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BOOK ON HISTORY OF RUSSIA'S CHEMICAL INDUSTRY REVIEWED

History of Chemical Shops and the Chemical Industry of Russia, by Doctor of Technical Sciences, Professor P. M. Luk'yanov, Senior Scientific Associate of the Institute of History of Natural Science, Academy of Sciences USSR, in two volumes, published in 1948-1949, won for its author a 1949 Stalin Prize Third Class.

Luk'yanov's basic work is devoted to the origin and development of the chemical industry in Russia. The author did a considerable amount of research in libraries and archives, studying both printed and manuscript sources, in order to establish the historical accuracy of his information.

Volume I is a general survey by periods of the history of the Russian chemical industry from ancient times to the end of the Nineteenth Century. Volume II is devoted to the history of the development of individual inorganic chemical products (potash, saltpeter, sulfur, vitriols, alums, nitric and sulfuric acids, alkalis, soda, and sodium hydroxide.)

The work contains interesting and little-known historical facts. The author shows, for example, that salt extraction in old Russia was extremely highly developed. As early as the Fifteenth Century, skilled Russian workers were able to work salt mines to a depth of 60-70 meters; and by the end of the Seventeenth Century to 165 meters. Sulfur was obtained from pyrites in Russia in the Seventeenth Century, considerably earlier than in Sweden, which is incorrectly credited with having discovered this method.

The reforms of Peter I, as Luk'yanov points out, aided greatly in the development of the Russian chemical industry, particularly in the production of saltpeter, sulfur, potash, glass, and mineral and vegetable dyes. Documents

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discovered by the author indicate that Peter I was greatly interested in chemistry and the art of assaying to determine the composition of metal ores. The first technical chemistry laboratory was established in Russia, in 1720, to experiment with ores, mineral dies, refractory materials, etc.

The work devotes considerable attention to the activities of Lomonosov, who set up the first scientific research chemistry study laboratory in the world in 1748 under the Academy of Sciences. The contrubitions of Severgin, Mendeleyev, and other academicians are also treated.

Volume II gives evidence of the advanced development of the Russian chemical industry, as compared to those in foreign countries. For example, Russia developed the production of sulfuric acid in closed (glukhoy) chambers in 1805, much earlier than did Germany. The utilization of waste gases containing sulfur dioxide for conversion into sulfuric acid was accomplished at the Peterburg Mint in 1829, more than 50 years before it was done abroad. Russia also originated the industrial production of liquid carbon dioxide and electrolytic plating of metals (galvanoplastic).

Noting these facts, the author points out the destructive policy of the Tsarist government, which led to Russia's backwardness in initiating the manufacture of such important chemical products as soda, artificial fertilizer, etc.

Luk'yanov's work is the first to disclose the creative independence of the Russian people in the field of chemical production and to destroy the false legend of the dependence and imitativeness of the Russian chemical industry.

/Comment: The above report is based chiefly on the Pravda review by Prof. S. Pogodin, honored worker in science and technology./

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CIA
Foreign Documents Division
U-889

REPORT ON ACTIVITIES OF THE SWEDISH ATOMIC COMMITTEE

1945 - 1949

Source: Redogörelse för Atomkommitténs Verksamhet, 1945 - 1949 (Swedish)

June 1950

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FOREWORD

The Atomic Committee, which ~~was established~~ as a coordinating and directing organ for Swedish atomic energy activities since December 1945, has now taken the time to prepare a short report on certain aspects of those activities.

The basic facts concerning atomic energy problems are undoubtedly well known, even outside scientific circles, as the result of articles in the press and popular scientific works. The Committee has therefore limited itself to simply outlining in the introductory chapter the principal facts which give atomic energy problems ~~their~~ special character and which furnish the reasons for ~~its~~ the special status in technical and scientific research which atomic energy research has come to hold. The following chapter reports on the organizational developments in ~~the various~~ countr~~ies~~y, following which is a report on that part of the research work which is being done with funds from the appropriation for atomic energy research, ~~the most important~~ basic research ~~among~~ the natural sciences. The research and activities more directly ~~connected with~~ related to a specific goal are finally reported on briefly.

Stockholm, 30 January 1950

Malte Jacobsson

/Gösta W. Funke

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THE LIBERATION OF ATOMIC ENERGY

An Extraordinary Discovery Which Requires Extraordinary Measures

No scientific discovery or technical invention, either in ancient or modern times, has attracted so much public attention as the demonstration of the possibilities of developing on an industrial scale the quantities of energy confined within the nucleus of the atom. This attention is completely justified, because even though we are still in the dark about most of the future consequences of this discovery, simply the political effects which the military applications of the discovery have already caused and the enrichment of our scientific knowledge brought about especially by the rapid development of research on tracer isotopes, would be reason enough to place the problem of atomic energy in its special position. From a theoretical standpoint the release of atomic energy also means that possibilities have opened up for a basically new source of energy. Before the invention of the steam engine engineers were dependent upon machines which used purely mechanical energy, primarily the kinetic energy of wind and falling water -- thus freeing themselves from dependence on draft animals and human labor. The first steam engine provided the possibility of converting heat from wood, coal, etc. into mechanical energy on a large scale. We all know what enormous significance the invention of the steam engine and of the power machinery based on it had on the world's economic, political, and cultural life; but from the scientific theorist's point of view this meant only that energy was being utilized which was released by changing molecular structure and the outer structure of the atom. After a certain amount of knowledge concerning the atom's inner structure became available during the first few decades of this century, scientists therefore began to speculate on the possibilities of releasing the enormous quantities of energy which, according to what experiments had shown, were contained in the innermost part of the atom, the atomic nucleus, and which could be released in some cases by splitting heavy atom nuclei already existing (example: uranium reactors, uranium or plutonium bombs), in other cases by

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It must be strongly emphasized that these theoretical and basic considerations concerning the significance of questions of atomic energy are strictly long-range. However, it is certainly necessary that an effort be made as soon as possible to determine clearly, first and foremost whether it is going to be possible within a forseeable time to master the purely technical problems which now stand in the way of the application of atomic energy, and also to draw up a more detailed picture of the special fields in which the attempt could first be made to utilise nuclear energy and what the economic significance would be within those fields. Available data are now too limited to permit any more exact evaluations of the latter type, but many studies have been carried out, especially in America. As an example one may cite one such study made by the Cowles Commission for Research in Economics at the University of Chicago (extract published in the Bulletin of the Atomic Scientists, November 1949), even though this does not give much more information than other such ~~experiments reported~~ ~~to~~ previously. It may be ~~noted~~ as a basic fact for the discussion at hand that atomic energy differs from other forms of energy in [illegible] one very basic respect, namely, that the cost is almost completely independent of geographical location. The price of coal and oil increases with increasing distance from the mines or oilfields because of the costs of transportation, and the same is true of hydroelectric power, the cost of which depends upon the distance from the waterfall. The freight costs for atomic fuel are negligible, however. Experiments are therefore concentrated on the following three problems:

1. The possibility of reducing costs in industry, which at present consumes large quantities of energy per unit produced.

2. The possibility that cheap atomic energy might be able to bring about changes in the present production methods, in that processes based on atomic energy might replace fuel-consuming or chemical processes.

3. The possibility that certain industries might be given a geographic location which would take into consideration the geographic equalization of costs for power. The industries which should be the subject of research are the aluminum industry, iron and steel production, rail transportation, and household heating.

It is not possible here to go into the matter of how the Committee arrived at its estimates. However, it is estimated that production costs per kilowatt hour will be established at about one cent (about 5 öre since devaluation) and that even with the methods which are now known in theory they ~~it~~ can scarcely be reduced to less than 0.4 cent (about 2 öre) per kilowatt hour. So far as the aluminum industry is concerned one may conclude that the cost for aluminum production will not be lower with atomic energy so long as the factories remain in their present locations, because these locations have been chosen so as to take advantage of power which is so cheap that atomic energy can scarcely compete with it. On the other hand it appears possible that prices might be lowered in the case of new factories erected at the points where the bauxite is obtained, in view of the fact that the cost of transporting the bauxite would be eliminated. Concerning the iron and steel industry it may be observed that certain technical methods which are now being developed in the iron industry (reduction with hydrogen gas obtained electrolytically in place of coke) might bring about a situation in which the distance from the coal fields would be of less importance than the distance from the ore fields. If this should be the case, atomic energy might come to be of great importance even in the iron and steel industry. So far as household heating is concerned, the committee came to the conclusion that the use of atomic energy might very well prove practicable in heavily populated cities. A more cautious view is taken so far as the use of atomic energy for railroads is concerned.

The experiments briefly referred to above, as well as practically all others which have been carried out, apply to American conditions. If we attempt to apply them to our conditions we must take into account the fact that we have relatively limited indigenous ~~xxxxxxxx~~ power resources (in effect, only the hydroelectric power, which is to be sure relatively important) and high fuel costs, whereas the USA has an abundance of fossil fuels at a low price. If we could produce atomic fuel from indigenous materials at a reasonable price it would help ~~x~~ out in the significant problem of conserving foreign exchange which now goes for the purchase of fossil fuel, and would also be important from the point of view of preparedness. There is therefore no question but that the solution of the atomic energy problem is of greater importance for a country such as ours than for countries such as the USA with its ~~xxxxxxx~~ great variety of resources of cheap ~~xxxxxx~~ power from other sources of energy.

Another report of great interest, concerning the technical and economic possibilities of atomic energy, has been published by the former members of the American Atomic Energy Commission, physicist Robert F. Bacher (Bulletin of the Atomic Scientists, March 1949). He gives a description of the program for the next two years which has been drawn up by the American Commission precisely in order to stress the technical and even the economic problems which are connected with the use of atomic energy as a source of industrial power and for other similar purposes. Four more reactors are being or are to be built for these studies, one for testing materials, one on Navy account to serve as prototype for a future reactor for propelling vessels, one for experiments on the utilization of rapid neutrons, and one for experiments on the utilization of neutrons with medium energy. Both the latter two reactors will also be used to study the extremely important problem of breeding, which may be said to mean the problem of utilizing the isotope uranium 233 (0.7 percent of natural uranium which uranium 235) and torium.

The intensive radiation in a reactor pose many new and growing problems for both scientists and constructors. The material-testing reactor is to be used simply to study the effects of the radiation on the properties of materials. It is to be operated using uranium concentrated the isotope uranium 235 as fuel, and is expected to produce a very high concentration of radiation.

The other reactors are also to be operated by concentrated uranium. Bacher emphasizes the importance for the Navy of a vessel with the increased range of operations which atomic energy drive would make possible.

Already there is a reactor in Los Alamos which utilizes rapid neutrons (fast reactor) with uranium and plutonium as fuel. The new fast reactor is to be operated by uranium concentrated to uranium 235.

An experiment is to be carried out with it using liquid metal as a coolant. The advantages of this are that one can obtain a high temperature without a high pressure and that it is possible to find metals suitable for this purpose , among other things, do not absorb neutrons to a sufficient degree to be a deterrent.

Of great interest is the reactor in which it is planned to utilize the medium-fast neutrons. Its use is otherwise similar to that of the third reactor described above.

Bacher also refers to long-range plans, among others, to a reactor to drive aircraft, reactors for the production of power by utilizing non-concentrated uranium and homogeneous reactors, reactors in which the fissionable material and the moderator material are blended into a relatively homogeneous mass, in place of the grid structure which characterises the present reactors and gives them their original name (piles).

Bacher also notes that the first peacetime application will probably be in regions far removed from other sources of ppwer. He thinks that in about 8 - 10 years there will be installations in operation which ~~x~~ will be able to give more definitive answers to questions concerning atomic energy's ability to compete with other sources of power.

As a start, the military application of atomic energy is regarded as one of the reasons why the problem of atomic energy is attracting, ~~xxxxxxxxxxxx~~ ~~xxxxxx~~ in practically all of the more important ~~xxxxxx~~ civilised countries, government ~~xx~~ on a heretofore unprecedented scale so far as scientific and technical problems are concerned. So far as our country is concerned, there is no necessity to develop atomic bombs or other atomic weapons, but it must be clear that in spite of that it is of extraordinary importance for us to follow in detail the military developments in this field, because these developments have a great effect on our defense measures. Obviously this means that comprehensive research on protective measures against atomic weapons must be carried out. This research is primarily the responsibility of the Defense Research Institute.

In the general discussions atomic ~~energy~~ research, that is, atomic bombs and the industrial applications of atomic ~~xxxxx~~ energy, has naturally come to the fore. However, one of the prerequisites for obtaining results in atomic energy research is that adequate attention also be given to research in the broader field which ~~xx~~ may be called nuclear research and ~~xx~~ the still broader field of atomic research. It may also be noted that scientifically and from ~~xxxxxxxxx~~ the standpoint of practical application the most important results have been and will be obtained within the field of nuclear research by applying the results obtained from atomic energy research. In this connection it is only necessary to recall the ~~xxxx~~ application of the tracer isotopes, which have given rise to a science of their own. They had already existed previously, independent of the construction of uranium reactors, but through these apparatuses great new possibilities were opened up, in that the number of artificially produced radio-isotopes could be increased to such an extraordinary degree that the quantities of certain isotopes which could be produced were likewise considerably increased and produced at a lower cost.

However, the hopes which have been awakened by the progress of the last two decades in the field of atomic research are much greater than indicated by the above. The most important aspect of this work on a long-range basis is the knowledge of nuclear structure which has already been obtained and which will be obtained in the future with the recently developed aids. It may be anticipated that this knowledge will come, step by step, to have a profound effect on all social activities which are based on our knowledge of nature, that is, on the natural sciences, technology, industry, medicine, agriculture, etc., and, strictly speaking, on society as a whole. This process has already begun; as yet it is confined primarily to the purely scientific aspects and certain therapeutic and industrial fields.

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It is against the background outlined here that one may see the uncommonly far-reaching measures which the problem of atomic energy has given rise to throughout the world. In America, in Russia, and in Great Britain enormous sums of money have been allotted for this activity, and the greatest possible resources in personnel and materials have been made available. In a number of smaller countries many appreciable sacrifices have been made, depending upon the circumstances, especially in France, Canada, South Africa, and Norway, likewise in Holland, Belgium, and Switzerland. The same is also true of our country.

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THE ORGANIZATION OF ATOMIC ENERGY RESEARCH IN OUR COUNTRY

An atomic bomb was dropped on Hiroshima on 6 August 1945. The perspec- tive which was thereby opened up was discussed in the preceding section, and the Swedish authorities were not slow to grasp its consequences. According to a decree of 23 November 1945, the head of the Board of Education was auth- orized to initiate a discussion concerning plans for research work on the liberation of atomic energy. A special committee of experts, the Atomic Committee, was set up for this purpose; its assignment was based on the fol- lowing directive:

"For some time natural scientists have regarded the utilization of atomic energy as their major goal -- a goal which many, even as late as a few years ago, regarded as doubtful of attainment. A solution to this dif- ficult problem now seems to be possible.

"The tracking down and utilization of atomic energy is the result of unbiased research on the structure of atoms carried out by experimental physicists and atomic theorists. During the past twenty-five years research on atomic nuclei has been progressing at a very rapid rate, and the discovery of atomic fission in 1938, which led to the present problems, was a part of that pure, unbiased research. The lead in the tremendous work on the utiliza- tion of atomic energy has been taken by theorists and experimental physicists.

"The determination of the properties of atomic nuclei is the most pressing problem in physics at the moment, and a number of fundamental problems depend upon its solution. During the next few years and decades one may certainly count on considerable progress in nuclear physics, which may also be of the great- est significance for various practical applications. It is of the greatest importance that research on atomic nuclei be given the opportunity for strong development even in Sweden.

"So far as research is concerned, it is of primary importance to find a suitable method for utilizing power for peacetime purposes. If our country

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is not to lag behind in technical developments, it is necessary that research in this field be carried out ~~in~~ within the country with the special aim of ascertaining our prerequisites and the possibilities of utilising atomic energy for practical purposes. This research must include a number of problems in other fields, and probably it will not be possible to obtain a satisfactory result in a short time unless the activities at the institutions and technical bodies concerned are effectively coordinated and directed toward a practical solution of the problem of the suitable utilisation of atomic energy. Accordingly, an organisational basis must be created for this purposeful research, and at the same time suitable measures must be taken to provide a sufficient number of research workers with the possibility of doing work on the utilisation of atomic energy. Possibly it will prove desirable to set up a special institute to handle the activities in coordination with other research units.

"The more detailed discussion which appears to be necessary in the connection now indicated could probably be turned over to special experts recruited from within the Board of Education. These experts should make it their principal assignment to offer suggestions as to how research on atomic nuclei may be suitably organised and how the theoretical and applied research can best support one another. Should it be found necessary during the discussion work to make temporary arrangements with a view to furthering the actual research work going on at the time, the specialists should be free to make the recommendations in this connection which seem to be called for.

"The discussion work, which will probably be carried on in cooperation with the Natural Science Research Committee, should ~~in~~ proceed as fast as possible and should be so planned that the recommendation for the necessary measures can be submitted at the beginning of next year."

The Committee started its work in December 1945. Its membership has been changed in a few respects since the original appointments, but now consists of the following persons: President, Governor Malte Jacobsson. Members, Professor Hannes Alfvén, Chief Director Albert Björkeson, Professor Torsten Gustafson, Professor Bo Kalling, Director Ragnar Liljeblad, Professor Edmund

Schjaanberg, Colonel Torsten Schmidt, Professor Manne Siegbahn, Professor Otto Stelling, General Director Haakan Sterky, Professor The Svedberg, and Professor Ivar Waller. The secretary is Gösta Funke.

On 13 March 1946 the Committee was finished with its first report entitled "Considerations Affecting the Preliminary Organisational Measures for the Promotion of Atomic Energy Research" (mimeographed). As may be assumed from the title, this memorandum discussed preliminary measures for the organisation of atomic energy research, and it was stressed that more experience would have to be acquired before the organisation could assume a more permanent form. As a result of the Committee's proposal, the 1946 Riksdag approved an appropriation of 2 million kronor for atomic energy research. In connection with this, His Majesty ordered that the Atomic Committee should act until further notice as a coordinating and advisory organ. In order to relieve the Committee of the routine assignments which were devolving upon it, and in order to prepare other assignments, before they were acted upon by the Committee as a whole, a Working Sub-Committee was set up which contains four members.

Atomic energy activities, as already pointed out, are in certain respects unique in human history. Simply the magnitude of the task is motive enough for such an observation, and it follows from this fact that no private industry, individual, or combine is able to undertake such a task. It is a typical assignment for the largest social organization, the state. In addition, it has become the most obvious example so far known of cooperation, or the need for cooperation, between scientific research -- a multiplicity of disciplines of both theoretical and experimental nature -- and industrial activities, likewise variable and of large-scale industrial scope. This state of affairs must be reflected in an organization which will be suitable for the tasks which fall to our country in line with developments in this field.

In another memorandum, "Considerations and Recommendations for the Organisation of and Economic Support for Atomic Energy Research" (26 April 1947), the Committee drew conclusions from these considerations and recommended that both the construction of several other uranium reactors and the assignments connected therewith -- which are predominantly technical in nature -- should be entrusted to a special, quasi-governmental company, the Atomic Energy Company. These assignments are extraordinarily comprehensive. The most pressing, the production of uranium, includes mining, concentration of ores, extraction of uranium, and refining, all on a large scale in spite of the fact that the end product, the pure uranium metal, is obtained only in small quantities, measured by industrial standards. The recommendation that a company be formed instead of, for example, a government institute or plant, was based on two considerations: in the first place, it was thought, perhaps especially in industrial circles, that a great flexibility could be attained in handling the matter with the use of the corporation form; in the second place, it was felt that in this way it would be easier to achieve the cooperation of industries experienced in the various technical fields which the project involved. It is obvious that the intimate cooperation with such industries is facilitated if they are stockholders and co-partners in the corporation. The Committee wrote the following in its memorandum:

"Furthermore, it appears no less important that intimate, confident, generous cooperation be established with all the forces of industrial life which either have already indicated their positive interest in this important problem or will be interested at a later date. Without access to the technical experience and the production resources which Swedish industry possesses, the Committee feels that the work on the exploitation of atomic energy cannot proceed rationally and with the desired speed. Marshalling Sweden's scientists and engineers with the economic support of the government and industry appears to be the only possibility for assuring the desired results in competition with the other nations."

In taking this stand on this question the Atomic Committee and the government authorities by no means closed their eyes to the fact that for some time to come the Atomic Corporation will have to have a manner of operation which will differ rather considerably from that of other enterprises in corporation form, in particular in that for a long time it will have no income but rather expenditures. Large government grants will therefore be needed for the Corporation's activities. The private shareholders' financial interests will be limited, in any case for the time being, to paying in the share capital.

The recommendations offered concerning the formation of the Atomic Energy Corporation were accepted by the government and by the Riksdag, and in the fall of 1947 the Atomic Energy Corporation started its work (the initial meeting was held on 8 November 1947).

The Corporation has a board of managers consisting of seven members and four deputies. His Majesty appoints four of the members, one of whom is the chairman, and two of the deputies. At present the board of managers consists of the following persons: Chairman, Governor Malte Jacobsson; members appointed by His Majesty, Director Claes Gejrot, General-Director Haakan Sterky, Professor The Svedberg; members appointed by the other stockholders, Director Erik Bengtson (vice-chairman), Director Carl Kleman, Director Ragnar Liljeblad. Deputies appointed by His Majesty, Professor Otto Stelling and Professor Ivar Waller; deputies appointed by the other stockholders, Director Elam Tunhammar and Professor Waloddi Weibull.

The government is the majority stockholder in the corporation. According to the articles of incorporation, the share capital is to be not less than 3 million kronor and not more than 9 million. At present it is 3.5 million kronor, of which the government has contributed 2 million and private enterprise 1.5 million. The corporations's address is Västmannagatan 13, Stockholm.

By and large the organization of atomic energy research has remained unchanged since the date mentioned above, with the exception of a few small changes which were designed mainly to give the Atomic Committee, which, since the splitting off of the activities with industrial emphasis has assumed a function approximately the same as that of the research councils, an authority similar to that of the research councils to make its own decisions concerning the use of funds in cases where the amount involved is less than a certain specified sum (10,000 kronor); and also to give the Committee a better opportunity to supervise the utilization of the funds granted. Cooperation with the other research councils has been facilitated in that the councils and the Atomic Committee have set up a special organ for cooperation between them, especially in matters of broader or more basic importance, the Research Council Delegation for Cooperation, whose members are the chairmen of the councils and of the Committee.

In connection with the setting up of the Atomic Energy Corporation it was possible to relieve the Defense Research Institute of some activities which had previously been assigned to it and to turn them over to the Atomic Corporation. This applied to both chemical and physics projects. The existence of the Defense Research Institute was of the utmost importance in making it possible to get those activities which are directed toward a specific goal under way rapidly, and the Committee is extremely grateful to the Research Institute for the extensive work which it did during the early stages.

An appropriation of 2 million kronor was set aside for atomic energy research by the Atomic Committee for the fiscal year 1946/47. An amount of 1.9 million kronor was planned for each of the fiscal years 1947/48 and 1948/49, or a total of 5.8 million kronor for the period up to 1 July 1949. Practically the whole of this amount had been disposed of by that date. For the present fiscal year also an amount of 1.9 million kronor has been appropriated, and the same amount has been requested for 1950/51 in the government proposals which are now being submitted. However, these are not the only funds at the disposal of atomic energy activities. An amount of 3.5 million kronor has been paid in in share capital for the Atomic Energy Corporation, besides which the corporation has

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been granted special government appropriations as follows: for 1947/48, 2 million kronor; for 1948/49, likewise 2 million; and for 1949/50, 500,000 kronor. Four million kronor have been requested for fiscal year 1950/51 in the government proposals for the year. The appropriations mentioned here amount to a total of 9.8 million kronor up to 1 July 1949, if we deduct the share capital of the Atomic Energy Corporation. However, about 3.5 million have been reserved, so that not more than 6 million kronor had been disposed of by that date. A large part of this sum was used for materials, personnel, etc. for the scientific institutions. Now, however, we have reached the point where large investments are needed for industrial installations, and a start will now be made to use the Corporation's share capital for this purpose, as well as the reserves mentioned above and the 4 million requested for the next fiscal year.

Even if this amount is not small for our activities, the question may certainly be asked whether it is possible to obtain any results with such expenditures, which are certainly very insignificant in comparison with what nations like the Soviet Union, the USA, the British Empire, and even France are spending for these purposes. It must be pointed out that we are of course working in a considerably more restricted field than Russia, the USA, and Great Britain, and that furthermore, with our limited resources, especially so far as trained personnel etc. are concerned, we are compelled to adopt a totally different work tempo. However, this also gives us time for a more thorough planning, whereby considerable sums are saved. On the other hand, it should be clear that no results of great importance can be attained without exceeding a certain minimum amount. Inasmuch as we have now increased the personnel strength and the instrumental equipment, and have also made a start toward developing the technical processes, we must now be prepared for increased economic resources to be made available, gradually, in any case so far as the field of activity of the Atomic Corporation is concerned. This situation is already reflected in this year's government work program proposals.

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DEVELOPMENT OF SWEDISH RESEARCH ACTIVITIES

General

Nuclear research has been carried out in our country on a limited scale ever since its beginning during the last decade of the eighteenth century with the discovery of spontaneous radioactivity. This research required scarcely any greater resources than natural science research as a whole required. This situation was changed by the discovery which was initiated by Rutherford's splitting of nitrogen nuclei in 1919 with a-particles from a radioactive compound, which subsequently led to nuclear fission by Cockcroft and Walton in 1932 with the aid of protons accelerated in a high-voltage installation. This experiment, and the cyclotron built by Lawrence in 1931, ushered in the epoch of experimental nuclear physics, which is characterised by the origin of all the large and complicated devices used to accelerate the speeds, and thereby the energy, of those particles which are used to produce artificial nuclear fission. With this, experimental nuclear research became an expensive science, probably the most expensive of all so far as equipment is concerned. Cyclotrons and high-voltage installations were only the first stages along the way. There followed in rapid succession: Van de Graaff generators (constructed in primitive form as early as 1929), synchro-cyclotrons, betatrons, and synchrotrons, which are now simply regarded as the heavy artillery of nuclear physics. At the same time, however, apparatus technology was being carried on in other respects, so that a nuclear physics institution now requires a great many complicated auxiliary instruments such as amplifiers, scales, calculators, etc. which likewise entail considerable expense. It is also obvious that research of this type requires adequate and well-trained personnel.

Primarily through Professor Siegbahn's efforts an attempt had been made in our country also, even before the second World War, to keep up with that epoch in the development of nuclear physics which was characterized by the heavy apparatuses. Thus as early as 1938-39 a cyclotron was built at the Science Academy's Research Institute for Experimental Physics with which deutons could be accelerated up to a speed corresponding to 7 million electron volts of energy, and the Institute was gradually provided with the corresponding complement of other needed equipment. Even before the Atomic Committee was formed, certain research in experimental nuclear physics was being carried at other institutions, but because of the lack of funds, personnel, etc. it was of limited scope. Theoretical physics does not require the same large-scale appropriations of funds as experimental physics, but even that was hampered by the shortage of positions for assistants, fellowships for lecturers, etc. However, theoretical physical research was carried on even in the field of nuclear physics so far as resources permitted.

Physics can certainly be said to be the central science for atomic energy research, but it actually represents only the foundation of the structure. As soon as it becomes a matter of the practical utilization of the discoveries made in nuclear physics, a number of other sciences must be called on; in fact, some of these other sciences may perhaps be said to be even more important than nuclear physics itself at this stage. Chemistry should perhaps be mentioned first among these, both as a pure science and in the form of chemical technology. In connection with these problems a new field has even been opened up in chemistry, generally designated as nuclear chemistry. Also, metallurgical problems appeared, even at an early stage. Electronics is likewise of considerable importance. The obtaining of uranium, for example, demands the application of concentrating techniques. Medicine, in the form of medical radio-physics, enters the picture in connection with the problems of protection. At a later stage a large number of other technical fields will also be involved, for example heating technology and electrical technology. The sciences thus affected themselves render a service in the solution of the problem of atomic energy and are necessary for it. If we then consider all the sciences which in their turn are influenced by these developments, then, as already pointed out, practically all activities which are in any way connected with the natural sciences are influenced in one way or another.

One of the reasons why our country is judged, both by ourselves and by other countries, to be one of the nations which should be able to render a valuable service in the further development of the atomic energy problems is that we have a well-developed industry and extensive scientific and technical knowledge in the fields of activity which are of importance for atomic energy developments. It therefore is a matter of utilizing those attributes and filling in at those points where special complementary work is needed. The Committee considered that in the first place the already existing institutions should be utilized, and that it should take charge of and coordinate the special knowledge and the fields of interest which have existed from the beginning, so as to fill in the gaps in the special fields where they exist. One of the Committee's first measures was therefore to apply to the institutions which could be considered to have an interest in participating in the activities, requesting them to stipulate what service they thought they could render and what requirements could be expected to come up in that connection. It developed, in the first place, that such interest was very great, and in the second place, that the various activities at the different institutions and their future objectives complemented one another in general to a very great degree. Very soon the following picture became clear, approximately as follows.

Equipment with Heavy Apparatus

All the physics departments at the universities, the Stockholm Institute, and the institutes of technology wished to take part in the work in the various fields. Nuclear physics has been such a central point for physics from a purely scientific point of view that physics instruction at the university level cannot claim to be up-to-date without facilities for experimental instruction in nuclear physics. From the standpoint of higher education it is also highly desirable that some form of nuclear physics research be carried out in every physics department, so that one or more nuclear physicists will be available for instruction purposes. Every physics department therefore should have a certain amount of equipment for instruction and some type of research in nuclear physics. Such equipment includes radioactive preparations, Geiger-Müller tubes, measuring instruments, amplifiers, scales, perhaps Wilson chambers, etc.

The cheapest apparatus for obtaining relatively high voltages, and the most suitable for the purpose outlined here, is the Van de Graaff generator. It can be built in any size, from small instruments designed solely for instructional purposes to large and relatively expensive installations. The design can also be altered for various purposes. It has proved to be desirable to equip the physics institutes at both universities and at both institutes of technology with Van de Graaff generators of various types and sizes. Also, the Defense Forces Research Institute has built a large Van de Graaff generator for two million volts. The voltages for which the apparatuses are built vary from 250 kilovolts (experimental instrument in the physics department Lund) to 800 kilovolts (physics department at Uppsala), one million volts (Institute of Technology in Stockholm), and 4 - 5 million volts for generators at Lund and Göteborg. The last two are not yet completed. The first-mentioned are of open type, the last two, like that at the Defense Forces Institute, are built into pressure tanks. The Lund generators are of the horizontal type, whereas the Göteborg generator is vertical. When the last two generators are completed, our country will have a valuable stock of various types of this instrument, up to and including the largest which it has been possible to build to date.

The more specialized research is generally connected with some particular, more extensive equipment. It has already been mentioned that the Science Academy's Research Institute for Physics had already started nuclear physics research before the war and had in connection with it built the first cyclotron in our country. In order to obtain higher particle energy, a large cyclotron was started in 1945, designed to furnish deutons with energy up to

25 – 30 million electron volts. At approximately the same time plans were started for building at the physical chemistry institute at Uppsala University a large cyclotron of a different type, a so-called synchro-cyclotron or frequency-modulated cyclotron, which is expected to produce protons with an energy of 200 million electron volts. (This cyclotron has now become the principal instrument at the newly established Gustaf Werner Institute for Nuclear Physics at Uppsala University.) Both of these last two cyclotrons were started and for the most part built with the assistance of private funds and enterprises, and the Atomic Committee took no part in planning them. However, they fit amazingly well into the Swedish atomic energy activities, particularly since the first-mentioned is of a conventional type which produces a fairly large stream of particles and is therefore suitable, among other things, for the production of isotopes, while the Uppsala cyclotron is suitable for those research projects which require very high energy. Among other things it is hoped that it will be possible to produce mesons with its assistance and to study them. At a later stage the Atomic Committee assisted with sizeable grants for equipping and completing both the cyclotrons.

Cyclotrons are also planned for the acceleration of ions, primarily protons and deutons, which in turn will be able to set off nuclear reactions. It is also necessary to be able to accelerate electrons to high speeds, and for this purpose betatrons and synchrotrons are used. Work on these is going on at the Institute for Electronics at the Institute of Technology in Stockholm, where a betatron for 5 million electron volts and a synchrotron for 35 million electron volts are being built. An experiment in the construction of another type of electron accelerator, a so-called linear accelerator, has been supported by the Atomic Committee at the Institute for Electronics at Chalmers Institute of Technology.

A relatively inexpensive instrument, when it comes to furnishing energy which is not too high, is the high-voltage installation (in a limited sense). There is one such, of the cascade generator type for 1.4 million volts, at the Science Academy's Research Institute for Physics. The Defense Institute also has a smaller high-voltage installation for 200,000 volts. Another such installation for [illegible] million volts is being built for a special purpose with funds from the Atomic Committee, at the Radio-Physics Institute at Karolinska Hospital. High-voltage installations are often used to furnish acceleration voltages in so-called neutron generators, that is, devices for the production of the neutrons which are so important in atomic energy activities. Accelerated ions set off a nuclear reaction in which neutrons are formed. Such neutron generators, built with funds from the Committee, are located at the Physics at Uppsala University (200,000 volts) and at the Nuclear Chemistry at Chalmers Institute of Technology at Göteborg ([illegible] volts). (The high-voltage installations located in some industries, at the Institute of Technology in Stockholm, and at the Institute for High-Voltage Research in Uppsala are not mentioned here because they are not used for atomic research.)

In work with isotopes, for example, in the separation of isotopes, the mass spectrometer is an important instrument. The Committee is paying the expenses for the operation of such an installation at the Physics at Stockholm's Institute. Another instrument is under construction at the Physics at Uppsala University. The Defense Institute and the Gustaf Werner Institute for Nuclear Chemistry also have mass spectrometers. An outgrowth of the mass spectrometer is the electro-magnetic isotope separator. One of these has been built at the Research Institute for Physics and is being operated with funds from the Atomic Committee. The Gustaf Werner Institute is also building one.

Beta spectrometers have been built for the study of beta rays in nuclear reactions, both at the Research Institute for Physics and for Professor L. Meitner's Laboratory at the Institute of Technology in Stockholm. Beta spectrographs are also under construction at the Physics at Uppsala University and at the Gustaf Werner Institute.

Instruments for the study of neutrons, including a neutron spectrometer, have been built at the Defense Institute's laboratory.

As may be seen from this summary of the larger apparatuses which have been built in our country, with or without the aid of the Atomic Committee, for activities in this field, we now have, or will have in the near future, [illegible] equipment which covers the majority of the more important aspects of nuclear physics and nuclear chemistry which are of interest at the present time. However, it must be strongly emphasised that developments along these lines are making rapid strides, and that it is obviously necessary to have the facilities to continue to follow this development. As an example, it may be mentioned that in the USA and England plans have been in progress for some time to build ~~xxxxx~~ accelerators which will be able to produce particles with energies of an order of magnitude of several billion electron volts, or more than 10 times the particle energy which our Uppsala cyclotron will provide. ~~xxx~~ To those who have followed developments in this field during the last five or six years it is clear that within just a few years people will be working with additional highly developed ~~xxx~~ apparatuses and equipment which is differentiated for various purposes to a much greater degree than now.

The Physics ~~Institutes~~ Departments; Nuclear Physics Research and Instruction

The physics ~~institutes~~ departments at the universities, the Stockholm Institute, and the institutes of technology, as well as the Science Academy's Research Institute for Experimetnal Physics, perform a very important service in the matter under discussion here; in the first place, they must see to it that ~~x~~ basic research of adequate scope has an opportunity to progress in our country; they must also be responsible for training the necessary research workers. It should be noted in this connection that these two tasks are inextricably bound up with one another. The training of research workers, ~~xxx~~ it is true, takes place only at a ~~xx~~ preliminary stage , by means of lectures and practice laboratory work, the actual specialized training, on the other hand, by directly executing scientific research in the special field. Free basic scientific research is therefore ~~xxxxxxx~~ necessary not only for its own sake and as our contribution as a civilised nation to general scientific development, but also in order to make possible our own training of research workers needed in the advanced practical work in atomic energy activities. The Committee has therefore tried to build up activities at the [redacted] mentioned to an extent which can be regarded as necessary from the given standpoint; the same is true also, in the applied sections, [redacted] of [redacted] scientific departments [redacted] other than physical.

Accordingly, in order for the basic nuclear physical research to be covered by the equipment at [redacted] the institutes mentioned -- in addition to which they obviously can also be used to carry out applied [redacted] research of any sort, especially that which requires the use of the large, expensive apparatus -- another requirement developed, namely that for a special physics laboratory more directly under the supervision of the authorities responsible for atomic energy activities than university laboratories could be. This problem was already mentioned in the directive for the [redacted] Atomic Committee. Problems of secrecy are also of importance in this connection. At the end of 1945 a nuclear physics research division was established at the Defense Research Institute, which by degrees came into control of very extensive resources. Since the formation of the Atomic Energy Corporation it has appeared proper that the Corporation should take over part of the basic research concerning both chemical and physical problems in the field of atomic energy, [redacted] which previously had been carried out by the Defense Institute and which are of considerable importance for the utilization of atomic energy for industrial purposes. Agreements on this have already been reached.

For the time being it may be considered that in the manner outlined here both applied research and basic research in the field of nuclear physics have been taken care of. However, it should be mentioned that proposals have come in from both the Institute of Technology in Stockholm and Chalmers Institute of Technology for the establishment of special nuclear physics departments [redacted] at those schools. It would probably be desirable to await further developments for some time before a definite stand is taken on these problems for either the institutes of technology or the universities.

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Following are reports made by the heads of the various institutions or departments. The first is a report by the head of the Science Academy's Institute for Experimental Physics, Professor Manne Siegbahn.

The Science Academy's Research Institute for Physics

"Research in the field of nuclear physics has been the main subject at the Science Academy's Research Institute for Physics ever since the Institute started its work in 1938. The first cyclotron was built for this purpose in 1938 - 1939. With it deuterons were obtained with an energy of about 7 megavolts. During the years the installation has been expanded in other respects in order to obtain greater intensity of radiation and greater operational safety. For the latter purpose, among other things, the high-frequency generator was altered, using transmitter tubes manufactured by the Georg Schönander firm. As long experience has shown, interruptions caused by tube repairs have been considerably reduced as a result. With the cyclotron active isotopes have been produced during the past years, partly for the Institute's own research work, partly for the large number of research workers in other institutions, primarily for biological and medical experiments.

"In order to attain higher particle energies, it was planned in 1945 to build a larger cyclotron installation. In the final shaping of these plans, the magnet and other equipment were designed for a particle energy of 25 - 30 megavolt deuterons. Funds for building this cyclotron, which is now in the final testing stage, were furnished by the Knut and Alice Wallenberg Foundation, the Rockefeller Foundation, the Nobel Foundation, and the Wennergren Fund, in addition to which a grant was received from the Atomic Committee.

"The isotope separation installation, designed and built at the institute, is of the greatest importance for the current experiments with isotopes. The planning for this was started in October 1945. In connection with it a smaller research installation was also built, to study the problem of the source and the focusing of ions. In January 1948 the magnets and accessories were

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installed, and in June of the same year the deflection chamber and the high-voltage aggregate were completed. In August 1948 the first isotope separation was carried out in connection with a nuclear physics experiment.

"The apparatus is expected to be used for the separation of isotopes of all elements in quantities sufficient for nuclear physical experiments. The ions formed in the ion source (magnet type) are accelerated to an energy of about 60 kilo-electron-volts, and the rays, which are focused parallel by electrostatic lenses, are bent 90° in a magnet with a radius of 160 centimeters and a weight of 6.5 tons. The isotopes are collected on metal sheets or foil.

"The isotope separator has been used mainly for the following types of experiments:

"1. Determination of the mass numbers of active isotopes. Exposing the element's stable isotopes to radiation produces clear burn marks on the collector plate which permit a precise determination of the mass numbers for the radioactive isotopes, whose presence can be established only by a measurement of activity. Thus mass numbers have been determined for the following active isotopes: Se 81, Pd 109, Ag 110, I 137, I 138, Xe 137, Xe 138, Cs 138, Hg 199, and Hg 203.

"2. Production of carrier-free preparations whose mass numbers have been determined, for betaspectrometric experiments. It has proved to be possible to collect active particles on very thin aluminum foil, whereby the otherwise very troublesome back-scattering effect is eliminated. Beta spectra have been made for Se 81 and for products of uranium fission, Kr 83m, Kr 85, Kr 87, Kr 88, Rb 88, Xe 133, Xe 135, Xe 138, Cs 138.

"In these experiments, the activation of the test material has taken place in the Institute's smaller cyclotron. After separation of the isotopes, a beta-spectrometric examination is made of the section of the collector foil which contains the actual isotopes.

"3. Separation of stable isotopes. In certain nuclear physics experiments it is necessary to start with pure, stable isotopes.

In addition to inert gases, the following metals have been separated out: Li, Mg, Zn, Se, Ag, Cd, Sn, Pb, U. Of these the Li and Mg isotopes are used for proton resonance experiments, in conjunction with the nuclear physics laboratory at the University of Oslo.

"The Institute's nuclear physics work has been directed primarily toward the study of the energy and radiation properties of the active isotopes. During this work a number of new apparatuses and instruments have been designed, and more precise methods for measuring the energy and the intensity of radioactive radiations have been gradually worked out. In many cases the designs of these apparatuses, especially the beta-spectrographs, have been based on new principles which have also come into use recently in other nuclear physics laboratories. For the great majority of experiments the demand for a very high intensity of light has been predominant; in other important cases increased solubility was of prime importance. In the first case, the magnetic lens method has proved to be superior to other types. By a systematic observation of the effect of the shape of the magnetic field on the image, a new focusing principle has recently been evolved whereby the image is formed in two stages, resulting in a considerable increase in the intensity of light ("medium picture spectrograph"). This type has been used, for example, in experiments with isotopes separated with the electro-magnetic isotope separator. Because of its great transmission ability it is especially suitable for coincidence spectrography, since this involves the study of the band among other radiation components. By means of a specially designed diaphragm system the spectrograph is able to separate effectively the positrons from the electrons. In this way it has been possible to study a number of interesting effects, such as inner pair formation, etc.

"The "double-focusing" spectrograph is especially suitable for high solubility. This spectrograph is also based on a new principle, namely the two-directional focusing which is obtained in a ring-shaped magnetic field whose field strength decreases as $1/\sqrt{r}$. The spectrograph which was built at the Institute according to this principle has large dimensions (the average radius of curvature is 50 centimeters), so that a very high degree of dispersion is attained. The prerequisites for very precise measurements have also been increased by the development of a comprehensive apparatus for precise measurement of the magnetic field. The definition of the lines which are obtained in the spectrograph from nuclear radiation is now approximately 1 o/oo. In conjunction with experiments concerning the photo-decomposition of deuterium, which have recently been carried out in the form of teamwork with the nuclear laboratory at Oxford, precision in determining intensity has been increased to 2 percent, compared with 10 - 15 percent formerly. Among the most recent results it might also be mentioned that a gamma radiation from active sodium, which is converted within the atom itself (inner conversion), could be registered and its intensity determined, in spite of the fact that in this case only one gamma-quantum per million was converted. If the peak of this conversion line is at 5 centimeters, the peak of the other, continuous spectrum is 1.3 kilometers. Among other apparatus which has been built, mention might be made of the so-called limegraph, for measuring very weak activities, and a pair-formation spectrograph of the lens type for the study of hard gamma radiation. Both cases involve a new idea, which has been tested and which is being used in the current experiments concerning the decomposition of isotopes.

A high-voltage installation, consisting of a cascade generator with an acceleration tube for 400 kilovolts, which had been built at the Institute earlier and used for electron acceleration, was rebuilt during 1946 - 1947 for the acceleration of ions. It has been used to obtain knowledge concerning the focusing of ion rays, the design of the lens system, etc. An old-type capillary curvature ion source is used with this installation; it has been improved by installing a quartz tube in the capillary, which increases the atomic ion yield from the ion source by 10 - 40 percent. A 30-microampere radiation current of D_1^+ ions is used, with 300 kilovolts, so that the tube can be used as a neutron generator by the D-D process, and produces about 5 curie Ra-Be equivalents.

"It was decided to use the experience gained with this installation to build a larger high-voltage installation for 1,400 kilovolts. This larger installation was built at the Institute during 1948 - 49. The principal data on it are as follows:

"1. Cascade generator for a maximum of 1,400 kilovolts, 10 milliamperes in 7 stages. The generator is operated at 500 p/s [sic], which in conjunction with the rating of the condensers (0.08 microfarads per stage) gives only 0.05-percent ripple at maximal voltage and 1 milliampere consumption of current.

"2. The acceleration tube and its pump system are properly proportioned so that the pump velocity is very great. The vacuum which is obtained is better than 10^{-5} millimeters of mercury in the lower part of the tube and better than 10^{-4} millimeters of mercury up to the ion source, when it is in full operation. The low gas pressure produces a strong radiation current without disturbing secondary ion formation. Another contributing factor is that the inner diameter of the lens is as much as 80 millimeters.

"3. The ion source is of the Thonemann type with high-frequency excitation. In tests it produced 1 milliampere, of which 400 microamperes of radiation current can be used in the acceleration tube. After the ion source was mounted in the acceleration tube, 100 microamperes of ion current were focused on the target, which is more than adequate for the current experiments.

"4. A deflection magnet for the separation of the ion beam and for energy stabilization has been produced. Its weight is 1,100 kilograms, and the ion beam is deflected 90° (radius is 40 centimeters). The magnet and deflection chamber are joined to the vacuum system of the ion tube in such a way that they can be rotated, with the ion beam as axis. In this way the separated ion beam can easily be directed toward any of the experimental equipment in the radiation room.

" The program for the installation includes among other things experiments on the excitation of the energy levels of light nuclei and Q values. The energy associated with the emanation of gamma radiation is measured with a double-lens spectrograph of a new type and a gamma spectrograph with a high intensity of light for Comton [Compton] electrons and photoelectrons (medium image type). The energy of the charged particles is determined with a double-focusing proton spectrograph. The latter, which is still in the process of manufacture, has a weight of 7 tons and furnishes a field of energy up to 20 mega-electron-volts. The spectrograph can be rotated about an axis through the surface of the target point, so that the angular dispersion can be easily studied.

"In conclusion it should be mentioned that an apparatus for measuring magnetic nuclear moment is being used at the Institute. This installation, which makes determinations with an extraordinary degree of precision, about 1 in 10^6, has been used for measuring the magnetic nuclear moment for some of the light atoms.

"A more detailed report on a large part of the Institute's measuring equipment and on the measuring methods used with them (up to 1947) is included in a compendium on nuclear physics which was published in conjunction with a series of lectures arranged for at the Institute. Communications (now totaling about 170) concerning the results of the research work in nuclear physics carried on at the Institute have been published in the Science Academy's Physics Archives and in other international professional journals.

"Among others, a report appeared in the publications mentioned on experiments on the energy and radiation properties, together with diagrams of levels, for active isotopes of the following elements: C, N, Na, Mg, Al, P, S, Cl, K, Mn, Fe, Co, Ni, Zn, As, Se, Br, Kr, Rb, Ru, Rh, Pd, Ag, Sb, Te, I, Cs, Dy, Ho, Hf, W, Au, Hg, Po, RaE, Th, U, Np. Experiments have also been conducted on gamma radiations from light elements upon irradiation with alpha particles. Extensive study has been given to the problem of the isomeric properties of atomic nuclei, for example with the elements Kr, Zr, Rh, Pd, Ag, Cd, Dy, Pt, Hg.

"On the basis of the increased need for chemical methods as a supplement to nuclear physics, a Nuclear Chemistry Department has been set up at the Institute during the last four years.

"In most of the processes for producing radioactive isotopes, isotopes of elements other than the starting element are also formed, and it is necessary to separate these nuclear types according to their atomic numbers. The Department has therefore been a complement to the cyclotron installation. Also, the radioactive preparations which are imported from the USA and England are generally not usable for nuclear physics purposes without previous chemical treatment. Many of the nuclear physics experiments which have been published have therefore been carried out in conjunction with the Department. Only in case something of special chemical interest has developed xxx have independent publications been issued.

"With the weak neutron sources which our country has had available to date, the Szilard-Chalmers method is of great value. A large part of the work has therefore been set up so that certain isotopes, primarily of higher elements, could be made available by this method for nuclear spectrographic research. This was the case with U 237, U 239 (with subsidiary isotope Np 239), and Sb 122 + 124. In the case of Th the experiments have led only to the production of certain new complex compounds.

"A method has been worked out for the determination of radioactive hydrogen, and tritium (which is obtained as a by-product from the Institute's smaller cyclotron) has been used for a rather extensive observation of the mechanism of aromatic substitution, the results of which are primarily of interest for physical organic chemistry.

"The laboratory has recently been equipped so as to be able to meet the requirements for the safety of the personnel which are demanded by the high preparation strength which the new cyclotron can be expected to produce.

"It has been and still is one of the Atomic Committee's main tasks to further the training of research workers in the field of nuclear physics. The Science Academy's Research Institute for Physics has been able to take an active part in this activity in that the Institute had already been working for several years in the field in question before the Atomic Committee was activated, and therefore had many research workers trained in the field who were in a position to take over the special training in question. With the support of the Atomic Committee, this training activity has gradually been considerably expanded, especially at the higher levels. Fifteen young research workers are at present employed at the Institute on research ~~xxxx~~ projects designed as doctor's projects for technical or academic doctor's degrees."

Photographs:

The smaller cyclotron for 7 mega-electron-volts deutrons, built in 1939 at the Science Academy's Research Institute for Physics.

The Research Institute for Physics' 225-centimeter cyclotron for 30-mega-electron-volt deutrons.

High-voltage installation for 1,400 kilovolts and acceleration tube at the Science Academy's Research Institute for Physics.

Isotope separation installation at the Science Academy's Research Institute for Physics.

Double-focusing beta spectrograph at the Science Academy's Research Institute for Physics.

Lens beta spectrograph of the medium image type at the Science Academy's Research Institute for Physics.

The Physics Institute at Uppsala

The head of the Institute, Professor Axel Lindh, submits the following report:

"The organization of nuclear physics work ~~at~~ the Physics ~~Institute~~ at Uppsala has been dependent upon the especially limited space ~~with~~ which the 40-year-old ~~Institute~~ building offers for work of this sort.

"The ~~Institute~~ has available at present two installations for nuclear physics work, an open Van de Graaff generator for 800 kilovolts with an acceleration tube, and a neutron generator installation for 200 kilovolts. The first of these was built entirely with the aid of grants from the Atomic Committee, the second partly. The two installations are installed in two provisionally equipped rooms in the attic of the ~~Institute~~.

"The Van de Graaff generator. The building of the Van de Graaff generator was started in the fall of 1946, and by spring of 1947 the generator itself was by and large ready for a trial run. Since then the acceleration tube has been designed and built, and a generating high-voltage voltmeter of a partially new type has been experimented with and installed. This work was completed during the spring of 1949, at which time the entire installation was tested by sending an electron current through the acceleration tube. At present work is in progress for installing an ion source.

"The low ceiling, barely 5 meters, was a determining factor for the dimensions of the generator. It was necessary to shape the generator in such a way that the greatest possible voltage could be obtained within the limited space. The generator therefore had to be provided with a comparatively large corona shield, shaped in such a way that the angle between the surface of the insulating column and the surface of the shields is about 60°.

"The generator's performance capacity varies to a great extent with the relative humidity in the room. During the winter months, when the humidity is low, the machine produces about 1,000 kilovolts when idling and a short-circuit current at 700 microamperes with a band velocity of 20 meters per second. In summer, when the relative humidity goes up to 70 - 80 percent, only about 300 kilovolts can be obtained. In order to be able to use the machine the year around, it is thus necessary to keep the relative humidity down with some sort of air conditioning, and the possibilities for this are being investigated.

"The acceleration tube is placed crosswise of the column, and consists of 21 funnel-shaped electrodes, fastened to aluminum plates and insulated from one another with ring-shaped porcelain insulators. The acceleration tube has shown satisfactory properties in the tests carried out so far. Its focusing properties have been studied with the aid of electrons. However, this test could not be carried out until the month of May, at which time the high relative humidity made it impossible to obtain voltages higher than about 300 kilovolts. With this voltage and with a current through the tube of 100 microamperes, a burned area 5 millimeters in diameter is obtained.

"Professor Ohlin and Assistant Beckman have published a short description of the Van de Graaff generator in "An Open Van de Graaff Generator for 800 Kilovolts" (Physics Archives, 1949). Assistant Beckman described the voltmeter in "A Generating Voltmeter" (Physics Archives, 1949).

"Neutron generator installation. The neutron generator which was started in 1946 was built with the idea of using the so-called D-D reaction for neutron production:

$$_1D^2 + _1D^2 = _2He^3 + _0n^1.$$

"In comparison with other nuclear reactions, this reaction produces a larger formation of neutrons at voltages which it was possible to obtain with an installation adapted to the small space which was available in the present Institute building.

"In comparison with other similar apparatuses, this one differs from the other types in that the transformers and rectifiers and the accessory alternating-current generator which is required to activate the ion source are placed in a separate corona shield supported by a porcelain insulator to the side of the acceleration tube itself. This arrangement has the advantages that the ion source is more easily accessible for the necessary adjustments and that the apparatus as a whole is more convenient.

"The acceleration tube itself is built in one stage for a maximum of 200 kilovolts acceleration voltage. However, the construction is such that the generator can be built up to an acceleration voltage of 600 kilovolts and over, if the Institute should obtain a special high-voltage room sometime in the future. After passing through the acceleration tube itself, the ion beam is deflected 10° with the aid of an electro-magnet, and after passing through a circular opening impinges upon the target surface, which, when the above-mentioned D-D reaction is used, consists of frozen heavy water.

"The high-voltages necessary for the activation of the neutron generator are obtained from a high-voltage aggregate in Greinacher coupling with a transformer grounded in the center. In order to be able to connect the entire available voltage of 200 kilovolts with the acceleration tube, the aggregate has been connected in such a way that the high-voltage and filament current transformers are insulated from ground and are fed from the 220-volt network through insulated transformers.

At present measurements are being made, using the neutron generator, of the angular distribution of neutrons from the D-D process; also, preparatory experiments are being carried out for the investigation of neutron energies using the photographic emulsion method.

"A more detailed description of the [redacted]s neutron generator installation will soon be published in the Physics Archives.

"Among other work at the [redacted], mention may be made of the construction of an analysis mass spectrometer; work is at present directed toward the construction of stabilized direct-and alternating-current sources and direct-current amplifiers. During the academic year 1948-49 a series of observations are being made at the [redacted], under the supervision of Professor Elias Melins, of the indications of radioactive radiations from mycelia which have been furnished with radioactive phosphorus.

"Work is going on at present in the [redacted]s workshop on the construction of a fairly large Wilson chamber, and the magnet for a large Svartholm-Siegbahn beta spectrometer is on order from the Hedemora workshops. The completion of these apparatuses, [redacted] the funds for which were granted by the Atomic Committee, has been considerably delayed by long delivery terms. However, it is estimated that the work will be finished during the academic year 1949-50.

"Thanks to a grant from the Atomic Committee, training experiments in electronics and nuclear physics have been reorganized and considerably expanded in the [redacted]s course laboratory for undergraduates and [redacted] students taking official examinations. The electronics laboratories [redacted] ~~considered the best place~~ intended to make the students familiar with the assistance which may be obtained [redacted] for the work in nuclear physics. Among other things, the nuclear physics training includes experiments and measurements with Geiger-[redacted] Müller tubes, experiments on natural and ~~artificial~~ induced radioactivity, fission products, etc. Additional experiments in nuclear physics are being worked out.

"The scientific work and the experimental instruction at the Institute, especially in the field of nuclear physics, are being carried out at present ~~on the basis of~~ inadequate working space under rather difficult conditions. The space is being utilized to the utmost, and until the Institute's building problems are solved, it appears that it will not be possible for the Institute to participate effectively in the planned joint work with Gustaf Werner's Institute for Nuclear Chemistry, since the latter will shortly be ready to start its ~~it~~ activities. Thus the strange situation develops where a physics institute located adjacent to one of Europe's largest cyclotron installations cannot utilize the possibilities for more extensive nuclear physics research which this installation would afford because of lack of space."

The Physics Institute at Lund University

Professors Bengt Edlen and Sten von Friesen report as follows:

"When the distribution of funds from the allotment for atomic energy research for 1946 was ~~xxxxxx~~ first made to the Physics Institute at Lund University, no nuclear physics work had ever done at the Institute. Therefore it was necessary as a beginning to first ~~xxxxx~~ undertake activities toward training the scientific personnel, both by means of special study in this country and abroad and by means of inviting lecturers to come to the Institute. Furthermore, there was the matter of procuring or constructing the necessary auxiliary apparatus. ~~xxxxx~~ Finally, it was necessary to set up a fairly complete course of instruction in nuclear physics in the training laboratory, in order to assure the supply of workers.

"The present laboratory director, von Friesen, therefore made a three-month trip to study at laboratories in the USA, and Assistant Minnhagen worked at Professor Bohr's Institute in Copenhagen for a total of eleven months.

"In order to be able to carry out experiments even before an accelerator had been built at the Institute, two radium-beryllium preparations were obtained on loan from the Committee, the smaller one consisting of 20 milligrams of Ra for instruction purposes and the larger one of 250 milligrams of Ra for

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scientific use. Arrangements were made in the existing detached transformer building for protected storing and handling of the preparations. Two "scales of sixty-four" were procured, one from the Berkeley Scientific Company and one from the Atomic Instrument Company. Also, a number of scales and amplifiers are being built ~~at~~ the ~~[illegible]~~, and Geiger-Müller tubes of various types are being ~~[illegible]~~ manufactured. Scintillation ~~[illegible]~~ are also being set up by degrees, some single and some for coincidence measurements. An automatic Wilson chamber has been built and is now adjusted and ready to be put into operation.

Because of the crowded conditions ~~at~~ the ~~Institute~~, it became necessary to transfer the main part of the nuclear physics work to a laboratory barracks. This was built with funds from the Atomic Committee, and ~~[illegible]~~ was put into operation in January 1948. Among other things, working space is set up here for the radio technicians who have been assigned to build the required electronics apparatus.

The speech given at Lund by Professor C. F. Powell from Bristol ~~[illegible]~~ and his co-worker Doctor Lattes awakened interest in the study of cosmic rays with the aid of special photographic emulsions. Laboratory director Minnhagen and Professor von Friesen studied the Bristol method on other occasions, and in 1948 the first packs of photographic plates were sent up in stratosphere balloons from Torslanda airfield. Valuable support was received from the Swedish meteorological and hydrological institute. All the film packs were late found. The experiments made so far have been mainly of a preparatory nature, but certain observations concerning nuclear decomposition processes and the absence of pi mesons will probably be published later. A complete pi-mu meson decomposition has been ~~observed~~ studied, probably the first in Scandinavia. Preparations ~~[illegible]~~ for sending up more balloons to greater altitudes and under better defined conditions of temperature and pressure have progressed so far that the balloons will probably be sent up in the immediate future.

"Concurrently with these experiments preparations have been made to build a horizontal pressure Van de Graaff installation for 4 million volts.

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Pressure tanks will probably be delivered in November of this year (1949) and the insulators, etc. at approximately the same time. A high-frequency ion source is at present being tested. A small open Van de Graaff installation has been set up to help in testing this ion source and ~~for~~ testing the insulators and other materials. This installation ~~is~~ produces about a quarter of a million volts.

"Experiments with scintillation ~~calculators~~ make it seem probable that a suitable method will be found to measure the energy of gamma rays in this way.

"Seminar training in electronics and nuclear physics has been going on regularly since 1947. A special course in electronics for nuclear physicists has also been given by one of the two assistants who ~~were~~ paid from the Atomic funds.

"At present 11 research workers and two assistants are taking part in the nuclear physics work."

Physics ~~Institute~~ at the Stockholm Institute of Technology

The followigg survey of the work going on ~~at~~ the ~~Institute~~ has been furnished by the head of the ~~Institute~~, Professor Erik Hulthen.

"~~The~~ research activities ~~at~~ the Physics ~~Institute~~ at the Stockholm Institute of Technology ~~was~~/almost entirely limited to spectroscopic research on molecular structure, ~~[illegible]~~. However, this problem had certain points in common with nuclear physics, for example, with regard to isotopes and nuclear spin, which properties may be observed in the structure of the band spectra. Therefore, when the setting up of the Atomic Committee opened up the opportunity for nuclear physics research, it followed quite naturally that problems concerning just these questions should be given first consideration. This development had/already had its beginning some years earlier, with the grant from the State Technical Research Council for building a mass spectrometer for quantitative isotope anglysis, an apparatus which was practically completed during 1946.

"One factor which stood in the way of beginning the new activities and which appeared difficult to overcome was the overcrowding and the lack of a suitable ~~space~~. However, through the consideration of the Board of Directors of the Institute of Technology a mezzanine containing five or six rooms was fitted up during the summer of 1946. The rooms were small, but otherwise well suited for work which did not require bulky apparatus. At the same time, a large, basement room well under ground was fitted up for heavier apparatus.

"Under those conditions, the nuclear physics activities at the Institute of Technology have come to follow mainly three ~~main~~ lines of development:

"a. The setting up of a nuclear physics laboratory, with the aim both of carrying out low-level experiments for undergraduate students and for official examinations and of stimulating persons studying for their master's and doctor's degrees to certain research projects.

"b. Mass spectrometric experiments with quantitative isotope analysis as the principal project. This part of the program also includes the development of the mass spectrometer to a precision instrument for rapid routine determinations of samples from general biological and geological experiments, and samples mentioned under c.

"c. The building of an ultracentrifuge for the concentration and separation of isotopes.

"The program as set forth above ~~has~~ by and large ~~been~~ adhered to without changes during the years which followed. It has only been rounded out with an electronics ~~department~~, whose task it has been to supplement the work of the other groups, ~~and which has~~ in addition undertaken an experiment on the absorption of centimeter-long radar waves in gases, a problem which is directly connected with the earlier spectroscopic experiments.

"In the following the work ~~of~~ the various ~~groups~~ is described in greater detail:

"Instruction in nuclear physics at a low level was started in the spring of 1947, since ~~the~~ instrumental equipment suitable for this purpose could be procured or assembled in the ~~Institute's~~ Department workshop and electronics laboratory.

The instruction is mainly in the form of rather advanced demonstration experiments, such as the electrical recording of beta particles, the determination of radioactive decomposition constants, the ~~demonstration~~ detection of thermal and rapid neutrons in photographic emulsions, the Szilard-Chalmers reaction with iodine, etc. The laboratory exercises are followed by discussions and are attended by ~~the~~ students who are ~~greatly~~ interested. They have also served to awaken an interest for continued ~~work~~ study.

"The more advanced nuclear physics studies are ~~xxxxxxxxxx~~ directed ~~xxxxx~~ at an early stage toward experiments on the new methods for recording nuclear particles which were successfully developed particularly by Kallmann in Germany. The so-called "Kallmann ~~calculators~~" are based on a photoelectric recording of the flashes of light (so-called "scintillations") which develop when nuclear particles meet a fluorescent material (anthracene or similar substances). They have already demonstrated their great applicability, especially in connection with the coincidence experiments with a high time resolution, which are so important in nuclear physics. To some extent the experiments ~~in at the Institute~~ in this new field of research have not yet advanced beyond the experimental stage, but certain interesting observations have been made and published.

"The mass spectrometric experiments are directed toward determining and measuring small deviations in the relationships in isotope mixtures in tests of geological interest or in tests with "marked", non-radioactive isotopes of biological interest, for example, from the point of view of the study of material conversion in living organisms. A very large number of such routine determinations on carbon and nitrogen isotopes have been made during the course of the years, among others, for the Wenner-Gren Institute. The uninterruptedly increasing demand for refined measurements of this sort ~~have~~ has led to the planning and the building of new analysis apparatuses (double column spectrometers) which are expected to multiply the precision of measurement many times.

"Among the many methods which have been pointed out for the concentration and separation of isotopes, centrifuging by no means holds a favored position.

The reason for this is difficult problems of stability and solidity must be solved in the construction of the large centrifuges which are needed for the purpose; and also, the comparatively limited degree of concentration which is obtained, unless the centrifuge is pushed up to the dangerous speeds which are characteristic of ultra-centrifuges. Therefore if one wishes to avoid difficulties and at the same time attain satisfactory results, this is best done by a combination of the pressure effects which develop in the centrifuge and the current method in the thermo-diffusion tube developed by Clusius and Dickel.

"On the basis of this viewpoint a column centrifuge has been built the has already given a measurable degree of separation of chlorine isotopes in carbon tetrachloride vapor, operating at moderate speed. However, since the course of the current cannot be controlled while the centrifuge is in operation, the results were erratic, corresponding to only a fraction of the expected effect. After the completion of a new centrifuge model, in which the separation processes take place through a great number of series-coupled stages ("plates"), it is expected that these difficulties can be overcome.

"The centrifuge method's advantages over all other methods of separation are, first, the increased output with increased atomic weight -- that is, it takes precedence in the separation of isotopes of the heaviest elements -- and secondly, the advantages which it has in the separation of large quantities."

Physics at the Institute of Technology in Stockholm

Report by the head of the Institute, Professor Gudmund Borelius.

"Up to December 1948, the activities were located at the research station of the Academy of Engineering Sciences, and were carried on to some extent in conjunction with the Defense Forces' Research Institute. During that time a number of laboratory investigations in nuclear physics were carried out, designed primarily for technologists in the third-year course in the department for physical engineering. The first laboratory courses were given during the spring term 1947, although the first special lecture course in nuclear physics had already been given during the spring term 1946. These courses have since been repeated each spring term. The transfer of activities to the Institute of Technology's new physics building was prepared for at the Research Station of the Academy of Engineering Sciences, principally by planning a 200-kilovolt acceleration tube and an MV Van de Graaff generator with acceleration tube.

"The transfer to the new quarters took place in December 1948. The work on setting up the two high-voltage aggregates was started immediately, and during the summer of 1949 both were ready for the first test runs, during which about 1,000,000 volts were obtained with the Van de Graaff generator.

"In the new quarters, where there is considerably better scope for both research work and laboratory training, it was possible during the spring term of 1949 to give two extra courses in nuclear physics, one for 30 conscriptees being trained as technicians for defense against radioactivity, the other for a number of officers and civilian engineers from the Defense Forces Border Authorities and Civilian Defense Board.

"A number of physics technicians who passed civil engineering examinations have reported that they are interested in taking their masters degrees with physics as their main subject and with the emphasis of their studies on nuclear physics. Two of these are doing their master's experiments at the Department for Physics I. One, civil engineer Arner, has designed and built an apparatus, equipped with an ionization chamber and impulse analyser, for detecting rapid neutrons; the other, civil engineer Carlvik, plans to study the absorption of slow electrons in materials, using an electron acceleration tube built for the purpose.

"In addition, a number of physics technicians have passed examinations in nuclear physics at the Department.

"The nuclear physics activities are under the direction of Sigvard Eklund."

Professor Lise Meitner submits the following report on the nuclear physics work being done in her department:

"It has been of great importance for the department's development, and for the construction of the beta spectrograph in particular, that through Professor Borelius' suitable quarters have been made available with access to the Royal Institute of Technology's Physics Department. The vacuum tank for the beta spectrometer (a large copper tube) and the completed vacuum system have been finished, and after fairly extensive testing a satisfactory vacuum of 10^{-4} millimeters of mercury has been obtained in the entire system. The spectrometer's four main poles (lenses) are mounted, the number of turns on the coil been controlled by determining the coil's electrical resistance, and the magnetic field has been measured along its axis of symmetry. The field's maximum strength has been found to be $\sim$ 1200 gauss with 15 amperes in all four coils. Various types of packing have been tested for making the coils' cooling jackets water-tight (the coil collars are cast from pure aluminum, in order to avoid disturbances in the magnetic field), and a suitable packing material has been found which guarantees that the layer of packing will resist running water for some years.

"A "scale of ten" has been built which can be used for heavy electric currents which require meters with a high resolving power.

"In addition, various types of Geiger-Müller tubes have been produced, some very thin for beta rays, some very effective for gamma rays.

"The following nuclear physics projects, aimed at determining the radioactive constants of natural potassium, have been carried out:

"1. Determination of beta disintegration constants by measuring the number of beta particles which one gram of potassium gives off per second.

"2. Measurement of the intensity of the weakest gamma rays with the aid of the above-mentioned highly-sensitive measuring tubes.

"3. Determination of the number of electron capturing processes per second.

"The intention is both to determine clearly the disintegration pattern of the potassium atomic nucleus and to derive certain geophysical conclusions which are of importance for the history of the earth.

"An investigation of the so-called "multiple scattering" has been made, which is of practical importance for the construction of Geiger-Müller tubes and furthermore of importance for basic theoretical problems.

"Several projects concerning various nuclear physics processes have been completed and published."

Physics Institute at Chalmers Institute of Technology

The head of the Institute, Professor Nils Ryde, reports the following:

"In 1947 a nuclear physics department was set up in the Physics Institute at Chalmers Institute of Technology which has carried on nuclear physics research and instruction since then with the support of grants from the Atomic Committee. Since a newly built addition to the Physics Institute was opened in the spring of 1948, adequate quarters have been available for the purpose, and in addition a new, well-equipped workshop has been doing its utmost to get a large-scale instrument and apparatus construction program under way. So far the scientific work has been directed mainly toward producing the instrumental equipment necessary for the research. The research program for the immediate future is based on a band generator for about 4 megavolts. It has been under construction since 1948 and is set up in the old Institute building. It is estimated that it will cost 215,000 kronor, which amount has been made available by the Atomic Committee. It is expected that the band generator will be completed during the course of the present year. It will make it possible to study atomic nuclei which have been excited by the influence of the ions accelerated in the generator; also to produce homogeneous neutrons with energies up to about 2 mega-electron volts.

"In order to obtain valuable experience for the building of the large band generator, a smaller generator of the same type was designed and built first, for a voltage of about 400 kilovolts. It is equipped with an ion source of the capillary curve type and with a rotation voltmeter. The generator has been used for laboratory training experiments in nuclear physics, but it is expected that it will also be used for special scientific purposes, such as experiments with the irradiation of photographic plates.

"In order to study the gamma rays which are given off in nuclear reactions, a gamma-ray spectrograph and also a beta-ray spectrograph have been built. The gamma-ray spectrograph is intended for measuring the energy of gamma rays and is based on the principle of the curved crystal. Both scintillation counters and photographic plates are used as radiation indicators. The scintillation method has been the object of thorough study; scintillation counters with and without coincidence measurement have been constructed, and crystals of various types have been produced.

"Most of the radiation experiments with band generators have so far been conducted without using separated isotopes, which leads to an uncertainty in interpreting the results. In order to make possible the production of separated isotopes, an electromagnetic isotope separator is being built at present. Especially since rare isotopes are involved, it may be desirable in this connection to carry out a previous concentration of isotopes; this may be done, among other ways, by fusion electrolysis. An expert in this field, Doctor Alfred Klemm from the Kaiser Wilhelm Institute for Chemistry, has been invited here and is working as a guest research worker. The possibilities for developing methods for the separation of isotopes by fusion electrolysis are under study.

"The technique for the investigation of nuclear reactions on photographic plates has been studied thoroughly, and valuable experience has been obtained in this field. The method has been used for the study of the processes when lithium is irradiated with slow and rapid neutrons.

"Every spring term since 1947 a voluntary course in nuclear physics has been offered to the students at the Institute of Technology. The attendance at this course has been variable; in one course the number of students was over 100. The course has included lectures and ten laboratory sessions. A number of guest research workers, from Denmark, Norway, Germany, England, and the USA, have given lectures, some of which were elementary, some more scientific in nature."

Institutions for Theoretical Physics

Experimental physics, no doubt, has a more general appeal to a larger public than does theoretical physics. The former, as recently pointed out, makes use of the large buildings of institutions, costly apparatus, and extensive staffs of scientists and technicians. Theoretical (or mathematical) physics, on the other hand, requires no other equipment than a library, calculating machines, etc, although modern theoretical physics often -- as at the Bohr Institute in Copenhagen -- works in extremely close cooperation with experimental physics. For the above reasons, theoretical physics is not a very costly activity. However, its significance in connection with atomic energy activity is fully comparable to that of experimental physics. The most important progress of our time in physics has been made through close cooperation between theoretical physicists and experimental physicists, in certain cases developing experimental discoveries, and in other cases ~~[illegible]~~ following theoretical speculations, which were verified and further developed through experiment. For the Atomic Committee, therefore, it has been an urgent matter to support the theoretical physicists in our country in every way to the extent that their work is devoted to problems of importance to atomic energy activity.

The ~~Institute~~ Department of Mechanics and Mathematical Physics at Uppsala University

The head of the ~~Institute~~ department, Professor Ivar Waller, has delivered the following report concerning the activity supported by the Atomic Committee:

"Research at the ~~Institute~~ Department of Mechanics and Mathematical Physics at Uppsala University has been supported up to 30 June 1949 by the Atomic Committee through a grant of 3,930 kronor to Fil. Mag. Lennart Hansson (during ~~budget~~ fiscal year 1947-48) and a grant of 4,032 kronor to Fil. Mag. Hans Haakansson (during the ~~budget~~ fiscal year 1948-49).

Mag. Hansson has investigated a problem of practical interest concerning the diffusion of thermal neutrons. It was assumed that certain sources of neutrons are situated in a medium, and the problem was to investigate the changes in the density and the directional distribution of the neutrons occurring if the medium, the absorbtion of which is assumed to be almost infinitely small, is partially replaced by a completely absorbant substance. With certain simplifying assumptions, the problem may be handled by means of an integral equation set up previously by the undersigned for the distribution of neutrons. This equation makes it possible to generalize an [redacted] iteration method previously employed by Fermi. Detailed calculations have been made for a special case. It is assumed that the sources of neutrons are very far away, that the introduced substance is in the form of a sphere, and that spherical symmetry prevails in the distribution of neutrons.

Mag. Haakansson has handled a problem of great actual importance, namely, the matter of the shifting of the electromagnetic level in helium-like atoms in the fundamental state. Professor Adolf Eriksson has recently pointed out that the discrepancy existing between the experimental values of the ionization energy of such atoms and the calculations thereof, previously determined by Hylleraas and Eriksson, should be intimately connected with the shift of level just mentioned. From Haakansson's investigation, conducted in [redacted] with the undersigned and published by Haakansson in the Physics Archives (Arkiv för fysik), it is shown that the calculations on the shift of the electromagnetic level recently made by Bethe, et al, must be [redacted] revised, if the formulae valid for high nuclear charges are to be retained. An improved theory is now about to be worked out [redacted] in collaboration with Mag. Hansson."

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The ~~Institute~~ Department of Mechanics and Mathematical Physics at Lund University

The following report is by the head of the ~~Institute~~ Department, Professor Torsten Gustafson:

"The ~~Institute~~ Department of Mechanics and Mathematic Physics at Lund has, in past years, received grants from the Atomic Committee for research and instruction, for study trips, and for invitations to guest lecturers.

Thanks to the support of the Atomic Committee, the ~~Institute~~ Department has had an opportunity to associate with it young scientists (I. Hansson, S.B. Nilsson, G. Källen), who have added greatly to the fruitfulness of the ~~Institute's~~ Department's scientific activity. Thus, the work on the eigen functions and photoeffect of deuterons and that on various problems in quantum electrodynamics may be mentioned.

The travel grant has been of particularly great value, as the rapid progress in nuclear physics and ~~the~~ atomic theory makes direct contact with other scientists practically unavoidable, if one wishes to keep up-to-date on developments. The grant has been used for rather long study trips (2-3 months) and for participation in scientific congresses, two ~~[illegible]~~ means of contact of great importance to theoreticians. For example, the head of the ~~Institute~~ Department undertook a study trip to the USA and England in March-July 1947 and was able, besides lecturing ~~[illegible]~~ about the results of ~~[illegible]~~ the research conducted at Lund, to participate in the lively activity ~~there~~ taking place in various branches of atomic and nuclear physics. The ~~Institute~~ Department has cooperated most profitably with Professor W. Pauli ~~[illegible]~~ in Zürich, one of the world's foremost atomic theoreticians. At his invitation and with the support of the Atomic Committee, Lund scientists have been afforded an opportunity to study in Zürich (since 1946). There they have had the advantages of close contact with the Swiss physicists, particularly with Pauli himself. Valuable results have been achieved in this way and they have been reported in a number of printed works:

On the Determination of the Potential from the Asymptotic Phase in the Problem of Diffusion, On the Exchange Effects between Neutrons and Electrons, On the Problems of Divergence in the Determination of Eigen Energy, and On Problems in Connection with Vacuum Polarization. Thus, the Department has profited a great deal from such trips.

"Visiting foreign scientists have also brought much to the Department. The grants of the Atomic Committee have made it possible for the Department to invite Professor Pauli (Zürich) and Professor Peierls (Birmingham) to hold guest lectures at Lund (1947 and 1949). Their visits also provided the opportunity for thorough discussion of actual problems in atomic theory."

__The Department of Mechanics and Mathematical Physics at the Stockholm Institute of Technology (Stockholms Högskola)__

The following account has been given by the acting head of the above institute, Docent __Björn Bruno__:

"Since 1946, the Atomic Committee has given grants to Docents Olof Brulin and Stig Hjalmars for the investigation of the meson pair theory of nuclear forces. It is believed in the meson pair theory that the forces between the nucleons have their origin in the transformation of a pair of mesons. By means of the theory, it may be explained that the nuclear force between two protons is approximately the same as that between a proton and a neutron, except that it is not necessary, as in the conventional meson theory, to take refuge in neutral mesons, which are not indicated experimentally. The possible types of such pair-exchange effects have been established by the research mentioned. By means of the nuclear forces derived therefrom, it has proved possible to a large degree to account for the experimental observations concerning the exchange effects between two nucleons. The results have been published in a series of rather short studies and two doctor's dissertations.

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Funds have been granted for research on the statistical distribution of atomic nuclei in a temperature equilibrium, conducted by Lic. Göran Beskow and Lic. Lars Treffenberg jointly in 1946 and 1947, and after that by Lic. Beskow. The research consists of continued work on the computations previously made and published jointly by Professor Klein and Beskow and Treffenberg. This research showed that an equilibrium distribution of atomic nuclei at 10 billion degrees agreed with the empirical distribution curve for elements in the universe only in the case of light nuclei. The continued research, partially published in two papers by Beskow and Treffenberg, shows that the agreement may be extended to the entire periodic system if the material in equilibrium is divided into stars with masses of the same order of magnitude as those of the present stars. The present distribution could then be explained as an approximative equilibrium distribution which has become "frozen" in a rapid expansion and cooling of these stars, to which our present stars possibly directly owe their origin. Investigations the dependence of the distribution on the temperature of equilibrium, on the coulomb exchange effect, the course of expansion, and possible continued nuclear reactions, are still in progress.

From 1948 on, grants have been provided Fil. Lic. Carl Victor Johsson, who has investigated a theory proposed by Professor Klein on the relation between the meson theory and the general field theory of the theory of relativity. In the course of this research, he has discovered that the only field magnitudes which cannot be eliminated are those which correspond to a field of mesons with a spin of 2. This meson field has been quantified (kvantiserats); in addition to this, its exchange effect ~~investigated by~~ with both the electro-magnetic field and the nucleon field has been investigated. It turned out in the latter case that terms (termer) of the pair-exchange effect type predominate.

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"An extraordinary docent stipend has been granted Docent Björn Bruno for the budget year 1949-50. During the fall term in 1949, Bruno gave lectures on theoretical nuclear physics, conducted seminars on actual problems in theoretical physics, and continued his research on the catching of mesons by atomic nuclei.

"Research at the ~~Institute~~ Department has also been promoted by grants for study trips, for help with numerical calculations, and for the purchase of two calculating machines."

<u>Electronics ~~Institutes~~ Departments, Electron Accelerators</u>

The work of these ~~institutes~~ departments is ~~purely~~ generally of great importance to nuclear ~~physics~~ physics, just as to most of the other branches of natural science. A large part of the nuclear physics results has been obtained by means of the technology of amplification and of other fields of electronics. However, this general work has not been supported economically by the Atomic Committee. On the other hand, as previously mentioned, the ~~institutes~~ departments of electronics at the Stockholm Institute of Technology and at the Chalmers Technological Institute have constructed electron accelerators, namely a rather small betatron and a synchrotron in the former case and a linear electron accelerator in the latter case.

<u>The ~~Institute~~ Department of Electronics at the Stockholm Institute of Technology</u>

Concerning the synchrotron, Assistant <u>O. Wernholm</u>, who supervised this work at the Electronics Department of the Institute of Technology, reports the following:

"The need for fast, electrically charged particles has increased very rapidly with the development of nuclear research. In high voltage installations, it is possible to directly accelerate particles to energies corresponding to several million volts, but if still higher energies are to be attained, it will be necessary to resort to some indirect method of acceleration because of the difficulty of insulation.

In the betatron and the synchrotron, the particles are caused to run in a magnetic field, which gives the path of the particles a circular form. Every revolution the particle makes in its path sees its energy increased by several tens or hundreds of volts, and after a great number of revolutions, the particles can attain energies corresponding to millions of volts.

Work with electron accelerators has been in progress at the electronics department of the Royal Institute of Technology for several years. The first accelerator, a small betatron developing electron energies of 1.5 million eV, was begun in the fall of 1945, and in the summer of 1946, a larger betatron developing 5 million eV was begun. A few years later, the designing of a synchrotron, also intended for the acceleration of electrons, was begun. The synchrotron has been in operation since the spring of 1949, and in its present form develops electron energies of 35 million eV. Trimming (trimning) of this machine is now in progress in order to increase its radiation intensity.

By far the greatest part of the cost of an accelerator lies in the arrangement used to produce the magnetic field, that is, the magnet with all its accessories. The magnetic field of the synchrotron, which is produced by 50-cycle alternating current, is ring-shaped and has a relatively small cross-section. Because of this, the magnet, in relation to the energies developed, is quite cheap, but it requires, on the other hand, that, if the radius of the path of the electrons is not to be changed too much, the electrons be started with a speed very close to that of light. The voltage with which the electrons are shot into the magnetic field of the synchrotron is limited for reasons of insulation to approximately 50,000 volts, and this corresponds to only 41 percent of the speed of light. The synchrotron, therefore, is combined with a betatron, in which the electrons, before acceleration by the synchrotron begins, are given a speed 98 percent that of light (2-3 million eV).

The vacuum tube in which the acceleration takes place is ring-shaped and is placed in the air gap between the poles of the magnet, which are also ring-shaped. Every other time the 50-cycle alternating magnetic field is weak, a 20,000-volt beam of electrons is [redacted] generated in the tube. The beam is diverted by the magnetic field and is led around in the vacuum tube. While [redacted] the magnetic field intensifies, [redacted] a tension of 30 volts is induced in the electron path by means of a magnetic flux, centrally and temporarily turned on. For every revolution made by the electrons in the tube, they are, therefore, accelerated by 30 eV, and after 85,000 revolutions, they have attained an energy of 2.6 million electron-volts. It is this acceleration, which takes place by means of [redacted] a voltage induced in the electron path, which is called betatron acceleration.

When the electrons have attained this energy, the central magnetic field is turned on and the betatron acceleration ceases. A high-frequency electrical field is switched on at a point along the electron path. The electrical field is produced by a high-frequency transmitter, the wave-length of which is equal to the circumference of the electron path (1.26 meters). The electrons are continuously given an additional impulse of 30 eV of energy per revolution in the electrical field, and after 1,100,000 revolutions, when the magnetic field reaches its maximal value, the energy of the electrons is 35 million electron-volts. The electron path is reduced and the electrons caused to impinge on a tungsten rod, where their energy is converted into very penetrative roentgen rays.

"The acceleration is repeated 50 times per second, and every course of acceleration requires 1/200 second. 1/20 of this time, or 250 microseconds, are required by the betatron phase."

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The Electronics Department at the Chalmers Institute of Technology

The director of the department, Professor Olof Rydbeck, reports as follows on the linear electron accelerator:

"The idea of the linear accelerator is a relatively old one. The first workable design was advanced by Sloan and Lawrence in the early 1930's. This was intended for the acceleration of ions. However, with the discovery of the cyclotron, developments in the field of the linear ion accelerator stopped. Several rather small-scale theoretical investigations were made on the linear electron accelerator during the 30's, but the shortage of suitable high-frequency generators hampered practical research. The development of high-effect magnetrons during the war, however, changed the situation radically. The construction of linear accelerators became part of the agenda of a number of research institutes throughout the world.

"Only the two projects which have progressed the most will be mentioned in this instance, namely, the Telecommunications Research Establishment (TRE) in England, where an accelerator of the so-called traveling wave type has been built which has developed energies of 4-5 MV, and the Massachusetts Institute of Technology (MIT) in the USA, which is building a so-called standing wave accelerator, which in the first stage will have a length of 6.5 meters with an expected energy of 30 MV. Furthermore, the construction of a traveling wave accelerator for high energies has been begun at Stanford University under the direction of the late W.W. Hansen, but as yet nothing has been published about it.

"The reasons for experimenting primarily with accelerators of this type are many. The most important reason is that the linear accelerator has negligible beam loss. On the other hand, the circular accelerators have such a high beam loss that they fix an upper limit to the attainable energies.

"But even overlooking the higher energies a linear accelerator can develop compared with a rather large synchro-cyclotron, a linear accelerator

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can be simpler to construct, despite the great length required by such an accelerator.

"The accelerator now under construction at the Chalmers Institute of Technology is of the standing wave type. The wave length used is 10.5 centimeters. The accelerator consists of a cylindrical wave guide, in which circular diaphragms have been placed. The distance between them is half a wavelength. The length of the wave guide is 85 centimeters in the first extension (utbyggnaden). The electrical field is obtained from 3 high-frequency magnetrons of the type HK7T, each one of which delivers 1 MW. When these work into a resonant load, about half of the effect must be used in an artificial load in order that a stable working point may be obtained.

"After the field has been built up, an electron impulse is fired through the resonator from an electron cannon of a special type. As it is desirable to be able to regulate very accurately the three magnetron impulses and the electron impulses in relation to each other, special equipment has been necessary. For the measurement of the speed of the accelerated electrons, a special speed spectrograph has been constructed. The electrons are deflected by means of a powerful, non-ferrous electromagnet, the current intensity of which is varied linearly. The current to a commutator (kollektor) deflects a cathode ray tube in the y-axis; the x-sweep is synchronized with the current through the magnet. The intensity, then, is indicated on the screen as a function of the electron speed.

"From the theory it is concluded that the indicated electrons are not all accelerated to the same speed. The distribution of speed can be directly observed from the screen, which is of great theoretical interest to know.

"When the electron beam is pulsed, the picture on the screen consists of vertical lines. Therefore, in order to have as many lines as possible, the sweep speed must be low and different from sub-multiples of the pulse frequency. The pulse frequency should also be low in order to avoid high tensions in the electromagnet. In this case, the pulse frequency is 50-100 pulses per second, while the sweep speed is one sweep per 10 seconds. A 12" tube with a strongly after-glowing screen was used as the cathode ray tube.

"Finally, naturally, a coaxially focussing magnetic field is required around the accelerator. The requisite intensity has been determined at approximately 500 G, which value it should not be particularly difficult to attain.

"Concerning the general scheme of the apparatus, see the figure (between pages 68 and 69 of the original)."

<u>The Gustav Werner Institute for Nuclear Chemistry, Frequency-Modulated Cyclotron</u>

The physics-chemistry ~~institute~~ department at Uppsala University is a ~~institute~~ department with one foot in the physical sciences and one foot in the chemical sciences. Thw work conducted this ~~institute~~ department for which the Atomic Committee had granted funds, was transferred in 1949 to the newly-organized Gustaf Werner Institute for Nuclear Chemistry. This institute has been built up around the previously discussed synchrocyclotron. This means that the new institute, despite its name, will occupy an intermediate position between physics and chemistry, for which reason it is dealt with separately in this account. The location of the institute, right between and a short distance away from the physics and chemistry ~~institutes~~ departments at Uppsala University, will also facilitate its function as a connecting link in atomic energy research between the two main sciences mentioned.

The Gustaf Werner Institute for Nuclear Chemistry with its cyclotron has received help primarily from private sources. However, the Committee has provided funds for certains parts of the Institute and for the operation of the laboratory.

Fil. Lic. <u>Helge Tyren</u>, who directly under Professor <u>The Svedberg</u>

heads the work at the laboratory, has delivered the following account:

"A cyclotron installation is being constructed at the Gustaf Werner Institute for Nuclear Chemistry, Uppsala University. This work has been in progress since 1946 and has embraced the following:

"Buildings: An underground building has been constructed in order that effective protection from radiation might be obtained. This building houses a large circular hall for the cyclotron, and directly connected to [redacted] this hall, but screened off [redacted] protective by against radiation, is a space designed for the registering instruments used in direct experimentation with rays from the cyclotron and a room for work with radioactive materials. There is an assembly shaft with a crab bar (lyftbok) for the transport of material to the cyclotron; in the hall there is a [redacted] with a capacity of 10 tons.

"The underground building is connectly with a newly constructed laboratory building on two levels. The basement level contains chemical laboratories especially equipped for the preparation of radioactive substances [redacted] and the ground floor contains a control room for the cyclotron, physical laboratories, a writing room, and an office.

There is also a special machine room, housed in a new building, belonging to the installation. This is connected to the laboratory building by means of a tunnel.

"The Design of the Cyclotron: The transformers and converters for the cyclotron magnet have been set up and the magnet has now been mounted. It contains about 600 tons of iron for the magnet yoke and the pole cores and about 50 tons of copper for the coils. Experiments with a model magnet in a scale of 1:10 have been carried out to determine the most suitable form for the pole plates of the magnet. The cooling system for the magnet coils, the oscillator system, and auxiliary equipment [redacted] have been installed.

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The acceleration chamber, the vacuum pumps, [redacted] two diffusion pumps connected in parallel, and the accessary preliminary vacuum pumps are made of stainless steel. This equipment has been received.

The oscillator is of the [redacted] American type, with frequency modulation[redacted] effected by a [redacted] rotary condensor. High particle energy may be obtained in this way. A full-scale model oscillator has been built and experiments with it concluded. The high-frequency system is now about to be [redacted] designed. The high-tension rectifier for the oscillator has been installed.

The ion source, the target, and the major portion of the control system of the cyclotron yet remain to be designed. The cyclotron will first be completed without the apparatus for deflecting the ion stream. It is intended that such a deflector be installed later. It is estimated that the cyclotron will deliver protons with 200 MeV of energy and a great yield of high-energy neutrons.

<u>Instruments</u>: The work has been further developed for the planned research activity by the development of instruments by the laboratory. An experimental column for thermal [redacted] diffusion has been set up. A mass spectrometer has been built for the determination of isotope conditions. This is provided with two slits for the comparative measurement of two close isotopes. A large mass-separator for the separation of stable and radioactive isotopes is planned. For the measurement of beta and gamma rays, a coincidence amplifier has been built , and a beta spectrometer is planned. A number of universal magnets have been constructed for determining the energy of fast [redacted] particles by deflection in a magnetic field. In addition to this, a large number of measuring instruments for the measurement of radiation and general electrical measurements have been purchased for the laboratory, as has also equipment for the planned chemical work.

Personnel: At the present time, 5 academicians, 4 engineers, 1 mechanic, 1 electrician, and 1 secretarial assistant. The designing of the cyclotron is being handled chiefly by the firm L.K.B.-Produkter, Fabriksaktiebolag, Stockholm. Grants from private sources have taken care of most of the expense of the cyclotron. The research activity has been financed exclusively by funds from the Atomic Committee."

The Chemistry ~~Institutes~~ Departments, Methods of Analysis, Uranium Chemistry, Nuclear Chemistry

The realization of the first goal of atomic energy research in Sweden, the construction of an experimental reactor, depends on the extraction of uranium from domestic shale; this is the most important problem. Work on the solution of this problem, therefore, was from the very beginning assigned the highest priority on the Committee's program. However, this work could not -- or in any case, could not only -- be turned over to a university ~~of~~ or technological institute department because it was too extensive and involved, having ramifications in various fields, both technical and scientific. Initially, before [redacted] atomic energy research activity assumed a more tightly organized form, the ~~Armed~~ Defense Forces Research Institute (Försvarets forskningsanstalt) was charged with conducting this work in cooperation with the [redacted] Swedish Shale Oil Corporation (Svenska Skifferoljeaktiebolaget) and suitable university departments [redacted]. The most important of the latter was the ~~Institute for~~ Department of Technical Inorganic Chemistry at the Stockholm Institute of Technology.

The first problem to be solved in this connection was to develop a reliable method of analysis, because it was on this that all geological, extraction, and refining research and methods would be based. This also became the first task of the chemical section, which was [redacted] expanded at the ~~Armed~~ Defense Forces Research Institute. This problem was solved, but work on improving these methods is in constant progress. This research activity on the methods of analysis and the routine analyses are handled at present by a special analytical laboratory, organized by AB Atomenergi (Atomic Energy Corporation) -- in fact, this was the first real activity taken up by the corporation after its formation.

At the same time, work on developing methods of extracting was being pursued, initially by the FOA (Defense Research Institute) and the Swedish shale oil corporation, and later by the Atomic Corporation and the shale oil corporation. The work of the corporation has been conducted at the inorganic chemistry department at the Institute of Technology and in its own research laboratories, and has been very fruitful.

<u>The Department of Technical Inorganic Chemistry at the Stockholm Institute of Technology</u>

The head of the department, Professor <u>Otto Stelling</u>, reports the following with regard to the above-mentioned work:

"Work on the extraction of uranium from shales or various shale products has been conducted at the Institute, of which the undersigned is a member, since 1946 and is still being pursued with all means available. During the period up to 1 March 1948, the research work was financed by the FOA, but since that date, those expenses have been assumed by AB Atomenergi.

"The great difficulty in this work, of course, is the particularly low uranium content of the starting material. For that reason, completely new procedures had to be developed. As a result of the work conducted heretofore, a technically completely satisfactory method of extracting uranium has been developed. This method is also being tried out on a half-scale in the plants of AB Atomenergi."

Of the chemical departments at Sweden's universities and technological institutes, only a couple of departments at the Stockholm Institute of Technology were at first conducting such research as was of direct importance to the work of the Atomic Committee. The department of technical inorganic chemistry at the above institute must be mentioned in particular. That entire, broad branch of chemistry now known as nuclear chemistry was practically unrepresented in Sweden. Since 1944, however, Docent K.E. Zimen has been conducting certain research in applied nuclear chemistry at the Department of Silicate Chemistry at the Chalmers Institute of Technology. In conformity with the proposal by the [redacted] board of directors of the Chalmers Institute of Technology, the Committee decided to recommend to His Majesty that funds from the [redacted] appropriation for atomic energy research be used to organize a laboratory for nuclear chemical research and investigation at the Institute and also to set up a special nuclear chemistry department. This department is the only one ~~the~~ buildings, equipment, and personnel ~~of which~~ have been paid for in toto [redacted] from the atomic research appropriation; in all other cases, the grants have been given to departments and institutes already in existence.

<u>The Laboratory for Nuclear Chemistry, Chalmers Institute of Technology, Göteborg</u> [redacted]

The head of the department, Docent <u>Karl Erik Zimen</u>, reports the following:

"<u>The birth and development of the laboratory</u>: In February 1946, the Atomic Committee sent a circular to the departments of technological institutes making inquiry about possible cooperation in atomic energy research. On occasion thereof, [redacted] a proposal was worked out by Docent K.E. Zimen, in consultation ~~counsel~~ with the faculty for nuclear chemical research. Docent K.E. Zimen had been engaged since [redacted] 1944 in applied nuclear chemical research, supported by the State Technical Research Board, at the department of silicate chemistry. The proposal was approved by the faculty and the board of directors, and research on nuclear chemistry began in the fall term of 1946. The further development of the nuclear chemical laboratory was hampered during the first two years by the shortage of suitable personnel and suitable quarters. For example, from the very beginning there were openings for two assistants (a chemist and an electrician), but competent personnel for those posts were [redacted] unavailable. Furthermore, the director of the laboratory during 1946 and 1947 had to share his time between the silicate department and the new laboratory, as it was necessary to see the work financed by the Technical Research Board to completion. However, the technology students [redacted] showed great interest in the new subject, and [redacted] many chose to write their theses on nucleur chemistry, with the result that from the fall of 1947 on, an increasing number of assistant posts could be filled by newly graduated civil engineers. This development is shown in Table 1.

Table 1

Fiscal [redacted] year	Grant (kronor)	personnel	
		scientific	technical
1946/47	25,455	1	--
1947/48	59,540	2	1
1948/49	122,140	3	3
1949/50	117,510	5	5

The question of quarters was a very difficult problem to solve, as the Chalmers [redacted] chemistry building, which now had to house the new laboratory too, was overcrowded. The overcrowded chemistry departments, however, all gave up space so that the nuclear chemistry section fortuitously had a number of laboratories made available, and work could begin. However, this laboratory was spread out over four stories [redacted] of the chemistry building and, naturally, were not equipped for work with radioactive substances. At a meeting with the work committee of the Atomic Committee on 18 December 1946 at Chalmers, these [redacted] difficulties were pointed out, and the work committee recommended that an investigation be made to determine if [redacted] it would not be better to seek a [redacted] quick, permanent solution [redacted] rather than a provisional solution of the laboratory quarters problem, and that a proposal, with an estimate of the costs, be then submitted to the Atomic Committee.

Therefore, the director of the laboratory worked out a proposal for a rather small building of suitable design, and the Chalmers architectural office drew up plans and got estimates of the cost of such a [redacted] new building. The proposal, with the faculty's opinions on the project, was submitted by the board of directors [redacted] in March 1947 to the Atomic Committee, and in May 1947, the requested funds were granted. The problem of the most [redacted] suitable location of the new building and the difficulties in obtaining a building permit delayed further developments, but in April 1948, the construction work began and it was possible to start moving [redacted] equipment and personnel into the [redacted] new laboratory in January 1949.

In May 1947, the Atomic Committee requested a grant for the construction of a 400,000-volt neutron generator for the laboratory, as the [redacted] production of radioactive nuclides is a prerequisite for nuclear chemical work. The high voltage element of this neutron generator could be was [redacted] purchased from the Nobel Institute of Physics, and several important parts of the acceleration tube were constructed by the LKB-Produkter firm from plans placed at the disposal by the physics laboratory of the Defense [redacted] Forces Research Institute. Other work was done by the precision instrument workshop of the nuclear chemical laboratory, under the direction of Civil Engineer I. Nilsson. After the [redacted] personnel and equipment had been moved into the new building, it was possible to install the neutron generator permanently in a high-tension room designed for that purpose. The designing and experimental work on the vacuum system, the procurement [redacted] of heavy hydrogen, the arrangement of the target, etc., have been in progress since that time, and in a very short time it will be possible to place the apparatus in operation. The neutrons are produced by the d,d-reaction, and the effect will correspond to that of a radium-beryllium-neutron source with about 30 grams of radium.

Heretofore, the production of radioactive nuclides in the laboratory has been done with a radium-beryllium neutron source with 0.35 grams of radium, which the laboratory has had available since August 1947. It has also been possible to obtain a number of cyclotron-produced nuclides from the Nobel Institute of Physics and to import some nuclides produced in the nuclear reactor from the USA.

"The measuring instruments for the laboratory have been purchased largely by Docent Zimen, on his Atomic-Committee-financed study trip to the USA in March-August 1948. Having moved into the new building, the laboratory workshop personnel are engaged in designing and producing other mechanical and electrical equipment necessary for laboratory activity, for example, equipment for the safe handling of radioactive preparations in chemical work and for the measurement of the preparations. A listing of the grants for these special purposes is given in Table 2.

Table 2

Date	Appropriation	Purpose
May 1947	47,000 kronor	For the construction of a 400,000-volt neutron generator
May 1947	179,000 "	For the laboratory building
Aug 1947	loan	350 mg Ra-Be neutron source
Aug 1948	45,800 "	Supplementary appropriation for the laboratory building

"Since both the personnel and quarters problems have been solved, that is, now that a research corps of nuclear chemists has been assembled and the new building has been procured and equipped, the Atomic Committee and the Chalmers Institute have a small, but well-equipped laboratory at their disposal.

[redacted] "The Work of the Laboratory: The following will describe in brief the policies determining the work of the laboratory and the results which have thus far been attained. Rapid developments in the field of nuclear chemical work or the rise of special requirements, obviously, could shift the emphasis in the future work of the laboratory.

"Instruction in Nuclear Chemistry at Chalmers: From the beginning it was clear, and also pointed out by the Atomic Committee on various occasions, that the shortage of [redacted] scientists and engineers trained in nuclear research and nuclear technology should be the first bottleneck to be rectified. The development of the nuclear chemistry laboratory supports the accuracy of this belief. Chalmers also stressed the necessity of the immediate institution of instruction in nuclear chemistry. The work of the laboratory, therefore, began in October 1946, with lectures on this subject, and since that time instruction has continued practically unchanged along the plan outlined below.

A general and basic course, carrying two credit-hours per week, is [redacted] held during the fall term. The course embraces (1) spontaneous and induced nuclear reactions, (2) the chemistry of radio nuclides, and (3) the applications of radioactivity.

"A continuation course, including laboratory work and discussion [redacted], [redacted] carrying four credit hours per week, is [redacted] held for a limited number of students during the [redacted] spring term. This course [redacted] embraces (1) methodology of nuclear chemical [redacted] work (measuring instruments, measuring technique, chemical technique, protection against radiation) and [redacted] (2) more thorough discussion of selected problems.

"It was decided by the faculty that the course should be voluntary and intended primarily for chemists in their junior year. Students of other scientific and technical subjects would be permitted to take the course; the course would be [redacted] open even to those interested outside the Chalmers Institute -- medical students, doctors, technicians, etc, who wished to orient themselves in that subject.

"A compilation of data on the instruction is shown in Table 3. Several works have been published for purposes of instruction (of Section 3), and a compendium "Course in Nuclear Chemistry" is being prepared (Berne, Nilsson, Zimen).

Table 3

Instruction Year	Students in Course	Theses (examensarbeten)	Master's Degrees (licentianter)
1946/47	ak 44 fk 10	3	-
1947/48	ak 18 fk 10	2	1
1948/49	ak 26 fk 10	1	2
1949/50	ak fk	2	2

(ak is general course, fk is continuation course)

"Research Activity: The most important result of the development of nuclear research is, and long will be, the military applications, and only the largest nations have the [redacted] resources to produce atomic weapons. The utilization of atomic energy for peaceful purposes -- the only task of the smaller nations in this connection -- can, from what is known today, be effected in two ways: the nuclear reactors can be used for the production of energy, and they can -- like accelerators -- be used for the production of radioactive isotopes of the elements. Of these two practical tasks, so far only one can be realized, namely the production of sources of radioactive radiation and of radioactive tracer isotopes for medical, technical, and research work with "marked" chemical compounds [redacted] (föreningar). This task will also be the most important for a "peaceful" nuclear reactor in the near future.

"The nuclear chemistry laboratory has as its primary research project the study of the chemistry of nuclides and radiation properties. Bearing in mind the practical utilization of nuclides and the coming domestic production of nuclides by means of a nuclear reactor, the [redacted] Swedish nuclear scientists felt it logical to concentrate particularly on the production and [redacted] characteristics of tracer isotopes. Thus far, tracer isotopes of silver and bromine have been studied, and similar investigations of the production, [redacted] yield, half-life, and absorption of radiation are in progress on radioactive pyrites (radiokisel) and on a number of fission products of uranium. In connection therewith, the Szilard-Chalmers method for the separation of isotopes (Civil Engineer E. Berne) has been worked out. Beta ray absorption has been the object of experimental study for an adequate description of beta radiation.

"Besides purely nuclear chemical research, the chemist also has the job of utilizing the radioactive nuclides as tools in the study of [redacted] yet unsolved chemical problems. Naturally, there must be considerable specialization in this practically [redacted] unlimited field, particularly as regards the special fields of research in physical, inorganic, organic, biological, or technical chemistry. The special problems of application thus far worked on in the laboratory concern both analytical and structural-chemical problems. Thus, the [redacted] previously developed radiometric method of analysis for uranium has been improved, and work on self-diffusion and similar problems of a structural-chemical nature have been published.

"<u>Consultation Activity</u>: Hundreds of chemical, technical, biological, and medical laboratories in the USA, [redacted] Canada, and Great Britain are already working with radioactive tracers. The importance attached to the use of tracer isotopes may be shown by the following words of the prominent American nuclear chemist Seaborg: "It is not at all out of the question that the greatest gains to humanity from the atomic energy development will result from the widespread use of tracers to solve a multitude of problems rather than from the harnessing of the power itself.[redacted]"The future seems to hold unlimited possibilities for the application of radioactive tracers to scientific problems. It is certain that the applications made thus far are just the beginning of what is going to become an extremely large and successful field of research." /G.T. Seaborg: Science 105 (1947) 349/.

"The use of tracers is limited at present by the shortage of readily available radioactive nuclides, of knowledge of the sensitive measurement technique, of the special chemical techniques of work, of the necessary protective [redacted] measures against radiation, etc. There is, therefore, a great need for consultative and even active help in connection with such work. The need is especially great in Göteborg because various physicians and teachers in the new medical institute are greatly interested in the methodology, and because of the -- in many cases -- prohibitive distance to the nuclear chemistry institutes at Stockholm and Uppsala.

"The laboratory, therefore, [redacted] also serves in an advisory capacity concerning the applications of tracer isotope technique; it also gives practical help in the production of suitable tracer isotopes or [redacted] the measurement of radioactive preparations. Thus far, for example, the laboratory has lent its assistance in various diagnostic and therapeutic investigations (carried out by Doctors Brattgaard, Gabriele, Lagergren, Lindquist, Turesson, Strandquist, and Westerborn) through the production of [redacted] radioactive bromine, the procurement of radioactive nuclides from other sources, the measurement and dosaging of radioactive phosphorus, the measurement of [redacted] diverse radioactive preparations, measurements on patients and the neutron irradiation of experimental animals."

Extensive work in the department of theoretical chemistry at the Stockholm Institute of Technology also has been financed with funds from the Atomic Committee. This work is of two types: both work on the separation of isotopes, primarily by the diffusion method, and instruction and research in nuclear chemistry.

The problem of the separation of isotopes is of very great importance in atomic energy activity; primarily, of course, in the production of atomic bombs, but also for other purposes, for example, in the development of small reactors for the propulsion of vessels or even of aircraft. Theoretically, there are a great number of methods of achieving this. In the USA, however, diffusion appears to play the completely dominant role. The Committee, therefore, has thought it ~~purposeful that every method be investigated~~ desirable that a certain amount of research be done in this field, although it is at present doubtful that this method will come into use in [redacted] Sweden for a long time, because of the [redacted] enormous cost of erecting and operating such an industrial installation for [redacted] diffusion and separation. Preliminary investigation of certain other methods of separation is being conducted at the [redacted] Institute.

Nuclear chemistry has already become, and is ever more becoming, so important that activity in this field is now being taken up in various places. For example, instruction and research have been [redacted] started at the department of theoretical chemistry at the Stockholm Institute of Technology; moreover, activity at the Physics Research Institute has made it necessary that a nuclear chemistry [redacted] section be set up. Work in nuclear chemistry will, furthermore, be taken up at the Gustav Werner Institute of Nuclear Chemistry in Uppsala, when the cyclotron there is finished.

[redacted]

<u>The Nuclear Chemistry Section of the Department of Theoretical Chemistry at the Stockholm Institute of Technology</u>

Professor <u>Ole Lamm</u>, the head of the department, has given the following account of the activities of the Department financed with funds from the atomic research appropriation:

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"**General Viewpoints**: Nuclear chemistry in its broadest sense may be divided into two fields: nuclear chemistry and applied nuclear chemistry. The spheres of activity of nuclear chemistry proper, then, should be the following: the decription of radioactive chain reactions, nuclear reactions, and the separation of isotopes. (This would also include the chemistry of isotopes, that is, the detailed description of the chemistry that occurs because of the chemical differences of the isotopes.) Applied nuclear [redacted] chemistry deals with the pure or beneficiated active or inactive isotopes (nuclides) used as tracer substances in various branches of science [redacted] or as sources of radiation in radiation-chemical and [redacted] radiological processes (radiators). The work of the Department takes in both of these fields

"The research activity of the Department deals with certain problems of application, particularly the relationship between matter and [redacted] radioactive rays [redacted] and the use of these rays as an aid in physical chemistry and technology. At the same time, work is in progress on the separation of isotopes by effusion (popularly called diffusion). Furthermore, work is being prepared on the separation of boron isotopes (distillation, processes of extraction), on the development of the ion-exchange [redacted] method with a view toward the separation of fission products, and on problems of basic research in radiation chemistry.

"As a whole, this field suffered a great decline in Sweden in the years between the wars. It should be remembered that O. Hahn's book, "Applied Radiochemistry" was published back in 1936. In Sweden, as elsewhere, it has now entered into a phase of rapid development. The Atomic Committee is the most important appropriation body in this connection. It has, in its supporting activity, admitted the [redacted] requisite of rather extensive basic research. This is particularly [redacted] valuable and necessary in such a new field, if the future development is not to suffer from the practical and economic viewpoints.

"Instruction runs side by side with research. Nuclear chemistry began at the Institute with theses on [redacted] the subject of theoretical chemistry. Through continued scientific work, and thanks to the Institute's course in nuclear physics, the department of nuclear chemistry was able to grow and the positions for assistants and the very recently established positions for assistant instructors filled with competent specialists. Important contributions [redacted] have been made particularly by Fil. Lic. K.E. Holmberg, and Civil Engineers G. Aniansson, O. Lindström, M. Maartensson, and T. Vestermark.

"<u>Isotope Separation</u>: Effective isotope separation requires a great deal of preliminary work, regardless of the method selected. Among the methods of procedure, the diffusion method occupies a special position because it relatively economically can be adapted to deal with great quantities. It has been [redacted] used for the separation of uranium isotopes on a large scale in the USA both during and since the war. ~~as well as thereafter.~~ Any installation for the latter purpose must be enormously costly, and this actually proved no exception in the USA.

"Our work has been aimed at gaining experience in the diffusion method, and has progressed to the point that an experimental 10-stage installation will soon be operable for non-corrosive isotope mixtures, or, at least, a gas [redacted] mixture considerably less corrosive than uranium hexafluoride, the gas used in the USA. Our work has consisted of [redacted] investigating the theory and modus operandi of the process, in designing suitable diffusors, in investigating problems on pumps and control [redacted] equipment, and in developing suitably finely porous (molecular) membranes. The latter is the most sensitive [redacted] point of the installation: for the separation of two nearly identical substances in a gaseous [redacted] mixture, the [redacted] mixture must be "sifted" through sieves, [redacted] thin plates, so finely porous that to the eye and the touch they appear impermeable and homogeneous. At the same time, their permeability should be high. This has required very extensive work, and a number of [redacted] tests have been made with various materials. At the same time, the studies of membranes have been of practical interest. Both steel and glass membranes of the types we tested may be used for industrial or laboratory purposes. At the same time, the resistance to corrosion of a number of materials has been investigated, inter alia, to uranium hexafluoride, in an extensive series of tests, taking into account the modern viewpoints on the influence of gas [protective] coatings on the susceptibility to corrosion. In this connection, uranium hexafluoride has been produced from uranium carbide obtained from the Defense Forces Research Institute. Work has also been done in the designing of electrolytic fluorine generators, in which connection Engineer O. Lindström has made great progress, just as he has in the study of corrosion.

Engineer Lodhammar's work with special steel membranes has been finished as a thesis. The study of glass membranes was begun later, but, according to Engineer C.L. Carlsson's report, this problem is also well in hand.

The figures for the cost of separating the uranium isotopes on a practical scale are frightfully high for a country of Sweden's size. Use for the production of deuterium lies within reach, but an estimate of the costs would require a special investigation by experts, particularly in the field of pumps, for which reason this new problem is yet a blank. Deuterium in the form of heavy water is, as is known, of particularly great importance in the atomic energy program.

Even in its present form, with 10 stages, the diffusion apparatus can be used for the separation of isotopes generally desired for research purposes (for example, for tracer experiments), as it is not necessary that the degree of purity be so very high; but the production capacity must be fairly high, namely 5-10 grams per day. The separation of silicon, chlorine, and bromine and the lighter gases is to be especially recommended. Compared with thermal diffusion, there is the advantage of low energy consumption; compared with exchange reactions, of economy of the material undergoing separation. Expansion to 50 stages would give a concentration in the ratio of 2:1 or more, depending on the absolute quantity of the desired production and possible improvement of the membrane.

"Preliminary studies have been made at our laboratory also on the concentration of boron 10, which also is of very great importance in nuclear physical research. Concentration of boron 10 is effected [redacted] primarily by [redacted] distillation or chemical exchange-reactions, and the work in this, to Sweden quite new, field meant the determination of the separation factor in distillation, which in literature is presented only in the form of uncertain theoretical calculations, and the investigation of the conditions under which an exchange reaction takes place.

"In connection with the preparation of isotopes, we are now prepared to conduct work on the production of the particularly corrosion-resistant materials known as carbon fluorides. Their characteristics may be varied for different uses, as lubricating oils, elastic packing, and as the hard material in diffusors, etc. (Besides our special interest in these products, upon which England and the USA have worked a great deal, they have important applications in a number of apparatuses of interest both to technology [redacted] in general and to the defense. In the USA, the products are highly secret, while their production in England has just begun recently.)

"In connection with the Department's work on ultrasonics (Engineer Ö. Lindström), [redacted] originally [redacted] supported by the Technical Research Council, particular attention is being devoted to the possibilities of isotopic effects in chemical reactions in ultrasonic fields. A rational [redacted] discussion of this problem requires especially extensive [redacted] knowledge of the physics and chemistry of ultrasonics. [redacted] Engineer Lindström's above-mentioned fluorine and corrosion research has not required all his time, but it has not been practicable [redacted] to get a part-time researcher, as that work requires considerable supervision. He has, therefore, been able at the same time to devote himself to the study of ultrasonic phenomona with a view toward the separation of isotopes.

"Of other research projects, great interest has been accorded [redacted] certain separation problems important to the uranium reactor, [redacted] to the [redacted] development of ion exchange methods for that purpose, and to radiation-chemical questions of importance in the same connection, although these problems are still in the preliminary stages of their solution at the department.

"<u>Basic Research: Alpha, Beta, and Gamma Radiation, etc:</u> At present ~~at the department,~~ very advanced research on the methods of emanation (Engineer Maartensson), on the absorbtion of beta-rays, and on radiography by means of beta-rays (Engineer Vestermark), ~~is in progress~~. [redacted] The Technical Research Council has supported this work, and the results will soon be presented as licentiate theses. Other nuclear chemical work is being carried out with the support of the Atomic Committee. As a complement to the above-mentioned work on absorbtion, measurements of [redacted] range (räckviddsmätningar) have been carried out, as has been the case with beta-rays, primarily with a view towards material dependence (materialberoendet). To investigate the material dependence especially is a great and complicated task, which also has a number of practical aspects, as [redacted] radioactive radiation ever more is being brought into use in technical control instruments and physical- [redacted] chemistry [redacted] equipment.

"Thus, a highly significant part of the work is being done on measuring equipment requiring very high accuracy. The thickness of a material must be varied in making measurements, and in order to avoid being limited to substances occurring only in foil form, much work has been done on the production of extremely accurate absorption cuvettes (bulbs) in which a thin layer of liquid (down to 10 μ) is placed between two thin mica windows, the distance between which can be varied with very great precision. For the most part, the workshop personnel hired with funds from the Atomic Committee have been indispensible in this connection and in setting up the training course (see below), etc.

"Civil Engineer Anianson has worked on a method for the precision measurement of the range of alpha-rays and with the utilization of radioactive waves of short range for the study of surface adsorption. The results were interesting, particularly those in the adsorption study connected with the verification and application of the Gibbs adsorption theory for the study of the micell structure of a soap solution. Work with the Gibbs theory places one in a classical field where great experimental difficulties were encountered earlier, but where radioactive indication of the surface-active element opens up completely new possibilities for experimental research.

"In addition to the basic research tasks already mentioned, there are two other current thesis projects in nuclear chemistry in progress. One deals with the measurement of the diffusion coefficient for a radioactive beta radiator in solution, and the development of a suitable method of procedure for that measurement. The other deals with gamma radiography in the detection of flaws in castings, welded joints, etc., a process often used in technology, but, nonetheless, one capable of further development.

"<u>The Training Course in Nuclear Chemistry</u>: The course was established in the fall terms of 1947 and 1948, and comprised 48 laboratory hours. It is planned for the current term in the same manner, but after it has been improved by Vestermark, Aniansson, and Civil Engineer Gösta Nilsson, who has been employed for some time for that purpose. The number of students was the maximum number possible, 25 and 34 respectively.

"A number of course experiments in radioactive measurement technique, radioactive tracer technique, exchange reactions, the technical radiological use of gamma and beta rays, etc, have been devised.

"Rather simple quantum ~~calculaters~~ counters for the course have been produced at the Department, as have first-class ~~calculater~~ counter tubes for special purposes, among others, of the bell type, 6.0 centimeters in diameter and with 12-15 milligram/square centimeter mica windows. Also, a number of laboratory utensils have been produced at our own workshop."

[redacted] <u>The Radiophysoial Institute at the Karolinska Hospital; Matters of Protection, the Production of Radon Preparations</u> [sic]

As there is a special institute in Sweden for research in medical radiophysics and for the supervision of protection against radiation in radiological work and the [redacted] radiation-protection tasks assigned it (under the law of 6 June 1941 on the supervision of radiological work, etc.), the Atomic Committee has had good reason to lend powerful support to this institute and its research activities. Work in atomic energy research is, as is known, associated with considerable risk of radiation. The problem of radiation protection will become of increasing importance with the further development of this field, and probably in many cases will be of overwhelming importance in the practical utilization of atomic energy. The support provided the radiophysical institute has been for:

1. The construction of a high-tension room and the procurement of equipment for the investigation of the biological effects of short-[redacted] duration, intensive radiation, [redacted] with the funds for the operation of the installation,

2. The construction of a small building and the procurement of equipment for the production of radon preparations, to be distributed especially to Sweden's physics institutes for research and instruction purposes, [redacted] with the funds for the operation of the installation,

3. The development of measuring methods for registering penetrating rays, especially for the measurement of small quantities of gamma-radiating substances in the human body.

4. Completion of statistical investigations on the correlation between radiation and blood changes.

Neutrons play a central role in the liberation of atomic energy by the splitting of uranium and plutonium. It is, therefore, necessary to have access to an apparatus producing neutrons. The simplest neutron source is a radium-beryllium preparation, that is, a sealed tube containing a mixture of powdered beryllium and a radium salt. For that reason, therefore, the Committee purchased in the very early stages of its activity 2 grams of radium, one gram of which [redacted] used for the production of the radium-beryllium preparation and one gram for the production of radon preparations mentioned under Point [redacted] 2 above. There are the following radium-beryllium preparations:

2 units with 250 milligrams Ra each
4 units with 100 milligrams Ra each
5 units with 2o milligrams Ra each,

The 20-milligram tubes have been distributed to the physics departments at the Universities of Uppsala and Lund, the Stockholm Institute of Technology, the [Royal] Institute of Technology in Stockholm, and the Chalmers Institute of Technology. The other preparations are intended to be loaned out for a limited period for special research work. This activity is conducted by the Radiophysics Institute. Fees determined by the Atomic Committee are charged for these loans.

As to the accomplishments thus far achieved with the grants from the Atomic Committee, Professor Rolf Sievert, the director of the Radiophysics Institute, has the following to report:

"1) The [redacted] Institute's new high-tension room was constructed in 1946/47 and was ready for operation in January 1948. The equipment was being prepared at this time and, for the most part, was finished during the spring of 1949.

"The installation is intended for two different purposes, the requisite equipment in both cases being essentially the same. One has to do with the biological effects of short-duration, intensive roentgen radiation in such [redacted] doses that death follows a short time after exposure. The intention, primarily, is to investigate the effect of such radiation on small mammals, like rats and mice, in order to draw conclusions as to the effects on human beings. [redacted]

The same radiation apparatus may also be used advantageously for the genetic effects of radiation, for example, by experimentation with cultures of banana flies. The second purpose for which the installation is intended is conclusive experimentation on new methods of treatment (behandlingsmetoder) with short-duration, intensive roentgen radiation. Preliminary work at the Radiophysics Institute has shown that one may use anode and diaphragm apparatuses which produce an X-ray which, up to a certain limit, [redacted] increases in intensity with increasing distance from the tube, in contradistinction to the tube now in use, in which the intensity decreases greatly with the distance. For this work, which lies outside the sphere of interest of the Atomic Committee and which is primarily of medical interest, the Institute has received a grant from King Gustav V's jubilee fund and from Knut and Alice Wallenberg's foundation.

Following are some details of the high-tension installation:

"The high-tension room has a floor surface of approximately 11 x 19 meters and a ceiling height varying between 10 and 12 meters. There is a balcony-like construction, containing an electrostatically protected control room [redacted], a photographic dark room, and a smaller room for the preparation of biological preparations, at one end of the room.

"The high-voltage generator consists of a cascade generator developing a maximum of 1.2 million volts. The generator was ~~has been~~ designed by the Sievert Cable Plant and the Physics Research Institute of the Academy of Science. Three such generators have been manufactured so far, one at each of the above-mentioned institutes and one at the Radiophysics Institute. The generator is completely finished and mounted in place; it has been tested and functions satisfactorily. It can be connected to a battery of condensørs, consisting of 40 (the illustration says 4) condensørs for a maximum of 250 kV and of about 0.1 micro Farads. The [redacted] condensørs were ~~have been~~ received

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as a gift from the Sieverts Cable Plant. The Radiophysics Institute installed them. The battery is divided into four parts so that it can be connected for maximum voltages of 250, 500, and 1,000 kilovolts; it has been tested and found satisfactory.

The roentgen tube consists of a water-cooled iron cylinder 1 meter in diameter and 80 centimeters high built into the ceiling of a radiation room with iron-ore-concrete walls. The anode is in the center of the cylinder. The radiation room was donated by A. Dunder, a contractor. Above the iron cylinder in the roof of the radiation room is a series of corona-shielded insulators, so the anode can produce a voltage up to 1 million volts. The vacuum aggregate, which consists of two 300 liter diffusion pumps, each with a preliminary pump of the double-action, rotary type (valstyp), is also placed in the ceiling. The necessary control of the vacuum attained is exercised by ionization and Pirani vacuum meters. The filament holders, between which 144 tungsten wires are fastened, are in a ring around the anode. The filament current is obtained from a 16-volt anode battery with a discharge current of 20,000 amperes maximum. The filament current is regulated by means of a remote-controlled, water-cooled resistor designed by the Institute. This makes possible very accurate adjustment of the filament voltage. Two motor-controlled current breakers, also designed at the Institute, are coupled into the filament current circuit. These break the current automatically if the pressure of the cooling water should go below a certain value. Temperature control is provided at the requisite points. The voltage at the filaments can be measured partially directly and partially by means of an accurate measuring bridge. A 10,000-ampere shunt has been installed for the measurement of the intensity of the current.

Safety devices are provided for the prevention of accidents due to high voltages. For example, the high-voltage aggregate cannot be switched on without the activation from the control room of a certain signal apparatus,

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consisting of red warning lights, a siren, which sounds the alarm if someone should open the door to the high-voltage room, and another siren which gives the signal several seconds before the high-voltage transformer receives current. All high-tension short-circuit and switching devices are operated by automatic lifting devices with worm-gear motors, which are started from the control room."

"The discharge through the roentgen tube is controlled in several mutually independent ways. By means of a fluxmeter connected to a frame antenna, one can find out whether the discharge through the roentgen tube is caused by electron [redacted] emission from the filaments or by spark discharge caused by cold emission. At the anode of the roentgen tube there is a gadget for the determination of the period of radiation. For this purpose, a small, commercially available compressed-air turbine, designed for emery grinding, is used. Capable of developing 60,000 revolutions per minute, it has been converted so that a photographic film, 7 - 8 centimeters in diameter, can be placed on the axle. Speeds of rotation corresponding to a periphery speed of about 100 meters per second can be obtained. Thus, one has the possibility of [redacted] directly determining the time during which roentgen rays were emitted by measuring the length of a darkened line caused by a hole in a lead screen. By using a gold diaphragm with a 0.1-millimeter hole, the determination of the time may be made within [redacted] an accuracy of a couple of microseconds. A special type of vacuum condensor chamber tested at the Radiophysics Institute gives radiation measurements with, practically speaking, unlimited intensities of radiation.

"Two anodes have been set up for the roentgen tube, a cylindrical one, 12 centimeters in diameter, the cylindrical surface of which is formed of tungsten plates, which is designed for the radiation of [redacted] objects lowered into the anode; and a conical experimental anode of copper, with a maximal diameter of 500 millimeters. The water cooling system and the temperature measuring device are installed in the stem of the anode so that temperature readings may be obtained by means of instruments set into the uppermost corona shield of the roentgen tube.

The roentgen tube was vacuum tested satisfactorily in early summer 1949, after which an accurate investigation of the conditions of incandescent emission was undertaken. This showed that the life span of the filaments coincided with that calculated. The installation as a whole also was shown to function without complications. The existing blocking and safety devices have proved to be satisfactory and to cause no inconvenience.

During the summer of 1949, 50-odd discharges were made and various data determined therefrom. For the time being, the voltages have been kept below 400 kilovolts in order not to overload the installation [redacted] to the point of possible damage to the equipment [redacted] -- we still have not had sufficient experience with the apparatus. A limited number of filaments have been used (48 instead of 144); ~~in which case~~ the filament current went up to [redacted] about 1,200 amperes and the discharge current to 1,500 amperes. The discharge tension has reached a maximum of 280 kilovolts. Preliminary radiation measurements have shown that quantity of radiation is of the order of magnitude calculated. The conical anode was used primarily ~~in the first place~~. Experiments have shown that with this anode the calculated radiation distribution can be obtained in principle, but that [redacted] protective housings must be placed inside the tube for the prevention of ruptures [redacted] due to cold emission. It was also discovered in the course of the experiments that a number of small adjustments and additions to the installation were necessary. This work is in progress at present, and the next series of experiments is estimated to begin around 1 December.

The installation described has proved an extremely valuable addition to the Radiophysics Institute for work in an actual field of [redacted] biophysics. The preliminary testing of the equipment [redacted]

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has given satisfactory results and it is hoped that within a short time it will be possible to start on the investigations planned by the Institute's specialists in physics and biochemistry in conjunction with its medical experts.

"2) The installation for the production of radon preparations is housed in a small building constructed especially for this purpose. It houses a well-shielded, specially ventilated chamber for the emanation equipment, a control room, and a measuring laboratory. In the control room there is an arrangement of mirrors with double reflectors, [redacted] by which means the emanation equipment may be observed from an observation point protected by over one meter of concrete. The apparatus was designed by Fil. Mag. Agnar Egmark and was completed in June 1948. Certain disruptions appeared after about six weeks' operation, and it was [redacted] necessary to change and partially redesign the unit, after which operation [redacted] was resumed in October 1948. The unit, which since that time has been in [redacted] continual operation, is remote-controlled, so that after the requisite coolant (carbon dioxide snow-alcohol and liquid air) has been introduced, the entire procedure of pumping it out can be directed from the control room. Only the melting of the concentrated emanation quantity (huh?) in the glass tube is done manually.

"The total number of radon preparations produced so far is about 150, of which approximately 55 have been delivered to various institutes. A number of the latter have been used in order to extract Ra D and its disintegration products. The installation has shown itself to function completely satisfactorily and, compared with [redacted] other similar installations, admits the production of emanation products with considerably less risk of exposure to radiation.

"3) A special apparatus has been developed for the registration of penetrating radiation. This is a real step forward, because all parts are of such design that they can [redacted] register for a long time without [redacted] maintenance, of considerable importance for a number of radiation measurements, "For the measurement of small quantities of gamma-radiating [redacted] substances in the human body, a special apparatus has been constructed which is particularly designed for examining persons who, by virtue of their work, may be suspected of having injurious quantities of gamma-radiating substances accumulated [redacted] in their systems. The apparatus consists of 10 high-pressure ionization chambers, arranged around a cylindrical cavity into which a person on a stretcher may be placed. The chambers are connected in parallel and connected to the grid of an electrometer tube, which is connected to a control device provided with both a light spot galvanometer, from which readings may be made directly, and a registering galvanometer. The apparatus is calculated for an accuracy corresponding to the radiation from 0.01 micrograms [redacted] total quantity of radium in the human body, but has proved to give results 2-3 times better than that.

"Experience gleaned from the apparatus is now being embodied in the construction of a new apparatus with which it will be possible to determine the normal quantity of gamma-radiating substances in the human body (about 0.007 micrograms of radium) with 10-20-percent accuracy. The construction of this device is being financed by funds from the [redacted] Knut and Alice Wallenberg Foundation. The original apparatus is being used at present in a series of investigations of persons working with radioactive materials. In some cases, persons have been found with such quantities of radioactive substances in their systems that their future health was [redacted] jeopardized. This apparatus has been made considerably simpler, so that it is suitable for routine measurements of those quantities of gamma-radiating substances (greater than 0.1 micrograms of radium) hazardous to life; this, obviously, is of importance in the future development [redacted] of atomic research. The investigation of the natural quantities of gamma-radiating substances in the human body is also of value to some extent in the determination [redacted] of the maximum amount of radioactive substances that can be accumulated in the body without danger. This question is of great interest abroad, as it is important in determining the requisite protective and decontamination equipment for atomic energy installations.

"4) A special appropriation has been granted Laboratorian Matts Helde of [redacted] the Radiophysics Institute for [redacted] conducting statistical investigations of the correlation between exposure to radiation and blood changes. Thanks to this grant, the processing of the extensive material to be investigated, [redacted] collected during the 10-year period the Institute has engaged in the field of protection against radioactive exposure, is now in progress. This work is also of great importance in the determination of the tolerance doses in atomic energy research. [redacted] An account of the preliminary results should come out in the near future."

<u>Geological Investigations</u>: As uranium at present is not available on the world market, every country is more or less obliged to seek it among its own natural resources. One of the prerequisites for Sweden's activity in the atomic field has been that uranium does occur, although in very low concentrations, in her [redacted]oil shales in, inter alia, Västergötland and Närke. However, the occurrence of uranium in these shales has been and, to a certain extent, still is insufficiently investigated, although extensive work has been done in such investigations. This work, of course, is still going on.

It is obviously necessary to investigate at the same time whether or not uranium is to be found elsewhere than in the shales; this has been and still is being investigated by the Swedish Geological research Society (Sveriges geologiska undersökning), which, among other things, [redacted] is going through its geological collections; this work is being financed with funds from the Committee. The geology department of Lund University is also conducting Committee-[redacted]financed expeditions in the field, The Boliden Mining Corporation, in conjunction with AB Atomenergi, is also doing prospecting and investigatory work. The geologists from the beginning have said that it was doubtful that deposits of any importance would be found, but obviously all possibilities in this respect should be explored, as even small deposits of high uranium content would be of value.

The Defense Forces Research Institute (FOA): It has been previously pointed out how fortunate it was that an institute like the FOA, with its possibilities of effectively conducting the requisite research work, was in existence in the initial stages of atomic energy activity in Sweden. It has conducted work in the nuclear physical and chemical fields, and in both cases experience, personnel, and equipment later could be transferred to AB Atomenergi; this has been of the greatest value to the corporation in its initial and later activity.

The chief of the research institute, Director-in-chief Albert Björkeson, has delivered the following account of the chemical and nuclear physical work conducted at the FOA on problems in the atomic energy field:

"In the chemical field, the FOA's work has touched upon all phases of the uranium question: methods of analysis, concentration, extraction, the separation of uranium out of solution, purification, and production metal.

The research, therefore, has swung from tasks approaching basic research to others approaching applied technical research. The decidedly greatest chemical task has been in the development of methods of producing nuclear-physically pure uranium from Sweden's domestic raw materials. This extensive research will be dealt with only in brief in this report.

"The FOA began to work on leaching research with culm and culm ash in the summer of 1947. The experience gained from these attempts (which lasted until early 1949) led to the development of a method satisfactory from the technical viewpoint. Experimentation with this method was carried on on a rather large scale.

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In the introductory experiments, the ether extraction method, with its [redacted] consequent precipitation, was applied in the extraction of uranium from the leaching solution. Since then, however, new methods of selective precipitation have been tested [redacted] which do not require the use of ether.

For the purpose of producing nuclear-physically usable uranium material, it has been necessary to develop methods for producing a [redacted] number of uranium compounds with a high degree of purity. For the most part, this work has been of an applied nature, although in certain cases basic research was conducted (for example, the investigation of the distribution of uranyl nitrate between ether and water, published in Sv. Kem. Tidskr. No 60, 1948, and other non-published investigations of the peroxides of uranium).

Methods of production have been developed for a number of uranium compounds serving as [redacted] intermediate products in ~~the course of~~ the production of nuclear-physically usable uranium material. For example, such uranium compounds as U_3O_8 (green uranium oxide), UO_2 (brown uranium oxide), UC_2 (uranium carbide), UF_6 (uranium hexafluoride), UF_4 (uranium tetrafluoride), and UCl_4 (uranium tetrachloride) may be mentioned. Several methods for the production of uranium metal have been investigated.

A number of problems, essentially basic research in character, are to be studied more closely.

When work on uranium began in 1946, one of the greatest difficulties was that there was no reliable method of analyzing [redacted] small quantities of uranium.

In order to make possible research [redacted] the beneficiation of uranium, therefore, it was necessary that an accurate and rapid method of analysis be developed. Also, a general laboratory for the service of various scientists had to be set up. During the spring and summer of 1946, an [redacted] FOA research group concentrated successfully on the development of a relatively rapid method of determining uranium. The method proved suitable for such low-uranium-content materials

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as shales and enrichment products. As the need for analyses was very great, the general laboratory was organized as rapidly as possible. This analysis laboratory, which was active from the fall of 1946 to the fall of 1948, served most of the research conducted during this period and lent valuable assistance in prospecting and beneficiation.

The research results attained in the development of methods of analyzing uranium have been described in a number of reports in Sv. Kem. Tidskr., No 61, 1949.

The Department of Inorganic Chemistry at the Institute of Technology, with funds from the FOA, has investigated the possibilities of employing polarographic methods for the determination of small quantities of uranium.

Since the end of 1948, when the routine analysis of small quantities of of uranium was shifted over to the AB Atomenergi, the analysis group of the FOA has devoted its attention to the determination of minute quantities of impurities in refined uranium material. In addition to this, when time permitted, attempts were made to develop more rapid methods of analyzing small quantities of uranium.

With funds from the FOA, the Inorganic Chemistry Department at Lund University has conducted research on certain uranium complexes, accounts of which have been published in Acta Chem. Scand, No 3, 1949.

On the basis of the study of literature, certain investigations have been conducted with regard to the medical problems arising from the use of atomic weapons and in the matter of the dangers of exposure when working with uranium compounds.

The FOA nuclear chemical laboratory was erected about two years ago. Its function is to study, in intimate cooperation with the other atomic research scientists, the nuclear chemical problems associated with the military use of atomic energy. Moreover, the laboratory is to put the chemical and medical research of the Institute to use in the employment of radioactive isotopes as research aids. The training of personnel for all forms of radiochemical work is a goal.

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"The physical measuring equipment procured for this laboratory includes GM-counters [redacted], proportional counters [redacted] for alpha-ray determination, roentgen dosimeters, and a special device for the determination of weak alpha and beta radiation (Q-gas counter). An impulse analyzer is being constructed in cooperation with the physics department; it is to be used in the determination of the quantity [redacted] individual alpha-radiating types of atoms in an isotope mixture (234_U, 235_U, and 238_U, etc.) or in mixtures of several different alpha-radiating [redacted] elements (Pu [redacted] in U).

"The chemical laboratory has been equipped primarily for semi-micro technology, which is of great advantage in working with radio-active elements. Actual analytical problems have been studied [redacted] by radiochemical methods, for example, the determination of [redacted] small quantities of uranium by the measurement of alpha-radiation and the use of specific reagents for the precipitation of small [redacted] quantities of quadrivalent uranium, a problem which, [redacted], in addition to the analytical application, also displays obvious similarities [redacted] with the separation of plutonium. Furthermore, methods of separating small quantities of rare earth metals from large quantities of uranium by the application of radioactive tracer isotopes [redacted] been studied.

"For quite some time now, such investigations on the chemical characteristics of actinides and lanthanides as of value in the development of methods of separation for plutonium have been conducted in intimate collaboration with the inorganic chemistry departments at the Stockholm Institute of Technology and the Chalmers Institute of Technology.

From all indications, plutonium belongs to a series of elements (the actinide series, Ac, Th, U, Np, Pu, Am, Cm, Bk ....) which forms various series of ions (UO_2^{2+}, NpO_2^{2+}, Th^{4+}, [redacted] U^{4+}, Np^{4+}, Pu^{4+}, U^{3+}, Np^{3+}, Pu^{3+}) with very similar chemical properties in each ion series (except for the redox characteristics). The quadrivalent ions also display considerable similarity to Ce^{4+} and Zr^{4+}, and the trivalent ions [redacted] closely resemble their rare-earth counterparts.

By studying more easily obtainable elements in the actinide and lanthanide series, which are thus used as "model atoms" (in the USA this is also a popular manner of investigating costly materials for atomic energy research; the expression "stand-ins" is used there in place of "model atoms"), a good idea of the chemistry of plutonium should be obtained. For this reason, ~~investigation of~~ the precipitability of lanthanides on carriers [redacted] in the presence of large amounts of uranium is being studied at the FOA, using radioactive tracer isotopes. At present, the formation of mixed fluorides in the fluoride precipitation of [redacted] tri- and quandrivalent cations, with lanthanum fluoride as a carrier, is being studied by roentgen crystallographic methods at the Stockholm and Chalmers Institutes of Technology.

The testing of radiochemical methods for the direct investigation of the properties of plutonium, ~~by~~ using minute quantities of plutonium, is in progress. These methods are tested first of all with the thorium isotope ^{234}Th (UX_1), whereby direct comparison with the previously known chemical characteristics of thorium may be made. In connection therewith, a method has been developed for the [redacted] production of pure carrier-free ^{234}Th from uranium material. The tendency of the Th^{4+} and Np^{4+} ions to form complexes with certain organic reagents and the extractability [redacted] of the complexes by means of organic solvents is also being investigated.

An investigation of [redacted] various adsorbtion phenomona as a source of error in work with traces of radioactive substances in solution has [redacted] also been [redacted] started.

Work in nuclear physics in the Research Institute has been conducted by a nuclear physics section established for that purpose. It has been of great significance in the rapid development of the laboratory that [redacted]xoffices suitable for the activities could be rented in the experimental [redacted] station of the [redacted]' Academy of Science, and that the recruiting of personnel was facilitated considerably by close cooperation with the department of physics at the Institute of Technology. During 1949, part of the activity was supported economically by grants from the Atomic Committee and AB [redacted] Atomenergi.

The work of the laboratory for the past few years has dealt with both the matter of protection against radioactive military agents which could conceivably be used in a future war and [redacted] problems of a neutron-physical nature [redacted] of importance in the construction of a reactor.

Significant research and developmental work has been carried out in the designing of radioactive-radiation detectors for use in the field. A number of different types of [redacted] detectors, based on different principles, have been produced.

Two accelerators have been built at the laboratory for the handling of problems in neutron-physics. One of them consists of a Greinacher-coupled, 200,000-volt high-tension unit, connected to an acceleration [redacted] tube in four stages. The other is a 2,000,000-volt, pressure-insulated Van de Graaff generator. In the spring of 1949, the latter machine accelerated electrons to a maximum of 1,800,000 volts with a load of 0.8 mA. During the fall of 1949, the machine was used as an ion accelerator, and ~~in which~~ an optimum of 1,700,000 volts was generated with a non-analyzed ionic current of 50 µA. In connection with the work with the accelerators, extensive work has been conducted on the design and testing of various sources of ions.

The smaller accelerator [redacted] used as a source of neutrons in an investigation carried out during 1949 in cooperation with [redacted] AB Atomenergi on the extent [redacted] of neutron diffusion in graphite, the preliminary results of which are now available. When operated for 5 - 10 hours, the accelerator has delivered a neutron intensity corresponding to about 3 grams of Ra-Be preparation.

A time analyzer, [redacted] as a neutron spectrometer when used with the Van de Graaff generator, has been built and subjected to lengthy testing. An investigation of the half-life period of RaC, undertaken [redacted] in connection with the above, is described in the manuscript. The neutron sprotrometer will make possible the measurement of [redacted] constants of great importance in the design of a reactor.

An account of the determination of the extent of [redacted] diffusion of neutrons in water, using a boron trifluoride chamber, is now being printed [redacted] the Physics Archives.

A mass spectrometer of the 90° type with a Nier ion-source and a resolving capacity of about 100 has been constructed and is now being tested.

Extensive work on the design and construction of [redacted] electronic and other equipment and the production of various types of Geiger-Müller counters is being conducted by workshops established within the laboratory.

A rather small nuclear chemical group is also attached to the laboratory. This group has conducted research [redacted] the separation of potassium isotopes by means of an electrolytic counter-current process developed in the USA. The positive results of the research have brought about its expansion to include other elements as well."

AB Atomenergi

In the chapter on the organization of atomic research in Sweden, the [redacted] considerations which led to the formation of AB Atomenergi were [redacted] described. Information on the composition of the

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executive board, etc, is also contained therein. In Paragraph 2 of the articles of corporation, the purpose and mission of the corporation is formulated as follows:

"The corporation has as the object of its activity the quest for and extraction of the basic materials necessary for the utilization of atomic energy, the construction of experimental piles for the utilization of atomic energy, and later, on a larger scale, the construction of piles for the utilization of atomic energy in research and the national economy, and the pursuit of research in connection with the above-mentioned activities as well as operation on an industrial and commercial basis."

The acting managing director of AB Atomenergi, Dr. Sigurd Nauckhoff, reports the following on the present activities of the corporation:

"As previously mentioned, the Atomic Committee assigned Section 1 of the Defense Forces Research Institute the responsibility of dealing with work in the chemical field, which, first of all, involved the development of an industrially applicable method of extracting the uranium content of the Swedish oil shales. Therefore, during the years 1946-1948, such experiments were carried out on a large laboratory-scale at the Institute. Extensive research on the purification of uranium products was also carried out at the Institute for the purpose of producing nuclear-physically pure uranium oxide and uranium metal.

"Other methods of extracing the uranium content of shales and culm, proposed by a number of inventors, were also the object of research on a laboratory scale, inter alia, at the Svenska Skifferoljebolaget (Swedish Shale-oil Corporation) and at the department of technical inorganic chemistry at the Institute of Technology. It was one of the Atom Corporation's first tasks to intensify this research, particularly on those methods which appeared to offer the best possibilities of quickly achieving the goal. For this purpose, a laboratory was set up in a rented factory building where half-scale extraction research could be carried out; experimental operation was begun there in April 1949. These experiments have been directed primarily at [redacted] beneficiating the uranium by concentrating the culm extracted from culm shale, and these experiments have been satisfactory. It also appears to be possible to process the low-percentage shales directly, and experiments [redacted] are currently in progress on this.

"In connection with the concentration experiments conducted at Kvarntorp, quite extensive test borings [redacted], diamond borings, and radiation measurements were made there for the purpose of determining the extent of the culm and uranium-containing shales at [redacted] various levels and its occurrence in the field.

"As this work, especially leaching experiments, [redacted] has required [redacted] uniform and extremely accurate uranium analyses, the Atomic Corporation has engaged in extensive analysis activity since the summer of 1948. To a large extent, the methods of analysis [redacted] applied [redacted] there are based on the research work conducted by [redacted] the [redacted] department of inorganic chemistry at the Institute of Technology and by [redacted] Section 1 of the Defense [redacted] Forces Research Institute.

"The Corporation has continued to supervise geological prospecting for other minerals which could serve as a source of uranium.

"During 1949, the Corporation began to organize a research and development section, established at the Experimental Station of the [redacted] Academy of Engineering Science, which is to plan the construction of the first reactor. According to a decision rendered by the Corporation, this reactor will be of the low-effect type and will be moderated by heavy water. Various alternatives for the location of the reactor are currently being discussed.

"Among the experimental projects begun may be mentioned the determination of the extent of neutron diffusion in graphite, carried out in collaboration with the Defense [redacted] Forces Research Institute. A rather small quantity of experimental [redacted] graphite was [redacted] produced by [redacted] the

Skandinaviska grafitindustriaktiebolaget (Scandinavian Graphite Industry [redacted] Corporation) ~~on an experimental~~ [redacted] specially selected raw materials. A neutron generator taken over from the FOA has been used as a neutron source in the measurements of diffusion. Since this neutron generator has been equipped with a new ion source, it has lately been able at times to generate a neutron beam corresponding to that of a 30-gram Ra-Be preparation.

A 150,000-volt [redacted] acceleration tube, designed for use in the measurement of intermittent neutron radiation in, inter alia, moderator material, is being designed.

An investigation has been initiated in order to establish the characteristics of the boron trifluoride chambers produced in the Section. In connection therewith, an [redacted] absolute determination will be made of the number of neutrons emitted from a neutron source.

The Section has extensively procured American, British, French, and Canadian declassified documents, besides making a register of all such reports at other institutes. Lists of reports have been compiled time ~~after~~ time and distributed to the institutes interested."

Schluss!