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P E S Q U I S A S

A survey for planning purposes, of the capabilities of Brazil, in the development of an atomic energy program.

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— PREFACE —

By the invitation of the Conselho Nacional de Pesquisas and through the courtesy of its President, Almirante Alvaro Alberto, an opportunity has been presented in order to make a survey of the facilities, manpower and planning for an atomic energy program in Brazil.

— SUMMARY —

It is within the capabilities and resources of Brazil, to establish a firm, organized and integrated program of technological development in the field of atomic energy, which would have as its ultimate objective, the industrial application and utilization as a source of electrical power.

— PROBLEM —

To provide the basic planning for the development of a realistic, practical program in the utilization of atomic energy, and the establishment of the required technology, within the responsibility and authority of the Conselho Nacional de Pesquisas.

for uranium, thorium, beryllium and zirconium, with the most modern methods and equipment, is being developed all over the country. This program includes radiological surveys of collections of minerals, sludges and residues collected or where there are geological probabilities of such occurrences. Two specialized companies, working under contract with the C.N.Pq. or the Geological Survey (Departamento Nacional da Produção Mineral - D.N.P.M.) are conducting surveys over definite areas chosen by common agreement between the technical people responsible for the geological research services of the C.N.Pq. and the D.N.P.M.

Quantitative evaluations of the monazite deposits of the eastern coast and of certain alluvial deposits in the interior of Minas Gerais and of the "djalmaita" deposits of São João del Rey are underway. New interesting occurrences of thorium and uranium bearing minerals have been recently located in the States of Minas Gerais and Espírito Santo, and are being carefully studied.

The stimulation of private industrial activities in the mining of uranium ores and in the separation of thorium and uranium salts from monazite is also being considered by the C.N.Pq. There is a program underway for buying uranium ores, thorium and uranium salts, and the establishment of suitable rewards to encourage the discovery of new occurrences of industrial significance and for the exploitation of uranium ore deposits in the country.

There is also the development of modern techniques for the metallurgical and chemical separation as well as the refining of uranium and thorium in a cooperative research program of the C.N.Pq. and the Institute of Technological Research (Instituto de Pesquisas Tecnológicas - I.P.T.) of São Paulo.

A similar cooperative program involving the radiochemical and other analysis of radioactive minerals and quantitative measurements of the rare earths is starting at the Institute for Radioactive Research (Instituto de Pesquisas Radioativas - I.P.R.) which, with the help of the C.N.Pq. has been recently founded at the School of Engineering, University of Minas Gerais.

The training of scientific and technical personnel and the formation of a suitable technology is being promoted by an intensive program of fellowships, granted by the C.N.Pq. to engineers, physicists, chemists and biologists, who are following specialized courses in nuclear engineering and physics, chemical engineering,

engineering, chemistry of radio-isotopes, electronics and electrical engineering, and protection against radiation hazards, in different Universities and Colleges of the U.S. This program will be presently expanded to Canada and Europe.

2 — The main facilities and principal centers of atomic energy work in Brazil for the preliminary program of the development of nuclear research and the training of technical and research people, are the following:

a — The Brazilian Center of Physical Research, a private institution under contract with the C N.Pq. where electronic and nuclear equipment is now being planned and built for research in the field of cosmic rays and nuclear physics. The scientific staff of the Center will operate the model cyclotron now under construction at the University of Chicago and the large syncro-cyclotron analogous to the one in Chicago, whose fabrication is underway at the Naval arsenal in Rio;

b — The Physics Departments of the School of Engineering and the Faculty of Science of the University of São Paulo, the latter having already in operation a 30 Mev Betatron and, in an advanced stage of construction (in operation January 1953) a modern type of horizontal Van de Graaff Generator;

c — The electrical department of the National Institute of Technology (Instituto Nacional de Tecnologia - I.N.T.) in Rio for testing and developing circuits in counting techniques and radiation detection equipment;

d — The Chemical and Metallurgical Departments of the Institute of Technical Research (I.P.T.) in São Paulo for the training in the fundamentals of chemical engineering and applied research in metallurgy which will later be used in the development of chemical separation processes and the fabrication of uranium and thorium;

e — The Geological and Chemical branches of the C.N.Pq. and of the National Geological Survey are in a joint program of prospecting for uranium and thorium, and controlling the mining and industrial operations involved in the recovery. Included in this program is the operation of the Orquima-Indústrias Químicas Reunidas S.A. for the separation of thorium and the rare earths from monazite;

monazite;

f — The Physics Departments of the School of Engineering and the School of Science of the University of Brazil in Rio are concerned with the training of personnel for further specialization in the field of nuclear research and operations;

g — The "President Vargas Factory", an Army chemical plant at Piquete, whose modern laboratories and technical personnel are related to the research programs of the C.N.Pq.;

h — The Technical School of the Army (Escola Técnica do Exército - E.T.E.) in Rio, whose laboratories and technical staff are also contributing to the preliminary program of the C.N.Pq.;

i — The newly formed Institute for Radioactive Research in Minas Gerais will be concerned with research in atomic materials including radio-isotopes;

j — The Biophysics Institute of the University of Brazil in Rio, is working in the program of personnel protection against radiological hazards;

k — The theoretical research in the field of nuclear physics is being developed specially at the Departments of Physics of the Faculties of Science of the Universities of Brazil and of São Paulo and at the Brazilian Center of Physical Research.

— D I S C U S S I O N —

With the establishment of the Conselho Nacional de Pesquisas by law in January 1951, there was provided an executive agency of the Brazilian Government for supporting and directing approved projects of research and development in the National interests. Under the dynamic leadership of Almirante Alvaro Alberto as President of the C.N.Pq., there was immediate attention devoted to those problems associated with an atomic energy program. From this initial

initial effort there has come the preliminary projects previously identified.

Educational Phase —

In as much as, one of the fundamental problems is the provision of suitable trained scientific and technical personnel, together with the minimum basic technology for the active support and expanding progress of such a program, first consideration should be given to this planning. It may be well to restate. The major assumption is that any atomic energy program in Brazil at least at this time will be devoted to a peace time application, specifically the development of atomic power and not one of a direct military significance. Undoubtedly, the military industries will be able to make use of any development for specific purposes, but there is no planning in this report toward the ultimate production of weapons. It is concerned primarily with the development of atomic energy for industrial purposes. The basic technology required to support this development as determined within the experience of the author of this report from the very beginning of the Manhattan Project in the U.S. shows it to be made of various scientific and technical training and skills. It is a team composed of the theoretical and practical, balanced so as to extract the greatest contribution from each group and combination. Engineers and scientists; mathematicians, geologists and medical doctors work together to produce theories of operation, materials of construction, completed plants and processes which can perform safely and in a hazard-free manner, the designed function. When there is a consideration of the long-range objective, namely the erection and operation of a nuclear reactor for industrial power, it becomes evident immediately that constructive planning must be initiated at once, for the training of those people who will be responsible for the attainment of this objective. This planning must be clear-cut, with a full recognition of at least the minimum requirements in technology and the necessary successive measures which should be taken to secure these requirements or better.

With at least, a partial understanding of the factors in Brazilian culture which have formed the present educational system, there is immediately evident the need for two constructive efforts in any long range technical training program.

1. Recognition of the scarcity of semi-skilled workers (technicians) and providing training as soon as possible in those fields of work commonly called trades such as operation of machine

machine tools, fundamentals of electrical equipment, wood working , glass blowing, pipe fitting, etc., and including elementary instruction in chemistry, physics and metallurgy. This training should be started early in the student studies probably at the high school level. A tentative pattern to consider is the approach used in S.E.N.A.I. (Serviço Nacional de Aprendizagem Industrial) and it may well be a part of the effort of C.B.A.I. (Comissão Brasileiro-Americana de Educação Industrial). It is entirely feasible to consider the establishment of a curriculum, fashioned after the technical high schools or courses in the U.S. This could be done with the advice and assistance of the Institute of Inter-American Affairs (C.B.A.I.) and the S.E.N.A.I. Any laws conflicting with the establishment of a strictly technical education will have to be abrogated, but it appears to be within the authority of the Conselho Nacional de Pesquisas to establish such an institution and program as contained in its responsibility for the development of technology in Brazil. A strong and well diversified group with this type of education and ability to work with the hands is quite essential to the sound development of any technological program such as atomic energy. It would also contribute materially to the rapid industrialization of Brazilian economy. To have highly trained and competent engineers and scientists is not by itself sufficient, they must be assisted by skilled workers who can be trusted to perform manual work, requiring some technical competency, with a minimum of supervision and direction from the professional people.

2. Continuation of the scholarship program already underway in the training of selected personnel as engineers, geologists, radio-chemists, metallurgists and other related and required technical subjects. A distinction and difference is indicated in this approach to identify the need for technological background rather than scientific. This means an emphasis on applied research, engineering and development instead of pure or scientific research. There is a sufficiency of the theory of nuclear physics already known in the international scientific world to proceed into the development of a nuclear power plant, preceded by a research reactor as a tool for training personnel and learning some fundamental facts of nuclear science. Advantage can be taken of the knowledge developed in the United States, provided there are trained engineers in Brazil to make use of this information. In the functioning of this scholarship program care must be exercised in the selection of students to determine their natural aptitude and personal preference in subjects, but at all time correlating with

with the requirements of the program when designating the technical colleges and courses of study. The administration of the scholarships must have reports from the schools on the progress of each student so that a record of his ability may be maintained and if proven not to be satisfactory, then corrective measures should be applied. When a student is selected and sent to the United States or elsewhere for study at government expense, it is only fitting and proper, there should be at least a verbal understanding that he is expected to work in the atomic energy program, for a stipulated time upon graduation. A contractural agreement to this effect would be preferred. This would insure the availability of the trained student for at least a certain period of time to be used in the atomic energy program. To wait 1-4 years for the training of these professional people only to find that they will not be useful or available to the program, is a waste of time and money. What is worse, would be the loss of that person's service in any assignment which had been planned for his attention. In addition to this long range scholarship program, there is a need for establishing as soon as possible, training, both theoretical and experimental in the fundamentals of engineering particularly chemical and metallurgical, within the existing structure of Brazilian education. A start in this direction has already been made at several of the Institutes and Universities, but it can and should be expanded and emphasized so that works can be started soon in applied research and development. This phase may well be a cooperative effort with Brazilian Industry. It is not inconceivable that there will be this industrial participation as a development program is firmed up and there may be even financial assistance when it is determined what industrial application of atomic energy will mean and especially to power companies and users of power.

Raw Material Phase —

This is both an immediate and long range consideration. It is quite essential not only to the atomic energy program but also to the general economy of Brazil that exploration, identification, and extraction of such minerals as may be located and of economic value proceed at once. This would include but not be limited to uranium, thorium, beryllium, zirconium and copper. The wealth of Brazil in these natural resources is barely scratched and still unknown. Much has to be done before the conversion into useful products. First of all they have to be located, the extent of any deposits determined, after which the details of recovery will have to to be worked out.

Emphasis should be directed also toward the search for Copper, Zinc, Lead, Tin and Tungsten, considering that these metals are critical, essential and strategic in Brazilian conception of raw material wealth. Besides, there is always the chance of recovering uranium oxides, which may be eventually associated with these other metal ores. The location and development of sulphur deposits is likewise important as this element is very essential and basic to strong chemical and allied industries.

In the first step, namely exploration, there will be the need of trained surveying teams, which assisted by all the modern instruments and techniques, will quickly examine the likely areas of occurrences of ore and so eventually to cover the topography of the country. With the many square kilometers to be covered, it is readily apparent that much time and effort will be required, even using aerial surveys and the most scientific methods. A two man team exploring only for uranium would take a great time just for those areas where this metal is likely to occur. Obviously, one of the more pressing needs is to place people in the field searching for these ores. Training must be given to properly qualified personnel so they will be familiar with the instruments in use and the minimum requirements of identification of pay dirt. This should be done at once, taking advantage of the presence of experienced investigators and the opportunity to utilize laboratories in the United States for additional training.

It may also be advisable to consider the establishment of incentives to stimulate the search for uranium by miners, farmers and others likely to be in a position to examine minerals in the fields. Here again is the need for some instruction and help in identifying the more likely ores. It would probably be impractical to educate this group in the use of instruments, but a short descriptive article covering the characteristics of the ores might be helpful. Details, such as bonus, ore concentrations of interest, sample testing stations can be worked out in the operation of the program. Of immediate importance is the requirement for an ore testing laboratory, properly staffed and equipped to analyse any ore which might be discovered. It should be designed so, that the radioactive ores and samples can be adequately examined, without contaminating other work areas or endangering the lives of the workers. The facility being considered in Belo Horizonte would satisfy this

this requirement, for fundamental study and analysis. In addition, a small testing laboratory is necessary for mineral examination in the field, so as to provide preliminary knowledge of what is being discovered and to assist in the definition of known deposits.

Concurrently with ore discovery and analysis there must be investigations into the methods of ore beneficiation and metal recovery. Provision is being made for this type of work, but arrangement should be made for receiving information on recent developments from all over the world and particularly the U.S. , where much work has been done in the extraction of uranium from various kinds of ores. In this connection, it is very desirable to know the concentration of uranium in natural sources other than the known types likely to show rich pockets or veins.

As a practical matter to economize on time and manpower and to have immediate results, it is highly desirable to concentrate field work in known areas of likely ore-bodies even if the concentration of the strategic material is low-large volumes of low concentrations, quickly available, will be far more valuable to the program and economy of Brazil than small volumes of higher concentrations.

The time is rapidly approaching when countries interested in atomic energy, will have exhausted all the deposits of the more concentrated forms and attentions will e directed to those other less concentrated but potentially good sources of the metal uranium, for instance, when investigations are being made of methods for extracting petroleum from the oil-bearing shales, there should be an analysis of the uranium content, likewise, the phosphate rocks or even coal and certainly the sea water. A knowledge of the form and concentration of any uranium occurrence would be valuable for later reference, when its recovery might be justified either on the basis of necessity or economical possibility when extracted with other desired materials. It has been estimated that there is 10^{12} tons of uranium in the water of the oceans, an amount comparable to that in the earth's crust, which is more difficult to locate and extract. It is relatively much easier to pump water than to move the many tons of earth required in recovery from the less concentrated forms. This is especially true if the sea water is to be processed for the recovery of other elements, such as magnesium or bromine.

bromine.

The immediate location of commercially worth while deposits of uranium or other strategic metals will go a long way toward establishing a firm financial basis and providing materials useful to the program as well as for sale elsewhere. The immediate exploitation of known deposits of zirconium oxides should be considered on its own merit distinct from the development in the extraction of uranium. The part this metal (Zr) will play in the technology of atomic energy is unknown at this moment but, as a supply of it becomes available, it will undoubtedly become very important. Its extraction as a local Brazilian industry seems to be very feasible for the potential use in industry as well as in the field of atomic energy. Any contractural arrangement for sale outside the country should include amongst its provisions, the agreement to return either part of the material sold as fabricated forms or else other materials either refined in the raw state or as finished products. This would provide for the procurement of those items in short supply or beyond the immediate capacity of Brazil to produce. Without going into details as they come within the scope of an established program, it can be emphasized that there is a need for considering process development for all these strategic metals but particularly uranium, zirconium and thorium. The extraction of the rare earths from monazite sands is a fairly well established process, but the refinement of thorium must be investigated especially if it becomes necessary to separate any uranium. Before providing for this latter chemical process it is advisable to determine if it would not be a nuclear possibil ty to utilize the naturally occurring combination of those two fissionable materials. A nuclear reactor designed around this raw material may be technically feasible and if so would remove the necessity of separating the uranium from the thorium, an expensive and not easy process. If there is the need for such a process, the industry should be capable of developing it assisted by any known information which can be made available to it. The chemical engineers necessary for the applied research should be available from either the training established in this country or from the scholarship program. Certain portions of this research may well form part of the experimental work in the teaching institutions where adequate course work is underway; other projects could perhaps be placed in contributing government or industrial laboratories, under a contract basis. Familiarity will have to be obtained with the ordinary equipment and methods such as liquid-liquid, ion exchange and other well

well known techniques, which will be used not only in the extraction of ores, but also later on in the reclamation of uranium, plutonium and fission products from the operation of the nuclear reactor.

Technological Development —

Consistent with the educational program discussed above, it may be well to consider some of the more important phases of technology which will form the basis for any development in nuclear energy and particularly the application to industrial power. This means then, essentially a study of nuclear reactor technology and its associated problems related to the accomplishment of this main objective. A clear understanding of the problems of reactor development must rest on a knowledge of what a reactor is and does.

A nuclear reactor, or pile, is a machine for containing and controlling the fission chain reaction which can be started and sustained in three materials — Uranium-233, Uranium-235, and Plutonium-239.

The nuclei of the atoms of these materials will fission or split, when struck by a neutron. The fission of these nuclei produces more neutrons, energy and fission fragments. At least one neutron from each fission must go to the fission of another nucleus in order to maintain the reaction. Any excess neutrons can be used to make new fissionable materials, and for research work requiring a supply of neutrons. As the nucleus breaks up in fission, the particles which fly out at great speeds dissipate their energy in the surrounding materials. The result is an intense local heating of the material. Thus the energy from the fission process is available in the form of heat.

The operation of a reactor requires systems for controlling the reactor and keeping it at desired levels of activity, for removing the heat, fissionable material and for handling the fuel. The nerve center and principal point of activity is the control board, where the operator by a few simple adjustments keeps the reactor at the desired operating levels. Since the theory and nuclear physics of uranium reactors is fairly well established, this can be secured in several colleges of the U.S. and the instruction can be installed also in Brazilian institutions, when the time is appropriate. This specific knowledge can best be acquired by competent students only after a firm knowledge of engineering princi-

principles has been secured.

The design, erection and operation of a nuclear reactor requires the services of many skills and professional talents, but in the main, there is nothing mysterious about it and the same knowledge that creates a chemical process plant or oil refinery can be utilized. The engineering data accumulated over the past 10 years are available for translation into an operating structure. It can be assumed that for a small research type of reactor a suitable design will be chosen from those existing in the world today, which will permit a simple duplication and thus eliminate considerable effort as well as saving a tremendous amount of time and money. A knowledge of the theory, operation and planned experiments can be secured by the selected personnel while the construction is underway (1-2 years). It is in the erection of the structure that there will be the need for engineering talent, capable of transferring a blueprint into an operating plant. Perhaps the easiest way to identify the problems and associated knowledge, is to enumerate the major components and materials of construction. The exact details will be dependent upon the choice in the type of the research reactor and subsequently the power reactor but there is a generalization applicable to all reactors, which will be sufficient to establish the required areas of technology. The major components are as follows:

1 - Uranium fuel containing U^{235} (fissionable material) and U^{238} (fertile material for production of Pu^{239}) in arbitrary proportions. This may also consist of Th^{232} (fertile material for the production of U^{233});

2 - Moderator, for slowing down neutrons;

3 - Reflector, for conserving and preventing the escape of neutrons;

4 - Shield, for protecting operating personnel and surrounding areas;

5 - Heat-transfer fluid, for transporting the heat energy out of the nuclear reactor;

6 - Control mechanism, for varying the reactivity of the reactor and the power level.

Based upon the assumption that the type of nuclear reactor (research and power) will be chosen from those available in the U.S. then it can be assumed further that the design and construction blueprints will be made available to the Conselho Nacional de Pesquisas. This will eliminate the need of early training in reac reactor theory and design, before construction of at least the research reactor. This specialized knowledge can be secured while erecting the initial machine. It is also assumed that insofar as practical and physically possible, use will be made of materials available locally in Brazil and fabricated here.

1. Fuel —

Under the first facility is obviously the mine for natural fuel, uranium, containing 0.7 per cent U^{235} and 99.3 per cent U^{238}. The mine is also the source of fertile materials or "source materials" as defined by the U.S. Atomic Energy Act of 1946. U^{238} and Th^{232} are fertile materials in the sense that from them can be produced Pu^{239} and U^{233} both fissionable materials. The location of rich ore deposits of "source materials" is certainly important and particularly so, are those of uranium, the source of the only important natural fissionable isotope known, U^{235}.

The problem of producing suitably pure metallic uranium was solved during the war well enough to permit successful operation of the large reactors in the U.S. A great deal of this technology is in the open literature and the restricted portion could become available to Brazil under the proper conditions. No consideration should ever be given to the preparation of U^{235}, for the isotope separation plants required, are beyond the capabilities of Brazilian economy and furthermore there is no need for such plants. Use can be made of natural uranium in the design of reactors, either research or power. If the type chosen requires enriched uranium or U^{235} then, its availability would have to be based upon procurement from the U.S. The magnitude of such an isotope separation is so great that it is beyond the industrial capacity of Brazil. In the refining operations, the reduction of impurities which absorb neutrons is an important problem. There is the need of personnel trained in ore dressing methods, chemical processes, metallurgical operations, which means essentially chemical and metallurgical engineers to make efficient use of the handbook data which will be presented to them. Small, applied research projects should be established now, training the engineers and metallurgists in the extractive metallurgy of uranium and the preparation of fabricated shapes.

2. Moderator —

The moderator is a material that slows down or moderates the neutrons from the energy at which they are produced by by fission to the energy at which they are to reenter the nuclear fuel and create further fission. Since we are trying to slow the fission - produced neutrons - down to very low energies because of the increased probability of fission at these low energies, it is obvious that any parasitic capture of these neutrons while they are bging slowed down will partially defeat the purpose of the moderator. In elastic scattering, the light elements are the best moderators because they cause the loss of the maximum average fraction of energy at each collision. As far as energy loss per collision is concerned, the lighter the element, the better the moderator. However, the competing process of neutron capture may be so great that a light element will be useless as a moderator despite its low atomic weight. There are other reasons which rule out certain of the light elements such as the noble gases where there are no known chemical compounds that might be used. For one reason or another many of the light elements are unacceptable. Magnesium or aluminum and their oxides might be substituted for beryllium and its oxide in cases where the extra fuel required is less important than the problem of obtaining beryllium or beryllium oxide. The leaves only carbon and beryllium or their compounds as the good, solid moderators among the light elements. Beryllium is one of the very good moderating materials because of its low capture cross-section. It has all the advantages of a metal and the carbide or oxide are refractory materials so that they make good moderators for power producing reactors that must operate at elevated temperatures. Ordinary water or deuterium oxide (heavy water) form ideal liquid moderators for reactors in which the operating temperature does not prohibit the use.

If there is no objection to using the extra nuclear fuel required thereby, other materials might be used as moderators that are less efficient from a moderating stand-point, but are more desirable for other reasons, such as greater structural or mechanical stability, or better thermal or chemical properties. Examples would be zinc, zirconium, columbium, copper or their compounds and the usual constituents of alloy irons and steels. The choice of materials for the moderator for any specific reactor depends upon a number of factors that may be quite contradictory and require careful weighing in making a choice. To reduce the amount of nuclear fuel to a minimum, metallic beryllium, or deuterium or beryllium compounds with oxygen or carbon appear to be the best moderators. When natural uranium is used as the fuel, any of these materials or graphite can be used as the moderator. This is especially true for reactors intended for research units or isotope producers opera-

operating at relatively low temperature levels. Specific applied research projects will be necessary to investigate the availability of these materials and to learn the simpler techniques of production, refinement and fatrication.

3. Reflectors —

For the most efficient propagation of the chain reaction, we must retain as many neutrons as possible at the end of each generation for every neutron that began the cycle. Therefore it is advantageous to prevent the escape of these neutrons, that would otherwise leak out of the reactor. This can be done by surrounding the active core of the reactor with a blanket of material - the reflector - that will scatter or reflect as many as possible of these neutrons back into the reactor without absorbing too many in parasitic capture. Good scattering characteristics and a low probability of neutron capture are the same requirements as for a good moderator. Hence, the same materials that are suitable as moderators are also suitable as reflectors and while they may be dissimilar materials, there is no reason why the reflector cannot be simply an extension of the moderator beyond the active section of the reactor, with no fissionable material contained therein. One important fact should be noted about the use of a reflector — a good reflector decreases the size of the active section of the reactor but it does not decrease the over-all size of the unit. A combined reactor and reflector are larger than the corresponding reactor without the reflector.

4. Shielding —

The neutrons which escape the reflector must be attenuated in the reactor shielding to a biological safe level. The neutrons at the reflector surface will have many different energy levels, and since thermal neutrons are more easily captured, one method would be to thermalize the neutrons in a moderator and allow them to be absorbed in a material with a high absorption cross-section placed just behind the moderator. For instance, several feet of beryllia and graphite followed by a sheet of cadmium will capture the escaping neutrons. An alternate method would be a hydogenous substance mixed with a high absorption cross-section material, such as a water solution of a boron, lithium or cadmium salt. The capture of a neutron by an absorber will often result in the emission of a gamma ray. The gamma shield must absorb the gamma rays that

that are produced in the reactor or by absorption of neutrons in the structure. This shield must attenuate the gamma radiation to a safe biological level, generally accepted as 0.3 roentgen unit per week (40 hours). Materials which have been used are the heavy elements, which have high inelastic scattering cross-sections and also large absorption cross-sections for neutrons. Examples are lead and tungsten. Concrete may be used with less efficiency on a volume basis but it is quite satisfactory for stationary reactors. Even ordinary water can be used as a shield if enough feet of it are employed. By peppering the water or concrete shield liberally and homogeneously with small units of other suitable materials (e.g. iron) the thickness may be further reduced from that required by the plain water or concrete alone. There does not appear to be any problem in the technology of these materials as it seems to be fairly well established.

5. Transmission of Heat —

Since the energy from the fission process is available in the form of heat and there is no means known for harnessing atomic energy other than by the removal of the heat generated in a reactor, it is necessary for the employment of this heat to use conventional apparatus for the conversion of heat into useable energy forms. In addition, there is need for the transmission of heat as a simple coaling mechanism where there is localized development of heat such in the shields and control mechanism. The consideration of the characteristics of the coolants is practically the same for both applications.

The type of material required to serve as a heat transfer medium, is dependent upon its nuclear and physical properties. Either gaseous or liquid compounds could be employed for this purpose. Some of the relatively common gases for coolants are air, hydrogen, helium and carbon dioxide. These gases could be used for removing the heat from any type of reactor, operating at any temperature. They are particularly useful, however, for the very high temperature reactors, since the thermal decomposition temperature of their molecules exceeds that of the maximum operating temperature of the reactor as dictated by the limiting temperature set by the materials of construction. Various types of compounds which are liquid at room temperatures or at higher temperatures could be used as heat transfer mediums. Some of these compounds are water, heavy water, organics, molten salts and molten metals. Con

Considerable technology in these materials and their use has been established in the U.S. and would be available to properly qualified individuals under an approved program. There should be no particular difficulty in developing the heat transfer system whether it is for a small research type reactor or later on in a power source reactor.

6. Control Systems --

Since the energy released in a pile is the result of fission, the amount of energy released at the operating power level of the reactor depends upon the number of fission processes occurring throughout the reactor in a unit of time. This in turn depends upon the neutron density throughout the reactor. The operating level of a reactor can be controlled by controlling the neutron density.

The reproduction factor K, is the ratio of the number of neutrons at the end of a single generation to the number at the beginning of that generation. And the number of neutrons surviving one cycle depends upon the relative number of neutrons escaping from the reactor, being absorbed in parasitic capture, or being absorbed in fission. Therefore, it is obvious that we can control the reproduction factor and hence the neutron density by changing the leakage, the amount of absorption by parasitic capture, or the amount of fissionable material for absorbing the neutrons. The first of these involves moving or changing any component that minimizes the number of neutrons leaking out of the reactor. The reflector is one such component and the surface-to-volume ratio is another factor. Changing the amount of moderator in the reactor not only changes the physical volume but also the leakage factors for the escape of neutrons. To control a reactor by changing the amount of fissionable material requires that the nuclear fuel must be arranged so it is readily removable and replaceable in increments suitable for controlling the reactor. While the above methods are better suited and, in some cases, the only methods by which small reactors can be controlled, thermal and low-energy intermediate reactors are usually more easily controlled by changing the amount of absorber in the reactor. This not only affects the diffusion lengths and also the fraction of thermal neutrons absorbed by the fuel, but it also changes the relative distribution of the neutron density throughout the reactor.

Absorbing controls may be introduced into the

the reactor in several different forms, but all of these must be made from a material having a very high cross-section for the absorption of neutrons. Typical examples of these are boron and cadmium or their compounds. As the operation of most types of reactors with the exception of low power research tools, is at power levels of hundreds or thousands of kilowatts, a coarse or large increment type of control is required for bringing the reactor up to power level, shutting it down, and making large changes in the operating level of the reactor. Once the reactor has been brought up to approximately the desired operating level, a fine or regulating type of control is required for making the small adjustments necessary to establish and maintain the exact operating level over long periods of time.

Since no mechanism is perfect and there are many potential hazards in a nuclear reactor and its accompanying power plant, it is obvious that there must be a third type of control designed for emergencies. This so-called safety control must be capable of stopping the nuclear chain reaction, under even the most adverse conditions, within a period of time that will prevent self-destruction of the reactor or any major change in that direction. Whereas the coarse and fine controls are mechanisms that must operate within a period of something like 5-10 seconds, the safety controls must be devices that function with such speed and assured mechanical perfection that the reactor control will become effective within 1-2 seconds. Since the coarse and fine controls operate to change the reproduction factor by entirely different increments, it is not easy to incorporate these two fuctions into one set of controls. Likewise, since the coarse and fine controls normally operate at a speed much slower than that of the safety-controls, it is not feasible to combine the functions of the safety-control with either or both of the other controls. Therefore, reactor-controls generally consist of three different systems, having different operating and absorbing-characteristics, with sometimes four separate sets of controls in which the fourth set is used as a super-safety control to operate in the event of any failure of the regular safety-control to function properly. Electronic, mechanical, and electrical engineers as well as metallurgists will be necessary to fabricate, assemble and operate this phase of the nuclear reactor.

Technical Information Service —

It is realized that one of the most effective tools in the development of any science or technology, is an efficient and

and up-to-date method for the exchange of the results of research and development as they occur. An isolated effort may provide a miracle in science, but the way is made much easier if there is a free exchange of information concerning the various projects underway, especially if those researches are supposed to be a part of an integrated program. It eliminates costly duplication, except where desirable to confirm results, and makes the value of an experiment helpful to others, thus saving time, money and effort as well as advancing the accumulation of knowledge. The establishment of such a service in Brazil seems to be very well planned in the recommendations of the Technical Branch of the C.N.Pq. for the fundamental objectives of setting up scientific and technical libraries and providing bibliographical and reproduction services including suitable abstracts for circulation periodically. It may be well to point out that it isn't sufficient to set up a system for distribution of information, but the potential users should be well trained and informed as to the availability and nature of such assistance. Every effort should be made to see to it that the report, abstract, microfilm or other media reach the attention of the worker. There is not much value to a piece of information if it reposes on a shelf or in a Director's office and no one is making any use of it.

Later on, as projects are established in research and development of atomic energy and results begin to accumulate, there will be need to consider the establishment of a similar system for the distribution of classified material. There will be, undoubtedly, information secured, which for one reason or another, will be restricted in nature and classified top secret; secret or confidential, with varying degrees of control in distribution to selected personnel and working areas. The details of such a system will be made available to the C.N.Pq. as required.

Cooperative Programs (International) —

As there is the greatest familiarity with the programs and policies of the U.S. especially the Atomic Energy Commission, this phase will be considered first and in more detail. Under the original Atomic Energy Act, as passed by the U.S. Congress in August 1946 there was not much possibility for the cooperation or exchange of information and assistance except in those fields of very general and basic science, to provide for free exchange of ideas and criticisms, which is essential to scientific progress. This provision by law, would not have been very helpful to any nation,

nation, desirous of establishing a nuclear energy program leading to reactors for power purposes. However, since the original law was approved, there has been a pertinent amendment which reads as follows:

> "(3) Nothing contained in this section (Control of Information) shall prohibit the Commission, when in its unanimous judgement the common defense and security would be substantially promoted and would not be endangered, subject to the limitations hereinafter set out, from entering into specific arrangements involving the communication to another nation of restricted data on refining, purification, and subsequent treatment of source materials; reactor development; production of fissionable materials; and research and development relating to the foregoing:
>
> PROVIDED,
>
> "(1) that no such arrangement shall involve the communication of restricted data on design and fabrication of atomic weapons;
> "(2) that no such arrangement shall be entered into with any nation threatening the security of the United States;
> "(3) that the restricted data involved shall be limited and circumscribed to the maximum degree consistent with the common defense and security objective in view, and that in the judgement of the Commission the recipient nation's security standards applicable to such data are adequate;
> "(4) that the President, after securing the written recommendation of the National Security Council has determined in writing (incorporating the National Security Council recommendation) that the arrangement would substantially promote and would not endanger the common defense and security of the United States, giving specific consideration to the security sensitivity of the restricted data involved and the adequacy and sufficiency of the security safeguards undertaken to be maintained by the recipient nation; and
> "(5) that before the arrangement is consummated by the Commission the Joint Committee on Atomic Energy has been fully informed for a period of thirty days in which the Congress was in session (in computing such thirty days, there shall be excluded the days on which either House is not in session because of an adjournment of more than three days)."

This amendment gives to the Atomic Energy Commission the authority to enter into specific arrangements with another nation for the purpose of transferring the type of restricted data, which will be most helpful to Brazil's program in the development of atomic energy. Such an arrangement does not have to secure the approval of the U.S. Congress as it goes directly to the President for his approval based upon the recommendations of the National direct channels for the distribution of responsibility and necessary authority from the top downward through the subordinate levels. It is also an axiom of good management that the more people there are working in a body, the greater the possibilities of divergent opinions and less direct action. This is especially true of a large group which is charged both with policy making and directing the operations.

With these thoughts in mind it is well to look at the make-up of the C.N.Pq. Here you have a good size-group of 18-20 people in the Deliberative Council, which is composed of many divergent interests, backgrounds and personal experience. The magnitude and diversity of the research problems presented to it, require such a body, particularly for policy and major decisions of national interest, but it is also concerned with operations, and their direction. This provides the atmosphere for unwieldy and time-consuming practices. It would seem conducive to more efficient performance to establish small sub-committees or task forces, where the members would have a similarity of interests and perhaps experience, and which would be given the responsibility of working up plans and recommendations to be submitted to the Council as a whole. Considering only the atomic energy problem, it appears to be highly desirable to establish an organization which would consist of a working component of the Deliberative Council. A workable sub-committee of not more than six members could act as a preliminary screening body to provide only those approved suggested projects, and policy questions to the main group for final evaluation and consideration. It doesn't seem reasonable that every question which arises, should be submited to the Council or its President for decision. The composition of such a group could consist of 3-4 from the present organization with 2-3 others chosen from industry with one of the latter group from the light & power companies, for they certainly should be interested in this program and by becoming a member of the team, there might be expected a greater cooperation or at least an appreciative understanding. Directly under this task force and subordinate to it would be a chief operating official. His responsibility would correspond to that of a general manager, with the authority required to direct all the operations. These would consist of the various research and development projects in the program, including the facilities and services which might be required. Contained in this organization for operations would be the various branches, such as geology, chemistry, etc., already recognized and others that may be added. This type of an operating

operating organization would be able to consider effectively any problem in the program and those of major significance could be transmitted to the Deliberative Council for action. In any case, that body would be kept fully informed of any action, but not necessarily for its approval or debate. Such an organizational set-up has been very successful and proven to be an efficient mechanism for program operation and should be given consideration for application in Brazil.

— C O N C L U S I O N S —

The realization of a well-balanced, diversified scientific and technological program in the field of atomic energy, with the ultimate goal of industrial power sources from nuclear reactions, is not only practical and feasible for Brazil but would seem to be an economic necessity of the first degree of priority.

While the magnitude of such a program could be very extensive with all of its technical ramifications, it does not have to go beyond the exact minimum requirements in order to arrive at the main objective and at the same time accomplish somewhat minor, but nevertheless important and essential attainments. Realizing that the economy of the country will allow the expenditure of a limited effort as represented by the budget, facilities and manpower available, it seems prudent to carefully analyse every action and to employ all means of securing the maximum results within any limitations. The scientific and technological world, especially in the U.S. has made tremendous advances in the past ten years, particularly in the field of industrial techniques and application development engineering. This know-how of technology represents the area of knowledge which must be explored by the engineers and technologists of Brazil so as to balance the effort in atomic energy investigations and to establish a firm base for building any worthwhile program. The details of the ways and means of tapping this source of knowledge can be worked out as the program develops and the picture takes

takes shape.

However, it will be advisable to recognize as many of the problems as appear at this writing and to consider their resolution. One of the first that appears and is very basic and fundamental will be the scarcity of trained engineers, scientists, physicians, geologists, and other professions and trades. The previous discussion should indicate the broad scope of technical participation with practically every aspect of engineering and science involved. A correction of this weakness is both immediate and long-range and of equal value to not only a specific program of research and development in atomic energy but also to the general industrialization of Brazil. Any technical information made available, will not be worth much unless there are competent people to understand work with and make full use of it in the most efficient application. A most excellent start has been made in this direction by the scholarship program and other training aspects undertaken by the C.N.Pq. In the former there are certain constructive moves which might be made to strengthen it. By what ever means passible, potential trainees should be selected on a basis of competence and natural personal interests and aptitude. Courses of training should be selected, upon advice from the C.N.Pq. to fit into, primarily the technical need of the program. By agreement with the authorities of the college to which the scholar is sent, these courses should be given him. Effective understanding of the progress should be made to the C.N.Pq. on perhaps a monthly basis, so that an accurate knowledge of the student's application is available. The lack of satisfactory progress would call for corrective action, in order that the student and the C.N.Pq. receive the maximum value of the effort and money. These scholarships should be recognized by the Brazilian public and the professional class in particular as goals significant of technical and all around competency and an acknowledgement of this excellency. If such prestige as exists for the Rhodes scholarships could be built up, it would go far toward insuring the availability of the best potential trainee material. At the same time, there must be established the guarantee that the trained student will be available for work in the atomic energy program during a known period, after the completion of his collegiate career. While the deviation of the services of these scholars into industry or other technical fields would be helpful to the basic technology of the country, yet his loss would be very harmful to the program of development of atomic energy ,

energy, unless this other work were directly related and approved for an occupation. This dissipation of expected service could be disastrous to any organized planned work, for instance, assuming a mechanical engineer had been especially trained in thermodynamics and heat-transfer problems so that he could conduct work in those fields for application to a nuclear power plant, and after waiting 1-4 years for the completion of his training, he no longer is available for that work. Not only will that period of time be lost but there would be an additional like amount needed before a replacement became available, making a total of 2-8 years before the work could commence. There is also at least double the amount of expense involved. A simple contract with the student should help and provide for certain assurances.

As far-sighted and constructive as this scholarship program is, it does not fill all of the needs for technical assistance in the ramifications of the atomic energy program. While it is recognized that a well-trained engineer or experimentalist is perfectly capable of operating machine tools to form metals and fabricate components of any development, design circuits and build measuring instruments, other tools and devices, but to have him perform these tasks is not always practical and certainly not economical of his high degree of training. Consequently, there is a need of a class of semi-skilled and skilled workers, trained in the fundamentals of these trades. These are people who will have enough education in this area of work so they can assist the professional personnel with a minimum of direct supervision and do not have any adversion to working with the hands. An adequate group of electricians, mechanics, machine shop operators, wood-workers, glass-blowers, metal workers and the like is quite essential to any program of industrialization and if not available, must be trained.

The C.N.Pq. can well consider this phase of education as a very desirable fundamental adjunct to its scholarship program. It is not sufficient to have a few well trained engineers and scientists for they will need assistance and plenty of it from these skilled workers. To make certain that they will be available, their training should be started early in the school curriculum, perhaps at a high school level. For the specific program of atomic energy, it may be desirable to establish the equivalent of a technical high school, so as to insure some of these trained people being available. This facility might well have the advice ,

advice, guidance, and other assistance of SENAI, CBAI and other interests in the field of industrial education. It appears to be within the authority of the C.N.Pq. to sponsor such an undertaking in the general interest of promoting research and specifically in the field of atomic energy development. If the teaching in such an institution could be limited to those courses immediately applicable to this type of a trade education it should prove to be very beneficial to the country as a whole. The law establishing the C.N.Pq. and its functions would seem to be adequate to provide for this most essential of educational functions.

Raw Materials —

There is no question of the availability of thorium as it occurs in the monazite sand deposits. The place which this element occupies in a power development from atomic energy is not as clearly defined in the open literature as that of uranium. However, it has been admitted, that by neutron absorption there is a nuclear reaction which produces U^{233} a fissionable material. This could serve as the nuclear fuel in a reactor or in a conventional type of natural uranium reactor act as a breeder material to increase the amount of fissionable material or nuclear fuel. Any classified information on the technology of thorium, or uranium whether it be the extraction from ores or separation from other elements and the chemistry and metallurgy of the element and their compounds and alloys, can be made available under proper conditions.

The extent of known deposits of thorium and uranium should be clearly established as well as continued search for new deposits. This applies particularly to uranium and perhaps more emphatically, as the location of commercially feasible ore-bodies would immediately introduce an asset which would catalyse the whole program. It seems very practical to assume the identification of such deposits in time. Large volumes of low grade ore should be processed immediately upon identification and should not be by-passed, while continuing the search for higher grade ore but perhaps less extensive in volume. To do so, however, calls for careful and detailed examination of many square miles in rough country by trained geologists. One of the most pressing needs of not only the atomic energy program but also, the general welfare of the country, is to have men in the field, competent to use the more advanced tools of exploration and to quickly explore likely areas and identify

identify the uranium and other deposits. While the difficulties of securing these men are recognized, yet they shouldn't be insurmountable. Ways and means should be found to attract capable people into the profession of geology and field surveys. Undoubtedly, incentives may have to be established, such as increased remuneration, greater prestige, higher standards of living, and other known methods will have to be considered in order to secure the required manpower. Adequate training can be secured from the experts already in the field and by sending selected personnel to recognized and willing laboratories in the U.S. for periods of 3-6 months.

Other known metals already available are zirconium and beryllium. The former, present almost as a by-product in the purification of the monazite sands, and as oxides in other ores is inherently of great value to the program. As its ultimate use is not known at the present, yet in the U.S. is actively investigating it so that the material immediately becomes an exportable item. The use of beryllium is more defined, especially as a moderator. The technology of extraction from ores is fairly well known but the fabrication of the metal into shapes is more difficult but yet feasible operation. The industry is characterized by considerable hazard and care will have to be exercised to fully protect the workers from the fatal disease of beryllicosis. This information and technology is generally available. Its use in the program would be dictated primarily by the choice of the type of reactors for development. Continued investigation in the field for both of these elements should be continued and if possible expanded as they are potentially of great value to any atomic energy program.

While it is recognized that zirconium is perhaps not critical to this program yet its value is such that all effort should be made to expand and increase the output from known deposits and to discover new ones. The current strong demand for it, creates a very favorable export position which should be capitalized upon as well as a potential local industry.

Other raw materials of immediate value and which should be kept in mind at all times are graphite and helium. While it is doubtful of any natural graphite would be pure enough for reactor use, yet its availabitity might be the starting material for refinement and purification. A reactor purity graphite is dependant upon an oil refinery industry but could be secured from

from other countries. Helium may be discovered as the search for petroleum is continued.

The export of any of the above materials and others which may be discovered of value particularly to the atomic energy program, must be, with the following in mind. Consideration should be given, not only to the immediate dollar value in a sale, but also the future value of the material to Brazil's program. The latter interest can be protected in at least two ways, first by stockpiling, which is expensive, uneconomical at this stage, and does nobody much good; and secondly, by releasing to a user nation with contractural arrangement for payment either in dollars, needed supplies or fabricated shapes and forms from the raw materials in part compensation. In this way there would be a return of needed dollars, supplies and equipment and fabricated materials of construction.

The predominant thought in this phase of operation is to quickly locate and exploit workable deposits of those strategic and critical materials immediately of value to the program and turn those assets into useful tools.

Reactor Technology --

As can be seen from the previous discussion there will be need of diversified engineering talent and essential facilities to permit the sustained effort toward a sound basis of reactor technology. It should be emphasized again that there is nothing supernatural about this new branch of science and technology. A sound training in any of several engineering courses as taught in universities and technical colleges in the U.S. will suffice for the fundamental knowledge that is required. This education has proven to be quite sufficient as a strong and broad base for projection into any specialized field or problem. When one examines the professional background of the personnel responsible for the experimentation, design, construction and operation of a Hanford or Oak-Ridge, there will be found the same type of training, mentality and philosophy which is present in any technological industrialization.

There can be no doubt but that there is this same type of background and competency existing in Brazil today. While it is true that the number of such trained people is not overabundant (there very seldom is, even in the U.S.), yet there is a suf-

sufficient number to serve as a hard core and nucleus for the start of a well defined program of related projects. Care will have to be exercised in order to make certain that this talent is not wasted on extraneous projects or work, no matter how interesting they may be from the fundamental or knowledge alone point of view. It has to be recognized from the beginning and the accompanying philosophy of operation firmly adopted, that a program of the development of reactor technology is essentially one of the applied research. At this time and for some time to come in Brazil, this approach should be recognized and supported to the fullest extent necessary to arrive at the desired objectives.

There is the firm conclusion that these objectives are within the desire and ability of Brazil to accomplish in a practical and efficient manner. The absolute necessity of seeking power sources other than the costly coal or unstable water supply, places this country in a unique position in regard to the urgency of nuclear reactor development. This essential requirement could well make it the first country to harness such power for industrial purposes. A start has to be made, and the sooner it is, then the quicker will the goal be reached. While all the details and ways of arriving at this goal may not be brought out in this report, they will become readily apparent as progress is made. Already the various paths are defined and can be established.

As an immediate and short range aim, there should be established the goal of a small research type of nuclear reactor. This one machine, if properly designed, will do more for an atomic energy program than any other single instrument of research or combination of instruments, even from a fundamental point of view to say nothing of the practical side of reactor technology. It will enable experimentalists to study nuclear transformations with neutrons, the motivating particle of the essential nuclear reactions in power development; radiation effects both biological and physical on proposed materials of construction; and radio-isotops, which if desired can be used as tracers and sources of radiation to promote knowledge and advances in medicine, agriculture, industry and other applications of interest. The designing, erecting and operation of this research reactor will also be a very valuable training medium for providing the technology and groups of engineers, scientists and technicians well acquainted with it for future utilization in the longer range and larger reactor development of a power source. Without this tool of a research reactor, the scientists and engineers

engineers are under such a handicap for the want of pertinent data secured from neutrons that a power development program, becomes very unrealistic, impractical and probably impossible to achieve in any period of time. No other instrument no matter how elaborate and expensive will give this combination of necessary values to be achieved by the operation of a research nuclear reactor.

Realizing that it is desirable to accomplish the greatest results in the shortest period of time with the minimum expenditure of effort and money, the C.N.Pq. may wish to consider the advisability of a cooperative program with the U.S. The basis of any such program would be a mutual faith and confidence in what the other person is trying to do and the way he is doing it. It is also based upon reciprocity, i.e., exchange of ideas, results of research and development, raw materials and other mutual assistance both in normal times and those of emergency. Brazilian raw materials may well form a part of this program and undoubtedly a very important share, but they cannot be the only factor. If this were so, then Brazil would simply be merchandizing a commodity or natural resource for the immediate return which would probably be in dollars, a very desirable but not the only important consideration. A most substantial contribution would be the additive presentation of a well thought out and defined plan, for establishing within the capabilities of Brazil, an atomic energy program for the ultimate development of power sources. It is very certain and positive that the presentation of a well integrated working scheme for such development, when coupled with other factors such as useful raw materials would be favorably received not only bu the Atomic Energy Commission, but also by other concerned agencies of the U.S. Government. The promotion of technological growth and expanding industrialization in Brazil would materially strengthen its economy, a fact which is of some considerable interest to the U.S.

As discussed previously, the legal procedure in the U.S. has been set up to provide the necessary requirements for the Atomic Energy Commission to execute an agreement which would not only render the usual technical assistance but also the unusual or classified information of greatest importance is the fact that this provision of information can be in the area of reactor technology, where Brazil's greatest interest should exist. The things which have to be done in order to satisfy the legal requirements of the U.S. Atomic Energy Act are quite clear and with proper guidance , they can be accomplished in Brazil for presentation to the U.S.

U.S. Not the least of these things is the planning and organization which would make effective use of any transferred information.

Organization, Economics and Miscellaneous —

Following the previous discussion, it would seem to be highly desirable that an immediate stream-lining of the operating body for an atomic energy program be put into effect without further delay. Since there is recognition of the fact that the Conselho has many responsibilities in diversified fields of research and development, all of which are important and of value to many segments of Brazilian culture, it is inconceivable that each and every member would have an equal intensity of thought and sustained interest in any one subject. This is especially true when one considers the new and rather nebulous theme of atomic energy which will always remain somewhat of a mystery to a social scientist or agronomist. The composition of the Deliberative Council and the number of members with diversified interests, makes it a very unwieldy group to consider and act upon any matter except that which is of fundamental importance, a major budget item or policy-making in nature.

Good management practice has shown and clearly demonstrated that there is a limit to the number of people, especially high level personnel with other responsibilities, to be used in a body for efficient operation and direction of a program. A research and development program, such as the one for atomic energy, where there may be differences of opinion not necessarily based upon experience, only intensifies this unwieldiness.

Accordingly, the conclusion is reached that for efficient, well organized and effective operation of an atomic energy program, there should be established within the frame-work of the Conselho, an organization similar to the one shown in the accompanying chart. The sub committee or task force atomic energy (TFAE) should have not more than six members, of which one should be from an electrical power company, one from a progressive chemical or metallurgical company, and perhaps one who might be a retired professor of science or engineering and who may be active in industry. The remainder can be selected from the present members of the Conselho, but should contain at least one person whose main interest is scientific and technological research and development.

Such a group would be a miniature policy making body for the atomic energy program, with major decisions, after ef effective screening being referred to the Deliberative Council, which would also be kept advised of all action and any significant operation. The actual direction of operations, however, would be the responsibility of the individual designated as a General Manager, who should have the authority necessary to run the show. To be done properly, it would require a very competent person of diversified experience, preferably from direct charge of operations, and on almost a full time basis. He would discharge those duties considered to be of an operating nature, but referring policy matters, major expenditures and unusual problems to the task force for decision or approval and advice.

Directly under this chief operating official would be the major components of the actual operations. For the beginning, at least, these components can well be grouped geographically by centers where it is likely that most of the early work will be done. Later on, as the program expands it may be well to consider a further break-down into a technological subject division, i.e., chemical engineering, geology, physics, metallurgy, etc... Still later it may be desirable to provide a functional basis for dividing the work classification, i.e., shielding, control systems, fuel preparation, radiation damage and protection, etc... In each area geographic or otherwise, there would be a key person responsible for the work in that area, reporting directly to and subordinate to the General Manager. There would be in addition to the scientific and technical projects, the usual auxiliary services, such as a library and technical information center; personnel health and property protection advice; and others, some of which may be peculiar to that area. Such an organization scheme would take a considerable burden from the minds of the Deliberative Council and at the same time provide an efficient mechanism for proceeding with the job. However, it must be pointed out and emphasized, that the degree of success depends to a large extent, upon the qualifications of these key people, particularly those of the General Manager. The selection of these individuals should be based, primarily upon technical competency and experience, together with the proper philosophy of operations. The conclusion is very firm that this organizational arrangement becomes a very considerable importance and an urgency of the first priority.

Economics --

There are at least two major aspects in this pro program which will not be realizable until some time in the future, yet they are important enough to be known and considered in the overall planning.

They concern the operation of a nuclear reactor for industrial power purposes. Current thinking, not only here in Brazil but also elsewhere, has been concerned primarily with the production of electrical energy in a form and quantity sufficient for power. This energy has been considered the main product saleable at a profit and satisfying a great need. While that attitude is perfectly correct, its concept is a trifle incomplete for the overall economics of the operation dictates a full examination of other potential products, concurrently available with the power, and of some considerable value and saleable for profit. These are plutonium and the fission products. Unfortunately, the latter class of products is always contained in the nuclear reaction and cannot be designed away or circumvented. These products accumulate in the nuclear fuel and eventually become poisons, which establish the cycle of fuel replacement. They are all highly radioactive, of varying half-lives, some in thousands of years so that their presence continues to be an expensive problem and considerable hazard. However, instead of being considered a useless waste product, these radioactive isotopes in the quantity and energy level available, can be looked upon as a very new and undoubtedly quite valuable tool for industry. The writer was able to establish a program before leaving the U.S. which will demonstrate this usefulness. In the short period of time that the experimentation has been going on, there is a clear indication, through a pilot-plant operation of one very significant use. Small, compact sources, compounded from these isotopes of a radiation level at 10 kilo-curies and higher, have been found to be very effective sterilization agents. For the treatment of pharmaceuticals and other heat sensitive materials this new method of cold (no temperature rise) sterilization will prove to be of great value in cutting costs of operation, increasing volume and profit . So in the future, when there are power reactors in operation, this waste product instead of being a costly factor of production, can be turned into an asset. While it is probably true that the income thus derived may not be a great factor in reducing power costs, indirectly there will be considerable saving, because of the elimination of expensive storage facilities, together with the intangible value contained in any developed use in industry.

As to the other factor, plutonium, its production

production may be controlled by the design of the reactor and its fuel system. It is desired to point out now, for proper consideration when the time comes to plan the design of a power reactor, that this element has tremendous value to any nation in the atomic weapon business. It should be remenbered, that it is a very saleable export item and it is quite reasonable to expect that the unit price would be such as to give an income which within a comparatively short period of time (5-10 years) will completely amortize the capital investment of plant costs. After that period the production of power becomes a matter of operating costs and its price per kilowatt hour is apprecia'ly lessened. The sale of this product plutonium should not be difficult and the expectation might be advanced that the U.S. Atomic Energy Commission would be interested in discussing this possibility. Any such negotiation should consider that the depleted fuel containing the plutonium would have to go through a chemical process for its extraction and purification. The required plants, all remotely operated and maintained present a tremendous problem to the economy and technology of any country and beyond the capabilities of Brazil to undertake for some time. But they would not be needed during that time or may be never in Brazil. Therefore, the sale of plutonium could be as a percentage of the uranium fuel, with the provision that the extraction of plutonium be done in the U.S. plants and the recovered uranium either be sold also or returned to Brazil, depending upon economic conditions at the time, such as availability of the raw materials. This arrangement would eliminate the necessity of providing the very expensive (100 million dollars) and extremely complicated chemical plants, and yet obtain a ready market for one of the products of power production. The significance should be strongly weighed in any power production project.

In this connection, consideration must also be given to the fact that it would be much more practical, cheaper and assured of success to capitalize on existing centers of learning and technology and to build the area of development around them. There would be no dislocation of personnel and they could continue to live and work in an atmosphere of familiarity and acceptance. The existing groups with technical competency and available facilities can be used to start the various work projects and as the need arises, new research can be allocated to the most appropriate area.

When the time is opportune for the erection of the research reactor any peculiar problems can be considered, but it is is beyond the scope of this report to go into details of a site selection. An evaluation of these fundamental aspects, however, should be always present in any such planning.

Miscellaneous —

Any technological program of research and development, with subsequent design, erection and operation of pilot plants and industrial activities will have problems of procurement. There may be more acute in an atomic energy program than in conventional research, because of the newness of the work with unusual requirements of purity and unique materials of construction including such things as instruments, equipment, tools and supplies. It has been shown that considerable time delay and expense is involved in correspondence directly with the vendor or agent when the availability, specifications or price of desired items are unknown. In as much as a great deal of the necessary material will be secured from the U.S. it is concluded that one way to expedite the flow of information and required items is to have direct channel from the Council into the markets of the U.S. This could be accomplished by having an engineering firm or individual stationed in New York City, under contract, and directly responsible to the Council on such matters. Such an arrangement would greatly assist in securing promptly the required data; as he would become familiar with the market and also the specifications of the requirements and could, on-the-scene, expedite the exchange.

A very necessary corollary to this arrangement, and regardless whether it is set up or not, will be to provide for the easiest and quickest entry into Brazil after the items have been secured and ready for the ultimate destination. Tremendous delays can occur once the material has been delivered to the wharfs or in Customs. It would appear to be within the authority of the Conselho to make the necessary agreements with the proper authorities so that the flow of material through Customs is with the minimum of delay from import considerations. The conclusion is that such delays should be eliminated in order to provide for a quick use of any import and to avoid the possibility of costly damage while being held in Customs. Valuable time and equipment should not be wasted on the docks.

Another conclusion reached and while it may be considered an operating detail, yet there is sufficient significance

significance to justify the identification in this report. Now that there is actual field work underway and the use of instruments becomes increasingly important in the exploration and location of strategic raw materials, a planned system of repair replacement and possible modifications should be established. A centrally located and readily accessible laboratory can be designed to perform these services, which are very essential to an efficient continuation of this phase of the program. There are in existence already, the work-areas and with the necessary competency to function in this manner if the required direction is given and the responsibility assigned. Such action should be taken very soon.

Still another conclusion, of an operating nature but important for the Conselho to be thinking about, is the method of developing ore bodies as they are discovered. This should be done by an operating company if at all possible within existing laws. While it is recognized that the production and disposition of uranium, zirconium and other critical and strategic materials will be the res ponsibility of the Conselho, yet the actual operation can be perfor med by an industrial company. The necessary controls to satisfy the requirements of the responsibility of the Conselho can be maintained from an administrative point of view. Where a company is already in the area producing other materials, then the operation could be extended to include the strategic materials. If no compa ny exists, then it would be desirable for the Conselho to have one created to do the specific work as directed. This philosophy of operation can well be a matter of established procedure with the Conselho, for it has been proven to be a very efficient way to get a job done for the Government, in a fairly simple manner, which also adds to the technology and manpower that can be applied to any parti cular problem. As an example, a laboratory desined for extractive metallurgy or chemistry may be necessary for applied research and development of processes and methods through a pilot plant stage. It is conceivable that a company already engaged in similar work, could be employed to operate this Government owned laboratory in the interest of the Conselho's objectives and under its over-all direction. Such an arrangement would utilize the technology and manager ial competency of the operating company, while applying the industrial approach to resolving the problem. The use of existing Government laboratories and the facilities of the various universities and tech nical institutes is a very essential part of any atomic energy program. However, it must be recognized that for some types of work, research

research and development, other arrangements will be more efficient and beneficial to everyone. One such arrangement is the employment of an existing appropriate company or other organization to perform a specific piece of work but if such an operating unit does not exist, then it might be advisable to cause the incorporation and formation of the required operating structure.

JHH/NB.

— R E C O M M E N D A T I O N S —

It is highly desirable to identify the conclusions and resulting action, necessary for the conception, and successful operation of an atomic energy program. The following recommendations are based on observations and derived from experience in what would constitute a practical and workable approach to satisfy the requirements of the Conselho and within the capability of the economy of Brazil. They are arranged in an approximate order of priority or relative importance and necessity of making a start because of long range implications.

1. Establish immediately a task-force type of organization within the existing Conselho, to centralize the direction of the atomic energy program, to eliminate expensive building-activities and keep to a minimum tangential and doubtful projects which can be very costly with little direct results;

2. Continue and expand within the limitations of the budget, and outside assistance, the scholarship program as initiated. Direct the courses of instruction into engineering subjects, particularly chemical, with coordinated control of both the curriculum and services of student upon return to Brazil;

3. Create a technical high school, modeled after those in the U.S. within the existing instructional frame work for industrial education in Brazil. Design curricula, so as to provide a well trained group of skilled workers;

4. Provide an officially recognized, directed effort to rapidly expand the number of trained geologists, both in the field and laboratory;

5. Establish an organized program, eventually to be on a country-wide basis, for promoting the search for the strategic materials of Uranium and Thorium at the same time noting other minerals which are of significant value to start with known deposits , working through likely areas and making full use of already existing State Government and other local agencies for this purpose. Stimulate interest and assist in the establishment of such state geological surveys where they do not exist. Lay out a scheme for this responsibility, making a small beginning on known and workable deposits and

and continuing the search in these areas;

6. Approve a nuclear reactor project for research purposes. This should be established immediately, at least, in the study phase to determine the optimum design and necessary work projects to prepare for the erection and operation of such an important nuclear research tool;

7. Establish at once, the required work projects in existing facilities and using available manpower to provide the extractive metellurgy and process development which will immediately exploit known deposits of strategic materials particularly, Uranium and Thorium;

8. Examine carefully, by referring to a small group of qualified engineers and scientists for recommendation, any plans for new buildings, laboratories or other major construction items;

9. Establish as soon as possible a small but adequate mineral examination and testing laboratory in the field for, at least, preliminary work as ore bodies are discovered;

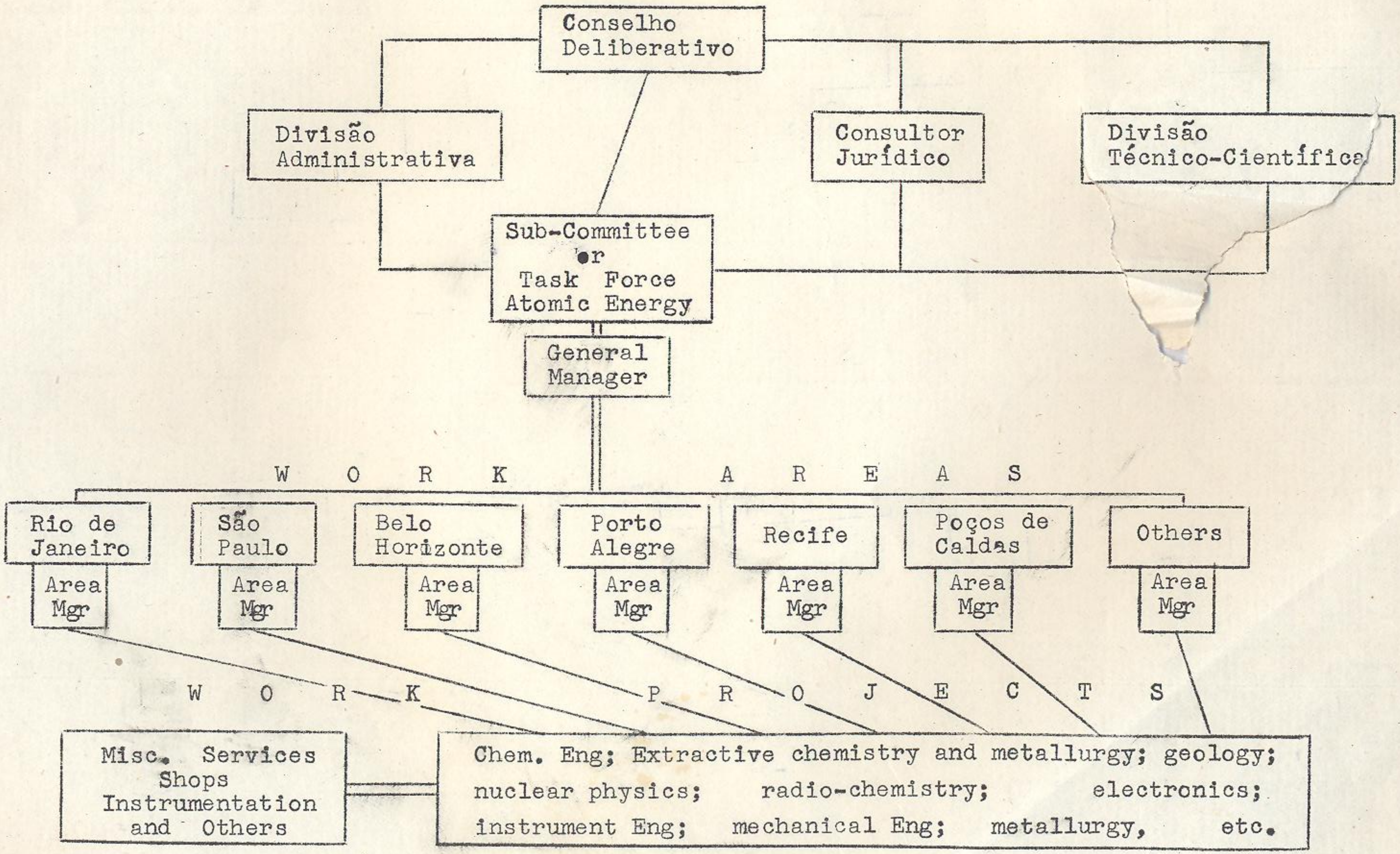
10. A study group should be formed in order to analyse all the requirements necessary for any cooperative program with the U.S. Atomic Energy Commission which will permit the availability of the latest technology, especially in the field of nuclear design and operation. One objective, at least, should be the formation of a definite plan of research, development and application of any such information, thus obtained;

11. Full use should be made of existing research centers at least, until a firm technology is established;

12. Initiate a study phase, which could be a cooperative venture with an electrical power company, to investigate the economies of producing power from nuclear reactors, considering the saleability of plutonium and fission products. This study should be conducted so, that all pertinent information will be available when it is required to justify the main project of developing this power source;

13. Examine the professional and scientific manpower, already available in Brazil, and possessing any knowledge which might contribute to teaching and training students locally, in the

PROPOSED ORGANIZATION OF OPERATIONS FOR AN ATOMIC ENERGY PROGRAM WITHIN THE CONSELHO NACIONAL DE PESQUISAS



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Hon. W. Moreira Salles
Ambassador of Brazil
Washington, D.C.

Dear Mr Ambassador,

It was most gratifying to have a meeting with you today and in accordance with our conversation I am outlining below, the principle thoughts to be conveyed to the U.S. Secretary of State (John Foster Dulles) or the Assistant Secretary of State for Inter-American Affairs (John M. Cabot) as you prefer.

To the U.S. Govennment:

It is with ever increasing interest, that I note the progress which is being made in the U. S. of the development of atomic power sources.

As you undoubtedly know, the Government of Brazil is acutely aware of the potential benefits to be secured from the industrial utilization of power from atomic energy. Within its capabilities there has already been established in Brazil, the fundamental program for research and development in atomic energy. This will in time, result in the ultimate objective of industrial power from atomic energy, which will bring about a new era in the industrialization and development of resources in Brazil.

It is the wish of my Government however, to shorten this time period to a minimum for a practical realization of this mutally beneficial goal. The state of knowledge already developed in the U. S. can be of material assistance in this respect.

Accordingly, I respectfully submit the intention of exploring and discussing, with respnnsible people the ways and means of all details present in a possible cooperative program directed toward an immediate utilization of atomic power.

In this connection, Mr J.H. Hayner, Consulting Engineer of Washington, D.C. will act as liaison and technical advisor to my office.

Your early consideration will be greatly appreciated.

Signed,

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A copy of this letter may also be sent, if you approve, to Hon. Gordon Dean, Chairman, Atomic Energy Commission and Hon. W. Sterling Cole, Chairman, Joint Congressional Committee on atomic energy.

I am very thankful to you for this opportunity of working with you and your Government in such a magnificent undertaking which will bring truly remarkable benefits to Brazil. It is true that there are many problems but they can be resolved, and the result certainly justifies a sincere effort which cannot fail.

Sincerely Yours,

J. H. Hayner

9719 Kingston Rd.,
Kensington, Md.

ØL-9-9412

April 7, 1953.

Washington, em 28 de setembro de 1953.

SECRETO

Nº 1122/592.01(22)

Energia Atômica. Proposta de um ajuste de cooperação entre o Brasil e os Estados Unidos da América.

Senhor Ministro,

Tenho a honra de, em aditamento ao ofício secreto nº 1083/592.01(22), de 17 do corrente, passar às mãos de Vossa Excelência a inclusa cópia da carta, acompanhada dos respectivos anexos, pela qual o Presidente da "U.S. Atomic Energy
1/1 Commission", em resposta ao memorandum de 17 de agôsto último, submete à consideração do govêrno brasileiro um resumo em que se contêm as bases preliminares de um programa de cooperação tecnológica no campo da energia atômica.

Aproveito a oportunidade para renovar a Vossa Excelência os protestos da minha respeitosa consideração.

Sylvio Ribeiro de Carvalho,
Encarregado de Negócios, a.i.

A Sua Excelência o Senhor Vicente Ráo,
Ministro de Estado das Relações Exteriores.

CRG/MTM

Emb.Washington/1122/592.01(22)/1953/Anexo único.

United States
ATOMIC ENERGY COMMISSION
Washington 25, D.C.

September 24, 1953

The Honorable
Sylvio Ribeiro de Carvalho
Brasilian Charge d'Affaires, a.i.

My dear Mr. Charge d'Affaires:

We have studied Ambassador Salles'memorandum of August 17, 1953, which sets forth the objectives of your atomic energy program and proposes collaboration between our two Governments looking forward to the sale of uranium to the United States Atomic Energy Commission and, in return, assistance by the United States Atomic Energy Commission to your planned program.

The Commission deeply appreciates the desire of your Government to cooperate with us in the field of atomic energy. It exemplifies the long standing spirit of cooperation which has existed between our two Governments and the solidarity which our Governments have had in the past, particularly when threatened by common danger to the Western Hemisphere.

The Commission has considered the points made in the memorandum, as amplified by Admiral Alvaro Alberto, President of the Brasilian National Research Council. I was agreed with Admiral Alberto that we would provide you, in an informal letter, with our preliminary comments on some of the points raised in the Ambassador's memorandum. It is understood that you wish to take our comments into consideration in formulating your views on the subject of cooperation in this field and these views would be transmitted to us through normal diplomatic channels. With this in mind, we have the following comments to make at this time.

We have noted with great interest your program for atomic development in Brasil and we earnestly share the hope expressed in your memorandum that there can be established a basis for a program of cooperation that will result in advantages for both nations. We are convinced that this can be accomplished. On our part, this cooperation could include information and assistance on reactor technology and training of your scientists which would help your Government in preparing for the time when atomic power may become a reality and assistance to your Government in the exploration and development of raw materials. As is recognized and stated in the Ambassador's memorandum, there are legal limitations on the ability of the United States to provide certain kinds of technical assistance and information in the atomic energy field. We believe, however, that within these limitations there is considerable assistance that we can give you in the

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the field of reactor technology. Therefore, we suggeste that several technical representatives of the Brazilian National Research Council be designated to meet with United States Atomic Energy Commission personnel in order to explore and identify the kinds of contributions that we could make and the manner in which these contributions could most effectively be carried out. As a result of the cooperation that presently exists between your Mines Department and the geologists of the United States Geological Survey, we believe there can already be identified certain ways in which we might make a substantial contribution to your uranium exploration program. Accordingly, we are attaching for your consideration an outline of a joint exploration program.

It is our understanding that, as a part of the cooperation between our two Governments, the Brazilian Government would be prepared to cede to the United States under an agreement between our two Governments, a portion of its supplies of ore concentrates. We realize that it is not practical at this time to determine the quantities of uranium which might be made available to the United States, or to discuss specific pricing arrangements. We believe, however, that it should be agreed now that the following factors would be considered in determining the quantities and the terms of the sale of this material to the United States when the time is appropriate:

(1) Productive capabilities of Brazilian deposits.
(2) Brazilian current internal requirements for uranium.
(3) The current needs of the United States for defense purposes.
(4) Costs of production, including a reasonable margin for profit.

We look forward to receiving your Government's views on a program of cooperation along the lines outlined above which could be initiated in the near future.

In view of the potential requirements of the atomic energy program which you have planned and the requirements of our program for defense purposes, and in view of the time required to find and produce uranium for these purposes, we believe that it would be mutually advantageous if the uranium exploration project were started as soon as possible.

Sincerely yours,

a) Lewis L. Strauss
Chairman

Enclosure
Outline of Joint Exploration Program