of Obninsk must be considered a major atomic center in the USSR.

In view of the extreme difficulty in obtaining information on the nuclear research and development organizations which were established in the Stalin period, it is a somewhat more pleasant task to be able to record the plans for an immense new scientific center in which atomic energy will play the dominant role. At various times in the past numerous scientific institutes have been established under the aegis of the Academy of Sciences of the USSR in the vast Siberian region. Institutes exist in Irkutsk, Yakutsk, and more recently, a Physics Institute was established in the City of Krasnoyarsk.

On May 18, 1957, the Council of Ministers of the USSR resolved to establish a Siberian Section of the Academy of Sciences of the USSR and, more significantly, to construct an immense scientific city on the bank of the Ob' River south of Novosibirsk. (53) It is evident from the published plans and from the names of the individuals associated with this new city that this community will eventually represent the greatest and most diversified scientific collective in the world. Indeed, it will be unique, for it is impossible to name a similar installation of smaller size. The main tasks of the western "atomic cities" are all subordinated to research in the field of nuclear physics and related subjects. In the USSR there are also cities like Dubna and the secret manufacturing sites similar to Oak Ridge and Aldermaston. The new Siberian scientific center will provide not only a major nuclear research installation, but will include important institutes of other sciences as well which will, to the greatest extent possible, also use nuclear techniques in their research.

Initial construction began during 1958 at the 1100-hectare (approximately 4-1/4 square miles) site with a 1958 budget of 290 million rubles (54) which corresponds roughly to \$50 million. Clearly, this is an ambitious project. During 1958 first priority was given to the establishment of three institutes at the site.

The Nuclear Physics Institute (sometimes simply referred to as the Physics Institute) will be a branch of Kurchatov's Institute of Atomic Energy in Moscow and will have as its Director Artzimovich's protege, G. I. Budker. A core of sixty to eighty scientists, mainly young, will form the initial group. Budker's main interests are in the field of

controlled thermonuclear energy problems, and it is the stated task of his new Institute to work upon that problem. It will also work on nuclear accelerators using new principles, and undoubtedly Budker's unorthodox ideas along these lines will be tested at the Siberian Institute (see "Attack on the Future"). The two other institutes which had first priority during 1958 are Academician Mikhail A. Laverentyev's Hydrodynamics Institute which, among its other problems, is charged with investigating underground explosions, a subject which is of vital importance to the testing of atomic bombs and toward using nuclear explosions for construction purposes. The third institute is that of Geology and Geophysics which will investigate strategic mineral deposits in Siberia. Ten other institutes will be constructed at the site, two of them almost entirely concerned with atomic energy. They are the Thermophysics Institute of the Inorganic Chemistry Institute. The former Institute will be directed by Doctor of Technical Sciences, I.I. Novikov, who is a member of the staff of the Moscow Engineering Physics Institute,⁽⁵⁵⁾ a major atomic energy technical training center in the USSR. Novikov is also the Chief Editor of the major atomic energy journal, ATOMNAYA ENERGIYA.⁽⁵⁶⁾ His Institute is specifically charged with the problems of developing the utilization of atomic energy for power purposes. A branch of the Kurnakov Institute of General and Inorganic Chemistry in Moscow, the Institute of Inorganic Chemistry will be charged with the investigation of chemical problems involved in the utilization of atomic energy. Because of this emphasis on nuclear energy and the charge to "conduct bold experiments in atomic physics,"⁽⁵⁷⁾ it is evident that, if the work of these institutes is to be effective, nuclear reactors and powerful accelerators will be built at the Siberian Center.

There are eight other institutes. The Institute of Mathematics and Computing Center will be directed by S. L. Sobolev, a former associate of Kurchatov. Its task will be the development of computing machines and techniques and to provide computational assistance, including the solution of complex numerical problems involved in atomic energy. The Institute of Kinetics and Combustion Engineering will work on problems involving very high pressures and extremely high temperatures. The institute of Automation and Electrometrics will develop new methods of measurement. The Institute of Theoretical and Applied Mechanics is charged with two major tasks, machine technology and aerodynamics. The Institute of Economics and Statistics will perform tasks in connection with economic problems of Siberia, and will work in conjunction with Sobolev's Institute on computing techniques. An Institute of High Tension Technology is to be established, but its functions have not been specified. The remaining two institutes will attack biological problems. They are the Institute of Cytology and Genetics, and the Institute of Experimental Biology and Medicine.

It is specified that all of these Institutes use isotopic research methods wherever applicable. This city, as yet unnamed, near Novosibirsk, is the forerunner of similar bases (but probably with less of a nuclear slant) to be established elsewhere. For example, in the period 1958-1965, a new scientific city is to be established near Irkutsk.⁽⁵⁸⁾ Later, cities near Krasnoyarsk and Vladivostok are being planned.

In 1956, plans were revealed to construct a new city called "Akademgrad" (for "City of the Academy of Sciences"), "on the picturesque high banks of the Oka not far from Serpukhov and 125 kilometers from Moscow."⁽⁵⁹⁾ This

description would place the city somewhat south of Serpukhov, at about Aleksin. Here would also be a complex of installations in which radioactive isotope laboratories would be built, though no institute devoted specifically to nuclear research has been mentioned. Eventually, 10,000 people would be living in Akademgrad.

Near Alma-Ata there will be constructed by 1960 a small, 140-million-ruble (approximately \$25 million) installation for nuclear physics research. It will be under the control of the Kazakhstan Academy of Sciences. As is the case in the other scientific cities, workers will be housed on the site which will be approximately two square miles in area. Servicing the 15 small laboratories of the Institute will be a nuclear research reactor and a cyclotron. (60)

Thus, eventually the USSR will literally be peppered with unique scientific communities, a phenomenon which almost constitutes a new social concept. However, the philosophy is not far different from that which has caused the Soviet Union in the past to establish other types of collectives--industrial and agricultural. The stated function of each of the scientific cities is to work on regional problems, as it is the stated function of, say, an agricultural collective. But the given tasks of the nuclear installations in the Novosibirsk scientific city and in the others transcend any regional problems and belie the simple explanation that the cities are collectives concentrating on regional problems.

Clearly, there are other reasons underlying the establishment of the new cities. Right after the war, for reasons of convenient contact, of obtaining required instrumentation and technical equipment immediately,

it was necessary to carry out the bulk of atomic energy development work in the areas of initial large concentration of scientific and industrial resources, mainly in Moscow and Leningrad. It was also necessary to train vast numbers of young technicians and scientists at locales where qualified instructors and equipment were available. For an entire decade the newly trained scientists and newly constructed research equipment were increasingly concentrated at a few locations. The net effect of this is that the Moscow area, particularly, is bursting at its seams with scientific laboratories, scientists, and technicians. Thus, there is the problem of actual accommodation in Moscow. Also, the scientists are reluctant to forego the amenities of a large city and are not eager to staff industrial complexes which have sprung up throughout the USSR. Of course, this situation is also true in many of the non-nuclear sciences and technologies.

Moreover, the concentration of huge scientific technical forces in a few cities is a strategically vulnerable situation for, if Moscow, Leningrad, and Kharkov were to be destroyed today, there is no question that the bulk of Russia's scientific resources would be wiped out, and the road toward recovery of scientific and technical self-sufficiency would be very long.

Will the collective nature of the new cities stifle the scientific talents within them, or will the long-range effect be beneficial to the Soviet Union? Here is an entirely new pattern which the West cannot ignore.

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BOMB DEVELOPMENT

Although two and one-half years were required from the time the Soviets completed their first nuclear reactor to the explosion of the atomic weapon which was announced by President Truman on September 23, 1949,⁽⁶¹⁾ the Soviets officially chose to date their possession of the atomic bomb from November 1947, which, as shown in "The Soviet Union and the Atom: The Secret Phase"^{*} is the date by which they felt they could proceed confidently. This claim is illustrative of the retrospective and quantitative projections which have been characteristic of many of the Soviet claims to arms superiority. Soviet disclosure philosophy seems to consider that once a certain qualitative stage is reached, that is, when it is known how to proceed and a weapon is effectively under production, then this automatically implies possession of the weapon. Consistent with this philosophy, an announcement of a weapon capability also usually falsely implies that the Soviet stockpile of that weapon is boundless, or at least sufficient. It is peculiar how western reaction bolsters the operation of such a crude propaganda device. For it seems that some western observers may be prone to express skepticism of a particular Soviet development, but once it has been developed, the same observers automatically assume the validity of anything else rumored or stated about that weapon.

Regarding the atomic explosion which occurred on August 29, 1949, one can take the interval of two years and several months which occurred

^{*} Kramish, Arnold, The Soviet Union and the Atom: The "Secret" Phase, The RAND Corporation, Research Memorandum RM-1896, 11 April 1957.

from the time of the operation of the first Soviet reactor and compare it with the two and one-half-year interval between the operation of the first nuclear reactor at Chicago on December 2, 1942, and the detonation of the first atomic bomb on July 16, 1945. Perhaps the proper inference is that the Soviet development rate was approximately the same as that of the United States in the early stages of its atomic program. However, it has been shown that the first Soviet reactor more nearly corresponded to the Hanford test reactor which came into operation in the United States in April, 1944. On a strictly comparative basis, the Soviet Union should have tested its first bomb in the fall of 1948! It is therefore possible that the early Soviet program was retarded and experienced difficulties of an unknown nature between the spring of 1947 and the fall of 1949. This delay, coupled with a similar one in bringing their first test reactor into operation indicates that up to 1949, at least, the Soviet developmental rate was slower than that of the U.S., but not as slow as many prognostications at that time suggested.

There is, of course, an alternative explanation to consider, and this relates to the possibility that the bomb announced by President Truman was not the first atomic bomb detonated in the USSR. The U.S. foreign test detection system was initiated only "in sufficient time to detect a Soviet nuclear explosion which occurred on the 29th of August 1949."⁽⁶²⁾ The initial Soviet reaction to the President's announcement was quite flustered, and for a number of days they were completely unprepared to exploit their achievement sensibly. It is quite conceivable that if a bomb or bombs had been detonated earlier, and they had not been detected by the United States, then they would not have been announced by

the Soviet Union. In the absence of other information, however, the 1949 detonation must be regarded, at least, as the first successful Soviet nuclear explosion.

Indeed, most of the statements about the Soviet test program have come from the U.S. Atomic Energy Commission. A few of the AEC announcements have been confirmed, but the Soviet Union evidently prefers to remain silent on the majority of them. It is essentially from the official statements of the U.S. AEC and of the Soviet Government that we must infer the probable nature of the Soviet nuclear weapons development to date, for no other information is available. The policy of the AEC is not to announce every Soviet atomic test; sometimes the AEC announcements only indicate that a series of tests has been held. To the spring of 1958 the U.S. AEC announced 39 Soviet tests or series of tests. Only a handful of Soviet test announcements has come initially from the Soviet Government. No Soviet test series, as such, has ever been announced in advance of its occurrence. Thus, the total number of Soviet atomic tests is in excess of 50,⁽⁶³⁾ and can be compared to the total (to April 1958) well over 100 tests conducted by the United States. However, these totals are not especially meaningful in making a comparison of the nuclear position of the USSR vis-a-vis the US. Some of the announcements which gave special information will be examined.

A period of two years passed before another Soviet test was held. Stalin confirmed the October 1951 test and commented that "tests of atomic bombs of different calibers will be conducted in the future as well."⁽⁶⁴⁾ Operation Ranger which consisted of five tests and was directed toward the development of tactical weapons had been conducted the earlier

part of the year in Nevada, and a number of tests relating to thermonuclear development had been conducted in April and May at Eniwetok. The announcement of a Soviet test on October 22, 1951, corresponded with the start of a new US test series in Nevada. Another two years passed without any Soviet tests. Then, on August 8, 1953, Malenkov boasted before the Supreme Soviet that, "The USA has long since lost the monopoly in the matter of the production of atomic bombs. . . . The government deems it necessary to report to the Supreme Soviet that the US has no monopoly in the production of the hydrogen bomb either."⁽⁶⁵⁾ This announcement was met with considerable skepticism in the west until the Soviets four days later detonated a nuclear device which involved both fission and thermonuclear reactions. TASS confirmed the US announcement with the following statement:

One of a variety of hydrogen bombs was exploded for experimental purposes in the Soviet Union within the past few days. Because a powerful thermonuclear reaction was created in the hydrogen bomb, the explosion was of great strength. The tests showed that the power of the hydrogen bomb is many times greater than the power of the atom bomb. It is known that the Soviet Union has had the atomic weapon for several years and has conducted suitable tests.⁽⁶⁶⁾

Malenkov took no risk in making his announcement previous to the test, for indeed, all that he claimed was that the hydrogen bomb was in production in the Soviet Union, and this was true. Had the August test not succeeded, it would not have been detected as an hydrogen bomb, the TASS announcement would not have claimed it as such, and the world would simply have waited with uncertainty for a Russian thermonuclear test.

It is probable that their first hydrogen device was an exceedingly

cumbersome affair--not a bomb. As the TASS announcement indicated, it was an experimental device, and a publication of the US Joint Committee on Atomic Energy states that the device was "non-deliverable."⁽⁶⁷⁾ The 1954 Soviet series was not confirmed by the Russians. Beginning in August 1955 an extensive series was started, culminated by the test of a deliverable hydrogen bomb dropped from an aircraft on November 23, 1955. At that time Khrushchev was visiting in India, and on September 26 in his Bangalore speech, said:

An announcement has been published today in the papers of many countries, including some Indian papers, that an atomic explosion has been set off in the Soviet Union. I shall not say that there has not been such an explosion. It was a terrific explosion. Tomorrow our press will publish an announcement to this effect.

Recently, in compliance with the plan for research and experimental work in atomic energy, new types of atomic and thermonuclear weapons have been tested in our country. These tests have confirmed completely the corresponding scientific calculations. They have also demonstrated the important new achievements of Soviet scientists and engineers.

The latest experimental explosion of an "H"-bomb has been the most powerful yet staged. Using a relatively small quantity of fissionable material, our scientists and engineers have managed to produce an explosion equal to that of several megatons of conventional explosives.⁽⁶⁸⁾

The next day's TASS announcement repeated much of what Khrushchev said and noted in addition that "the explosion was set off at a high altitude in order to prevent radioactive effects."⁽⁶⁹⁾ In a speech before the Supreme Soviet of December 29, 1955, Khrushchev recalled the November test and declared "that its power of many millions of tons of explosives could be substantially increased."⁽⁷⁰⁾

An extensive Soviet test series was conducted in 1956. Many of these tests were for the purpose of perfecting atomic warheads for tactical

purposes. Up to October, 1956, according to a White House statement, approximately 80 per cent of the US tests had been of fission devices and the remainder thermonuclear. Examination of the meager data available indicates approximately the same ratio for the Soviets.

Available data does not permit a comparison of the US and Soviet thermonuclear technologies or a description of whether or not the US claims represented a more sophisticated or advanced approach. Although the US tested two types of hydrogen bombs in November 1952 and March 1954, the first US H-bomb to be tested in an actual drop from an aircraft was detonated on May 21, 1956.⁽⁶⁷⁾ It should be noted that in both the US and USSR programs there was considerable lag between the achievement of non-deliverable and deliverable devices.

At a 1954 presidential press conference the Chairman of the US AEC confirmed the initial Soviet lead. Mr. Strauss stated:

In August of last year the Russians also tested a weapon or device of a yield well beyond the range of regular fission weapons and which derived a part of its force from the fusion of light elements. There is good reason to believe that they had begun work on this weapon substantially before we did.⁽⁷¹⁾

Retrospectively, it must be seen that President Truman's decision in January 1950 to proceed with the construction of the H-bomb did not initiate an "H-bomb race." That contest had already begun.

Evidently, the Soviets chose to rely on the impression ingrained by the November 1955 test, for except for the announcement of some tests in the autumn of 1956, the Soviets have confirmed few of the numerous later announcements of the US AEC. Some of these tests were to perfect "new types of weapons for various arms of the services."⁽⁷²⁾ The Soviet test

program had been conducted at a continuously accelerating rate to the extent where in early 1958 there were a number of instances of two tests being conducted on the same day. Where this was so, one of the tests was carried out at the Central Asian proving ground (near Semipalatinsk,⁽⁷³⁾ about 300 miles west of the Chinese-Mongolian border), and the other at its test site above the Arctic Circle at a location on the Barents Sea⁽⁷⁴⁾ (in the vicinity of Novaya Zemlya Island).⁽⁷³⁾ Generally, the larger tests (in the megaton range) have been conducted at the northern site, with the lower yield detonations occurring in Central Asia or another internal site.

The emphasis on minimizing fallout in the Soviet test announcements and the physical fact that fallout from the southern site could likely occur on nearby communities indicates the possibility that the Soviet test program had been hampered by fallout considerations until the northern site was available. It is not known whether or not Russian cities have ever experienced serious fallout, but following the April 1956 detonations the Peking radio warned of high levels of fallout in the area. Madam Le Teh Chuan, the Minister of Public Health urged the public to wash food in boiling water before consuming it. It is extraordinary that the announcements specifically identified the fallout as originating from the Soviet Siberian test site.⁽⁷⁵⁾

The Peking situation was probably not unique. The Central Asian test site lies approximately at the 50th parallel; the shots occurring at that location have been particularly "dirty" as regards fallout. In fact, the greatest amount of latitudinal fallout has occurred in a band around the earth roughly defined by that area between the 45th and 55th

parallels, and virtually all of the deposition of long-lived fission products in that band is due to the Russian test program. (76)

The accelerated test schedule in 1958 was probably coupled with the intense Soviet drive for the abolition of nuclear tests. Three megaton range weapons were exploded within a period of five days, and six more nuclear weapons within a period of nine days. By the spring of 1958 the Soviets had a broad family of nuclear weapons. Although we could infer from the relative numbers of tests that the number of types of nuclear bombs incorporated in the Soviet stockpile is not as extensive as that in the US stockpile, the entirely different strategic position of the USSR and the methods of accomplishing its ultimate aims differ quite sharply from those of the west. It is not reasonable to expect an identical atomic weapon program nor an identical philosophy of utilization. (77)

Until Stalin's death there was an insufficient realization of basic nuclear facts among Soviet military planners for effective political exploitation and military preparation in atomic warfare. Starting on January 14, 1954, a series of articles in Red Star, the official military organ, heralded the general release of atomic information to all levels of the military. (78) Four years later the nuclear facts of life were sufficiently ingrained in the Soviet political and military leaders to embolden them to display various degrees of flexibility in their nuclear weapons policy.

The Soviets have realized that perhaps the most important use of their atomic stockpile, whatever may be its composition, is as a political weapon. History may show that inert nuclear weapons, adroitly handled in a political sense, may have produced changes dissimilar to all-out global conflict, but just as profound.

In a speech to his Kalinin constituents on March 14, 1958, Khrushchev made the following points.

The past four years have been years in which the Soviet Union, together with other peace-loving nations, has persistently tried to relax international tension, to stop the armaments race, and to avert a new war. The most burning and vital problem for all mankind at present is the problem of peace and war. Wars between states always bring many victims and vast destruction. But a future war, should it break out in spite of the will of the peoples, threatens to be the most destructive of all--a nuclear war. Apart from the direct damage, the use of nuclear arms will poison the atmosphere by radioactive fallout and this may lead to the destruction of nearly all living organisms, especially in countries with restricted territory and dense population. Everything there can quite literally be wiped off the face of the earth.

The level of armaments in certain countries has reached such a stage that the time will come, and perhaps it has come already, when these countries themselves, irrespective of whether or not an agreement on the cessation of production of atomic and hydrogen arms has been reached, will have to say "enough." If formerly, old arms and military techniques were replaced as new models were created, now it appears that a stage has been reached when it is difficult to invent more powerful arms than the hydrogen weapon, the power of which is limitless. It is no accident that scientists, though as yet shyly, declare that if the stocks of nuclear arms which have been stored were exploded, the atmosphere of the entire terrestrial globe may be poisoned. (79)

Thus Khrushchev indicated that the Soviet Union might unilaterally decide to suspend tests and the production of nuclear arms. A "decision" to suspend testing was announced by Gromyko before the Supreme Soviet on March 31, 1958. The obvious advantage of a unilaterally declared suspension is that it places no obligation on the declarer to accept internal inspection. Moreover, the conditional phrasing of Gromyko's declaration to the effect that if other powers possessing such weapons continued their tests, the Soviet Government would consider itself free to resume its tests provided adequate insurance for this powerful

propaganda play. Resume the tests they did, in the fall of 1958, at their Novaya Zemlya test locale just before more serious test suspension talks were to begin. Indeed, even during the initial conference days, more weapons were tested at an internal USSR site.

It is possible that the types of atomic weapons which are now in the Soviet stockpile may be deemed sufficient for any foreseeable military operation during the trial period of a test suspension.

It should be noted, moreover, that the Soviets in their 1955 statements were proud to mention that their tests confirmed the calculations which had previously been carried out. Then, of course, there is inherent in Malenkov's August 8, 1953, speech a confidence that their first H-bomb test would work. The Soviet leaders may feel that if it does become necessary to re-fabricate their atomic stockpile into more advanced types, as demanded, their scientists' calculation techniques are sufficiently reliable to guarantee operable weapons without tests. Also, the U.S. long-range monitoring program is able to detect certain characteristics of Soviet weapons by comparison with data collected in US tests. (62)

It follows that a reciprocal relationship must be valid to some extent, and that it may be unnecessary for the USSR to test certain bomb design parameters because they have already been tested by the US. But the military commander will always feel that there is some risk in employing untested weapons; regardless of political gains that may arise by proposing test cessation, there will always be strong internal pressures in the USSR to continue testing.

Soviet political and military planners undoubtedly are cognizant that increasing the number of bombs may offset certain disadvantages of design

curtailment. The production of power from atomic energy is essentially a peaceful pursuit, but a necessary by-product of nuclear reactors producing electricity is the production of additional fissionable material, namely plutonium and uranium-233. The Russian industrial atomic power program is expanding at an exceedingly high rate which means that the production of fissionable material in their atomic power reactors will soon match and exceed the production of the military reactors. In fact, their largest "peaceful" atomic power station produces electricity inefficiently, apparently for the purpose of optimizing plutonium production. Having created a peaceful program on the basis of a military atomic energy program, the former will soon be able to give significant support to the latter.

Much of what the Soviets do militarily, economically, and in their political offensive will depend on the atomic energy structure that has been created, their peaceful atomic energy program, their natural resources, and the unknown advances that further research may bring. And for quite some time Soviet scientists have spoken of certain applications of atomic energy which are only now beginning to be appreciated in the west.

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THE GENERAL'S PLOWSHARES

In a poem published in July 1949 by Stalin Prize-winner Yevgenij Aronovich Dolmatovskij, a father comforts his baby daughter who has just been disturbed by the "distant hollow rumble" from the Taiga far away.

He whispers:

You shuddered. The distant hollow rumble
Of your carriage
Sounded like a wind.
Sleep, my baby,
Your doll, your teddy bear and your little black devil are
sleeping peacefully like children.
Where did that sudden jolt come from?
What does that signify?
In the Taiga, far away from here
In quite another end of the country,
Where the color of the yellow leaves
Does not glow away until spring.

There stands a granite mountain
Which is barring our way.
Long, long ago it should have been turned
Upside down
Long, long ago it should have been forced to give up its ore.
Sleep, my daughter,
The night is dark,
Sleep, my baby.
At that place there lived a group of geologists
In frost and heat.
Twelve months long
They were groveling around on the mountain.

Then there came an airplane full of professors to that place
and then a platoon of army engineers,
First class lads,
And their young commander,
And he was ordered to lay down an explosive shell.
It was not gunpowder, nor dynamite.

There is far more powerful stuff
Now in your country.
I will not tell its name.
Sleep, my baby.

At the pre-arranged hour, the explosion occurred.
The granite was blown asunder to dust.
The Taiga around the mountain was illuminated
By golden radiance.
The old mountain disappeared and the roar of the explosion
interrupted at five in the morning
The sleep of children
As a breath of wind
From far, far away.

Sleep, little girl,
Your hand lies in my hand.
May the sound wave reach the foreign coasts
And warn our enemies
Who hear it there.
The mountain moldered away like flame and gave away its ore,
Not long ago only a fairy tale,
This has now occurred.
Sleep, my baby.⁽⁸¹⁾

On March 6, 1958, the US AEC announced that it is engaged in a
"Project PLOWSHARE" the purpose of which is to investigate the possible
applications of nuclear explosions for peaceful purposes, and as one of
the applications, it is suggested that nuclear explosions could crush
large masses of rock and thus be used to break up ore bodies for removal.⁽⁸²⁾
Did Soviet scientists anticipate these applications a decade earlier?
Dolmatovskij's poem would suggest so. For several years the bomb itself
was the major tool of Soviet "peaceful atom" propaganda.

The sound waves from Dolmatovskij's new explosive evidently did not
reach the foreign coasts as quickly as intended. Unless western nuclear
detection systems had failed or had not been fully developed yet, the poem
would seem to have been published prematurely. The official TASS announcement
which appeared two months later, on September 25, 1949, coyly and indirectly
recognized US detection of the first Soviet A-bomb in the following words:

As is known, construction work is being conducted on a large scale in the Soviet Union--the construction of hydroelectric stations, mines, canals, and roads, which necessarily call for much blasting, using the latest technical methods. As this blasting has taken place and is taking place rather frequently in various regions of the country, it is possible that this could attract attention beyond the borders of the Soviet Union. (83)

Again, there is reference, through the use of the words, "latest technical methods," to the application of nuclear explosions for peaceful purposes.

The TASS applications were again unconsciously echoed in the US AEC's March 6, 1958, release wherein it is stated that application of nuclear explosions would be "moving earth in quantity such as digging a large canal."

The TASS announcement was exuberantly exploited by the late Andre Vishinsky in the United Nations (on November 10, 1949) to the extent that he claimed atomic energy was being used in the Soviet Union for "razing mountains, . . . irrigating deserts, . . . cutting through jungle and tundra . . ." Changing political aims dictated that no nuclear detonation should be recognized as having a benign application, and the Chief Soviet Delegate at the 1958 Geneva Conference on the Peaceful Uses of Atomic Energy confessed to a cloistered existence the greater part of his life: "I do not remember what Vishinsky said, because I never used to listen to politicians, although I now do." (84)

Because of the growing technical and political importance of peaceful atomic applications, it is important to examine whether or not the USSR has indeed seriously considered such applications despite Comrade

Yemel'yanov's assertions, and whether it has some incentive to utilize atomic explosions for peaceful purposes. The outstanding - and virtually the only - public spokesman for such applications in the Soviet Union has been Doctor of Technical Sciences, Professor Gorgii I. Pokrovskij, Major General of Engineering Services. General Pokrovskij has the distinction of being the most prolific spokesman on almost every technical matter, with major emphasis on atomic energy and space travel, in the Soviet popular and technical press. General Pokrovskij is an individual of some technical ability, having originally been a nuclear physicist who in the 1930's switched to problems of soil mechanics. During the war General Pokrovskij worked on problems of conventional explosives and the development of shaped charges, so that his general background should make him expert in the moving of earth by means of nuclear explosions.

Writing mainly in such popular journals as OGONEK (Little Flame) and TEKHNIKA MOLODEZHI (Technology for Youth), General Pokrovskij has consistently advocated the application of large scale explosives for large earth-moving projects⁽⁸⁵⁾ and he has noted that the size of the explosions required in such projects would be approximately the same as the yield of atomic bombs.

Large scale detonations of conventional explosives have been carried out behind the Iron Curtain. Some of them are comparable or larger than any equivalent operation conducted in the west. In order to tap an ore body near the Northern Chinese City of Lanchow the Soviet technical group which specializes in large scale explosions, Soizvzryvprom, set off in the last half of 1956 several immense explosions. On the 7th of July a charge of

1,640 tons was exploded, on the 12th of November a charge of 4,000 tons,⁽⁸⁶⁾ (according to another article of Pokrovskij's,⁽⁸⁷⁾ these explosions occurred on the 19th of July and the 15th of November, respectively), and on the 31st of December a charge of 9,200 tons was detonated. Pokrovskij's article also states that up to 1956 no conventional explosive charge had ever been set off which exceeded 2,500 tons. Evidently, even this charge which Pokrovskij belittles, must have been set off by the Soviets, for the largest non-atomic explosions ever detonated in the west have not exceeded 1,500 tons. The largest western non-atomic charge, involving 1,375 tons of explosives, was detonated on April 5, 1958, to destroy a channel hazard in the Alaskan waterway.⁽⁸⁸⁾

At a Utah construction project where engineers blasted loose a cliff-side to obtain dirt for a railroad causeway over an adjoining lake, the total amount set off was a mere 1,065 tons.⁽⁸⁹⁾ Pokrovskij had stated that a project, which seems quite similar to the Utah project, would be undertaken for a railroad which runs from Paochi to Chengtu, China.

The US AEC has also suggested that Project PLOWSHARE could be used for "Piping water into a rock formation heated by a contained nuclear detonation to form steam for producing power or for other purposes."⁽⁹²⁾ This application and others of a more imaginative nature have also been anticipated by General Pokrovskij.⁽⁹⁰⁾

Recently, (at the end of 1957), and apparently only for the purpose of obtaining more detailed experimental data, a 1000-ton charge was exploded at Tagansai, seventy miles north of Tashkent, in Uzbekistan.⁽⁹¹⁾ The experiment was conducted with a great deal of auxiliary experimentation to obtain explosive effects. The "complex expedition" conducting the operation

was composed of members of many institutes, including representatives of the Institute of Chemical Physics, the Institute of Earth Physics, and Moscow State University. Led by the Vice-President of the Academy of Sciences, M. A. Lavrentiev (who is also Director of the new Siberian Hydrodynamics Institute), the expedition evidently had extraordinary status. Because of its special nature, it is possible that the Tagansai explosion was an attempt to emulate the US underground nuclear shot "RAINIER" which occurred on September 19, 1957, (with a TNT strength of 1,700 tons).

It was stated that the information obtained from the Tagansai explosion will be helpful in solving an important problem which exists with respect to a gigantic new power station which is being built in Siberia on the Angara River, above Irkutsk. The Bratsk hydroelectric station will dam up the Angara River and will have a capacity of 3,600 megawatts which will make it one of the largest hydroelectric stations in the world. ^(b) The construction of the Bratsk station is almost completed, but the difficulty is that at the rate at which the Angara's waters presently flow northward from Lake Baikal, it will take eight to ten years to fill the Bratsk reservoir. It is contemplated then to increase this flow by widening the bed of the Angara by a single, 30,000-ton charge to be placed under the river bed. A 30,000-ton charge is one and one-half times the size of one of the first U.S. nominal atomic bombs. It is therefore an impressive explosion. If 30,000 tons of conventional explosive were placed in a single chamber, the cavity would be of huge dimensions (of the order of one million cubic feet), and it is probably out of the question to build such

a chamber under a river bed. Moreover, it would be difficult to detonate all parts of such a massive explosive simultaneously. One can only conclude that if an atomic bomb has not been considered for this application as an obvious and convenient explosive instrument, the Soviets may be missing a good bet.

In connection with their explosives construction program, Soviet seismologists have conducted extensive physical investigations relating to the detection of distant nuclear detonations. This was a matter of considerable interest among western specialists in the spring of 1958. ⁽⁹³⁾ The official Soviet position was expressed by Gromyko on May 10, 1957:

It is usually said that it is possible to test atomic and hydrogen bombs without the explosions being detected. This is at variance with the facts. ⁽⁹⁴⁾

Coordinated by the Central Seismic Station in Moscow, data from a network of 70 seismic stations is continuously analyzed. After boasting of the detection of the U.S. bomb tests the Soviet seismologists said:

It should be pointed out that the instruments of such seismographic stations register all types of shocks -- surface, underground, over water and under water. Thus, contemporary technical methods make it possible to detect all kinds of tests of atomic and hydrogen weapons at any point of the earth's globe. ⁽⁹⁵⁾

The day Gromyko announced the conditional suspension of Soviet nuclear tests, the leading personality in the Soviet atomic program, Igor V. Kurchatov, made a very strong statement regarding detection.

It is sometimes said that it is impossible to check whether one state or another is carrying out tests of atomic and hydrogen weapons. This is simply irresponsible talk. It is well known that many methods exist with the aid of which explosions of atomic and hydrogen bombs can be detected at long-range distances. This includes, for instance, the study of seismic

oscillations, sub-sonic waves, and the radioactivity of the atmosphere.

The Supreme Soviet should know that we also have at our disposal other, even more sensitive means of detecting distant explosions of atomic and hydrogen bombs⁽⁹⁶⁾

Some of these means, which involved acoustic radio and other physical phenomena, were discussed in the summer of 1958 at the Geneva conference of East-West Experts. And while the western scientists were unable to acquiesce to Soviet claims approaching 100 per cent detectability, agreement was reached on detection networks and systems which would indicate high probabilities (but not absolute certainty) of detection of nuclear tests carried out under various conditions.⁽⁹⁷⁾

In an inspection arrangement on the monitoring of nuclear tests, it would be extremely important that attention be given to the status of explosion construction programs. Many of the detonations of conventional explosives which the Soviets have and will employ are of the same size as a small atomic bomb. Such explosions will probably be undistinguishable, as far as seismographic detection is concerned, from explosions of small nuclear bombs and vice-versa. Would the Soviets allow inspection of all such explosions by international teams to confirm their nuclear or non-nuclear origin? Or would they claim that all or most of such detonations are of non-nuclear origin, involving construction projects which are the internal concern of only the USSR, and therefore not subject to inspection?

Then there is the question of how China enters into the picture. China is not a member of the United Nations, and it is difficult to see how, under these circumstances, she would fit into the inspection system. Designed without regard to politically inaccessible voids, the detection system

proposed by the East-West experts in the summer of 1958 would be seriously weakened if a large area of the world were closed to instruments and inspection. A precedent is already established for conducting very large explosions in China. The Soviets (and later the Chinese) could continue to do so using and testing nuclear devices with an immunity guaranteed by the vast geographical and political void of Red China.

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ATOMS FOR POWER

The Soviets may have made their first bid in the atomic power race as early as the fall of 1949, for that is when serious work began on the small power demonstration reactor which came into operation four and one-half years later on June 27, 1954. The Russians boast that this is an unusually short development time.⁽⁹⁸⁾ Perhaps it is, considering the fact that during most of that period governments were not overly enthusiastic about the use of atomic energy for power.

In a society where art must reflect the accomplishments of the people, a poem was written by Igor' Vol'sky to commemorate this achievement:

Atoms for Peace

Read,
 drink with your eyes the lines:
The inevitable came true, the newest
 of the miracles of the earth --
The uranium forces
 by electric current
Over Soviet wires started to run !
And somewhere,
 echoing to hearts inspired,
In this festive -- humdrum hour,
In honor of peace
 new motors began to drone,
And flashed up
 the lamps of Il'ich.
The river of Time
 will carry away into silence
The cannibal's pyre
 on the island Eniwetok,*
But our Atom of Peace --
 child of Five-year plans,
For people
 will shine for ages,
What was a dream, a fledgling yesterday,
Today is trying out
 its powerful wings.
Glory be to those masters,

* (TND's Footnote): The Island Eniwetok in The Pacific Ocean is a proving ground for American atomic bombs where the tests brought about many sacrifices.

Who, out of the fairy tales
of the days bygone,
Created this reality (99)

The poem reflects a major purpose of this station which is to divert attention from the military nuclear program of the USSR. In implementing the propaganda, many foreign delegations have visited the station during the four years of its operation. These delegations included such eminent individuals as the Prime Minister of India, and the heads of various satellite states as well as scientists and statesmen from western countries. The station forms the nucleus of the new town and scientific center of Obninsk (100) which is located southwest of Moscow near Maloyaroslavets.

Regardless of its political functions, the Soviet scientists must be credited with putting into operation the first atomic power plant of any appreciable size which has delivered electrical current to a community. Many well-known scientists, including Igor Kurchatov, A. P. Aleksandrov, and A. I. Alikhanov, gave important counsel during the construction of the reactor. (101) However, the major credit for the development of the station is given to four individuals, D. I. Blokhintsev, N. A. Dollezhal', A. K. Krasin, and V. A. Malikh, who in 1957 received Lenin Prizes for their accomplishment.

The electrical output of the station is small -- approximately 5,000 kilowatts -- which is derived from a reactor (abbreviated GVF) operating at a thermal capacity of 30,000 kilowatts, using a graphite moderator and a coolant of water under pressure of 100 atm which circulates through the reactor core and gives up its heat to water in a second circuit through a system of heat exchangers. The fuel is uranium enriched to approximately 5 per cent in the U-235 component. (102) The fact that the station has operated

continuously and successfully for over four years is a matter of great satisfaction to the scientists at Obninsk.

The station has also contributed a large measure of the encouragement which Soviet planners must have needed to project as part of the Sixth Five-Year Plan in 1956, a large atomic power program which would involve the construction of a number of atomic power stations with a total capacity of 2000 to 2,500 megawatts of electrical output.⁽¹⁰³⁾ The first of these stations was to come into operation in 1958, some in 1959, and the rest in 1960. There is considerable evidence that all parties concerned in the planning of these stations were not fully coordinated at the time the initial announcements were made. The statements of various scientists of the Academy of Sciences, of officials of the Chief Directorate for the Utilization of Atomic Energy (Glavatom), and of the Ministry of Electric Power Stations often were in direct conflict. From the data given on the individual plants it was impossible to see how the total capacity added up to 2000 to 2,500 megawatts by 1960. Indeed, the sums corresponded to something like one-half of those amounts.⁽¹⁰⁴⁾ Evidently, the atomic power goals were only one of the economic and industrial plans which had to be revised, for in the fall of 1957 the Sixth Five-Year Plan was officially abandoned and most of its aims extended to 1962. The atomic power targets were among those which were extended.⁽¹⁰⁵⁾

It is still not clear how the various governmental agencies are coordinated in the atomic power program. Certainly the fuel supplies must be obtained from the Ministry of Medium Machine Building which controls the major military and manufacturing nuclear establishments. But whether or not that Ministry is allowed to exercise any measure of technical control over the peaceful atomic power program is not known. The major engineering organization appears

to be "Glavatomenergo" which is a Chief Directorate of the Ministry of Electric Power Stations, and certainly must also be subject to the strong direction of Glavatom. The Chief Engineer of Glavatomenergo is Georgi V. Yermakov⁽¹⁰⁰⁾

The organizational aspects of the peaceful atomic energy program were not the only facts that were obscure. The entire scheduling as to which type of large atomic power stations was first to come into operation as well as correlation of power levels, types, and location were impossible to ascertain from the changing and conflicting public statements about the progress of the atomic power program.

Moreover, lurking in the background was the fact that the Sixth Five-Year Plan called for a "fifth" station of 600 megawatts capacity at an unknown "fifth location" and of an unstated type. Indeed, even this amount of information was only tenuously derived from a single speech of Igor Kurchatov before the Supreme Soviet in February 1956.⁽¹⁰³⁾ Until the Second Geneva Conference on the Peaceful Utilization of Atomic Energy which occurred in September 1958 there was no published official information to give the existence of the mysterious fifth plant any credence at all.

Professor Francis Perrin who is head of the French atomic effort visited the Soviet Union late in 1957, and at that time was told that a power plant with capacity of 100,000 electrical kilowatts would come into operation toward the end of 1958.⁽¹⁰⁵⁾ This information conflicted with current Soviet press reports that the first section of their first large atomic power plant would come into operation in 1960, and so, received scant attention.

However, on September 6, 1958, TASS released a communique⁽¹⁰⁶⁾ consisting of just a few lines stating that a nuclear atomic power station of that capacity had indeed just been put into operation in the Soviet Union, and two days later the Chief of Glavatom, Vasily Yemel'yanov, astounded the delegates at the Geneva Conference by showing a movie of that plant.⁽¹⁰⁷⁾

The plant which was put into operation was the first of six identical units which will comprise the station, thus giving it a capacity of 600,000 electrical kilowatts. Furthermore, the plant is at a location in Siberia which Professor Yemel'yanov declined to identify. It appears, then, that this is the fifth plant of which Kurchatov spoke; aside from the surprise value of the comparatively great secrecy surrounding this plant, there must have been other compelling reasons for the abnormal silence.

The plant itself does not represent an advance in atomic power engineering; indeed, it is somewhat old-fashioned and if atomic power alone were the goal, it is difficult to see why five more identical plants would be built. The reactor which supplies the heat is graphite-moderated and fueled with natural uranium. The coolant is water which is heated to a very low temperature, in comparison with other nuclear power designs, and thus the efficiency of conversion of heat to electrical energy is very low. The plant appears remarkably similar to the "dual purpose" plutonium and electricity producing station authorized by the U.S. 85th Congress at the Hanford plutonium plant in 1958. The primary purpose of the U.S. plant was to provide additional plutonium for weapons, with power a secondary goal. This could be the only justification for a plant of that type since for some time to come the only use for such quantities of plutonium will be for nuclear weapons. One is then forced to conclude that the 600 megawatt

Soviet station also represents a significant extension of the Soviet Union's plutonium producing facilities. Since it may be located at the site of one of Russia's earlier plutonium production centers, it is easy to see why the location is being kept secret.

The propaganda value of having so large a station come into operation so soon probably exceeds the technical contribution of that particular plant to the Soviets' and the rest of the world's atomic power technology. Taking a realistic look at this particular plant, its most sobering aspect should not be the atomic power technology it represents but the extension of the Soviet nuclear weapons stockpile. The Soviet Union can only hope to impress nuclear scientists and engineers by the other nuclear power plants which it has in its program.

One of the advanced-type plants which is projected will be based on experience gained at the GVF station, which is currently being used for engineering studies in the larger station.⁽¹⁰⁸⁾ It will be graphite moderated and will operate under boiling-water conditions, which will obviate the need for some of the bulky intermediate steam equipment. It is expected to have a thermal capacity of 1,150 megawatts, a gross electrical capacity of 400 megawatts, with a net electrical of 375 megawatts, since 25 megawatts will be expended in the operation of the station itself.⁽¹⁰⁹⁾ In February 1956 when the designs for this large station called for an output of one-half the contemplated amount, that is, 200 megawatts, it appeared that it was to be coupled with the GVF station.⁽¹¹⁰⁾ However, this plant is presently being constructed near the village of Beloyarskoye in the Urals.¹¹¹ Some 60 kilometers east of Sverdlosk,

Beloyarskoye's only previous claim to fame or notoriety has been as a prison camp.

While their first power reactor was of the GVF type, the Soviets seem not to have a strong preference for it, for at least two of their stations will be both moderated and cooled by water under pressure. These are of the PWR type (in Soviet terminology, VVR) which has received major emphasis in the United States. In describing one of their VVR reactor stations, a Soviet scientist stated, "As can be seen from the foregoing, the reactor described in the report is of the pressurized water type, like the Shippingport, Pennsylvania,* reactor, but has a considerably greater capacity. It is an interesting fact that the individual development of these reactors in different countries has led to analogous design decision."⁽¹¹²⁾ One of the Soviet VVR stations will come into operation⁽¹¹¹⁾ in 1960 at Voronezh in the northeast Ukraine with a rated output of 420 megawatts gross electrical power, or 390 megawatts net. (It is not stated, however, that the station will reach full rated power by that date.) This station will be expanded to an even greater capacity by the addition of more reactors after 1960.

The third type of atomic power stations is that which has been developed by members of the Thermotechnical Laboratory working under the direction of A. I. Alikhanov. It is a reactor moderated by heavy water and cooled by carbon-dioxide gas, initially described as having a rating of 100 megawatts.⁽¹¹³⁾ The latest data indicates that this station may have been boosted⁽¹¹⁴⁾ to a rating of at least 300 megawatts electrical; and again, its location

* This reactor went critical on December 2, 1957, and will supply 100,000 electrical kilowatts or more to the area.

is unknown. The special fuel elements for this reactor have been under development for several years and have already been tested at the Institute of Atomic Energy.⁽¹¹⁵⁾ The absence of any specific declaration on a Soviet D₂O-gas-cooled reactor at Geneva in 1958 (except for a 150 megawatt unit being built in Czechoslovakia) and the lack of other information as to siting, etc., temporarily placed this plant in limbo. But lest there be temptation to consider this station abandoned, the lesson of the "fifth station" should not be forgotten.

In addition to the three major types of reactors described another reactor test station will be established near Ulyanov on the Volga to investigate several reactor concepts of an advanced type. The first of the installations at the test station will be a boiling-water type reactor such as was pioneered at the Argonne National Laboratory in the United States. The electrical output of this installation will be about 50 megawatts. A boiling water reactor has been built and successfully operated by General Electric near Pleasanton, California. A second Soviet experimental reactor will use a graphite moderator with molten sodium as a coolant. This type of reactor has been constructed and is being operated by the Atomics International Company at Santa Susana, California. The third type of Soviet reactor using a suspension of uranium oxide in heavy water as fuel will be designed to breed uranium-233 from thorium-232. Successful operation of this reactor is regarded as a prelude to the construction of one rated at from 300 to 500 electrical megawatts.

A fourth type of reactor in the Soviet test station will be a fast breeder reactor (Soviet code: BM-50) which uses plutonium as the chain reacting substance and uranium-238 as a breeding blanket. The reactor will use

liquid sodium alloy as a coolant. The design of this reactor is based upon experience gained in the operation of several experimental fast reactors (non-electrical) since 1955 at the Institute of Physics of Glavatom which is located at the site of the first Soviet atom power plant. These include an advanced-type reactor, with a rating of 5 megawatts, which came into operation in the summer of 1958. Looking beyond the operation of BN-50, Soviet physicists are designing a fast reactor (BN-250) with an electrical output fivefold that of BN-50. Similar programs using enriched uranium and plutonium in fast breeder reactors, have been underway for some time in the United States and in Britain.

The electrical capacity of all of the four installations at the reactor test station will be approximately 500 megawatts, giving a total output for the stations of perhaps 2000 megawatts. Thus, it seems that if each of the five major stations does operate with an average capacity of about 400 megawatts, whether or not the Soviets intended to include the capacity of the small experimental stations in their goals, they should reach them by 1962.

The economic incentive is strong for installing atomic power stations at an even greater rate after 1962. The great bulk of Soviet industry and population is concentrated in the European part of Russia. Four-fifths of the total power produced in the USSR is required by the European economy. This energy requirement is almost symmetrically reversed with respect to energy resources, for well over 70 per cent of the unexploited reserves of energy resources is to be found in the Asian part of the USSR. As the eastern regions begin to become more industrialized and use a greater share of their domestic resources, the relative demand will still be some-

thing like two-thirds of the total national power consumption figure. By that same time most of the hydroelectric resources in European Russia will have been tapped. If other sources of energy were not available, the rest of the demand would have to be met by conventional fuels. But because of the poor coal-bed conditions in the European part, the cost of mining coal there is increasing, and, in fact, is higher than the cost of coal production in Siberia. And the cost of transporting the cheaper Siberian coal to regions of greatest demand is prohibitively high. (118)

There are several areas in the USSR with abundant supplies of power but little industry as yet to use that power. Essentially, atomic fuels must be thought of as highly concentrated fuels, i.e., packaged power. If processed in areas where power is cheap and plentiful, nuclear fuels can then be shipped at very low cost to those areas where power is required.

Some localities are so isolated and so poorly endowed by nature that no domestic power resources are available and it is uneconomical to transport large amounts of energy to those regions. A good example is the diamond fields in western Yakutia. Apparently, the deposits which have been found there rival those in South Africa and will enable the USSR to become independent of outside diamond supplies. However, the areas in which they are found are among the most desolate in the USSR. In some parts power is available only at the cost of as much as two rubles, or approximately forty cents, per kilowatt hour. This is about one hundred times the normal cost of industrial power. While present atomic energy costs from small so-called packaged power reactors are very high, they in no way compare with the two-ruble figure. It is probable, then, that small atomic energy plants would at the present time be economically (119)

feasible for these remote locations. In December 1957 Academician A. A. Blagonravov espoused the need for small atomic power plants on mobile caterpillar tracks to serve important areas of the far north.⁽¹²⁰⁾

And it was evident that work on such plants was well underway by then, for a year later an experimental mobile unit was to have been tested at the Institute of Physics of Glavatom.⁽¹²¹⁾ This prototype unit utilizes ceramic-type fuel elements, is gas-cooled, and has a rated output of 2 megawatts of electrical energy.

Another important energy consumer is residential and factory heating. For example, Moscow uses four times as much fuel for heating as it does in the production of electrical power. Large atomic energy stations could provide heat for cities. Soviet atomic engineers fear to have the large stations directly in populated areas and do not contemplate using atomic plants for residential and industrial heating in the early stages of their program. However, it should be expected that as reactors are made more safe and operating experience is gained, atomic stations for space heating will be employed in the USSR.

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ATOMS FOR TRANSPORT

The Soviet program for the use of atomic energy for propulsion is interesting in that it shows that the same forces which contribute to make that subject a controversial political and technical problem in the United States are, quite naturally, present in the USSR. It does not always follow that simply because a particular US technical program is bogged down by internal controversy, the way may be clear in another country, particularly in the USSR, for the rapid and satisfactory solution of that problem. Nor is the contrary always the case.

The major problem in using atomic energy to propel one type of vehicle or another is that of shielding. For in a manned vehicle it is necessary to protect the passengers from the dangerous nuclear radiation which always accompanies large-scale atomic power units. In both manned and/or unmanned vehicles, electronic and physical materials are subject to radiation damage. Although there are various ingenious methods for minimizing radiation effects, all of these schemes require large amounts of bulk weight, and it is not likely that this weight penalty will ever be substantially reduced.

Although there is a great deal in the popular Soviet press on the atomic propulsion, there is practically no information to indicate how advanced the soviets really are in that field. It is pertinent, then, to look at some of the technical developments in this field even though Soviet writers do not identify their contributions as such. Early in 1950 one of Igor Kurchatov's groups began the construction of a nuclear reactor in which shielding materials and other materials might be tested. (122)

A first test stand, although not a reactor, was operated in the spring of 1950 to obtain certain experimental parameters necessary for the test reactor itself. During the course of this work it was decided to build two reactors, one to test shielding materials, and the second to test other properties of the materials.⁽¹²³⁾ The latter reactor, known as the Reactor for Physical and Technical Investigations (RPT) was completed in March 1952 and started in April 1952. No starting date has been publicly released for the shielding reactor.* However, it is reasonable to assume that since its development was parallel to that of the RPT reactor, the shielding reactor went into operation at about the same time. It is pertinent to note that the U.S. materials testing reactor which in function is the counterpart of the RPT, went into operation almost exactly at the same time, on March 31, 1952.⁽¹²⁴⁾ Just as our bulk shielding reactor and materials testing reactors were important to studies in the submarine propulsion reactor, the Soviet reactors could have been (but were not necessarily) intended for a similar development purpose. The same type of reactors are also needed in the development of industrial atomic power plants.

The experimental atomic power station of the USSR went critical on May 9, 1954, and first produced electricity on June 27 of that year.⁽¹²⁵⁾ The powerplant is a direct extension of the RPT reactor but, more significantly, it is not much different from a type of reactor which is adaptable to marine or submarine propulsion problems. In the U.S. a pressurized water reactor (the PWR) is currently favored for propulsion applications. The Soviet atomic power station uses pressurized water as a coolant, but is

* Recently the capacity of this reactor has been raised from 300 kw to 3000 kw.

moderated by graphite. There is an extensive Soviet PWR development program, but this was not revealed until two years after their power station was unveiled. The latter may represent an abandoned technology as far as nuclear propulsion is concerned. Thus, there is a possibility, but no proof, that the prototype power station was initially built for purposes which were other than purely for the generation of civilian electrical power.

The most obvious application to which these reactors might have been directed is the propulsion of nuclear submarines. The first nuclear submarine in the world was the US Nautilus which was launched on January 21, 1954, without all of its nuclear equipment installed. About a year later it was undergoing sea trials under nuclear power. The Nautilus was the forerunner of a family of nuclear submarines which is now under construction. Although there is much speculation in the popular Soviet press about nuclear submarines, there is no published evidence that they possess one. But it is important to note that Soviet fleet emphasis has long been on submarine warfare and the USSR Navy possesses an extensive component of conventional submarines (an active fleet of 475 compared to 110 in the US fleet). Numerous articles in Soviet military and naval media show that the possible advantages of nuclear undersea craft are appreciated. One expert has written:

Submarines with atomic engines can cover enormous distances concealed, and approach, undetected, hostile ships, ports and bases, and deal them surprise blows. Especially notable will be such blows by submarines using atomic weapons. (126)

In view of this philosophy, it would be prudent to conclude as has the Undersea Warfare Advisory Panel of the US Joint Committee on Atomic

Energy that "We must presume that the Soviets will soon possess nuclear submarines which can fire ballistic missiles. The threat from the sea against our cities may assume completely new, and more ominous, dimensions beginning about 1962. ... Their capability in this area should increase rapidly thereafter." (127)

One might further hypothesize that if the shielding and RFT reactors were parts of the atomic submarine development program, the Soviets might have chosen for their first power-producing reactor one which would at the same time provide further information on propulsion and serve as a prototype for their nuclear propulsion program. It would make some sense to proceed in this manner instead of putting their first "Model T" reactor directly in a submarine, for they might feel that a few years' experience would soon make their first atomic submarine obsolete. It should be noted that the initial operation of the Nautilus reactor and the Soviet atomic power station were approximately coincident.

If and when the existence of Soviet nuclear submarines is officially revealed, they are likely to be coupled to such "peaceful" uses as oceanographic research and cable-laying. A recent pamphlet on the subject ascribes only a military intent on the part of the U.S. and suggests that nuclear submarines would only be used for benign purposes by the Soviets. (128)

Another military application of atomic propulsion is in the field of aviation. In the United States this has been a subject of much political maneuvering, the issue appearing to be whether or not one should provide a "Model T" type of aircraft regardless of utility for the purposes of prestige, or world-wide political effect, vs. the long-range development of a military aircraft having advanced operational utility. As a result

(129)
of presidential decision, the United States has adopted the latter course. On the basis of actual and inferred Soviet behavior in the extremely costly field of nuclear development, one would guess that the Soviets have chosen to follow a similar course aimed toward some measure of utility. A major article by Peter Kapitsa on "Some Problems of Organizing Scientific Work" appeared in PRAVDA of May 4, 1957, and indicated that a cautious well-organized approach is being urged. Kapitsa said:

A characteristic feature of the scientific and industrial research institutes is the organization of their research work according to fields of knowledge. Until recently such organization satisfied life's demands.

In the past decade, however, life has increasingly posed the need for solving big scientific and technical problems that embrace several fields of knowledge. Take, for example, an atomic-powered airplane: Its creation requires atomic physicists and specialists in heat and power engineering and in aerodynamics, not to mention designers, metallurgists and others. (130)

It is, of course, entirely possible that the Soviets made their decision some time before we did and may therefore be the first to claim a nuclear aircraft as an operational reality. Despite strong suggestions of military interest by such men as Chief Marshall of Aviation P. F. Zhigarev and Marshall K. Vershinin, there is no published data to indicate actual Soviet progress in nuclear aircraft propulsion. There is, however, a very interesting Soviet text published by the Popular Science Library of the Military Publishing House of the Department of Defense in September 1957. It is entitled, "The Application of Atomic Engines in Aviation." (133)

Although it does not reveal anything which might be considered to be of a secret nature, it does provide -- as no western book published to date provides -- a very comprehensive text for the engineer on the possible modes of achieving nuclear powered flight. The text makes a claim to Soviet priority in this field by referring to a 1935 article of the Soviet scientist O. Petrovsky who described a model of an aircraft which would operate on the energy from nuclear fusion. Petrovsky was aware of the shielding problem at that time and solved it by suggesting that the nuclear components be towed at some distance behind the aircraft itself. (134)

Regardless of the status of their submarine or aircraft programs, the Soviet Union will have on the seas a nuclear-powered ship. It is their icebreaker, The Lenin, which was launched on December 5, 1957, in the Leningrad shipyards without having all of its nuclear components fitted. (135) The latter phase was completed in about ten months and the icebreaker was scheduled for operation in the spring of 1959. The Lenin contains three nuclear reactors powering four turbogenerators, which in turn, enable the motors to develop a maximum shaft output of 44,000 horsepower. The Lenin will be able to ply the northern sea routes for periods of about a year at full power without refueling. Under normal conditions, two of the reactors would be operating; the third would be used only when heaviest ice conditions were encountered. A staff of "specialist-physicists" will be aboard to supervise the complex reactor controls. (136)

Conventional icebreakers are able to perform their tasks for a period of only about one month before refueling. Clearly, in the desolate Arctic wastes, the atomic icebreaker will have a definite advantage. It is also planned to construct more icebreakers for rivers and large inland reservoirs.

The nuclear "heart" of the Lenin is a pressurized water reactor of almost the same type as that powering the U.S. submarine Nautilus.⁽¹³⁷⁾ Its nuclear power plant may have been already well developed for a classified function like the propulsion of a submarine. In any event, the Lenin is now clear evidence of that capability.

It is doubtful that there are strong motives for Soviet construction of large, ocean-going vessels or merchant ships since this has never been a strong point in their conventional maritime policy. Popular and technical discussion of such ships exists, but there is no indication of official interest. (138), (139)

That there is more than a superficial Soviet interest in the problems of nuclear propulsion is indicated by the recent creation (in 1954) of the Institute of Complex Transportation Problems in Moscow.^{(140)*} The importance of the Institute was evidently enhanced by the directive of the Twentieth Party Congress in February 1956 which read:

Begin work for setting up atomic-powered apparatus for transport purposes. Construct a nuclear-powered icebreaker. (141)

The appellation "Complex" may be synonymous with "atomic", since this seems to be the major interest of this Institute. The bulk of the work of the Institute of Complex Transportation Problems seems to be concerned more with the associated problems and economics of coupling of conventional transport systems to atomic cores than with work on the development of atomic reactors themselves. The Director, Tirgan Sergeyevich Khachaturov,

* At Nizhnaya Krasnosel'skaya Ulitsa, No. 39, in the northeast sector of the city. (MOSCOW BRIEF ADDRESS-GUIDE BOOK, 1956, p. 100. Unless otherwise noted, other Moscow addresses footnoted are from the same source.)

is a well-known economist specializing in transportation problems. (142)

The Institute is also working on tasks of nuclear propulsion for locomotives and automobiles. (143) For example, they note that only a few grams of uranium would be needed to operate the average-sized Soviet car, the Pobeda, for 62,000 miles instead of the 12 to 15 tons of petrol usually required. But the great practical difficulties for these applications can be related to the radiation problem. Even if it were possible to overcome the weight aspect, the normal incidence of train and automobile accidents would seem to present the problem of radioactive contamination from damaged atomic motors, and it is doubted that the Institute has made great progress toward an atomic automobile.

(144)
A study on atomic locomotion which received considerable western notice did not come from the Institute of Complex Transportation Problems but originated as a student's thesis from the Bauman Higher Technical School in Moscow. The study was based on western data and should not be taken as any indication of a serious Soviet atomic locomotion project. The Institute regards the electrification of railway power lines by means of atomic power stations as more meaningful than an atomic locomotive. (140)

What is more interesting, however, is the fact that students are encouraged to look into problems such as these and to use their imaginations in projecting future applications of atomic energy. Indeed, all segments of the Russian public and specialized audiences are stimulated to think about extremely advanced problems. To take an example from the propulsion field, Doctor of Physical Mathematical Sciences, Ye. Balabanov, has discussed the problem of driving aircraft with thermonuclear motors, using certain ionic propulsion techniques which seem to be developing in the thermonuclear research program. (See "Harnessing the Sun.") (145)

Herein seems to lie an important bit of Soviet philosophy, to wit:
If a particular scientific development is foreseeable but seems to be particularly remote, there is a definite advantage in publicizing those concepts to encourage ideas which may make such developments less remote. Perhaps here is a philosophy which western classification experts would do well to ponder more carefully.

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"BUY USEFUL ISOTOPES!"

The most versatile atomic tool for almost every experimenter in all of the sciences is the radioactive isotope which, with the aid of the radiation detector, can be used to trace physical and biological processes. Radioactive tracer studies have been conducted in ever increasing number since the beginning of the century. The first investigators were limited by the few appropriate radioactive isotopes which could be found in nature, and later by the several that could be manufactured in extremely small amounts by accelerating machines like the cyclotron.

One of the most ambitious early radioisotope programs was undertaken in 1940 by the All-Union Institute for Experimental Medicine which constructed a radioisotope laboratory with the aid of scientists from the Lebedev Institute in Moscow. In that same year the All-Union Institute ordered from the Ukrainian Physical Technical Institute the construction of a linear accelerator for the production of isotopes for medical biological research. However, most of this work was terminated by the onset of World War II.

With the coming of the nuclear reactor, it became possible to obtain fantastically large amounts of radioactive isotopes in considerable variety. Radioactive isotopes were manufactured in the first Soviet reactor, but because of its extreme low power and because of its low priority in relation to other studies, isotopes could not have been available at that time in any great amount. As the more powerful Soviet nuclear reactors came into operation, isotopes began to be used on a very wide scale throughout the USSR. Radioisotope laboratories have been built in higher educational institutes in Moscow, Leningrad, Kiev, Gorki, Kharkov, and Minsk. They

are also used in numerous industrial laboratories in those areas and in the most remote areas of Uzbekistan, Kazakhstan, and in the Latvian Republic. They are used in medical and industrial laboratories from Archangel to Vladivostok, and on the Arctic ice island research station, "North Pole - 5."⁽¹⁴⁸⁾

In 1955 the total number of shipments of radioactive isotopes to various areas of Russia amounted to 1,500 packages per month.⁽¹⁴⁹⁾ This may be compared to approximately 900 per month for that same year shipped by the US AEC to users in the United States. By the first quarter of 1957, the Russian monthly average had risen to 2,250 shipments.⁽¹⁵⁰⁾

The over-all technical aspects of the Soviet isotope program are supervised by the Chief Directorate for the Utilization of Atomic Energy of the Council of Ministers.⁽¹⁵¹⁾ However, distribution is arranged by a state All-Union Trust, "SOYUZPEAKTIV," of the Ministry of Chemical Industry. Occasional newspaper advertisements are taken by SOYUZREAKTIV to plug its products.⁽¹⁵²⁾ "Buy Useful Isotopes!" they proclaim.⁽¹⁵³⁾ A slick paper prospectus and accompanying price list is periodically issued by SOYUZREAKTIV listing over five hundred different compounds of specific isotopes. The SOYUZREAKTIV catalogue bears some similarity to that issued by the US AEC Oak Ridge operation. However, there is no exact correspondence between certain isotopes which are available from the Soviet agency and from Oak Ridge. Regarding prices, it should be noted that the ruble/dollar ratios for the same isotopes are generally less for those isotopes produced by neutron beam irradiation in a reactor than for those which must be separated from fission products. This might indicate that there is an abundance of atomic reactor facilities in the USSR with what is termed high reactivity (that is, lots of excess neutrons) as compared with the United States. But this comparison

cannot be made with certainty since all Russian prices of any commodity are artificially established.

The SOYUZREAKTIV catalogue also lists stable isotopes which must be separated from a mixture of isotopes as found in the artificial state. This separation of stable isotopes seems to have been pioneered in the USSR by a group in the Institute of Atomic Energy and by other groups of Soviet scientists working with captive German specialists. (151)

Two of the German scientists are given major credit for the development of some of the techniques. This is indeed unusual, for the Soviets would prefer to have the West believe that the Soviet atomic energy program developed entirely on the basis of native talents. So the credits are hidden in papers authored by Soviet scientists. Manfred von Ardenne is credited with the development (in 1950) of special ion sources for use in separation mass spectrometers. (154) Gustav Hertz, who conceived the notion of using gas diffusion for separation processes, led a German-Soviet group during 1946-1952 in the development of several diffusion-types of isotope separation. (155) As a non-Soviet citizen, Hertz can claim the unique distinction of having been awarded both the Nobel and Stalin Prizes. Von Ardenne and Hertz have been repatriated to direct the East German atomic energy program. (156)

There are now in the Soviet Union over a dozen large-scale isotope separators, operating on the electromagnetic principle, to provide research institutions with a wide variety of stable isotopes. During a five-month period on 1958, over 100 isotope shipments were made from the separators of the Institute of Atomic Energy. (157)

As to specific uses of isotopes, it would be impossible to label any

of the "SSR or western applications as unique, for it is in this field of atomic energy that it can be said that there seems to be unlimited exchange of information by all scientists concerned. Information on isotopes was the first to "unfreeze" (about August 1953) in the USSR, and there has been an uninterrupted flow ever since. Since that time scientists everywhere have been quick to adapt a particular isotope process as soon as it has been publicized.

At an international meeting held in April of 1957 in Moscow, and at the Second Geneva Conference in 1958, representatives from a wide variety of Soviet industries discussed the ways in which they are putting isotopes to use. Scientists from the silk industry research institutes told how they are using radiations from isotopes to change the sex of silk worms, to preserve their cocoons, and to remove static charges as the silk is being processed. (Irradiation of raw silk produces a stronger, better-knitting silk than does the usual heat treatment of cocoons.) The fur institutes use radiation to measure hair depth of fur pelts, and the shoe leather institutes measure the thicknesses of raw and cured leather by means of radiation. The milk industry uses isotopes for automatic regulation of a number of the milk production processes, and the USSR River Fleet employs radioactive isotopes as soil gauges for suction dredgers in checking the water level in the Moscow-Volga Canal and for corrosion studies on mechanical components of ships. In addition to the small radioactive isotope sources there are available large sources which have an equivalent strength of up to 20,000 grams or more of radium. These large sources are used in medical institutions for therapeutical purposes, by food research institutes for preservation of food, by the rubber industry for vulcanization

of rubber, and for the polymerization of certain plastics.

There is considerable interest in using radioactive isotopes for special power purposes. While the cost of electricity generated by such "atomic electric batteries" may be prohibitive, their use with poor economies may be justified by the importance and urgency of specific applications. For future earth satellites it is planned to use atomic batteries weighing 110 to 115 kilograms, generating 100 watts of electricity. Strontium-90 is contemplated as one of the energy sources. Since this isotope has a half-life of 27 years, the sputnik will be powered effectively throughout its useful life span.

Nature also produces her own radioactive substances in the atmosphere, the most abundant of which is carbon-14. The use of the extremely low amounts of carbon-14 as tracers in archeological, biologic, and other sciences was pioneered by W. F. Libby at the University of Chicago, and the Soviets have been quick to adapt his method in special carbon-14 laboratories.

All of these applications, which are merely illustrative and do not pretend to encompass the vast scope of radioisotope application in the USSR, must be backed up by an industry which produces instrumentation for the proper use of isotopes. Many items of equipment which the Soviets have displayed at international fairs and at their atomic pavillion in Moscow are commonly available and are often advertised in the newspapers. Specific institutes do draw up specifications for instruments which have a specialized or particular application. There are, however, generally available to industry the services of the laboratory of Atomic Instruments which is a branch of the All-Union Instrument Research Institute. Factories or other institutes having particular problems in the application of isotopes can

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request the assistance of the Laboratory of Atomic Instruments.

Thus, the use of isotopes is given maximum encouragement in the USSR, resulting, for example, in a saving for the national economy of 1.5 billion rubles in 1957 ⁽¹⁶¹⁾ (compared to a US figure of \$500 million ⁽¹⁶²⁾). And, while they are perhaps not as spectacular as nuclear reactors or gigantic accelerators, isotopes have a vast economic and medical potential which should not be under-rated.

MATERIAL RESOURCES

Any atomic energy program must have as its basis an abundance of accessible uranium-bearing ores. The most celebrated of the USSR deposits are those which are found in the Fergana Valley in the Central Asian Republics of Kirghizstan and Tadzhikstan. In the pre-World War II period these deposits had been mined for their radium content and the then useless uranium simply dumped. The main centers of mining at that time were near the villages of Tyuya-Muyun and Taboshar. (163)(164)

Since the war Soviet geologists have carried out an extensive program of uranium prospecting throughout the USSR. However, the locations and richness of the various deposits are guarded almost as zealously as the atomic bomb stockpile figures. In fact, no published information is available to indicate the extent of the internal USSR uranium deposits. USSR geologists at international meetings do not respond to questions regarding location.

The Soviets, however, obtain a good fraction of their uranium from abroad, chiefly in several of the satellite countries. As soon as the war with Germany was concluded, Russian geologists under the direction of Colonel General I. A. Serov (recently deposed head of the Committee of State Security, KGB, and an old hand in secret police work), went into the uranium rich Saxony region of Germany. This "Geologic Prospecting Group No. 1" was able to confirm the presence of tempting ore bodies. However, since the region at that time was occupied by American troops, it was impossible to proceed with the prospecting. When the US troops retreated from the Elbe to the agreed lines of zone demarcation, Soviet geologists followed and initiated exploitation of the uranium deposits in Saxony.

Further expansion occurred in 1946 with the appointment of a high secret police official, Major General Mikhail Mitrofanovich Mal'tsev, to head the operation under the code name of "Wismut A. G.," which means bismuth in German. A decree dated July 17, 1947, formally established the East German Corporation of Wismut. This date again confirms that June 1947 was the critical decision period in the Soviet atomic energy program. Although highly secret at first, the existence of such a large operation in Germany could not possibly have been kept hidden, and there have since appeared occasional references to the activities of the organization in East German newspapers.

Another important source of Russian uranium has been Czechoslovakia, where, using forced labor, uranium has been mined in the Joachimsthal area of Western Czechoslovakia and in the Pribram region of Central Bohemia. The Joachimsthal mines are six hundred years old and for centuries were exploited as sources of silver and lead. After the discovery of radium, the site became an important production center for that material. It was natural that the Soviets would covet the uranium content of the mines after World War II. The deposits are still producing and, for the most part, are now under the direction of Czechoslovak experts. In the past few years Czechoslovakia has negotiated a price with the Soviet Union, and it is claimed that the uranium is sold under the same conditions that Belgium sells her Congo uranium to the United States.

Other deposits of uranium are being exploited in Poland, Rumania, and Hungary. In the latter country the uranium miners at Pecs were among the first to strike in the general revolt of 1956. Because of the possibility of instabilities in the satellite uranium situation, and because of the

general drive toward self-sufficiency, the development of domestic USSR sources continues. There have been many indications that the number of deposits thus far found in the USSR is not deemed to be satisfactory to meet the expanding needs of the Soviet atomic weapons and power programs, and that they envy the West its vast uranium resources. For example, a 1955 book by A. A. Santalov entitled, "The Imperialist Struggle for Raw Material Resources," charged that the U.S. was monopolizing the non-Communist world supply of uranium, and soon after publication of the book, (171) PRAVDA echoed the same charge in stronger terms.

Since the announcement of the goals of the Sixth Five-Year Plan in 1956, Petr Yakovlevich Antropov, the Minister of Geology and Preservation of Resources of the USSR, has been publicly urging the expansion of exploration for rare minerals, including uranium. In articles called, "Search for Uranium!", the Ministry spokesmen have been urging young people to look (172, 173) everywhere on their hunting, fishing, and camping trips for uranium. "Look in old quarries and under your houses." Geiger counters (in Russian parlance, "radiometer indicators") had been furnished the young pioneer groups by the Ministry. However, there has been some criticism that the instruments are not sufficiently widely available. Of course, more extensive and complex prospecting, which includes the use of survey aircraft, has been carried out by the Ministry. What they have discovered is not likely to be published.

Never neglecting an opportunity to assert priority, the Soviets claim (174) the discovery of a number of new uranium-bearing minerals, although they are reluctant to state where the minerals can be found. In 1947, the (175) minerals gidronasturan (hydronasturan) and urgite were claimed. A new

silicate-type uranium mineral was named nenadkevite, in 1952, for a Soviet geochemist K. A. Nenadkevich. In 1953 there appeared natrootenite, and even a nineteenth century poet is now enshrined in the annals of Soviet atomic mineralogy in the naming of a uranium-phosphate ore lermontovite, after Mikhail Lermontov. Lermontov is often styled as the "Poet of the Caucasus"; perhaps it is not too risky to surmise that lermontovite is also native to that area.

An indication of Soviet intent in exploiting uranium resources to the fullest extent is provided by their interesting work in the extraction of uranium from natural lake waters. The uranium content of such waters is exceedingly low, but the comparative ease of extraction from such a source has led Soviet geologists to conclude that this process is more economical than that of processing several types of poor uranium ores. So an industrial scale operation for extraction from water was initiated during 1952-53.

Much of the work in the identification of the new minerals is performed by the Moscow Institute of the Geology of Ore Deposits (IGEM).^{*} Prospecting and identification instrumentation is developed by several institutes. One of the more interesting developments for rapid ore assay as it comes from the mines is a special apparatus called the Stationary Radiometer Control (RKS) which is placed on the tracks which carry the wagons of ore from the mines. The bulk radiation from the ores serves to indicate the uranium content. This apparatus has been under continuous development since 1946, and is apparently used extensively in Soviet uranium operations.

*Staromonetny Lane No. 35, south Moscow.

The other main atomic energy material is thorium which after appropriate processing and irradiation in a nuclear reactor can be changed to a fissionable material, uranium-233. Thorium has not extensively been used yet in atomic energy programs. However, the Soviets have shown an intense interest in the mineral; and since they have carried out thorough metallurgical research on thorium and have performed the requisite measurements on its nuclear properties, it is assumed that at the appropriate stage the Soviet thorium resources will be developed, if they have not been up to the present time.

There are other resources involved in atomic energy programs. In processing most of the materials the main problem is to eliminate impurities which will capture neutrons in a nuclear reactor, and thus be detrimental to the operation of the reactor. The purity problem is most critical in the manufacture of the nuclear fuel and the moderator materials. One of the common moderators is graphite, which is found in a natural state. However, natural graphite is difficult to purify and does not possess certain other requisite properties pertaining to density. It is therefore necessary for the atomic energy program to make artificial graphite from petroleum pitch. The existence of a number of nuclear reactors using graphite moderators in the USSR is proof enough that the barriers in manufacturing artificial graphite have been overcome. Substantial amounts of graphite will be required for the USSR atomic power stations. This is now the basis of a small thriving small industry in the USSR.

Another important moderator material is beryllium which has some promise for future families of nuclear reactors. In the USSR beryllium production has been developed and an experimental nuclear critical assembly

(186)
was actually built in 1954 using a beryllium moderator. This material is also being alloyed with magnesium as a cladding for certain fuel elements.

Heavy water, another moderating substance which is present to the extent of one part in 6,000 in ordinary water, has been used extensively in the USSR. There are many methods of obtaining heavy water from natural water. One of these methods is to use electrolysis in conjunction with the operation of nitrogen fertilizer plants. This was the process used during the war at Trail, British Columbia, to obtain heavy water for the US project. It was also the method used in the USSR at Chirchik in Central Asia before World War II and at Dniepropetrovsk to obtain small amounts of heavy water for experimental purposes. Recently, Kurchatov has praised the development by the Institute of Physical Problems of a method of using low temperature rectification of hydrogen for obtaining heavy water. This method was described in greater detail at the 1958 Geneva Conference by both Soviet and US scientists. The low-temperature distillation method had been under development in the USSR since 1946, and a large-scale production plant has been operating now for several years. Production of heavy water in the USSR is not confined to this method, and Kurchatov has stated, "We now produce deuterium on an industrial scale by various methods."

There are several institutes in the USSR which are devoted to problems of rare metals, some of which have application to the atomic energy program. Three of these organizations are the Institute of Mineralogy, Geochemistry, and Crystal Chemistry of Rare Elements, the Scientific Research Institute of Rare and Light Elements (in Moscow), and the Irkutsk Scientific Research Institute of Rare Metals. However, when a technology of a rare metal has to be developed for the atomic energy program, this work is usually carried

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out by one or more of the institutes directly engaged in atomic energy work. For example, the Moscow Engineering Physics Institute has done extensive research on the metallurgy of thorium, zirconium, and niobium alloys. As in any country embarked on a large scale atomic energy program, a broad network of supplementary institutes and industries has evolved in the USSR.

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ATTACK ON THE FUTURE

The most costly and perhaps the most impressive of the physicists' tools are the machines which accelerate elementary atomic particles to exceedingly high energies -- energies at which the most complex of nuclear particles can be made to disintegrate and, indeed, entirely new strange particles begin to appear. A prominent physicist was once asked by an administrator for a justification of the costs of a gigantic accelerator which the physicist was about to build. He was asked in particular what he expected to find after the machine had been constructed. The physicist replied that if he knew what he expected to find he would have no use for the machine in the first place. Thus, the accelerator is the physicists' tool for probing into the unknown. And since this probing on a nuclear scale is extremely forceful, in a sense the accelerating machines can be considered the physicists' artillery.

For the most advanced of these machines which produce energies of cosmic magnitudes there are few, if any, foreseeable practical applications, yet the construction of these machines has received unprecedented financial support in the post-World War II period from many governments. Indeed, the USSR is not only not an exception, but has achieved some spectacular successes in this field.

There is now in the USSR such a profusion of small nuclear accelerating machines in use in scientific institutes and in factory laboratories that a complete listing of the accelerators would be a major project in itself and would probably serve no useful purpose except to show the extent of the USSR accelerator program. This is already evident from general considerations. It will, perhaps, suffice therefore to list here a few of the

major accelerator developments. In doing so, it will be necessary to define only too briefly some of the different types of accelerating machines which will be encountered. Some of the labels are peculiar to Soviet literature so their western equivalents will also be given. The Soviet scientists themselves are beginning to use the terms interchangeably.

The basic types of accelerators for obtaining high energy nuclear particles are:

The Linear Accelerator in which, by a suitable combination of electric and/or magnetic fields particles are progressively accelerated down a long tube. This is the earliest type of accelerator developed, and several variants of it producing particles of small energy are to be found in different USSR laboratories. At the Kharkov Physico-Technical Institute, a group under the direction of K. D. Sinel'nikov specializes in designing linear accelerators for use as beam injectors for the larger accelerating machines. Most of the significant USSR accelerators, however, are of the circular type and fall into the following categories.

The Cyclotron. This was invented and developed by Ernest O. Lawrence at the University of California in the early 1930's. The first cyclotron in Europe was constructed in the USSR by Kurchatov and his collaborators. However, there are definite limits to the energies which can be obtained in a cyclotron and it was therefore necessary to devise new principles to accelerate particles to higher energies. These principles essentially consist of providing various types of variations of electric and magnetic fields. The variations are complex and will not be elaborated upon here,

* The versatile Sinel'nikov also directs programs in thermonuclear research and in special alloys for nuclear reactors.

but a few of the different types of machines will be listed. They are:

The Synchrotron, which accelerates electrons, represents the first step forward after the invention of the cyclotron in obtaining higher energies. The principle of the synchrotron was invented by a Russian, Vladimir I. Veksler, and it was communicated and published in a Russian journal as early as April 1944. This was at the time when some Soviet physicists had just resumed their work so that this must have represented one of the earlier fruits of Veksler's renewed labor. Subsequently, an American, Dr. Edwin McMillan, a colleague of Lawrence's independently invented the same principle in July 1945. McMillan's work was published in September 1945 but Veksler protested and claimed earlier priority. McMillan gracefully acknowledged in a later letter that, "... it is clear that Veksler's discovery of the principle was earlier." Veksler stated in his letter of protest that a 30-million-electron-volt (Mev) machine using his principle was nearing completion at the Lebedev Physics Institute of the Academy of Sciences of the USSR, and it would seem that this was the first high energy electron accelerator to be built in the USSR in the post-war period. Later, in 1948, a machine having a tenfold larger amount of energy than Veksler's came into operation at the University of California, but the Soviets were not far behind in placing into operation in the last days of 1949, also at the Lebedev Institute, a machine of approximately the same size as the American machine. The 30-Mev and 280-Mev machines are still being usefully employed at the Institute for advanced research.

*An electron volt is the amount of energy an electron will acquire by being accelerated through an electrical field of one volt. Chemical energies are usually measured in terms of electron volts or less, while nuclear energies occur in quantities of thousands, millions, or even billions of electron volts.

It is pertinent to note the time at which this larger machine went into operation, for it corresponds roughly to the time of the achievement of the first Soviet atomic bomb. It therefore represents a diversion of men and materials during a period when such were scarce and the atomic bomb had highest development priority. And the decision to proceed with a large accelerator construction program must have been made in 1947, concurrently with the vital decision on the atomic bomb. But, more significantly, the Veksler accelerator was not the largest nor the most expensive one to be put into operation in this critical period. This honor belongs to the gigantic phasotron (which in US terminology would be called a synchro-cyclotron) at a then highly secret laboratory some 60 miles north of Moscow, at Dubna. The construction of this phasotron, as might be supposed, was one of the multiple responsibilities of Igor Kurchatov, and "it is to him that much of the credit for its ultimate success is due." (202) Coming into operation on December 14, 1949, the phasotron was designed to accelerate much heavier particles than electrons, namely, protons, to energies of 280 Mev, and alpha particles to energies of 560 Mev. At the end of 1950 the phasotron was converted so that it could accelerate protons to energies of about 500 Mev and in 1953, after an extensive nuclear research program with the various particles of the above energies, the machine was converted to give proton energies of 680 Mev. This is an indeed impressive machine and is so arranged that as many as 12 to 16 different experiments can be carried out simultaneously on it. As Dr. Luis Alvarez, another colleague of E. O. Lawrence, described it, "I have seen all the large American cyclotrons, and this is better engineered than any of ours." (204)

The modest manner in which the Dubna phasotron first came to the

attention of the western world is rather curious. The first papers giving results of experiments done on the machines were submitted to a Russian journal in November 1954, and published in a December issue of that journal. (205) US scientists did not become fully aware of the implications of those papers until March 1955. (206) It should be recalled that during the Stalin period and approximately for a year afterwards, all of Soviet nuclear science, whether pure or applied, was classified. There is therefore no reason why the Russian phasotron work which was performed up to 1953 would have been declassified at that time. After the phasotron was reconstructed to provide particles of higher energy, Soviet scientists probably wished to report their best work so that, allowing time for further experimentation and analysis, the actual publication date at the end of 1954 appears to be explainable.

Until the middle of 1956 the Dubna phasotron was the largest of its type in the world. However, since the operation of the University of California machine at energies in excess of 700 Mev, the Dubna installation has had to take second place. But the Soviets had been working on still more powerful accelerating machines of different types.

A synchrophasotron which operates on still different principles and is capable of producing exceedingly energetic nuclear particles, came into operation during March, 1957. (207) When it did so, it took the lead from two US similar machines: the cosmotron at Brookhaven National Laboratory operated at approximately 2 billion electron volts (Bev); and the 6.2-Bev bevatron at the University of California Radiation Laboratory. Proton beam energies of 10 Bev were obtained in the new Russian synchrophasotron in May, 1957; this represented the greatest energy ever attained in a nuclear

(208)
machine. In size, the 10-Bev machine is most impressive, for the weight of its magnet alone is 36,000 tons (the weight of a heavy cruiser), and the diameter of the device is about 200 feet. (209) The estimated equivalent US cost for such a machine would be about \$100 million. There appear to have been a number of difficulties in getting the device to operate (210) properly, and many of the Russian scientists themselves feel that its initial operation had been mainly for prestige purposes.

The physical location of the 10-Bev synchrophasotron is at the Electro-Physical Institute directed by Veksler and is part of the Dubna research complex which now bears the name of the Joint Institute for Nuclear Research. (Veksler's Institute is now officially termed the High Energy Laboratory of the Joint Institute.) In the international race for machines of higher energy, the Dubna device will be outstripped, about 1960, by a machine being built at Brookhaven and by one at the European Organization for Nuclear Research (CERN), at Geneva. These western machines will be in the range of 25 to 30 Bev. However, the Russians do not like to be left behind, and at the Institute of Electro-Physical Apparatus (apparently the major (211) accelerator engineering design organization in the USSR) in Leningrad, a 50-Bev synchrophasotron is in a late design stage. Using new principles, the new machine will weigh less than the 10-Bev machine, that is, approximately 22,000 tons. It will, however, have an impressively large diameter of over 1,500 feet. The location of the 50-Bev machine is not know, and because it definitely does not seem to be called for in the published advance plans of the Joint Institute for Nuclear Research, it seems likely that it will not be at Dubna. Moreover, the plans are being made under the direc- (212, 213) tion of V. V. Vladimirovsky who is not usually identified with Veksler's group but with the Thermotechnical Laboratory of A. I. Alikhanov. Undoubtedly,

after this 50-Bev machine is built, the Russians will again temporarily lose their lead to a western machine. However, it is certain that they will bid higher and higher and Veksler himself has given some indication of how high their final bid might be:

I do not doubt, however, that experimental physics will succeed in solving this problem too, and that we shall learn how to create artificially particles with enormous energies of the order of a million million to ten million million electron-volts. (214)
(215)

At international meetings held in Russia in May 1956 and at Geneva in (216) June 1956, Soviet scientists gave some indications of how they are going to attempt to reach these higher energies and to improve accelerator designs. Veksler described the concept of making the accelerating field appear only in the vicinity of the accelerated particle itself. This is a very advanced relativistic concept, and the reader should not be bothered if it is not clear to him, for at least one of the prominent US accelerator experts present at Veksler's talk has confessed an inability to understand (218) the concept. Another, even more speculative idea was presented by a young scientist in Kurchatov's Institute, G. I. Budker, who described the possibility of using the so-called pinch effect, which is important in thermo-nuclear work, to provide in accelerators of very small diameters intense (219) proton beams having energies as high as 100 bev. A very small-scale model (220) has already been built. If Budker's large-scale machine can actually be built, then the energies obtained will be a tenth of the way toward Veksler's envisioned goal.

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HARNESSING THE SUN

In 1927, when Nikolai Bukharin offered the entire electrical output of the city of Leningrad for research in the production of thermonuclear (221) energy, it is quite clear that if this offer had been accepted by the scientists it would have been to no avail. But the story is illustrative of the willingness of Soviet planners to venture into untried fields, then and now. For, in the 1920's, the knowledge required to simulate the types of nuclear reactions which occur in our sun and other stars was entirely inadequate and undeveloped. Much of the required information came into being during the 1930's which, the world over, represented a period of remarkable discoveries in the field of nuclear physics, particularly at the Cavendish Laboratory in England and at the Enrico Fermi Laboratory in Rome. It is interesting that almost all of the experiments on the nuclear physics of light elements, which were to prove to be so important later, were immediately repeated and extended in the laboratory of Igor V. Kurchatov as soon as they had been performed outside of Russia. It is (222, 223) thus not unnatural that after the Soviet physicists had accomplished their primary mission of achieving the atomic bomb, they should turn to research on a promising new energy source, and the year 1950 appears to be the date (224) when Soviet research on controlled thermonuclear reactions was started. This is approximately one to two years before similar work was initiated (225) on a serious scale in Britain and the US.

As the name "thermonuclear" implies, the problem involved is to heat an appropriate isotope such as deuterium, a heavy isotope of hydrogen, to a temperature so high that by virtue of their thermal motions alone the deuterium nuclei will collide, combine, and thus emit large quantities of

energy. If the emitted energy can be used for the further heating of gas, the reaction will be self-sustaining. As Kurchatov has pointed out, the amount of energy required to heat such a gas initially "is about the same amount of energy required to boil water in the family samovar." ⁽²²⁶⁾ The problem involved, however, is to transfer all of this energy to the deuterium nuclei and to prevent it from radiating out into space again. It is interesting that the major approach to this heat containment problem is remarkably similar in the US, the USSR, and the UK. The first opportunity to make such a comparison occurred when some of the Soviet experiments were described by Kurchatov at the British Nuclear Research Establishment at Harwell on April 25, 1956.

Both the US and the USSR, the latter perhaps a bit earlier, were able to produce "spurious" thermonuclear reactions in their apparatuses, and by very interesting diagnostic and theoretical work were able independently ^(227, 228, 229) to recognize the spurious reactions as such. The British and US work was announced simultaneously on January 24, 1958; ⁽²³⁰⁾ and on January 29 a Soviet broadcast ⁽²³¹⁾ hailed the UK work and depreciated that of the US simply by not mentioning it. On February 28, Academician Kurchatov drove the wedge still further by a fuller description of the British work and stating that ⁽²³²⁾ the American work basically did not represent any new facts. Within six months after the specifications for the British thermonuclear machine, "Zeta", had been released, the Russians had constructed in Leningrad a faithful reproduction named "Alpha." This can be taken as an indication that the Soviet controlled thermonuclear program was still seeking direction and that all possibilities were being considered and tried.

What is perhaps more interesting than the relative technical progress

of the three countries in the thermonuclear field is the fact that the Soviets have recognized the emotional and political appeal of a development of such promise. There are strong indications that the Soviets may feel that the momentary political value of their work may be more important than the possible future end results. And in this respect Igor Kurchatov represents the political as well as the technical instrument for implementation of the Soviet controlled thermonuclear reaction program.

Because of a possible military application of controlled thermonuclear reactions, the actual work of the various nations engaged in this field was classified until the spring of 1956. It was Igor Kurchatov and his Harwell talk which broke that classification barrier for the first time. The world reaction to his talk was more than he possibly could have desired, and the Soviet press and radio were quick to follow this coup with self-praise. In 1956 Kurchatov also made an offer to the scientists of the world to the effect that if they could persuade their governments to agree to a ban on the use of nuclear weapons, the Soviet scientists could cooperate in thermonuclear research with their western colleagues and this would open the way for full scientific cooperation among all nations of the world. (233) (234) Two years later Kurchatov re-emphasized this issue. He pointed out that such eminent American physicists as Edward Teller who were closely connected with the hydrogen bomb were also working on the peaceful controlled thermonuclear reactions; he also emphasized the possible military applications of controlled thermonuclear reactions. Kurchatov concluded that in this atmosphere it would be impossible to expect complete frankness among scientists of different nations and concluded again that complete cooperation was possible only if nuclear weapons were banned.

On the technical level the controlled thermonuclear work is the responsibility of Kurchatov's Institute of Atomic Energy in Moscow, and to a lesser extent, of Moscow State University, and of institutes in Sukhumi, Leningrad, and Kharkov. The special thermonuclear section is headed by Academician Lev Andreevich Artzimovich whose background marks him as an expert in the fields of electron optics and atomic accelerators. Both of these related arts are important in the controlling of thermonuclear reactions. Also, as was the case in the US, many individuals engaged in the thermonuclear effort were recruited from the cadres which earlier worked on the electromagnetic separation of isotopes. Artzimovich played an essential and perhaps the leading role in the latter effort. The theoretical thermonuclear work is directed by Academician M. A. Leontovich assisted by a number of able young theoreticians including Academicians A. D. Sakharov, V. D. Shafronov, and G. I. Budker. In June 1956, young Budker impressed his western colleagues by describing, at a meeting held in Geneva, an imaginative and revolutionary type of nuclear accelerator (described in "Attack on the Future") which quite likely will have important application in the thermonuclear problem. Rewarded for his outstanding work Budker has recently been sent to head the newly established Institute of Physics of the great scientific complex which is to be established near Novosibirsk in Siberia. Budker's Institute will act as an extension of Artzimovich's laboratory so that it should become one of the two most important centers of thermonuclear research in the USSR.

In August 1958 Chinese scientists at the Institute of Atomic Energy in Peiping were treated to a preview description of an experimental thermonuclear device (named "Ogra") which had just been built at the Moscow

(241)
Institute. Resembling a long wind tunnel 65 feet long and 4-1/2 feet in diameter, Ogra dwarfed any other thermonuclear device in the West. It has certain similarities to another, smaller device known as "DCX" developed at the Oak Ridge National Laboratories. At the 1958 Geneva Conference on the Peaceful Uses of Atomic Energy the US and Britain formally lifted all secrecy on data that will be obtained from DCX and all other controlled thermonuclear experimentation. It would be hoped that Ogra (which is a contraction of the Russian word for "fenced in") and its kin will be discussed just as freely as data is obtained.

Artzimovich and several of his colleagues have already been honored for their thermonuclear research as recipients of the 1958 Lenin Prize. (242)
But the controlled thermonuclear reaction problem is still far from solution, and it is meaningless at this point to give a "lead" to any one nation. But with its extensive program, at least as large as that of the U.S. and several-fold that of Britain, the Soviet Union stands a very good chance of establishing further thermonuclear guide posts of political and technical significance.

Kurchatov has noted that the earth's deposits of uranium and thorium would be sufficient to last only several hundred years if all of the world's power were made dependent on the fission process. This is probably an underestimate, but whether the fission time scale is in terms of hundreds or thousands of years, there is sufficient deuterium present in the earth's oceans to meet the world's power requirements, at the present rate of consumption, for about one hundred million million years. Clearly, there is an incentive here for the Soviet Union as well as for any other nation to be the first to tap this enormous resource.

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REFERENCES*

1. Kramish, Arnold, The Soviet Union and the Atom: The Secret Phase, The RAND Corporation, Research Memorandum, RM-1896, April 11, 1957, p. 70.
2. Kravchenko, Victor, I Chose Freedom, Scribner, New York, 1946, p. 404.
3. Izvestiya, December 17, 1953.
4. Vedomosti Verkhovnogo Soveta, March 11, 1955, No. 3(821), p. 68.
5. Ibid., June 20, 1955, No. 9(827), p. 268.
6. Pravda, May 11, 1957.
7. Vedomosti Verkhovnogo Soveta, August 6, 1957, No. 15(882), p. 481.
8. Pravda, January 2, 1957, p. 2.
9. Komsomol'skaya Pravda, January 4, 1957.
10. The New York Times, February 21, 1957.
11. Pravda, July 25, 1957, p. 4.
12. Ibid., December 31, 1957, p. 1.
13. Yemel'yanov, V. S., et al., "Research on the Iodide Method of Refining Zirconium," Atomnaya Energiya, No. 1, 1956, pp. 43-51.
14. Yemel'yanov, V. S., and A. I. Yevstyukhin, "Research on a System of Fused Salts of Base Fluorides of Thorium," Atomnaya Energiya, No. 4, 1956, pp. 107-112 (Part I); No. 5, 1956, pp. 80-85 (Part II).
15. Ogonek, No. 49, December 1957, p. 5.
16. Pravda, August 29, 1955.
17. Vedomosti Verkhovnogo Soveta, issues 46-48, 1945. (Ukaz dated July 10, 1945).
18. Vechernyaya Moskva, June 16 and August 9, 1954. (Announcement of scientific awards dated November 17, 1949.)

*References "Geneva I" and "Geneva II" refer respectively to materials presented at the 1955 and 1958 Geneva Conferences on the Peaceful Uses of Atomic Energy.

19. Izvestiya, May 24, 1957.
20. Alvarez, Luis W., "Further Excerpts from a Russian Diary," Physics Today, June 1957, pp. 22-32.
21. Marshak, Robert E., "Sixteen Days in the USSR," The Rochester Review, September 1956.
22. Nemenov, L. M., et al., "1.5 Meter Cyclotron with Fixed Frequency," Atomnaya Energiya, Vol. II, No. 1, January 1957, p. 36.
23. Sjostrand, N. G., "Russian Nuclear Progress," Nucleonics, Vol. 14, No. 6, June 1956. (Report of visit)
24. Mostovoi, V. I., et al., "Measurement of Neutron Spectrum in Uranium-Water Lattices," Geneva II Paper P/2152, 1958.
25. Goncharov, V. V., et al., "New and Modified Experimental Reactors," Geneva II Paper P/2185, 1958.
26. Slavsky, Ye. P., "Atomic Energy in the Service of Peaceful Construction," Izvestiya, May 23, 1956.
27. Fortune, February 1957, p. 120; also Aleksandrov, A. P., "New Landmarks of History," Izvestiya, November 18, 1957.
28. Hughes, D. J., "Soviet Said to Lag in Basic Research," The New York Times, October 22, 1957.
29. Vladimirov, V. V., et al., "Interactions of Slow Neutrons with Nuclei (Survey)," Atomnaya Energiya, Vol. III, No. 11, November 1957, pp. 444-458.
30. Alikhanov, A. I., and V. V. Vladimirov, et al., "A Heavy Water Research Reactor," Geneva I Paper P/623, 1955.
31. Hughes, Donald J., "Physics in Poland and Russia," Physics Today, December 1957, pp. 10-15.
32. Vladimirov, V. V., E. G. Komar, and A. L. Mints, "Project of a Proton Ring Accelerator for 7 Bev," CERN Symposium 1956, Vol. I, pp. 118-121.
33. Sobranie Postanovlenii i Rasporyazhenii Soveta Ministrov SSSR, (Gosurizdat), Moscow, September 15, 1943.
34. Izvestiya, (Nominations to the Academy of Sciences), October 9, 1953; also Vestnik Akademii Nauk, (Subsequent Biographies).
35. Aspirants for Higher Educational Establishments, Moscow, 1949, p. 200.
36. Vechernyaya Moskva, June 6, 1954, announcements of dissertations.

37. Ministry of Culture of the USSR, Handbook for Entering Higher Educational Establishments, February 5, 1957, p. 92.
38. Panov, D., "Science and Socialism," Kommunist, No. 1, January 1958, pp. 11-25.
39. Lavrishchev, A. N., "Assistance of the Soviet Union to Other Countries on The Peaceful Uses of Atomic Energy," Geneva I Paper P/619, 1955.
40. Promyshlenno-Ekonomicheskaya Gazeta, April 10, 1957, p. 4.
41. Vechernyaya Moskva, March 3, 1958, p. 4.
42. Kurchatov, I. V., "In the Name of a Great Purpose," Pravda, March 16, 1958, p. 3.
43. The New York Times, August 14, 1946, p. 6.
44. Izvestiya, September 30, 1956, p. 4.
45. Pravda, March 21, 1956, p. 3.
46. Komsomol'skaya Pravda, March 27, 1956, p. 3; also Pravda and Izvestiya, same date.
47. Pravda, July 12, 1956, p. 3; also Soviet News, No. 3435, July 23, 1956, pp. 3-4.
48. Trud, March 22, 1956, p. 3.
49. Pravda, February 18, 1957, p. 1.
50. The New York Times, December 21, 1957, p. 4.
51. Soviet News, No. 3733, November 26, 1957, p. 4.
52. Hughes, Donald J., op. cit.
53. Vestnik Akademii Nauk, December 1957, pp. 3-14.
54. Pravda, December 20, 1957, p. 2.
55. Termoenergetika, December 1955.
56. Atomnaya Energiya, No. 1, 1956, p. 1.
57. Pravda, November 3, 1957, p. 6.
58. Ibid., November 30, 1957; also Izvestiya, November 30, 1957.
59. Vechernyaya Moskva, October 23, 1956.

60. Nucleonics, Vol. 16, No. 3, March 1958, p. 27.
61. Truman, Harry S., Memoirs by Harry S. Truman, Vol. 2, Years of Trial and Hope, Doubleday, New York, 1956, pp. 307-308.
62. The White House statement by the President for release in the morning papers, October 24, 1956.
63. Statement of Prime Minister McMillan before the House of Commons in debate of March 27, 1958. (London Times, March 28, 1958, p. 6.)
64. "Response of Comrade I. V. Stalin to a Correspondent of Pravda, October 6, 1951, Moscow, 1951. (In addition to publication in many media, this reply was printed in a pamphlet edition of two million copies!)
65. Pravda and Izvestiya, August 9, 1953, pp. 1-4.
66. TASS announcement, Pravda and Izvestiya, August 20, 1953, p. 2.
67. The Nature of Radioactive Fallout and Its Effects on Man, Part 2, U.S. Government Printing Office, Washington, D.C., 1957, pp. 2063-2065.
68. Pravda, November 28, 1955.
69. TASS announcement November 26, 1955; New York Times, November 27, 1955.
70. Pravda, December 30, 1955, p. 4.
71. The New York Times, April 1, 1954, p. 20.
72. TASS statement, Moscow News, No. 7, September 1, 1956.
73. The New York Times, March 27, 1958, p. 4.
74. Statement by Chairman Lewis L. Strauss of the U.S. Atomic Energy Commission, U.S. Atomic Energy Commission Press Release No. 879; The New York Times, August 27, 1956.
75. Peking broadcasts (two) August 25, 1957. Reported in The Times, London, April 27, 1957.
76. Presentation of Dr. Willard F. Libby, Swiss Academy of Medical Sciences Symposium on Radioactive Fallout, Lausanne, Switzerland, March 27, 1958.
77. Garthoff, Raymond L., Soviet Strategy in the Nuclear Age, Praeger, New York, 1958; also Dinerstein, Herbert S., War and the Soviet Union: Nuclear Weapons and the Revolution in Soviet Military and Political Thinking, Praeger, New York, 1958.
78. Krasnaya Zvezda, January 14, 1954, and later issues.
79. Pravda, March 15, 1958.

80. The New York Times, April 1, 1958, pp. 14-15.
81. Dolmatovskij, Ye. A., "Your Strength," Novy Mir, July 1949, p. 170. Translation from Margaret Mead's, Soviet Attitudes Toward Authority, McGraw-Hill, New York, 1951.
82. Background Information on the Deep Underground Shot, U.S. Atomic Energy Commission, March 6, 1958. Also, The New York Times, March 14, 1958.
83. Pravda, and Izvestiya, September 26, 1949.
84. The New York Herald Tribune, September 4, 1958; also The New York Times, September 4, 1958.
85. Pokrovskij, G. I., "Physics of Earth Works," Tekhnika Molodezhi, No. 2, 1953, pp. 9-12.
86. Pokrovskij, G. I., "Creative Explosion," Tekhnika Molodezhi, No. 7, July 1957, p. 7.
87. Pokrovskij, G. I., "Explosion Builds," Ogonek, No. 32, August 1957, p. 7.
88. "Tunneling Under Sea to Blast Channel Clear," Business Week, March 29, 1958, pp. 78-80; also The New York Times, April 7, 1958, p. 6.
89. "Largest Non-Atomic Explosion," The Washington Star, January 6, 1958.
90. Pokrovskij, G. I., "The Beginning of the Era of Atomic Energetics," Tekhnika Molodezhi, September 1954, pp. 2-6.
91. Soviet News, No. 3778, February 12, 1958, p. 109; also, "The Tagansai Explosion," Stroitel'naya Gazeta, February 9, 1958; p. 3; and "Explosion in Tagansai," Ogonek, No. 4, January 1958, p. 19.
92. "Siberia in Winter," The Times, London, March 12, 1958, p. 11.
93. Teller, Edward, and Albert L. Latter, Our Nuclear Future, Criterion Books, New York, 1958; and Orear, Jay, "Detection of Nuclear Weapons Testing," Bulletin of the Atomic Scientists, Vol. XIV, No. 3, March 1958, pp. 98-101.
94. Pravda, May 11, 1957, p. 5.
95. Goncharenko, A., "At the Central Seismic Station Instruments Register Nuclear Explosions," Krasnaya Zvezda, September 23, 1956, p. 2.
96. Pravda, April 1, 1958.
97. "Report of the Conference of Experts to Study the Methods of Detecting Violations of a Possible Agreement on the Suspension of Nuclear Tests," Document EXP/NUC/28, 20 August 1958, Geneva.

98. Atomnaya Energiya, Vol. III, No. 8, August 1957, p. 90.
99. Trud, July 4, 1954, p. 2.
100. Yermakov, G. V., "The Powerful Force of the Atom," Nauka: Zhizn, No. 11, 1957, pp. 17-22; and "Atomic Power Progress," USSR (In English), No. 14, 1957, pp. 36-37.
101. Krasin, A. K., et al., "Investigation of the Physical Characteristics of the Reactor of the Atomic Electric Stations," Atomnaya Energiya, No. 2, February 1956, pp. 3-20.
102. Blokhintsev, D. I., and N. A. Nikolayev, "The First Atomic Power Station of the USSR and the Prospects of Atomic Power Development," Geneva I Paper P/615, 1955.
103. Kurchatov, I. V., speech at Twentieth Party Congress, Pravda, February 22, 1956, p. 7.
104. Kramish, A., The Soviet Atomic Power Program: Large or Small?, The RAND Corporation, Paper, P-1076, May 1, 1957. Also, Nucleonics, June 1957, p. 23, and July 1957, p. 20.
105. Perrin, F., "Selection Hebdomadaire," Le Monde, November 28 - December 4, 1957, p. 8.
106. Pravda, September 7, 1958, p. 1.
107. The New York Times, September 9, 1958.
108. Dollezhal, N. A., et al., "Uranium-Graphite Reactor with Superheated High Pressure Steam," Geneva II Paper P/2139, 1958.
109. "Perspectives for Utilization in the USSR of Nuclear Heat for Energy Purposes," World Energy Conference, Belgrade, 1957, Section B.3, Paper 7.
110. Blokhintsev, D. I., and N. A. Nikolayev, "The Future of Atomic Energetics," Krasnaya Zvezda, February 3, 1956, p. 3.
111. Kondaritskii, V. S., "The Soviet Atomic Exhibition in Geneva," Trud, September 2, 1958, p. 4.
112. "Project of a 420-mw Atomic Electric Station," World Power Conference, Belgrade, 1957, Section B.3, Paper 8. Also available as U.S. Atomic Energy Commission Translation No. 2941.
113. Vladimirovsky, V. V., talk presented before the National Industrial Conference Board, New York, October 27, 1955.
114. Nikolayev, N. A., "The Development of Atomic Energetics in the Soviet Union," Atomnaya Energiya, Vol. III, No. 11, November 1957, p. 385.

115. Khristenko, P. I., et al., "Rod Fuel Element for Gas-Cooled Heavy-Water Power Reactor," Geneva II Paper P/2053, 1958.
116. Leipunsky, A. I., et al., "Studies in the Physics of Fast Neutron Reactors," Geneva II Paper P/2038, 1958.
117. Leipunsky, A. I., et al., "Experimental Fast Reactors in the Soviet Union," Geneva II Paper P/2129, 1958.
118. "Economic Applications of Atomic Energy," Report of the Secretary General of the United Nations, New York, 1957, pp. 54-55.
119. Kondakov, K., and G. Naumov, "Importance of the Yakut Republic Diamond-Mining Industry to the National Economy," Voprosy Ekonomiki, No. 6, 1957, pp. 135-140.
120. Blagonravov, A. A., "Great Progress," Sovetskaya Aviatsiya, December 29, 1957, p. 3.
121. Yemelyanov, V. S., "The Future of Atomic Energetics in the USSR," Geneva II Paper, P/2027, 1958.
122. Nikolayev, Y. G., "The Experimental Nuclear Reactor with Ordinary Water and Enriched Uranium," (prepared on the basis of materials available at the Academy of Sciences of the USSR), Geneva I Paper P/621, 1955.
123. Kruzhilin, G. N., "Reactor for Physical and Technical Investigations," (prepared on the basis of materials available at the Academy of Sciences of the USSR), Geneva I Paper P/620, 1955.
124. "Nuclear Reactor Data No. 2," Raytheon Corporation, Waltham, Massachusetts, December 1956, p. 8.
125. Blokhintsev, D. I., and N. A. Nikolayev, "The First Atomic Power Station of the USSR," Geneva I Paper P/615, 1955.
126. Voyennaya Mysl', No. 9, September 1955, p. 30.
127. Report of the Underseas Warfare Advisory Panel to the Subcommittee on Military Applications of the Joint Committee on Atomic Energy, U.S. Government Printing Office, Washington, D.C., August 1958.
128. Bykhovsky, Israel Adol'fovich, Atomic Submarines, Leningrad, 1957.
129. Letter of President Eisenhower to Representative Malvin Price, The New York Times, March 7, 1958, p. 9.
130. Pravda, May 4, 1957, p. 6.
131. Ibid, June 24, 1957, p. 2.

132. Izvestiya, June 24, 1957, p. 2.
133. Nesterenko, G. N., A. I. Sobolev, and Yu. N. Shushkov, The Application of Atomic Engines in Aviation, Moscow, September 1957.
134. Tekhnika Molodezhi, No. 1, January 1955.
135. Sovetskii Flot, Special Edition, December 7, 1957, p. 3; also, Ponomarev, P. A., "Arctic Icebreaker," Promyshlenno-Ekonomicheskaya Gazeta, December 8, 1957, p. 1; and "Atomic Icebreaker Launched," Soviet News, No. 3739, December 6, 1957.
136. Ponomarev, P. A., "The Atomic Icebreaker, 'Lenin'," Izvestiya, November 29, 1957.
137. Khlopin, N. S., "The Nuclear-Propelled Icebreaker," Geneva II Paper, P/2140, 1958.
138. Lakhanin, V. V. and N. M. Shilov, The Atomic Powered Ship, Sea Transport Press, Odessa, December 1956.
139. Lakhanin, V. V., "Atomic Engines for Ships," Atomnaya Energiya, Vol. III, No. 9, September 1957, pp. 222-226.
140. Yermakov, A., "Atom and Transport," Sovetskaya Rossiya, December 4, 1957, p. 3; also abstracted in Soviet News, No. 3739, December 6, 1957.
141. Twentieth Session of the Communist Party of the Soviet Union, Moscow, Vol. II, 1956, p. 437.
142. Bol'shaya Sovetskaya Entsiklopediya, Vol. 46, February 18, 1957, p. 98.
143. Zvonkov, Vasily, "Atoms for Transport," Moscow News, October 24, 1956, p. 6.
144. "Atomic Locomotive," Tekhnika Molodezhi, No. 6, June 1956.
145. Balabanov, Ye., "On the Way to Aircraft with Thermomuclear Engines," Sovetskaya Aviatsiya, September 28, 1957.
146. Kudryunov, G. V., M. B. Neiman, and G. M. Frank, "Application of Radioactive Isotopes in the USSR," Atomnaya Energiya, Vol. III, No. 11, November 1957, pp. 465-476.
147. "Where Atomic Energy Serves the People," International Affairs No. 8, 1955, pp. 80-85.
148. Pravda, December 10, 1955, p. 2.
149. Pamphlet of the USSR Scientific and Technical Exhibition, Geneva, 1955, p. 81.

150. Frolov, Yu. S., et al., "Development of Isotope Production in the USSR," Moscow, 1957. (Available as U.S. Atomic Energy Commission translation No. 3093.)
151. "Session on Isotope Production," All-Union Conference on the Application of Radioactive and Stable Isotopes and Radiation in the National Economy and Science, Moscow, April 2-5, 1957; also Atomnaya Energiya, Vol. III, No. 8, August 1957, pp. 162-166.
152. Vechernyaya Moskva, July 30, 1957, p. 4.
153. Isotopes Prospectus and Price List, Moscow, 1957.
154. Gusev, V. M., D. V. Chkuaseli, and M. I. Guseva, "The Separation of Isotopes of Germanium and Magnesium in a Small Electromagnetic Separator," Atomnaya Energiya, Vol. III, No. 9, September 1957, pp. 215-221.
155. Gverdtsiteli, I. G., and V. K. Tskhakaya, "Isotope Separation by Gaseous Diffusion," All-Union Conference on the Application of Radioactive and Stable Isotopes and Radiation in the National Economy and Science, Moscow, April 2-5, 1957.
156. "Nuclear Developments in East Germany," Atom Industry, London, October 1957, p. 2.
157. Zolotarev, V. S., et al., "Isotope Separation by Electromagnetic Separators in the Soviet Union," Geneva II Paper P/2305, 1958.
158. Blagonravov, A. A., "Great Progress," Sovetskaya Aviatsiya, December 29, 1957, p. 3.
159. Grigorenko, A., "The Principles of Electrical Supply," Krasnaya Zvezda, November 20, 1957, p. 3.
160. Krasnaya Zvezda, October 4, 1955, p. 3.
161. Kondaritskii, V. S., "Soviet Atomic Exhibit in Geneva," Trud, September 4, 1958, p. 1.
162. Libby, Willard F., "Progress in the Use of Isotopes," Geneva II Paper P/2390, 1958.
163. Shabad, Theodore, Geography of the USSR, Columbia University Press, New York, 1951, pp. 379 and 385.
164. Shcherbakov, D. I., "The Raw Material Base of Rare Metals of the USSR," Redkiye Metally, No. 1, 1938.
165. Grishin, Nikolai, "The Saxony Uranium Mining Operation," Soviet Economic Policy in Postwar Germany, Research Program on the USSR, New York, 1953, pp. 127-155.

166. Kramish, Arnold, The Soviet Union and the Atom: The Secret Phase, The RAND Corporation, Research Memorandum RM-1896, April 11, 1957, p. 69.
167. Die Wirtschaft, June 25, 1954, (announcement of awards to three Wismut A. G. operations.)
168. Sulzberger, C. L., "Soviets Spur Rise in Czech Atom Ore," The New York Times, May 4, 1952.
169. Rude Pravo, November 28, 1956.
170. The New York Times, January 28, 1957.
171. Ibid., June 13, 1955.
172. "Search for Uranium," Komsomol'skaya Pravda, April 11, 1957.
173. Ibid., June 6, 1957.
174. Polikarpova, V. A., and Z. L. Ambartsumian, (eds.), "New Data on Uranium Minerals in the USSR," Geneva II Paper P/2060, 1958.
175. Getzeva, R. V., "Gidronasturan and Urgite--New Minerals of a Group of Aqueous Oxides of Uranium," Atomnaya Energiya, No. 3, March 1956, pp. 135-136.
176. Polikarpova, V. A., "Nenadkevite--New Silicate of Uranium," Atomnaya Energiya, No. 3, 1956, pp. 132-134.
177. Chernikov, A. A., et al., "Natrootenite," Atomnaya Energiya, Vol. III, No. 8, August 1957, pp. 135-140.
178. USSR Exhibition Bulletin, Geneva, 1955, p. 8.
179. Laskorin, B. N., et al., "Extraction of Uranium from Natural Water," Geneva II Paper P/2063, 1958.
180. Shashkin, V. L., "Quantitative Radiometric Measurement of Radioactive Ores in Natural Deposits," Atomnaya Energiya, Part I, Vol. II, No. 1, January 1957, pp. 48-53; Ibid., Part II, Vol. II, No. 2, February 1957, pp. 157-162.
181. Posik, L. N., and I. M. Tenenbaum, "A Special Apparatus for the Rapid Gamma-Ray Analysis of Run-of-Mine Ores," Atomnaya Energiya, Vol. III, No. 7, July 1957, pp. 28-35.
182. Meyerson, G. A., "Powder Metallurgy of Thorium," Geneva I Paper P/635, 1955.
183. Kaplan, G. Ye., "Metallurgy of Thorium," Geneva I Paper P/636, 1955.

184. Goncharov, V. V., "Graphite in Reactor Construction," Atomnaya Energiya, Vol. III, No. 11, November 1957, pp. 398-408.
185. "Technology of Manufacturing Items of Pure Beryllium and Beryllium Oxide for Use in Nuclear Reactors," Geneva I Paper P/633, 1955.
186. Krasin, A. K., and B. G. Dubovsky, "Physical Beryllium Reactor," Atomnaya Energiya, No. 4, April 1956, pp. 147-148.
187. Kramish, A., and M. J. Ruggles, The Soviet Union and the Atom: The Early Years, The RAND Corporation, Research Memorandum RM-1711, April 2, 1956, p. 26.
188. Kurchatov, I. V., "Thermonuclear Energy--The Principal Power of the Future," Pravda, February 28, 1958; also Soviet News, No. 3790, March 3, 1958, pp. 157-158.
189. Malkov, M. P., et al., "Industrial Separation of Deuterium by Low-Temperature Distillation," Geneva II Paper P/2323, 1958.
190. Bailey, B. M., "Some Aspects of Heavy-Water Production by Distillation of Hydrogen," Geneva II Paper P/1063, 1958.
191. Pravda, February 28, 1958.
192. Dubinin, M. M., "Chemistry at the Service of Technical Progress," Pravda, November 11, 1955.
193. Vestnik Akademii Nauk SSSR, No. 12, 1956.
194. Vechernyaya Moskva, October 3, 1957.
195. Promyshlenno-Ekonomicheskaya Gazeta, January 3, 1958.
196. Sinel'nikov, K. D., et al., "Possible Modification of the Linear and Cyclical Method of Acceleration," CERN Symposium, 1956, Vol. I, pp. 215-217.
197. Kramish, A., and M. J. Ruggles, The Soviet Union and the Atom: The Early Years, The RAND Corporation, Research Memorandum RM-1711, April 2, 1956, p. 16.
198. Veksler, V., "Comptes Rendus," Doklady Akademii Nauk SSSR, 43, No. 8, p. 444, 1944; Veksler, V., op cit., 44, No. 9, p. 393, 1944; Veksler, V., J. Phys., USSR, 9, No. 3, pp. 153, 1945.
199. McMillan, E. M., "Radiation from a Group of Electrons Moving in a Circular Orbit," The Physical Review, Vol. 68, Nos. 5 and 6, September 1 and 15, 1945, pp. 144-145.
200. Veksler, "Concerning Some New Methods of Acceleration of Relativistic Particles," The Physical Review, Vol. 69, Nos. 5 and 6, March 1 and 15, 1946, pp. 244-245.

201. McMillan, E. M., "The Origin of the Synchrotron," The Physical Review, Vol. 69, Nos. 9 and 10, May 1 and 15, 1946, p. 534.
202. Dzhelapov, V. P., and B. M. Pontecorvo, "High-Energy Particle Research with the Synchrocyclotron of the Laboratory of Nuclear Problems at the Joint Institute of Nuclear Studies," Atomnaya Energiya, Vol. III, No. 11, November 1957, p. 413.
203. Sovetskaya Rossiya, December 3, 1957, p. 2.
204. Alvarez, Luis W., "Excerpts from a Russian Diary," Physics Today, May 1957, pp. 24-32.
205. Doklady Akademii Nauk SSSR, Vol. 99, No. 6, December 21, 1954.
206. Ubell, Earl, "Russia Lets World Peak at Its Atomic Work," New York Herald Tribune, March 12, 1955; also, Laurence, William L., "Russians Issue Atomic Secrets," The New York Times, March 13, 1955.
207. Veksler, V., "At the Speed of Light," Moscow News, No. 30 (134), April 13, 1957, pp. 1-2; also, Pravda, April 11, 1957, p. 3.
208. Veksler, V., "The Starting up of the 10-Bev Synchrophasotron and First Results of Physical Research," Geneva II Paper P/2229, 1958.
209. "Gigantic Installation for Research on the Atomic Nucleus," Pravda, March 18, 1957, p. 3.
210. Hughes, Donald J., "Physics in Poland and Russia," Physics Today, December 1957, pp. 10-15.
211. Trud, January 3, 1958, p. 1.
212. Veksler, V. I., "Principles of Acceleration of Charged Particles," Geneva I, 1955; also in Atomnaya Energiya, No. 1, 1956, pp. 75-82. (However, the reference to Vladimirovsky's being in charge has been censored from the published version.)
213. Vladimirovsky, V. V., and Ye. K. Tarasov, "On the Possibility of Eliminating the Critical Energy in Accelerators with Strong Focusing," Various Problems of the Theory of Cyclical Accelerators, Moscow, July 1955, pp. 13-22; also, Vladimirovsky, V. V., et al., "Main Characteristics of a Projected Strong-Focusing 50-60-Bev Proton Accelerator," CERN Symposium, 1956, pp. 122-124.
214. "Gigantic Installation for Research on the Atomic Nucleus," Pravda, March 18, 1957, p. 3.
215. Wilson, R. R., "Particle Accelerators," Scientific American, March 1958, pp. 65-76.

216. "In the Depths of the Atomic Nucleus," Izvestiya, May 16, 1956; also Orlov, Vladimir, "In the World of the Atomic Nucleus," Izvestiya, May 20, 1956; also, Soviet News, May 31, 1956.
217. "The Inexhaustible Atom," Izvestiya, June 22, 1956; also, Proceedings of the Geneva (CERN) Symposium, Vols. 1 and 2.
218. Veksler, V. I., "Coherent Principle of Acceleration of Charged Particles," Proceedings of the CERN Symposium, Vol. I, pp. 80-83.
219. Budker, G. I., "Relativistic Stabilized Beam I: Physical Principles," CERN Symposium, Vol. I, pp. 68-75.
220. Budker, G. I., and A. A. Naumov, "Relativistic Stabilized Beam II: Brief Review of Experimental Work," CERN Symposium, Vol. I, pp. 76-79.
221. Kramish, A., and M. J. Ruggles, The Soviet Union and the Atom: The Early Years, The RAND Corporation, Research Memorandum RM-1711, April 2, 1956.
222. Budnizki, D. Z., I. V. Kurchatov, and G. D. Latyshev, "Disintegration of Lithium by Slow Neutrons," Physik. Z. Sowjetunion, Vol. 7, No. 4, pp. 474-483 (1935).
223. Artzimovich, L. A., "The Physics of the Atomic Nucleus in the USSR," Physik. Z. Sowjetunion, Vol. 12, No. 5, 1937, pp. 526-541.
224. Kurchatov, I. V., Pravda, May 10, 1956, p. 3.
225. U.S. Atomic Energy Commission Press Releases Nos. 700 to 705, October 3, 1955.
226. Kurchatov, I. V., "On the Possibility of Producing Thermonuclear Reactions in a Gas Discharge." Copies of this talk were distributed in both Russian and English versions to the April 25, 1956, audience at Harwell, England. It was widely reprinted (with the translation varying on several points) in journals throughout the world, including: Nucleonics, Vol. 14, No. 6, June 1956, pp. 36-43; The Journal of Nuclear Energy, Vol. 4, No. 2, February 1957, pp. 193-202; and Atomnaya Energiya, No. 3, 1956, pp. 65-75.
227. Kurchatov, Artzimovich, Leontovich, and colleagues, Atomnaya Energiya, No. 3, 1956, pp. 65-106; also, Shafronov, V. D., "The Stability of a Cylindrical Gaseous Conductor in a Magnetic Field," Atomnaya Energiya, No. 5, 1956, pp. 38-41.
228. Allen, K. W., "Observations on Transient Pinched Discharges," Proceedings of the Third International Conference on the Phenomena of Ionization in Gases, Venice, July 11-15, 1957, pp. 26-32; also, Allen, N. L., et al., "A Stabilized High Current Toroidal Discharge Producing High Temperatures," and Thonemann, P. C., et al., "The Production of High Temperatures and Nuclear Reactions in a Gas Discharge," Nature, January 24, 1958.

229. Anderson, O. A., et al., "Neutron Production in Linear Deuterium Pinches," The Physical Review, February 1, 1958; also, Hagerman, D. C., and J. W. Mather, "Neutron Production in a High-Power Pinch Apparatus," Nature, January 24, 1958.
230. U.S. Atomic Energy Commission Press Release, No. A-12, January 24, 1958.
231. "Soviet Radio Hails British on Fusion," The New York Times, January 20, 1958.
232. Kurchatov, I. V., "Thermonuclear Energy--The Principal Power of the Future," Pravda, February 28, 1958; also, Soviet News, No. 3790, March 3, 1958, pp. 157-158.
233. Kurchatov, I. V., speech before the Twentieth Party Congress, Pravda, February 22, 1956.
234. Pravda, February 6 and 28, 1958.
235. Artzimovich, L. A., "Research Into Controlled Thermonuclear Reactions in the USSR," Geneva II Paper P/2298, 1958.
236. Artzimovich, L. A., et al., "A High Resolving-Power Electromagnetic Isotope Separation for Heavy Elements," Atomnaya Energiya, Vol. III, No. 12, December 1957, pp. 483-491.
237. See Reference 226.
238. See Reference 234.
239. Budker, G. I., "Relativistic Stabilized Electron Beam," Proceedings of CERN Symposium on High Energy Accelerators and Pion Physics, Geneva, June 11-23, 1956, Vol. I, pp. 68-75; also, Atomnaya Energiya, No. 5, 1956, pp. 9-19.
240. Vestnik Akademii Nauk, December 1957, p. 14.
241. The New York Times, August 23, 1958, p. 2.
242. Izvestiya, February 15, 1958, p. 2.

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