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SCIENTIFIC INTELLIGENCE REPORT

LONG-RANGE CAPABILITIES OF THE SOVIET UNION IN MAJOR SCIENTIFIC FIELDS 1957-67

MONOGRAPH VII
CHEMISTRY

CIA/SI 2-58
31 January 1958

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

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Scientific Intelligence Report

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NOTICE

The conclusions, judgments, and opinions contained in this finished intelligence report are based on extensive review of scientific literature as well as general classified source data and represent the immediate views of the Office of Scientific Intelligence.

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PREFACE

This monograph on Soviet chemistry is one of eleven reports on Soviet capabilities in major scientific fields over the next 10 years. Monographs II through XI in the series are designed to support the conclusions found in Monograph I which is an overall evaluation of Soviet science and will be published last. The intelligence provided in this volume (VII) emphasizes the trends in Soviet chemical research. It also points out the significance of such research, gives the probability of the Soviets attaining their stated goals within the next 10 years, and includes some comparison with Western efforts in strategic and priority areas of work. It should be noted that this monograph emphasizes fundamental research and does not include such topics as chemical warfare agents, which are discussed in other intelligence reports. The titles of all publications in this series are as follows:

MONOGRAPH NO.	TITLE
I	Summary Estimate
II	Policy, Organization, Planning, and Control of Soviet Science and Technology
III	Scientific and Technical Manpower in the USSR
IV	Physics
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VI	Geophysical Sciences
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LONG-RANGE CAPABILITIES OF THE SOVIET UNION IN MAJOR SCIENTIFIC FIELDS 1957–67

MONOGRAPH VII

CHEMISTRY

SUMMARY AND CONCLUSIONS

An assessment of Soviet activity and capabilities in selected fields of chemical research indicates that the quality of Soviet research varies considerably from field to field. In general, the Soviet Union has made few significant original contributions in recent years and is definitely behind the United States in the magnitude and level of the research effort. The consistently high quality of Soviet research in a few fields and the marked progress in others of priority importance, however, indicate that at the end of this estimate period USSR research in chemistry and chemical engineering will be close to that of the United States in all fields of importance.

ORGANIC CHEMISTRY

Basic research in organic chemistry is excellent in several fields but is generally concentrated in areas exploited 3 to 5 years ago in the United States. Access to U.S. work is current, however, and during the period of this estimate, USSR research should more closely parallel that of the United States. The greatest improvement will probably be in organometallic compounds, synthetic fibers, acetylene chemistry products, pharmaceuticals, rubber, and plastics.

Soviet organophosphorus research is quite advanced and has produced significant contributions to the literature. The USSR capability in this field is probably greater than that of the United States; and from a military standpoint, the USSR may be five years in advance of the United States. Soviet strength in this field, because of its direct connection with CW nerve agents, will pose a major threat to the United States for the next 10 years. During this latter period, we believe the Soviets will continue or possibly increase their efforts in this field.

Research and development in macromolecular chemistry is aimed at problems which were current three years earlier in the United States. In the development of new high-temperature-resistant polymers the Soviets have definite capabilities because of extensive research in organophosphorus and organosilicon chemistry. Research in polyamide chemistry and related synthetic fibers is almost on a par with that of the United States. In other synthetic fiber research, the USSR lags. Despite an early and excellent history of research in synthetic rubber, recent research has been reflected only to a limited extent in

the technology of the rubber industry. During the period of this estimate, USSR capabilities in macromolecular chemistry will increase at a fairly rapid rate but will not surpass those of the United States.

During the next decade, USSR research and development in ion exchange resins as applied to nuclear energy fields will probably reach a par with that of the United States because of the great emphasis given to nuclear energy. In addition, the USSR will receive support from Czechoslovakia and East Germany who also have strong capabilities in ion exchange resin research and development. Both of these countries are actively using these resins in uranium ore processing and for other industrial uses. The Soviet Union, however, will probably not proceed at a very rapid rate within the next ten years in other applied aspects of ion resin technology directed toward the consumer market, such as utilization of this work in food, medical, pharmaceutical, power, and water purification industries.

Plastics incorporating glass fibers (e.g. fiberglass) have taken on a particular importance because of the potential use in guided missiles; e.g., radomes. Although the Soviets have conducted some research on the chemical treatment of glass fibers, we believe that USSR research is behind that of the United States and will remain so during the estimate period.

The Soviet Union is giving increased emphasis to pharmaceutical research to correct the present poor quality of a number of medicinal preparations. Because of this emphasis and the demonstrated capabilities to develop original analgesic antispasmodic, and alkaloid-type drugs, effective and safe preparations should appear which will adequately replace presently inferior products over the next 10 years. It is probable that in a few areas of pharmaceutical research, USSR work will be more advanced than that in other countries. It is highly doubtful that overall USSR capabilities will approach the present high position of the United States in pharmaceutical research for many years.

PHYSICAL CHEMISTRY

Soviet physical chemists have a clear understanding of basic combustion and chemical kinetics theory. Their research in these areas is on a par with that of Western chemists and can be depended on to solve fundamental and applied problems of military significance as demonstrated by rapid advances in Soviet high-performance aircraft and missiles.

Progress of nuclear chemistry as applied to chemical, chemical engineering, and metallurgical problems has been extremely rapid and has successfully supported the development and expansion of a significant nuclear energy program.

A few electrochemists in the USSR are competent, original, and outstanding experimentalists. Soviet electrochemists as a group however, probably will do little unique research meriting world recognition.

Soviet research in catalysis is generally comparable with that of the West and has a great potential for significant advances.

During recent years, there has been an increasing diversification of Soviet work in spectroscopy to include high resolution spectroscopy, new applications of infrared, and determination of flame temperatures. By 1967, in the few fields, such as high resolution spectroscopy, in which there is now a lag, USSR research will become equivalent to that of the United States.

CHEMICAL ENGINEERING

At the present time, the USSR is considerably behind the United States in chemical engineering research and development, in large measure because of the insufficient number of trained chemical engineers. In view of the large number of well-trained chemical engineers now graduating, however, this gap should progressively narrow and possibly disappear entirely by 1967.

PROPELLANTS AND EXPLOSIVES

Soviet propellant research is primarily directed toward the development of reliable materials and combinations which are logistical-

ly available in the USSR. An unknown proportion of work is probably aimed at obtaining exotic fuels with high energy content. The Soviet boron fuels program and other programs directed toward the development of exotic fuels appear to be relatively modest if judged by the limited amount of data available for intelligence analysis. However, these programs could be at the same state of development as they are in the United States. The Soviets have recently boasted of having "a new superpowerful liquid fuel," but the uncertainty as to the size of their program precludes a firm appraisal of their probable attainments within the next ten years. We believe, however, that Soviet research in this field is capable of developing these materials although the probable inadequate amounts of unusual chemicals for unconventional fuel formulation, testing, and research may limit their progress.

Soviet Union efforts in two important solid propellant materials, double-base smokeless powder and ammonium nitrate, were about on a level with those of the United States prior to 1949 when research specifically aimed at guided missile use was initiated in the United States. Soviet Union research in solid propellants through 1967 could equal that of the United States in all aspects including fabrication if present probable high priorities are maintained.

In applied and fundamental explosives research, the USSR is on a par with the United States and can be expected to remain so throughout the period of this estimate.

PETROLEUM TECHNOLOGY

Fundamental research in refining, synthetic fuels, and petrochemicals has been excellent, although the Soviet Union has made no significant contributions to industrial technology in these fields. Soviet scientists have shown a high capability for adapting foreign processes to their own needs. In the adjunct field of mechanical engineering, USSR research has resulted in the development of a superior turbine drill for oil well drilling. The Soviets display a sound knowledge of lubricants and additives, although their publications and the examination of samples of Soviet lubricating oils do not disclose the use of new or novel materials. The Soviets have a capability for synthesis of new lubricants for use in high temperature engines. By 1967, the Soviet Union will make some advances in petroleum technology but the general level of their work will remain significantly behind that of the United States.

ORGANIZATION, PLANNING, AND CONTROL*

Chemical and chemical engineering research is conducted primarily by the Department of Chemical Sciences and Department of Technical Sciences of the Academy of Sciences, the Ministry of Chemical Industry, and the Ministry of Higher Education. Other agencies of the Soviet government such as the Ministry of Petroleum Industry conduct chemical research of immediate concern to themselves. Specialized military research such as unconventional fuels testing, is carried out at Plant 456, Khimki, and Plant 1, Podberezhye, under the sponsorship of the new State Committee of Aviation Technology, and at NII 88, Kaliningrad and Branch 1 at Oshtashkov under the Ministry of Defense.

The plenum sessions of the Central Committee of the Communist Party usually establish broad chemical research and development plans. Fundamental research in many topics frequently shows little coordinated planning, however, and duplication of work is evident. Scientific findings often are not utilized or systematically followed-up in a logical manner. These tendencies exist in other fields also and have resulted in a general reorgani-

* This topic is treated in detail in Monograph II, *Policy, Organization, Planning, and Control of Soviet Science and Technology*. The general discussion here serves to emphasize certain details of the control of chemical and chemical engineering research in the Soviet Bloc.

zation of science as part of the recent economic reorganization. Research programs now are planned to result in the greatest gain to industry in the shortest time possible. In addition, academicians currently act as consultants to the ministries in formulating their work programs.

Special groups have been formed to study or coordinate research efforts where problems of major importance are recognized. Examples of these groups have been the Committee of Rocket Technology and the Academy of Sciences' Commission on Chromatography. Annual conferences on a wide variety of technical topics attempt to keep the public and workers informed of progress and desirable new lines of endeavor.

Applied research is under varying degrees of control. The glass fibers program, for example, shows little evidence of centralized planning as contrasted to the petroleum research program where there is concerted planning and control. Effective control of research and proper security appear to be maintained in work which is monitored by the Ministry of Defense.

Exchange of information among Bloc countries is being implemented through the Council for Economic Mutual Assistance (CEMA). The use of this organization for exchange of research information is a new role and will provide for a wide exchange of technology between Satellites and the USSR, with the USSR gaining the greatest benefit.

EXTENT AND ADEQUACY OF PRESENT AND FUTURE RESEARCH FACILITIES

Soviet library and reference facilities are excellent. There is evidence that the Soviets receive and exploit most U.S. chemical research literature.* Open published Soviet literature frequently is a masterful compendium of U.S. research work. Literature-survey type of applied research will probably be carried out more frequently during the next ten years thus shortening laboratory research time but leaving process and "know-how" problems still to be solved.

The USSR has spent enormous amounts of money in buildings and equipment to support organic and biochemical research. Equipment in these facilities is comparable to that in the best U.S. research laboratories. Soviet Union facilities appear adequate for all phases of organic chemistry research. These facilities are adequately equipped with automatic recording spectrographs (frequently Soviet-made) for ultra-violet, infra-red, and Raman spectra. The USSR has developed a good electron microscope of moderate resolution (30–50A°). Soviet-made X-ray diffraction equipment is also widely used.

There are no indications that ion exchange resin research facilities will be greatly expanded during the next decade. On the other hand, laboratories concerned with macromolecular chemistry may show a growth of about 25 percent because of the Soviet desire to build a strong rubber and plastics industry. Present facilities are adequate to cover the entire spectrum of macromolecular research but are too few to perform adequate applications research. These facilities are headed by outstanding men and are located in the Leningrad and Moscow areas.

Among the notable USSR physical chemistry facilities are the Institute of Physical Chemistry imeni L. Ya. Karpov, Ministry of Chemical Industry, and the Institute of Chemical Physics, Academy of Sciences, USSR, both in Moscow. There are many other institutes with quality equipment of Soviet origin; e.g., the Institute of High Pressures and the Institute of Physical Chemistry imeni Lebedev. In the field of spectroscopy, the Soviets have built a satisfactory ruling machine; and specialized gratings for high resolution work are now available.

Nuclear chemistry currently occupies a favored position in the USSR as a result of major Soviet emphasis on nuclear weapons and peaceful uses of nuclear energy. When

* Monograph II discusses the availability of foreign scientific literature in some detail (see Preface).

the Presidium of the Academy of Sciences, USSR, established the Commission on the Problem of Uranium in 1940, it was only necessary to re-orient and intensify existing programs on nuclear chemistry at the Radium Institute imeni V. G. Khlopin, Leningrad; the Institute of Chemical Physics; the Moscow State University imeni M. V. Lomonosov; other leading institutions; and to also allocate research to less well-known organizations. By 1957, additional specialized facilities existed in the Soviet Union.

Other outstanding institutes concerned with nuclear chemistry are the Institute for Physical Chemistry imeni L. V. Pisarzhevsky of the Ukrainian Academy of Sciences, Kiev, the Institute for Geochemistry and Analytic Chemistry imeni Vernadskiy, and the Research Institute for Physical Chemistry imeni L. Ya. Karpov.

At the present time, the Soviets are concentrating on providing more and better chemical engineering research facilities in both educational and industrial institutes. The equipment in these facilities is quite good, although much of it is developed from foreign designs.

Extensive and adequate research facilities for fundamental research related to solid propellants and explosives are available in laboratories of the Academy of Sciences, USSR, and institutes under various industrial ministries, the Ministry of Defense, and the Ministry of Higher Education. The same is generally true for basic research in unconventional fuels. In the latter case, there has been some evidence that facilities under the old Ministry of Aviation Industry * and the Ministry of Defense have not been very good. This deficiency should be overcome during the period of this estimate because of the high priority on unconventional fuels research. Soviet solid propellant technology lags that of the United States. There is a shortage of the necessary fabrication research which will probably be overcome if sufficient priority is accorded the solid propellants research program. Such priority may now be in effect.

The expanding facilities of the Soviet Union are adequate to conduct all types of fundamental research necessary for the support of an active program in conventional liquid fuels and petrochemicals. Facilities for synthetic fuels research, however, are not likely to be expanded.

The most significant institute likely to produce new lubricants with properties required by future high-temperature performance engines is the Central Scientific Research Institute of Aviation Fuels and Oils, of the old Ministry of Aviation Industry, Moscow. Arctic lubricants were developed at this institute earlier and the present program of synthetic organic chemistry could develop new and effective high-temperature lubricants.

Routine research has improved instrumentation in refining processes, and the Soviet Union claims self-sufficiency in instrumentation. With the general improvement of petroleum technology in the last ten years, it is believed that USSR research facilities will be on a par in quality, if not in extent, with those of the United States in all fields of importance.

QUALITY, QUANTITY, AND EFFECTIVE UTILIZATION OF MANPOWER **

There are a large number of well-trained chemists performing quality research in most fields of chemistry in the Soviet Union. A breakdown of scientific personnel by specialty is not available; but there are reported (1957) to be 58,000 Soviets trained and employed in chemical technology and an additional 18,000 Soviets doing research and teaching in chemical sciences which is a slightly greater number than the estimated 14,000 (1951) U.S. scientists in the same category. The reported 6,000 (1957) advanced degree holders in chem-

* This ministry was replaced by the State Committee of Aviation Technology on 14 December 1957.

** Monograph III provides a detailed discussion on Soviet scientific manpower (see Preface).

istry compare much less favorably with the approximate 17,000 in the United States (1957). It should be noted, however, that a large number of Soviets with advanced degrees in technical sciences are trained in chemistry. In the macromolecular phase of organic chemistry, USSR chemists are generally comparable in training to U.S. chemists in similar positions of responsibility. We believe, however, that the United States has a larger number of such chemists; and their overall training, background, and competence as a group is better than in the Soviet Union. Among the outstanding Soviet contributors are I. N. Nazarov, whose work in acetylene and its application in synthetic rubber is on a par with Walter Reppe in Germany; B. A. Dogadkin, known for work on vulcanization and mechanisms of elastic deformation; A. P. Aleksandrov, dielectric and stability properties of elastic polymers; and A. A. Balandin, polymerization, hydrogenation, and catalytic action.

Physical chemistry is notable for the quality of its outstanding workers such as N. I. Frumkin, an electrochemist; N. N. Semenov, a kineticist and Nobel Prize winner; and V. A. Frank-Kamenetsky, Ya. B. Zeldovich and V. N. Kondrat'iev who are also well known for their work in combustion. Other physical chemists worthy of note are B. V. Deryagin in surface chemistry and M. M. Dubinin in structures and adsorbtion.

Scientists working in unconventional fuels, solid propellants and explosives are fewer in number but comparable in quality to those in the United States. The quality and quantity of Soviet petroleum technologists are inferior to those in the United States.

The apparent numerical disparity between U.S. and USSR manpower in chemical sciences should be evaluated in view of several important factors. The U.S. chemical industry is much larger than the USSR chemical industry and has a far greater consumer goods effort in such fields as paints, plastics, and synthetic fibers. It is significant that a large proportion of the Soviet effort is in research and teaching. In critical and priority areas of chemistry, they have utilized their scientific manpower very effectively. This can be seen in many fields such as organophosphorus chemistry where they are probably superior to the West and also in Soviet advances in the nuclear field. The present reorganization of Soviet science should further increase the effective utilization of their chemical manpower, although the rapid expansion of facilities now underway will be a major obstacle for many years. In the field of industrial science and consumer goods, the emphasis on design for minimal use will probably result in poor utilization of manpower and materials. We estimate, however, that Soviet chemical manpower will be adequate for priority research efforts during the period of this estimate with an increasing ability to devote at least moderate attention to consumer goods research.

SOVIET OBJECTIVES, MAJOR ACHIEVEMENTS, TRENDS, AND FUTURE CAPABILITIES IN BASIC RESEARCH

ORGANIC CHEMISTRY

Basic Research

The Soviet objective in basic organic research is complete mastery of the fundamental and theoretical aspects as a basis for building up their synthetic organic chemical industry.

While much Soviet research in organic chemistry has been empirical, the extent and quantity of published work indicate that they have achieved a good background of knowledge and capability in the field. This is true especially in those areas important to national defense. Much of their work is generally concentrated in areas exploited 3 to 5 years ago in the United States. Access to U.S. work is current, however, and within the next ten years, USSR research should more closely parallel U.S. research. Trends already exhibited in the Soviet Union will be continued for the period of this estimate as follows: (1) develop-

ment of a wide variety of organic compounds through synthesis from acetylene to provide monomers, compounds of medicinal importance, and new organopesticides; (2) synthesis of organosulfur compounds, organometallic mercury, organolithium, organoboron, organotin, and organolead compounds; (3) increased research on fluorocarbons and ferrocene; (4) increased study of theoretical structure and correlation of structure with color and spectral characteristics of organic chemicals.

Advances will probably be made in the area of plastics, synthetic fibers, pharmaceuticals, rubbers, foodstuffs, food processes, and organic chemical intermediates.

Organophosphorus Chemistry

Organophosphorus research is one segment of basic organic research where Soviet chemists have conducted outstanding work and made significant contributions to the literature. The extensive and intensive research and the high professional qualities of Soviet chemists working in the field of organophosphorus chemistry indicate that the USSR has a capability for research in this field which is probably greater than that of the United States. From a military standpoint, the Soviet Union may be five years in advance of the United States in this field. The Soviets have been active in the field of organophosphorus chemistry for years, and since 1945, it has been one of the more important fields of chemical research. These compounds have a large number of valuable industrial and military uses. The two most significant applications are for insecticides and CW nerve agents. The achievements of such leading men in the field as A. Ye. Arbuzov, B. A. Arbuzov, and M. I. Kabachnik are secluded by Soviet secrecy regarding some of their work. However, the papers published by these men and the research groups under them are far more numerous than the total work published in the West and are of comparable quality. The Soviet Union will probably continue or increase the current level of research. The Soviet objectives in the continued emphasis on research and development of these types of compounds are to provide new and improved products for both industrial and war uses.

Macromolecular Substances

General Soviet research in macromolecular chemistry is directed toward utilization of vast resources, especially natural gas which could well become the most important source of raw materials for the entire macromolecular materials industry. The goal is to bring the USSR macromolecular industry to a par with, or if possible to surpass, that of the United States. In the period of this estimate, the Soviet Union will show some improvement in applying basic research to industrial processes, control, and production, but in general the USSR will still lag the United States.

The Soviets have had an annual Soviet Bloc Congress in Moscow on "The Chemistry and Physics of High Polymers" for the past nine years. This annual meeting is giving the Soviets a far greater capability in plastics research than they could possibly hope to achieve by themselves. The Council of Economic Mutual Assistance (CEMA) which was founded in 1949, held its first meeting in 1956 in its new role of planner and coordinator of all research efforts of the Satellites in synthetic fibers, plastics, and dielectrics. Effective coordination of work of the many Bloc laboratories and scientists involved will pose a threat to the technological superiority of the free world in macromolecular materials.

The Soviet Union has made no significant original advances in rubber chemistry within the last five years; it has, however, developed tubeless tires which are copies of U.S. tires. Soviet scientists are developing basic data in rubber polymerization, in structure as it related to performance, in compounding, and in curing. They are also advancing in use of modern laboratory techniques employing infrared and/or ultraviolet rays, X-ray technology, and modern ultra-centrifuges. Future achievements will probably include better quality finished products.

The Soviets have conducted little basic research on the established products of the plastics industry such as phenolics, amino plastics, polystyrene, and vinyl plastics. Most of their research effort has been to improve the utilization of these products. The low USSR

capability in plastics is expected to continue for the next ten years. The Soviets are intent upon achieving an adequate industrial technology in ethylene and fluorocarbon plastics. As their research capability has not resulted in any major accomplishments, progress in fluorocarbon resin chemistry will be slow and difficult. During the period of this estimate, however, there will be progress in advancing pilot plant operations to limited production of fluorocarbon resins, utilizing purchased Western technology and equipment.

The Soviets can be expected to make progress in silicone and other high temperature resin chemistry. They have been successful in applying Soviet-developed silicone resin technology to pilot operations. Laboratories of the world including those of the Soviet Union are actively engaged in basic research work to develop new classes of high temperature polymers. High-speed and supersonic missile and aircraft developments are stimulating this work, but little progress is expected to be made by the Soviet Bloc and possibly the entire free world during the period of the estimate.

The Soviets have shown appreciable progress in synthetic fiber research during the past five years. They have made rapid strides in polyamide fiber development and production. During the period of this estimate, the USSR synthetic fiber industry will probably show more rapid expansion than any other segment of the macromolecular industry and the USSR may come close to but still will not surpass the level of the U.S. technology in synthetic fibers.

Most Soviet produced finished plastics items are simple and of plain design, and barely adequate for their intended purpose. There is an apparent lack of knowledge on fabrication of intricate parts which limits the usefulness of their plastics. The USSR lags the United States by 3 to 5 years in the development of design data suitable for greater utilization of plastics. The Soviets probably will not reach a par with the United States in application of plastics within the period of this estimate.

Ion Exchange Resin Research and Technology

Soviet objectives in ion exchange resin technology are very extensive. They plan vast utilization of ion exchange resins in industrial and economic development of desolate areas where water resources are unusable because of salt and mineral contamination. It will require a hundred-fold increase in Soviet efforts to accomplish these objectives and to serve adequately the food, pharmaceutical, metallurgical, electric power, and medical industries.

Soviet scientists have published fairly extensively on ion exchange resin research. The International Conference on "Peaceful Uses of Atomic Energy" held in Geneva, 8–20 August 1955, exhibited Soviet scientists' knowledge on the use of ion exchange resins for nuclear materials analysis and refinement. D. I. Ryabchikov presented an excellent paper entitled: "Chromatographic Determination of Uranium in Various Materials," which is a good example of the high Soviet capability to do this work. The Soviet advances in the field of semi-conductors may have been helped by their ability to utilize ion exchange resins in the chemistry of rare earths. E. N. Gapon, T. B. Gapon, V. V. Rachinsky, O. M. Todes, and N. A. Izmaylov are outstanding in the theoretical aspects of ion exchange research. The effect of ionizing radiation on ion exchange resins encountered in nuclear energy research is important in connection with disposition of radioactive waste and separation of radioactive isotopes and is considered an important research problem in the United States. The amount of research that the Soviets have published in this field has been small.

The Soviets have published little on specific process applications of ion exchange resins. It is believed that these products are not used as widely in the USSR as in the United States. The trend will be to develop more effective and specific ion exchange resins for many segments of Soviet industry. Their capability to do basic research to obtain improved and possibly new ion exchange resins, however, will probably continue at the present level. A major problem will be the development of

applied technology for specific use of ion exchange resins in various segments of industry. Progress will be slow but published Western technology should assist them appreciably.

Pharmaceutical Research

The Soviet Union is currently using many pharmaceuticals which do not meet drug standards as specified in the U.S. Pharmacopoeia. New Soviet regulations, however, require that vaccines and biologicals meet adequate standards for protection of the public, and it is believed that correspondingly improved standards enforcement will also be established for pharmaceuticals. These actions should result in the removal of many preparations from the market and in the improvement of a number of Soviet preparations. Examples of preparations which could not be sold ethically in the United States include: Albomycin (antibiotic, a 10 percent pure preparation of grisein); Pantocrine (a tonic made from powdered reindeer horn); LSB or therapeutic serum of Belen'kiy (detoxifying agent and partial blood volume expander made from animal tissue); VNS or species non-specific serum (despeciated animal plasma); and Ekmoline (antibiotic, fish tissue extract).

Over the next ten years, effective and safe preparations will appear in the Soviet Union which should more than adequately replace presently inferior products. The Soviets are well-aware of their deficiencies and are being encouraged to adhere to a comprehensive research plan during the next five years to correct them. Pharmacological research has supported work in critical areas but pharmaceutical preparations have varied greatly in quality. The Soviet Five-Year Plan in this field indicates areas that require increased emphasis and will result in broadening the scope of pharmacological research. It is probable that in a few areas of pharmaceutical research, USSR work will be more advanced than that in Western countries. Soviet scientists have achieved some excellent research results in spasmolytic drugs related to atropine, on the pharmacology of alkaloids obtained from native plants, on sulfa drugs, and on blood plasma expanders and additives. The Soviets are also giving increased research emphasis to fields where they now have less competence. This emphasis should ensure some progress in tranquilizing agents, antibiotics, cardiovascular therapeutic agents, cytotoxic agents, vitamins, and hormones. The USSR and U.S. research programs should become more similar by the end of this estimate period with continued USSR strength in the areas of present competence. It is highly doubtful, however, that USSR capabilities will approach the present high position of the United States in pharmaceutical research for many years.

PHYSICAL CHEMISTRY

Reaction Kinetics and Combustion

Soviet past and current research in the field of theoretical reaction kinetics is equivalent to or more advanced than similar research in the West. However, Soviet chemical kineticists have not advanced as far as those in the West in experimental technique and utilization of theory in applied research. In the past, their experimental data has not always supported their sound theoretical research. An exception to this is in the field of combustion where since 1943 research has been slanted toward military and industrial end-items. In both basic and applied combustion research, the USSR matches the Western countries and is possibly ahead in some aspects. The outstanding performances of Soviet aircraft and guided missiles attest to the effectiveness of the combustion research effort.

The center of Soviet basic research in the above fields is the Institute of Chemical Physics, Moscow, where world renowned physical chemists such as N. N. Semenov, Ya. B. Zeldovich and D. A. Frank-Kamenetskiy have advanced the understanding of chemical kinetics. These scientists introduced the theory of chain reactions to explain combustion phenomena. Useful concepts resulted which advanced the understanding of detonation, flame propagation, and combustion. These developments were made first in the USSR and are now also used extensively in the West for clarifying crucial problems connected with combustion in burners and engines.

Soviet research in chemical kinetics is making increased use of mathematics in the study

of chemical reactions involving free radicals and radioactive elements. The concept of reaction mechanism which has been developed will be applied to investigation of reactions of industrial value.

The Soviets will continue to emphasize the theoretical rather than applied study of chemical kinetics. Quantitative rather than qualitative knowledge of chemical process will be sought and much effort will be expended to improve experimental techniques with the aid of new and improved instruments.

Nuclear Chemistry

Nuclear chemistry was already well-established in the Soviet Union in 1940, when the Commission on the Problem of Uranium began to emphasize the importance of this field. Since 1947, when the first Soviet nuclear reactor became critical, extensive reviews have appeared on radioactive isotopes. Nuclear chemistry techniques in the Soviet Union now play important roles in medicine, agriculture, geology, and other sciences. These techniques are especially advanced in chemical engineering and metallurgy.

Nuclear chemistry research appears well on its way to becoming one of the most popular and successful endeavors of the Soviet Union. The trend will be to continue and expand highly successful programs such as those on the chemistry of rare earths which have been in progress at the Moscow State University since about 1946 and also at the institutes of the Academy of Sciences, USSR.

The Soviet Union did not appear to compare favorably with the United States in the field of nuclear chemistry at the 1955 Geneva Conference on Peaceful Uses, but this condition probably resulted from Soviet security measures in most aspects of nuclear chemistry which were covered at this conference. The fundamentals of nuclear chemistry in some of these restricted areas evidently were well known by the Soviets, as confirmed by subsequent publications and discussions on ion exchange, solvent extraction, redox reactions, and coprecipitation phenomena essential to the recovery of fissionable materials and radioisotopes.

Electrochemistry

Soviet electrochemical research is predominantly theoretical and is directed toward the investigation of chemical sources of electric current and the mechanisms of electrochemical synthesis, electro-processes of metals, and oxidation-reduction reactions. A. N. Frumkin, an outstanding authority on electrode processes and mechanisms, is a pioneer in the field of electrochemistry of surface phenomena. As a consequence of his early fundamental work in this comparatively new field, Professor Frumkin has conducted some interesting theoretical and applied studies on protection of metals against corrosion. The balance of the applied electrochemical research program in the USSR has concentrated largely on electrolytic processes which are important in the recovery of metals and on the improvement of standard processes such as are used in caustic soda-chlorine cells. The primary fields of emphasis are currently the mechanisms of electro-processes in electrolysis of solutions, the problems of chemical sources of current, and protection of metals against corrosion.

Catalysis

The Soviet catalysis research program is extensive and comprehensive as determined by the variety and quality of publications in this field. This Soviet research has been notable for many years. The most significant accomplishment was that of S. V. Lebedev who synthesized butadiene from ethanol, opening the way to the commercial manufacture of synthetic rubber. Recent research at the Institute of Physical Chemistry imeni I. Ya. Karpov and at the Institute of Physical Chemistry imeni Pisarzhevsky, Kiev, has developed methods to simplify catalysis research.

The Soviet program for improving methodology is characterized by an increasing use of the technique of low-angle light scattering as an investigative procedure. This technique gives promise of substantiating certain theories suggesting that surface defects are possible centers of catalytic activity. The increasing volume of work in deposited catalysts, particularly platinum on charcoal, indi-

cates that there will be an intensified effort to study these materials and to benefit Soviet technology by using those unusual catalytic reactions which can be effected by many of the rare metals.

Spectroscopy

The objective of Soviet research in spectroscopy is to use this optical method for investigating the composition, structure, and basic energy relationships of matter. A current specific objective of Soviet work is to eliminate the few neglected fields such as high resolution spectroscopy.

Soviet spectroscopy has had a few achievements to its credit. Accomplishments which have been published and received Soviet rewards generally have been of the applied type. Fundamental research, however, has aided in the compilation of dependable Raman spectra data for the identification of individual substances. The recent work of A. M. Prokhorev and B. M. Kozyrev in microwave spectroscopy and the work of A. N. Terenin on molecular spectroscopy is receiving high evaluation by foreign scientists.

There will be an increasing trend toward a greater volume of research in atomic structure and high resolution spectroscopy because of the availability of high precision gratings. These gratings are available through the existence of a satisfactory Soviet ruling machine or through purchase from abroad. Certain fields such as spark, emission, and adsorption spectroscopy will receive increased emphasis at the expense of analytical spectroscopy.

CHEMICAL ENGINEERING

The Soviet objectives to modernize and enlarge the existing chemical industry and to start the production of new materials now in the laboratory stage depend greatly on chemical engineering. The area of chemical engineering which plays the most important role in the scaling-up of laboratory processes and also in the improvement of existing processes through equipment design and procedural changes is the so-called unit operations, such as distillation, heat transfer, and fluid flow. The Soviet Union and the United States were the first countries to treat these operations as unitized concepts, studying the pertinent variables without regard to specific industrial applications. This approach in great measure has contributed to the creation of a very efficient chemical industry in the United States, the most important factor being the efficiency achieved in going from small to large-scale operations. The Soviet Union does not have a sufficient number of trained chemical engineers to apply this concept of unit operations to create a chemical industry comparable to that of the United States. This fact is fully appreciated by the Directors of the three most important chemical engineering research and teaching installations within the Ministry of Higher Education which are the Moscow Institute of Chemical Technology imeni D. I. Mendeleyev, the Moscow Institute of Chemical Machine Building, and the Leningrad Institute of Chemical Technology imeni Lensoviet. Facilities for training chemical engineers are being greatly increased and the most modern equipment provided to remedy the situation. Although the top chemical engineers in the Soviet Union are comparable with those in the United States and the plans for training new chemical engineers are possibly more extensive, the Soviets are not equal to the United States in this field.

Engineers are trained extensively in the industrial ministries in addition to those trained in the general field of chemical engineering by institutes of the Ministry of Higher Education. An example of the product of industrial training is the quite impressive study on the drying of peat conducted by engineers in the Moscow Peat Research Institute. This degree of specialization in the basic training is much more prevalent in the USSR than in the United States and could accrue to the advantage of the Soviet Union when sufficient numbers of chemical engineers with more general training are available. However, specialization does not lend itself to the flexibility that is possessed by U.S. trained chemical engineers.

Within the period covered by this estimate, the Soviet Union might well approach equal-

ity with the United States in the field of chemical engineering research when the impact is felt of the current emphasis on increased number of students with good training in the field. The one factor which might delay this possible equality could be the introduction in the United States of an improved and broader fundamental theory which would provide a basis for correlating all heat and mass transfer operations.

PROPELLANTS AND EXPLOSIVES

The quite limited information available since World War II on Soviet interests in propellants and explosives is obtained primarily from open scientific literature and returned German scientists who were recruited by the Soviets after World War II.

Unconventional Liquid Fuels

Hypergolic Fuels. The Soviet program for the development of liquid propellants for rocket power plants is emphasizing overall reliable performance rather than high energy content.

Since World War II, extensive research on the selection of fuels hypergolic with nitric acid has been carried out by the Soviets and by the Germans in the USSR. The reasons for Soviet interest in these fuels are probably their safe and sure ignition and smooth-burning qualities, plus their adaptability as additives in high-performance fuels without reduction of overall performance. A large number of chemicals suitable to varying degrees for self-ignition with nitric acid have been tested in the USSR. Of these potential fuels, triethylamine seems to be of greatest interest to the Soviets because of availability of raw materials and existence of production facilities. It is probably being used and will be used in the future in the form of Tonka 250 * in a Wasserfall-type missile since combustion chamber tests in Wasserfall engines have already been made by the Soviets with Tonka 250 and nitric acid.

* 50 percent xylidene and 50 percent triethylamine.

The Soviets will probably continue to use these reliable hypergolic fuels and will continue to be capable of producing them in time of war.

Oxidizers. During 1946–51, the Soviets extensively investigated concentrated hydrogen peroxide as an oxidizer in bipropellant systems for rocket-propelled aircraft. This work was carried out by German scientists at Plant 1, Podberezye. Although the Soviets are capable of manufacturing concentrated hydrogen peroxide either by electrolytic or non-electrolytic processes, they are not using the compound as an oxidizer in rocket motors.

The current Soviet use of white fuming nitric acid as an oxidizer for antiaircraft missile fuels follows past German practice in the field. The choice of nitric acid by the Soviets is probably because nitric acid is easier to handle than hydrogen peroxide. In addition, nitric acid is more economical to produce and more abundant in supply.

The Soviets followed former German lines of development in the use of liquid oxygen and ethyl alcohol in their modified V–2 missile. Experiments on replacing ethyl alcohol with kerosene were carried out in 1950 by Germans at NII 88, Branch 1, Ostashkov. It is estimated that the Soviets are now using kerosene instead of ethyl alcohol. The changes carried out by Germans at Plant 456, Khimki, and at NII 88, Branch 1, Ostashkov, to gain increased thrust in the propulsion system involved operation at a higher combustion chamber pressure and an increased propellant consumption rate. Hypergolic ignition so far has not been considered important for this type of missile, and innovations in design to provide for the use of a high-energy fuel have not been attempted. However, the possible use of high-energy fuels may be an important factor in future designs.

High-Energy Components. Chemicals with heat of combustion per unit volume exceeding 110 percent of the value for kerosene are called high-energy fuels. High-energy fuels are generally harder or more expensive to manufacture and handle. With the exception of hydrazine hydrate and boron high-energy fuels,

there is only limited evidence of Soviet activity leading to the use of high-energy chemicals as propellants at this time.

The Soviets have had a competent boron fuel program since 1949, which appears to be relatively modest if judged by the limited amount of data available for intelligence analysis. This program has been carried out primarily at the Institute of General and Inorganic Chemistry imeni N. S. Kurnakov and could be at the same level of development as that of the United States. The Soviet boron fuel program should continue to develop as fast as that of the West. Adequate quantities of diborane, an intermediate in the production of boron fuels, are available for experimentation. During the time of this estimate, boron fuels will be used in air-breathing engines of airplanes.

Hydrazine hydrate has been tested in rocket aircraft in the USSR and probably is available for limited operational use at the present time.

Solid Propellants

Problems having direct bearing on solid propellant research have included formulation of a propellant with a burning rate which changes relatively little with a change in pressure (the "plateau" effect). So far as can be determined, the Germans never achieved this objective. The Soviets are cognizant of the need for attaining a "plateau" effect and, if actively interested in the use of solid propellants for rockets of greater size than those in use during World War II, they will undoubtedly achieve this goal by the end of the estimate period.

For a long time, the USSR has been actively interested in ammonium nitrate both as an explosive and for use as a fertilizer. Ammonium nitrate has been under consideration by the Western powers as an oxidizer in certain propellant compositions; but it has the disadvantage of being extremely hydroscopic, and it also undergoes an undesirable phase change at operational temperatures. The Soviets have successfully solved the hydroscopic problem in fertilizer applications. Their published articles also indicate an awareness of the phase change problem, and it is possible that a successful solution has been devised for this problem as it has been in the United States.

Much of the Soviet literature on potential materials for solid propellants is directly associated with other applications. A recent paper on the compatibility of nitrocellulose with other high polymers, for example, was written by a worker at the Central Scientific Research Institute for Leather Substitutes, Moscow.

The status of the USSR on double-base smokeless powder was revealed in specifications supplied the United States during World War II. The USSR product was more easily extruded but was inferior in storageability to those of the United States and United Kingdom. Beyond this creditable beginning in comparison with the United States, USSR achievements in the development of solid propellants are not known. Considering their capability in combustion and other related fields of basic research, it is estimated that the Soviet Union is probably on a level with the United States in solid propellants.

Explosives

Research and development efforts of the Soviet Union in the field of explosives are primarily along the following lines: 1) Research for new mixtures and compounds which have not been tried and reconsideration of known explosives which had been considered and dismissed; 2) Attempts to overcome shortcomings in stability, process procedures, and safety features which would enable the military to use known powerful but presently deemed unsuitable explosive compositions; 3) Fundamental research efforts to better understand the mechanism of producing explosives including the effect of pressure, temperature, and density upon the burning of explosives and the theory of explosions.

Available information has not revealed the development of any greatly improved new Soviet explosive nor is any such product anticipated within the period considered in this study. In view of the classified nature of research in military explosives, it is possible but not probable that the Soviets have pro-

duced improved explosives composed of substances or mixtures unknown outside the Soviet Union. Since USSR acceptance, specifications for military explosives are not as stringent as those of the United States some of the known powerful explosives might first find acceptance by the USSR. In the field of applied explosives research, significant work is being carried out by A. T. Titov in the Laboratory of Organic Chemistry at the Military Academy of Chemical Defense imeni K. M. Voroshilov, Ministry of Defense and by K. K. Andreev at the Institute of Chemical Physics, Academy of Sciences, USSR. In addition, fundamental research in explosives has been carried out by D. A. Frank-Kamenetskiy and N. N. Semenov of the Institute of Chemical Physics.

No major achievements in explosives are expected within the period covered by this estimate. The existing explosives do not allow much room for an increase in energy output by chemical reaction, especially when compared with the order of magnitude available by other mechanisms such as nuclear explosions.

PETROLEUM TECHNOLOGY

Conventional Liquid Fuels

Much of the basic research in organic and physical chemistry conducted in the Soviet Union has been and is oriented towards the study of petroleum, its derivatives, and catalysts for processing it. Organic chemical research includes attempts to develop additives, which will improve storage stability, and to reduce engine knock. Physical chemistry efforts are directed toward understanding the general laws governing catalysis so that cheap native clays can be used in refining processes. The most notable trends in the basic research program are toward an increasing use of radioisotopes, improvement of polymerization techniques to support lubricant development, and the use of oxidation techniques to support petrochemical development.

Soviet research includes exploration, drilling, and recovery. Less conventional exploration methods * have been investigated for the purpose of developing a positive method of locating oil deposits. Inconsistent results in these methods, however, have caused a return to research on the more conventional methods of exploration. The microbiological method of oil exploration has resulted in a microbiological mapping of large areas of the Caspian Sea bottom near Baku. The geochemical method was investigated by Dr. V. A. Sokolov.

The outstanding USSR achievement in the field of petroleum production research has been the successful development of turbine drills, which are being licensed for fabrication in France and the United States. There appears to be a trend toward expansion of drilling research with investigation of new techniques such as "blast-drilling."

The USSR is conducting a research program for improving the rate of flow of crude oil from dormant wells, which is comparable to that of the United States.

The Soviets conduct research on underwater drilling at a special institute near Baku, Gipromorneft (State Institute of Sea [Underwater] Petroleum Projects). The Soviet Union has made some advances in this field but they will not reach the level of Western technology in a decade.

The Soviets have made some significant contributions to refining technology. The outstanding contribution was the discovery by A. M. Rubinshteyn (published in 1940's) of the transforming properties exerted by platinum catalysts on certain hydocarbons, improving their octane rating. Commercial application, however, lagged the United States by about six years.

There have been numerous studies in the USSR on the catalytic activity of certain natural clays as possible Houdry catalysts. Catalytic refining and the general level of refining technology in the USSR, nevertheless, lag the United States and will continue to do so through 1967.

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*Soviet research in conventional oil exploration methods such as the seismic, gravimetric, etc. is treated in Monograph VI, *Geophysical Sciences*.

The only known Soviet accomplishment in the field of synthetic liquid fuels has been the publication of a series of well-received papers on the Fischer-Tropsch (coal gasification) process by Ya. T. Eidus and A. N. Bashkirov of the Academy of Sciences, USSR. The establishment of a chair of "Technology of Synthetic Liquid Fuel and Gas" at the Moscow Institute of Fine Chemical Technology imeni M. V. Lomonosov is indicative of a continuing but probably not highly significant Soviet research effort in synthetic liquid fuels.

Petrochemicals

The production of useful chemicals through petrochemical development was stressed in June 1955 by the Communist Party of the Soviet Union. As a result, new facilities are being built and a gradual introduction of hydroforming and platforming (aromatization processes) is modernizing practices for the production of aromatic compounds.

The most active segment of petrochemical research in the USSR is the oxidation of paraffins such as kerosene to produce edible fatty acids as a way of increasing the food supply. In 1956, a conference on this subject was held in Moscow and was attended by nearly 200 scientists.

The Soviets have conducted a narrow but adequate petrochemical research program devoted to the synthesis of alcohols; and, currently, the USSR is building several plants to operate on refinery waste gases. There is no discernible trend toward diversification of the Soviet petrochemical research program.

Lubricants

The objectives of the Soviet research program in lubricants are lower cost components and stable products through careful selection of base materials or additives. The objective of recent research on additives has been to overcome the deleterious effects of oxidation at high temperature.

The most significant results of Soviet work in the field of lubricants are the published fundamental research studies on the plasticity of oils and greases by P. A. Rebinder at the Institute of Physical Chemistry of the Academy of Sciences, USSR, and applied research on cold weather lubricants by the Central Institute of Aviation Fuels and Lubricants, Moscow.

The trend of Soviet lubricant research is to emphasize the investigation and synthesis of new liquid compounds to meet the demand for increasingly higher temperature service lubricants.

SATELLITE AND CHINESE COMMUNIST SUPPORT IN BASIC RESEARCH

East Germany, Czechoslovakia, and Poland have made some contributions to Soviet Bloc organic research. The quality of East German research is considered superior to that of the Soviets.

East Germany, Czechoslovakia, Hungary, and Poland are making very substantial contributions in macromolecular research. Czechoslovakia is also doing basic research in most fields of plastics with emphasis on synthetic fibers. Hungary has a small but high caliber group of scientists working in the field of plastics.

The East German plastics research program is probably further advanced than that of the Soviet Union in the fields of fluorocarbons, films, and ethylene polymerization. East Germany has competent research scientists such as Dr. Werner Winkler, the Minister of the Chemical Industry (since 1956) and a professor at the Technische Hochshule fuer Chemie, Leuna-Merseburg; Dr. Johannes Nelles, the Director of VEB Werk, Buna; and Dr. Richard Mueller, the Head of the Institut fuer Silikon und Fluororganische Chemie in Dresden, to name only a few. Plastics research in Czechoslovakia is mainly carried out at the Research Institute of Macromolecular Chemistry in Brno, the Research Institute of Rubber and Plastics Technology in Gottwaldov, the Research Center for Technology of Plastics and

Rubber in Prague, and the Institute of Synthetic Fibers in Svit. Czechoslovakia is not as advanced in plastics as is East Germany; Czech laboratories are not as well equipped nor do they have the quality or quantity of scientific people.

The Soviets are planning to center leadership of Satellite research in various aspects of plastics in the particular country that has demonstrated an ability to conduct successful research in the specific field. The Satellite macromolecular research contribution to the Soviet effort will increase appreciably within the period of this estimate and will assist greatly in reducing the U.S. lead over the USSR.

East Germany and Czechoslovakia provide most of the Satellite support in research and development of ion exchange resins. VEB Farbenfabrik Wolfen is the center of such research in East Germany. The research staff of this center has collaborated extensively with Soviet chemists.

Catalysis is a field in which Satellite support may be significant during the period of the estimate. Outstanding Satellite contributions will probably be in basic reseach from Hungary and particularly from East Germany where a strenuous effort is being made to develop the Institute for Catalytic Research of Rostock into an important center of catalytic research.

Satellite support in chemical research strictly of military significance will be limited. Although there is no Sino-Soviet Bloc unconventional fuel program, individual workers such as the Polish chemist, Tadeusz Urbanski, who has written extensively on the preparation of potential solid propellant materials, may turn out work of value to the Soviets.

Although almost all of the Satellites have conducted research on synthetic liquid fuels, most support will probably come from East Germany which has experience in synthetic fuel development and numerous synthetic fuel plants.