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DEPARTMENT OF STATE

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Amembassy RIO DE JANEIRO June 23, 1967

Status of Nuclear Energy Development in Brazil

Rio de Janeiro's A-1142 and A-1143

1. In view of the recently enunciated Brazilian position on the peaceful uses of atomic energy as expressed by top GOB authorities, including President Costa e Silva, Foreign Minister Magalhães Pinto, Foreign Ministry Secretary General Correia da Costa, Minister of Mines & Energy Costa Cavalcanti, CNEN Chairman Costa Ribeiro and others, the Scientific Attaché and other members of the Country Team have collaborated in the preparation of background documentation for the Chief of Mission.

2. The attached report on the "Status of Nuclear Energy Development in Brazil" is one of the initial studies. Other companion pieces have been incorporated into the airgrams cited above. Significant developments have been reported by telegram.

3. The Mission is gratified that USAEC Chairman Seaborg is coming to Brazil next week, pursuant to the Ambassador's recommendations to which the Department gave strong support (see also A-1142 in this connection). The Embassy trusts that the attached study and the others presented in A-1142 and A-1143 will be of assistance to him and his party in their appreciation of the Brazilian scene in advance of arrival.

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4. That these deficiencies can be overcome in a relatively short period of time, given the plus factors which she does have and which are set forth below, if she really launches herself earnestly on a program so to do; and finally, that

5. Meanwhile, the United States should carefully weigh all factors in this situation and offer now to cooperate fully in this announced major effort by our major partner in all of Latin America.

The study is presented in four parts:

I. The Status of Nuclear Energy in Brazil, including data on the cooperation provided by the United States;

II. Comment on that Status;

III. Nuclear Energy Development in the other American Republics;

IV. Conclusions and Recommendations.

Comparisons of relative capabilities are presented at various points, particularly in Parts II and III.

The attached text, therefore, is not an energy study or a political study, but an analysis of the progress Brazil has made in the last 10 years in atomic energy development and the capacitation of its technicians and scientists, as the basis for related policy decisions.

André C. Simonpietri
Scientific Attaché

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Part I: The Status of Nuclear Energy Development in Brazil

The present Atomic Energy program in Brazil is under serious review at this time that so much emphasis is being given to Science and Technology and to Nuclear Energy as a major tool in Technological Development. As of early 1967, before the recent emphasis was given to Atomic Energy by the new Costa e Silva Government, the following was the picture insofar as organization, facilities, raw materials, international cooperation and nuclear power are concerned.(1)

Organization: The National Nuclear Energy Commission (CNEN) is the responsible body for atomic energy matters in Brazil. Professor (General) Uriel da Costa Ribeiro, formerly Professor of Nuclear Engineering at the Army Engineering Institute, is Chairman of the five-member Commission, which reports directly to the President.

Facilities: The CNEN's Institute of Atomic Energy(IEA), located at University City on the outskirts of São Paulo has a 5 MW(t) U.S. grant reactor, IEAR-1, which reached initial criticality on September 16, 1957. Primary use of the reactor has been for the production of radioisotopes, cross-section measurements, activation analysis, and training. Fuel for the reactor was provided by the USAEC. The fuel elements are currently being reprocessed. Other facilities at the IEA include a uranium refining and fabrication plant (including laboratories for the IEA's Chemical Engineering Division), a subcritical assembly, and a linear accelerator. A new Institute of Metallurgy was dedicated at the IEA in September 1966, on the 8th anniversary of the reactor.

In addition to the work being carried out at the IEA, the University of São Paulo itself has an active nuclear medicine program which is conducted at the Faculty of Medicine's Center of Nuclear Medicine. Courses conducted by the Center include Radioisotopes Tracers, Biological and Biochemical Applications of Radioisotopes, Physics Applied to Radioisotopes, and Radiation Hygiene. The University of São Paulo also has a nuclear physics program and an associated accelerator laboratory. The latter has had for years a cooperative agreement with the University of Wisconsin, financed by the U.S. National Science Foundation. Details on other accelerators in the São Paulo and Rio university complexes are provided later in this paper.

The ten KW Brazilian-built Argonaut reactor which achieved criticality on February 19, 1965, is located at the Institute of Nuclear Engineering (INE) at the University of Brazil in Rio (now the Federal University of Rio de Janeiro, UFRJ). The Institute is intended to be the center of education and training in all fields of nuclear energy. Fuel elements for the reactor were fabricated by the Metallurgical Laboratory of the IEA in São Paulo. The U.S. supplied 6,000 grams of contained U-235 at 20 percent-enriched uranium oxide for the production of the fuel elements. The reactor is used principally as a training device.

(1) Taken from USAEC and Embassy sources.

A third reactor center is the Institute of Radioactive Research, University of Minas Gerais near Belo Horizonte at which is located a 100 KW (t) Triga Mark I reactor. The reactor achieved criticality in November 1960, and is usually operated at 30 KW (t). It is used for training, radioisotope production, and research. Fuel for the reactor is leased from the USAEC.

In addition to the INE, the Institute of Biophysics is located at the UFRJ. The Institute, as well as the Catholic University of Rio de Janeiro (PUC) under contract with the USAEC's Division of Biology and Medicine, is conducting research in such fields as high-level, natural background radiation, which occurs in the regions of Guarapari, Morro de Ferro, Poços de Caldas, and Araxá.

Located at Piracicaba in the State of São Paulo is the Luiz de Queiroz Agricultural College, part of the University of São Paulo. As the result of a contract signed between the CNEN and the College in August 1962, the National Center of Nuclear Energy for Agriculture was established. The Center offers post-graduate instruction in the application of nuclear energy to agriculture but research is the main, long-range objective of the Center.

Another of Brazil's principal facilities is the Aeronautical Technical Institute (ITA) at São José dos Campos. At the Nuclear Physics Laboratory of the ITA is located the subcritical assembly which was obtained under the U.S. equipment grant made in FY 1959. The Institute is being assisted by the University of Michigan under sponsorship of USAID. The ITA has a well-developed curriculum in electrical engineering.

Raw materials: Brazil has both uranium (in limited quantities) and thorium (in ample supply). From July 1955 through December 1960, the USAEC's Division of Raw Materials (DRM) supported a joint U.S.-Brazilian uranium exploration effort. During this period there were three to four American geologists assisting the Brazilians in prospecting for radioactive materials and in training them in the geology of uranium minerals. The AEC supplied all radiation detection equipment, as well as the greater number of the vehicles, and donated these to the CNEN at the end of the program.

This work was carried out by personnel of the U.S. Geological Survey under contract with the AEC and was supervised by the AEC (DRM) staff. In addition, there have been four specialists from Brazil who have visited the United States for periods ranging from one to three months to study and gain experience in exploration, chemistry and milling. Twenty-eight Brazilians have also visited AEC Headquarters or installations for one to four days in connection with raw materials work. A Brazilian nuclear raw materials specialist visited U.S. mining facilities recently at USAEC invitation.

In recent years Brazil has been receiving strong French support in its exploration program. French geologists are working with local Brazilian field groups on a long-term basis. Further reference is made to this below.

International cooperation

With other countries: Brazil has peaceful uses of atomic energy cooperative agreements with Bolivia, Euratom France, Israel, Italy, Paraguay, Perú, Portugal, Switzerland and the U.S. The Embassy has reported to the Department as these various accords came into being. She also has special diplomatic relationships with Argentina and Mexico. Brazilian specialists have been trained in the U.S., U.K., France, Italy and Portugal.

With international agencies: Brazil is an active member of the IAEA and IANEC. Details are provided below. See also UN, UNESCO and ICSU.

Cooperation with the United States

Our current joint program with Brazil consists of the following: The U.S. and Brazil entered into a research-type Agreement for Cooperation on the peaceful uses of atomic energy in August 1955. This was subsequently amended in 1958, 1960, 1962, and 1965. A superseding agreement, which consolidates the original agreement and its amendments, has now been approved by the Brazilian Congress. The U.S. had previously completed all of its statutory and constitutional requirements necessary to bring the superseding agreement into effect. A tripartite agreement is scheduled to enter into effect in the near future (U.S.-Brazil-IAEA).

Equipment grants: In addition to the $350,000 reactor grant which was contributed toward the cost of the IEAR-1 project (the São Paulo reactor), the U.S. has contributed the following equipment grants:

FY 1959 - $140,550: subcritical assembly and fuel (Aeronautical Institute of Technology at São José dos Campos)

FY 1960 - $163,300: six laboratory irradiators (CNEN)

FY 1961 - $ 11,000: equipment for agricultural research with radioisotopes (CNEN)

FY 1962 - $ 2,160: 3 plutonium-beryllium sources (Aeronautical Institute of Technology)

$ 12,000: Cobalt-60 irradiator (Institute of Biophysics, UFRJ).

Research support: The USAEC's Division of Biology and Medicine supports three research contracts concerned with Brazil's high-level natural background radiation (mentioned earlier as a joint USAEC-UFRJ-PUC program), and natural and radiation-induced lethals in population of Drosophila Willistoni (the latter being with the Institute of Genetics of the University of São Paulo). AEC support of this research has totalled $325, 535 since 1960, when the first contract was entered into.

A USAEC Depository Library has been established at the Instituto Brasileiro de Bibliografia e Documentação, Rio de Janeiro, an agency of the Conselho Nacional de Pesquisas (CNPq), and at the CNEN's Instituto de Energia Atomica, São Paulo. A similar deposit library was maintained for years at the Brazilian Academy of Sciences in downtown Rio. This support was discontinued in 1965.

The first U.S. Atoms-for-Peace Mission to the American Republics visited Brazil in 1956. The USAEC's "Atoms at Work" Exhibit was shown in Rio de Janeiro in 1961.

The total of outright grants and research support since 1957, therefore, totals well over one million dollars.

Nuclear power: Although Brazil has not begun construction of nuclear power plants, the CNEN's plans in 1963 took cognizance of three proposed projects: a reactor of about 300 MWe for the South-Central region, in the Rio area; a 60 MWe reactor for the Southern region, near Rio Grande do Sul; and a third reactor of approximately 50 MWe for the Northern region, possibly at Terezina. In 1963 a study of power resources of the South-Central region was initiated under contract with CANAMBRA (a consortium formed by Montreal Engineering Co., Ltd., G. E. Crippen and Assoc., Ltd. of Canada, and Gibbs and Hill of the U.S., which was formed specifically to undertake the study), with the support of the UN Special Fund.

In January 1965, Brazilian President Castello Branco issued a directive for the establishment of a nuclear power plant in the South-Central region of Brazil. The directive was addressed to the CNEN, and ordered it to reactivate previous studies in this field and to give its recommendation to the type of reactor needed, the location of the plant, and other technical details.

In March 1966, Professor do Prado, the then CNEN Chairman, visited AEC Headquarters and during his discussions, he noted that the CNEN 1965 study had been completed and that it calls for medium and long-range programs to study and encourage the development and construction of the reactor system or systems which have the greatest promise for utilizing thorium as reactor fuel. As a result of the study, two feasibility study working groups have been established. One group, at Belo Horizonte, is working with the French. The other, at São Paulo, is working largely with the U.S. and Canada.

Under the auspices of the International Atomic Energy Agency, a thorium reactor specialist from the USAEC's Oak Ridge National Laboratory, Mr. John A. Lane, visited Brazil for several weeks in the spring of 1966, and returned again in the fall for some six months, to assist in planning and conducting the feasibility study undertaken by the São Paulo group. (One outcome of Mr. Lane's recent visit was the recommendation that the São Paulo group's study be broadened to a comprehensive study of the economic feasibility of introducing nuclear power into Brazil; all types of reactors, in addition to thorium utilizing reactors, would be considered.)

Overall direction of the power studies of the two groups has been assigned to a steering committee comprised of representatives from each State Government involved, the World Bank (as executive agent for the UN Special Fund), the Central Elétrica de Furnas (as a delegate of Eletrobrás, the government-owned power utility holding company) and from the Ministry of Mines and Energy.

Part II: Comment

The above statement on Brazil's program is in the nature of a factual report. Comment follows:

Brazil's capabilities in Atomic Energy are limited at this time by several factors: manpower, heavy installations (i.e., the so-called Atomic Energy "park" or "nuclear center"), fuel and fuel elements, and adequate planning. Each of these limiting factors is analyzed below:

Re planning: In the opinion of many qualified observers, this has been the most serious deficiency, hence it is treated first.

Opportunity has been lost by lack of continued effort over the years, but perhaps principally by dissipation of whatever effort has been made. For example, from its entry into the Atomic Energy field, Argentina modeled its program along the lines of the USAEC and the French Commission. A large body of qualified personnel was concentrated into one center in Buenos Aires. Here several hundred specialists, with good staff, have their own reactor-connected laboratories for their research in biology, chemistry and energy physics. Expansion came later in related fields such as radiobiology, metallurgy and other industrial uses of radiation and radioisotopes. The Commission has had the same Chairman, Admiral Guihillalt, for years, and is housed at headquarters where the principal work is done. Financial support by the Government has been rather liberal.

On the other hand, Brazil's Commission has had four chairmen in the last five years, has suffered continuously from budget cuts, and from the non availability

of funds from approved budgets, has a very small headquarters staff, and its "laboratories" are dispersed throughout the country. Capable units function at the universities in São Paulo, Belo Horizonte, Rio de Janeiro and Pôrto Alegre (the latter has no research reactor). Such dispersion, of course, has advantages and disadvantages, but the total program has undoubtedly suffered.

Until earlier this year there was not even a planning unit as such in the CNEN. Whatever planning was done was carried out by ad hoc commissions, e.g. CANAMBRA cited above. The man in charge of this planning function is Col. Horácio Antunes Ferreira Jr., CNEN observer at the recent Conference at UCLA on the use of Atomic Energy in the Development of Latin America, who was trained at Oak Ridge National Laboratory.

The reactors in operation are not being used anything like full time, another indication of inadequate planning and programmin. A liberal estimate of reactor time-in-use would probably not exceed 30 to 35 percent. Another example of what some call misplaced emphasis is the program of yellow-cake and monozite sand stockpiling, to which much effort and money has been devoted.

Again, much time has been spent in organizational matters, so dear to the Brazilian heart. The Commission was placed under the National Research Council (CNPq) when first organized. Almost immediately a campaign was started by interested parties to have it made autonomous, that is, to get it out from under the CNPq.

This was achieved, but again another campaign was started to make it subservient to the Ministry of Mines and Energy. An article to this effect in the 1963 Regulamento was actually approved by the Congress, but vetoed by the President. Meanwhile, much time and effort has been devoted to these non-productive ends, at the expense of program advancement.

The principal effort has been in the search for radioactive raw materials, but here again there has been discontinuity. Started first with the U.S. Geological Survey, USAEC supported, it was switched in mid-stream when a really effective program was underway, and placed under the auspices of the French Atomic Energy Commission. This policy change was effected by Prof. Marcelo Damy de Souza Santos, overtly francophile in outlook while pretending to treasure American friendship. The program suffered as a consequence, for the French have found no new deposits of any real importance and in fact, are only following up on promising leads discovered by the USGS, but at a much slower pace, to the extent that many CNEN officials have been vocally unhappy about the situation for some time. These facts have long since been duly reported to the Department. Lacking on our part has been any sustained effort to keep our foot in the door.

A second major effort has been to provide Brazil with the specialized manpower that she needs.

Re manpower: Trained manpower needs in atomic energy work fall into a number of fields of specialization. Principal are physicists and mathematicians, nuclear physicists and nuclear engineers, for reactor operation and use. Specialists in safety and safeguards, eletronics and electrical engineering, and reactor-use programming, are also required. In addition, and depending upon the end-use in mind, radiobiologists and radiochemists, biochemists and biophysicists are needed, as well as experts in radiation and radioisotope use in agriculture, biology and medicine and industry.

A significant number of Brazilian scientists have been trained in the States, the U.K., France and Italy over the past ten years. Many have returned with their Ph.D.s from California, M.I.T., Chicago, and other of our best centers of higher learning. The first nuclear engineer graduated with his doctorate from North Carolina was a Brazilian, Hervásio de Carvalho, who worked with CERN for years, has done research in Switzerland and Italy, and is now Scientific Director of the Brazilian Center for Physics Research (CBPF). These men are now working at the CNEN or related Brazilian centers.

In addition, as stated in part above, well over 50 Brazilian atomic scientists have been given special training or familiarization tours at our major national atomic energy laboratories and installations.

The Instituto de Física of the Faculty of Philosophy and Science of the University of São Paulo, under Oscar Sala, is recognized throughout the world as a fine institution in high energy physics. Their present 3.5 MKW accelerator will soon be replaced by a 15 MKW machine, jointly financed by the University, the State of São Paulo, the CNPq and the IADB. In addition, Stanford University is making a third accelerator available to them. Sala has been working closely with the University of Wisconsin for some years. The Instituto de Física of PUC is another good institution, and they will shortly have a new Van de Graaf accelerator, jointly financed by a Ford grant and the IADB. The first LA laser installation is functioning well at the University of Rio Grande do Sul under Gerhard Jacob. Nuclear engineers in surprising numbers are being trained at three principal points, the Instituto de Engenharia Nuclear at UFRJ, on Ilha Fundão, at the Army School on Praia Vermelha in Rio, and at the IEA in São Paulo.

It will be seen, therefore, that Brazil has a good cadre of trained scientists in a number of the fields cited above, particularly physics and mathematics, nuclear physics, nuclear engineering, reactor-use planning, safety and safeguards, electronics and electrical engineering. These are adequate for the immediate purpose of

operating the reactors currently functioning for research purposes. She apparently does not have manpower trained for the operation of the big power reactors, nor has she had need so far. Concomitant with her plans eventually to go in for power reactors are her plans to detail people for such advanced training and experience abroad.

She also has some very fine biophysicists, e.g. the Instituto de Bioffsica of the UFRJ, started by Carlos Chagas, has a good reputation internationally. It was also one of the first such institutes in the world. But Brazil is weak in biochemists, as she is in chemistry generally and chemical engineering. She is weaker yet, I fear, in radiochemists. But, on the other hand, she has some good radiobiologists, as for instance at the Instituto de Medicina Nuclear at the USP, under Tede Estes.

She has people who are familiar with the use of radioisotopes for agriculture, medicine and industry. The Instituto de Radioisotopos of the Federal University of Minas Gerais, at Belo Horizonte, has concentrated its attention in this field, but little use outside of the laboratory is being made of the isotopes produced in their Triga III reactor.

The agricultural school at Piracicaba (the Luis Queiroz Agriculture College, commonly referred to as "Piracicaba") is making some use of radioisotopes in its genetic studies and application, but little work so far has been done on the massive scale open for isotope utilization in agriculture.

The Instituto de Energia Atômica at the USP, which operates the swimming pool reactor there for the CNEN, is concentrating recently on some industrial applications, as mentioned above under "facilities", after using the reactor for years primarily for training and demonstration. Unfortunately, Prof. Leão, who was knowledgeable in the industrial use of radioisotopes and for whom a program of visits to our related industrial installations was prepared, on his return from travel in Europe fell ill and died in Rome before ever reaching the States.

Some examples of where Brazil is concentrating attention in industrial uses of nuclear energy are provided by the stated principal objectives of the Metallurgy group at the Instituto de Energia Atômica at São Paulo, namely: (1) Production of Metallic uranium and thorium and their alloys on a pilot scale starting from refined salts of these elements; (2) Studies on the rolling and swaging of these metals and alloys; (3) Research and development work on nuclear ceramics; (4) Construction of prototypes of fuel elements; (5) Mechanical, physical and metallographical tests of nuclear materials and non-destructive tests of fuel elements; (6) Studies on the pyrometallurgical reprocessing of irradiated fuels;

(7) Fabrication of fuel elements for the Argonaut reactor in Rio and for sub-critical assemblies.

The 1965-66 program of the Metallurgy Division at IEA included:

1. Processing of Ammonium diuranate for the production of UO_2 and U_3O_8; production of thorium and iranium tetrafluoride.

2. Production of uranium and thorium metal from the above salts.

3. Melting and casting of ingots of uranium and thorium alloys.

4. Rolling and swaging of uranium.

5. Production of UO_2 pellets by sintering under argon and hydrogen; studies of ceremets and dispersions of U_3O_8 and aluminum.

6. Production of the fuel elements for the Argonaut reactor, Instituto de Engenharia Nuclear, Rio, and for a sub-critical assembly, and testing of these elements.

The newest Brazilian reactor, the Argonaut, built on the grounds of the UFRJ under the joint auspices of the CNEN and the University, and placed under the Instituto de Engenharia Nuclear of the University, was dedicated less than two years ago. It is used primarily for training purposes at the present time. It should be noted, however, that, although the design is U.S., the reactor was entirely constructed by Brazilians, the fuel elements were manufactured in São Paulo, and 93 percent of its components are Brazilian. The 7 percent remaining is represented by the U-235 fuel, provided by the USAEC, and the graphite coming from France.

Concerning installations

a) Reactors: Brazil's four reactors are of the research and training type. Reference has been made to them in the text above:

1. São Paulo: 1957: 5 Megawatt swimming pool reactor, IEAR-1
2. São José dos Campos: 1959: sub-critical assembly (no chain reaction)
3. Belo Horizonte: 1960: 100 Kilowatt Triga Mark I
4. Rio de Janeiro: 1965: 10 Kilowatt Argonaut.

b) Nuclear Energy research institutions: These have been mentioned in the preceding text. Here is the list of the principal institutions:

1. São Paulo: Institute of Atomic Energy (CNEN)
   Center of Nuclear Medicine (USP)
   Van de Graaf Accelerator Laboratory (USP)
   (will have three accelerators shortly)
2. Belo Horizonte, MG: Institute of Radioactive Research (UFMG)
3. Piracicaba, S. P.: National Center of Nuclear Energy for Agriculture (USP)
4. São José dos Campos, S.P.: Nuclear Physics Laboratory (ITA)
5. Rio de Janeiro, GB: Institute of Nuclear Engineering (CNEN-UFRJ)
   Institute of Physics (PUC)
   Institute of Biophysics (UFRJ)
   (has USAEC research grant)
   Brazilian Center of Physics Research - CBPF
6. Porto Alegre, RGS: Institute of Physics (URGS).

The above are the outstanding centers of physics teaching, training and research in Brazil today. Other centers, having a good basis for development, are becoming stronger every day, such as: the University of Ceará, the National University of Brasília, the group at Mackenzie University in São Paulo and, to a lesser extent, the groups at Curitiba, Recife and Salvador.

c) Site selection is a preliminary step of major importance in heavier-type installations such as power reactors. This is because safety considerations are either paramount or equally important with those of proximity to the community and its industry to be served. It should be noted in this connection, however, that recent studies indicate that the location of atomic energy power plants practically within the heart of a big city are feasible, because of improved safeguard know-how. Brazil has already completed preliminary studies on site selection related to the power studies as cited above. Developing techniques, and policy shifts may change the site selection for the third power reactor (Terezina), or add a fourth. The most recent news is that thought is being given to the needs of the North-East -- Recife and/or Fortaleza.

d) A Dual Purpose installation, that is, electrical power plus desalination of sea-water capabilities, is being given consideration for the Fortaleza area, according to a CNEN spokesman, Prof. Waldyr Pollis, who presented a paper on this topic at the UCLA conference in March, 1967.

The U.S. and Mexico have finalized an agreement for a feasibility study of the same type for the North-West area of Mexico, including Baja, California.

The U.S. and Israel have devoted major attention to the possibilities of such an installation. There is also a recent U.S.-Greece agreement for the same purpose. Present findings are, I believe, that a very large plant will be required to make such a dual installation pay off. This type of plant is quite attractive because one of the best desalination methods requires high temperature treatment, and one of the products of fission is, of course, tremendous heat. (An associated problem in the power reactor is the dissipation of that hear.)

Concerning fuel

The fuel used in a reactor is introduced via the fuel element. The fissionable fuels are three:

Uranium 235
Plutonium 239, and
Uranium 233

The only fuel that is found in nature is U-235. The other two have to be produced in the reactor itself from other natural materials, Uranium 238 and Thorium. The latter are fertile materials, but not fissionable.

Despite intensive search Brazil has found practically no uranium. She has found thorium, in quantity.

The Breeder reactor

The utilization of thorium requires the breeder reactor, the slow type, and no one has yet produced a feasible plant, although several have been designed. Until such a breeder reactor is available to Brazil, she has apparently only two choices: to use enriched U-235, which she would have to obtain from the U.S., or to use natural uranium reactor for power generation, and has been pressuring Brazil to adopt this type of power plant. A by-product would be the virtual exclusion of U.S. industry from atomic energy power plant construction in Brazil. Mention here is made of the fact that when Brazil announced in 1961 that she would entertain bids for atomic energy power installations, eight western companies submitted such bids. Of these three were from U.S. companies (General Electric, Westinghouse and Nuclear Chicago). The others were from the U.K., Canada, France and Italy. The U.S. bids for enriched uranium were, if I remember correctly, in the neighborhood of 160 million dollars, totaling delivered ready for operation, some 190 million. The French bid, for natural uranium fuel, was appreciably less. (Pertinent is the consideration that the initial cost of the unenriched uranium plant is higher, operation costs lower.)

The USAEC is now concentrating attention on breeder reactors, of which there are several in the fast breeder-slow breeder categories. Most promising of the slow-neutron type of reactor is a thorium breeder[1], using ordinary pressurized water as a coolant. The engineering problems seem to be largely solved, because the U-235 reactors also use water coolants, and only the fuel itself has to be developed. The AEC will probably decide which way it will move in this area in 1968. This will be very important for Brazil.

In connection with this brief discussion on breeder reactors, in which the GOB is intensely interested, I should like to make two comments:

1. The essential point is fuel. On this point the GOB has a good memory, and a long one. Officials today recall the total dependence of the country on petroleum products from the U.S. during World War II, hence the battle cry "O Petróleo é nosso!" I saw and photographed many of the ingenious "gasogênicos" used at that time. These were coke-burning furnaces tucked into the trunks of cars to produce the gas for firing in the combustion chamber of the motor. Many Brazilian officials have privately vowed never again to let the country be caught in a similar situation in any area of such vital importance. Hence, the French system, using natural unenriched uranium for power production is particularly attractive to them, and France knows this. It means that Brazil could use her own native fuel. On the other hand, if she opted for the enriched uranium reactor, she would have to depend on the U.S. for her fuel. Many consider it a national disgrace to have to import U-235 from abroad. They realize that in the case of an emergency the supply could or would probably be cut off immediately. Hence their impassioned search for U-235 and, not finding it, their desperate turn is to thorium-using reactors.

2. The GOB may plunk for developing its own breeder reactor. This is admittedly somewhat far-fetched, but not so much so in the case of this country, which decided that the population should be attracted inland, selected a site some sixty years ago for Belo Horizonte and built the city. Today it has more than a million inhabitants. Similarly, Brasília. A demonstration-type breeder reactor could probably be built for about fifty million dollars. Considering the stakes, that is "small change".

Gas centrifuges

Gas centrifuges, with their chain-reaction type of operation, are capable of producing the neutron fission necessary for the production of nuclear explosives.

[1] SCIENCE NEWS, 15 April, 1967, Vol. 91

when operated in cascade. A rather sophisticated installation is required for this use of the centrifuge, and Brazil attracted much attention several years ago when she purchased three small units from West Germany. We provided the fuel needed for their operation and watched the developments with some concern. (I reported on this in 1963) However, there just about haven't been any developments. Of the 400 kgs of thorium hexo-fluoride provided (UF^6), less than one kilo had been used as of the inventory check of December 31, 1966. (x)

The gas centrifuge process (for the limited production of highly enriched uranium) lends itself to construction of small plants and may therefore represent a nuclear weapons proliferation potential. Hence the highly classified nature of our own developmental efforts in this field and no export of either gas centrifuge technology or equipment is permitted.

Atomic Energy for Diplomats: It might be well to recall, before closing this brief comment on some aspects of Brazil's development in nuclear energy over the last decade, that for some time the Foreign Office has been giving much more than ordinary attention to atomic energy. For example, in May of 1966, the Ministry organized a "Symposium on Nuclear Energy for Diplomats", conducted by CNEN.

Part III: Nuclear Energy in the other American Republics

General

National Nuclear Energy Commissions: These have been set up in Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Perú, Uruguay and Venezuela. Some brief details concerning the program and status of development of each are set forth below. No information is available in Rio de Janeiro re Panamá and Central America. Cuba had a National Commission in 1958.

Reactors: Five LA countries now have research reactors in operation: Argentina, Brazil, Colombia, Mexico and Venezuela. Uruguay's reactor may be in operation as of this date (see below). The first reactor in each country was acquired from the U.S. during President Eisenhower's Atoms-for-Peace Program, whereby the U.S. could and did contribute, in a matching operation, up to $350,000 of the total cost of a research reactor installation. At that time this was approximately half the cost involved. Chile also expressed its intent to

(x) This installation is located at the Instituto de Pesquisa Tecnológica (IPT) at São Paulo.

acquire an Atoms-for-Peace reactor but, just as the authorizing legislation was about to expire in 1962, decided to desist.

Argentina, Brazil and Mexico are now giving serious consideration to power reactors, much more so than Colombia and Venezuela. Brazil has support from the UN Special Fund in the amount of $2,500,000 for the necessary advance feasibility studies, as stated above, pages 4 and 5. Mexico also has international financing for its current feasibility study in the amount of $1,000,000. Reference has been made above to her current thinking about a dual purpose installation.

Country-by-country

Argentina: See particularly page 7 above. The IADB has made $1,000,000 available to the National Commission for the development of metallurgy.

Bolivia: The National Commission has been giving preferential attention to the use of radioisotopes in biology and medicine in connection with high altitude physiological studies.

Colombia: The 10 KW Lockheed research reactor went critical on January 20, 1965 at the Institute of Nuclear Affairs in Bogotá. It was dedicated one month later and is being used actively in research. The Institute has developed a sister-laboratory agreement with the Puerto Rico Nuclear Center. It is presently drafting a program for the use of tracer elements in hydrological studies, jointly with other federal agencies and the Universidad del Valle.

Ecuador: The National Commission has a very modest budget and has made little real progress. Some very fine agricultural genetics work, however, was done there by Levy some few years ago with the use of tracer elements. Outside support provided the means for this research, which attracted world-wide attention.

Mexico: The National Commission has suffered from many of the same vicissitudes that have delayed Brazil's progress, although it has many capable physicists of international reputation, such as Sandoval Vallarta, who taught at M.I.T. for many years. It now appears to be on the move.

Paraguay: The Commission has no budget and its members serve without compensation. It is developing a program in the use of radioisotopes in agriculture, radiation chemistry and medicine.

Perú: The development of Perú's program has been retarded recently by a minor fiscal scandal, involving a quite insignificant amount of funds. To the outside observer it appeared to be more an excuse to unseat the Chairman of the National Commission. One ambitious project that has not prospered was that of pumping water from Lake Titicaca over the mountain rim to the parched coastal area of Southern Perú, using Atomic Energy for this purpose. However, the water level in the lake has been dropping for some time, which discouraged further efforts in this direction.

Uruguay: The Lockheed 10 KW pool research reactor and fuel elements remained stored in a lift van in a commercial warehouse in Montevideo as of early 1965. The Commission had firm plans to purchase the reactor, but the Congress had taken no action on their recommendation since it was presented in 1963. Lockheed representatives presumably completed contractual arrangements in early 1966. A U.S.-Uruguay joint text for cooperation in the peaceful uses of Atomic Energy was presented to the Uruguayan Congress on December 17, 1964. The 17-man commission, duly appointed by the GOU, has had a rather negligible budget. This was $4,000 in 1965. However, some commission members enjoy an international representation, e.g., Walter Hill and German Villar. Villar's theoretical studies in physics lead him to postulate the existence of one element in the Periodical Table, long before it was actually discovered. The USAEC has paid tribute to him for his work.

Venezuela: The 3 MW General Electric pool type research reactor, located at the Instituto Venezolano de Investigación Científica (IVIC) went critical in July 1960. The USAEC contributed $350,000 towards its purchase. Because of the lack of adequately trained Venezuelan scientific manpower, the reactor was shut down in 1961, when Marcel Roche assumed the Directorship of IVIC. It was reactivated in 1966, when some 32 Ph.D.'s returned from study abroad (U.S., France, U.K.; Italy, Spain, Germany).

The IAEA

Brazil became a member of the International Atomic Energy Agency (IAEA) on July 29, 1957. As of the end of 1965, Agency assistance to Brazil totalled $657,600 in the form of equipment, fellowships, and the services of experts.

For years Brazil held the chair of the regional representative for Latin America on the IAEA. The choice presumably falls to the most advanced nation. During the past several years there has been active consideration of alternating this seat between Argentina, Brazil and Mexico. Brazil and the U.S. proposed recently that the seat go to Argentina, which I believe it still holds.

The OAS

Brazil has been a member, and a relatively strong supporter of the IANEC (Inter-American Nuclear Energy Commission) since the latter's creation in the late 1950s. It has held the chairmanship for two or more annual periods and has hosted both meetings and symposia organized under IANEC auspices.

The UN

Brazil has been represented on the UN Committee on the Peaceful Uses of Atomic Energy for a number of years.

UNESCO

Brazil's permanent representative to UNESCO, Paris, is a scientist: Carlos Chagas, mentioned above. The UNESCO-sponsored Latin American Physics Center (Centro Latino Americano de Física - CLAF) is headquartered in Rio de Janeiro at the Brazilian Physics Research Center (CBPF). The Center functions principally because of GOB support.

ICSU (International Council of Scientific Unions)

Brazil is a member of both ICSU, the parent organization, and of the specialized associate union, the International Union of Pure and Applied Physics (IUPAP), and is one of the most active LA countries in both.

Part IV: Conclusions and Recommendations

Conclusions: Brazil has a good basis in atomic energy. She has a number of fairly sophisticated research institutions and a reserve of trained manpower. She has at this time, however, neither atomic energy power plants nor the technology for the production of nuclear explosives, whether these would be for peaceful or military purposes.

Nonetheless, should the Government make the decision to go all out for this renewed status symbol, which has tremendous emotional appeal in Latin America, there is little doubt that it would make extraordinary progress in a relatively short period of time. Whether the GOB would make the decision on a technological basis to build a nuclear industry, constructed around nuclear power plants, but stop short of nuclear explosive capability, as did Canada, or make that decision on the political basis, as did France and the ChiComs, and not stop until she reached nuclear explosive capability, remains to be seen.

Brazil is the fifth largest nation in the world in size and eighth in population (China, India, Russia, the United States, Indonesia, Pakistan and Japan are larger, the latter two by a very small percent). She is our most important sister republic in the Americas, linked to us for a century and a half by common ties, mutual and complementary interests. Her outlook is global and she is growing in international stature day by day.

In the middle to late 1950s, USAID's predecessor agency, the International Cooperation Administration, had a Peaceful Uses of Atomic Energy Program in collaboration with the USAEC. With support provided under this program, some of Brazil's present nuclear energy authorities received training in U.S. institutions.(x) This program was phased out at about the same time that the USAEC program petered out. Since 1960, although we have provided some scientific research support as mentioned above -- which was for our own benefit also -- we have neglected Brazil in atomic energy matters. One net result is that she has turned elsewhere, particularly to France, and France has had an Atomic Energy Attaché stationed in Brazil for years. The U.K. is also courting her. She has not, however, yet turned to the USSR.

The possibility, however remote, that she may turn to that quarter should not be discounted, in the light of her newly independent (i.e. independence of the U.S.) attitude in her foreign policy announcements, reminiscent of the Janio Quadros actions in 1961, when he decorated "Che" Guevara, reestablished relations with the USSR, and sent his Vice President to visit the ChiComs. One straw-in-the-wind here might be the fact that she has agreed to the Trilateral arrangement on Atomic Energy Safeguards Inspections (U.S.-Brazil-IAEA) after steadfastly resisting our pressures in this direction for years. To my personal knowledge, one reason she resisted the IAEA arrangement before was because she was unwilling to commit herself to accepting IAEA inspectors, since the Agency might send Russians or other East European specialists on the team "and we might find it embarrassing to deny an IAEA inspector a visa."

Recommendations

1. That the United States reactivate at once its program of collaboration with the GOB in the field of atomic energy and in a manner commensurate with the political importance which the Mission attaches thereto.

2. That the Ambassador convoke a meeting of the country team, including representatives of all U.S. agencies knowledgeable about Atomic Energy.

(x) There were 20 Brazilian participants in this program.

or which might be involved, to elicit their comments and suggestions concerning the present announced Brazilian position and policy in atomic energy matters, and to formulate recommendations anent such an intensified collaborative program (POL, ECON, DAO, and SCIATT; USAID, including the USGS Mission: JBUSMC; USIS and possibly the USRSO).

3. That the Embassy maintain unrelenting pressure on the Department to urge the USAEC to station a permanent representative in Brazil at the earliest practicable moment.

4. That pending the arrival of said permanent representative, the USAEC send a top authority, preferably one of its five commissioners, to Brazil to enter into a meaningful discussion with Foreign Ministry and Nuclear Energy Commission officials on the extent and nature of the program, recommended in paragraph 1) above. A visit at this time by Chairman Seaborg could have a very telling effect and would certainly mitigate the hostile press attitude prevalent today, which depicts our attitude towards all non-nuclear powers, including Brazil, as repressive.

A final word. Time is of the essence. While we are endeavoring to obtain action at the Washington level, through an impressive number of telegrams, airgrams and recommendations for that action, Brazil is moving away from the U.S. Today is April 28, 1967. Tomorrow the Secretary General of the Foreign Office, Sergio Correia da Costa, and their permanent representative to the UN, Ambassador Sette Camara, will sign the Tlalteloico Latin America Nuclear Free Zone Treaty in Mexico City. They then proceed to Geneva to participate in the Non-Proliferation Treaty discussions there, which reopen May 9. En route, next week, they will visit France and Israel. At Geneva they will "ask for more technology" from the nations assembled there, according to O GLOBO headlines today.

Meanwhile, Government spokesmen, and every news media, press, radio, TV and magazines, hammer away at the Atomic Club, but principally at the U.S., and castigate us for condemning them to atomic servitude. Our reaction should be prompt and convincing.