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THE FRENCH NUCLEAR WEAPONS PROGRAM

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Scientific Intelligence Report

THE FRENCH NUCLEAR WEAPONS PROGRAM

NOTICE

The conclusions, judgments, and opinions contained in this finished intelligence report are based on extensive scientific intelligence research and represent the final and considered views of the Office of Scientific Intelligence.

[redacted]

13 November 1959

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

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THE FRENCH NUCLEAR WEAPONS PROGRAM

PROBLEM

To assess French capability to produce fissionable material and to develop, test, and produce nuclear weapons; and to estimate the likely timing of the first French nuclear weapons test.

CONCLUSIONS

1. France began research and development activities in atomic energy that had application for nuclear weapons about 1954. In 1958 France decided to complete the development and testing of a nuclear weapon and could test a nuclear weapon by November 1959. [redacted]

2. France has sufficient uranium ore available for its planned program and has in operation 3 reactors and a chemical separation plant for the production of plutonium. France probably had 15 to 25 kilograms of plutonium suitable for weapons purposes by July 1959 and could increase the production of plutonium to 100 kilograms a year by late 1960 and to about 550 kilograms of plutonium a year by 1965.

3. A gaseous diffusion plant is being built at Pierrelatte and should enable the French to produce uranium enriched in U-235 to about 3 percent by 1962. Uranium highly enriched in U-235 (suitable for weapons use) could be produced in small quantities by 1965.

4. The French nuclear weapons test site headquarters is located at Reggane in the Sahara Desert, and the test range is believed to be about 60 miles almost due south of Reggane. The first test will probably be a 300-foot tower shot of an all-plutonium implosion weapon yielding about 20 kilotons.

SUMMARY

In 1952 after several years of basic research, the French introduced a 5-year plan for atomic energy development. The major aim of this plan was the establishment of a large plutonium production facility. Such production indicates a general intention to develop nuclear weapons, but weapons development did not receive public support and high priority until 1958. Now the French apparently intend to conduct a test regardless of any East-West test ban agreement by the present nuclear powers.

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Construction work on the plutonium production center, begun in 1954 at Marcoule in the Rhone Valley near Avignon, was completed in mid-1958. The major facilities at Marcoule are three natural uranium, graphite moderated reactors and a chemical separation plant for the separation of plutonium from irradiated uranium. The French probably had obtained about 15 to 25 kilograms of plutonium from these facilities by mid-1959. When in full operation, probably late in 1960, the Marcoule center will be able to produce approximately 100 kilograms of plutonium per year. The production of plutonium could be increased to about 550 kilograms per year by 1965 upon completion of the announced nuclear power reactor program. The present French nuclear weapons capability is limited to those weapons using plutonium as the basic fissionable material.

In mid-1957 the French decided to incur the large expense of building their own gaseous diffusion plant for the production of enriched uranium. A full scale gaseous diffusion plant is being erected at Pierrelatte, 15 miles south of Montelimar on the Rhone River. Plans call for the plant to be in partial operation in 3 years and in full production in 4 years producing a product enriched in U-235 to about 3 percent. Additional stages may be added to the plant later to secure a product of higher enrichment suitable for weapons purposes.

Nuclear weapons research and development was carried on for several years before the French publicly announced their intentions to proceed with the actual fabrication and testing of nuclear weapons. The French have actively sought information and support in nuclear weapons design and test instrumentation from the United States and United Kingdom but the support received has been limited largely to unclassified information and test equipment. Therefore, the first French weapons will be the product of an almost completely native effort.

Little information is available on actual French nuclear weapons research and development, and the principal scientists involved have never been identified. It is believed that the *Department de Techniques Nouvelles* (DTN) of the French *Commissariat a l'Energie Atomique* (CEA) has responsibility for the overall development of nuclear weapons. The centers at Bruyere-le-Chatel, Vaujours, Saclay, and Paris (Fort d'Issy) may be doing research and development on the non-nuclear components of nuclear weapons under or for the DTN. The French have had sufficient time to develop or acquire the non-nuclear components for these weapons. Because only small quantities of plutonium are available at the present time, it is likely that the first nuclear weapon to be tested by the French will be an implosion type.

The weapons tests have been delayed by a combination of technical difficulties in acquiring fissionable material. Although the chemical separation plant was completed in July 1958, it did not reach production scale operations until about January 1959, and weapons grade plutonium did not become available until the summer of 1959. [redacted]

DISCUSSION

INTRODUCTION

From the beginning of the French nuclear energy program in October 1948 until about 1955, the French government and the majority of the French people were strongly opposed to the development of nuclear weapons by France. Nevertheless, since 1952 (the beginning of the first 5-year plan for nuclear energy), rapid development of nuclear research has taken place in France, and certain

[redacted]

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sections of the military have claimed since 1954 that the French need a nuclear bomb for adequate defense. Some preliminary weapons research may have been started in 1954. By 1956 France had the economic and technological capability to proceed with the development of nuclear weapons.[1,2] Apparently the decision to proceed with the manufacture of nuclear weapons came after the humiliating Anglo-French withdrawal from Suez in November 1956. Since General de Gaulle came to power in June 1958, his determination to increase French stature and independence in NATO and the increased feeling among military and government officials of a need for a native nuclear deterrent to protect vital French interests have made it highly probable that France will proceed with the manufacture and testing of nuclear weapons regardless of any East-West test ban agreed upon by the present nuclear powers.

AVAILABILITY OF URANIUM

France obtains most of its uranium from domestic sources, although small quantities are imported from Madagascar, a French possession. Major uranium deposits are located at La Crousille near Lemoges, Vendee in Brittany, Grury in Saone et Loire, Fores, and possibly at Lachaux, southeast of Vichy. Extensive exploration for new deposits is carried out throughout France, Algeria, Madagascar, and French West Africa. French proven reserves of uranium oxide amount to 10,000 tons with possible unproven reserves of from 50,000 to 100,000 tons. Present French production of uranium oxide amounts to 600 to 700 tons per year with a planned production of 1,000 tons by 1961, 2,500 tons by 1970, and 3,000 tons by 1975. Thus, France should be capable of meeting the uranium requirements of its planned reactor program from native sources.

PLUTONIUM PRODUCTION

The first French research reactor (Zoe) began operation at Chatillon in late 1948. Basic research on the extraction of plutonium from uranium was undertaken concurrently, and by 1950 the first milligrams of plutonium in the form of a purified salt had been obtained. [redacted] it was decided to construct a pilot plant at Chatillon for the extraction of plutonium from irradiated uranium.[3] The pilot plant was completed in early 1954 by the St. Gobain Chemical Company (*Manufactures des Glaces et Produits Chimiques de St. Gobain*). This pilot facility is a solvent extraction plant using mixer-settlers, and by January 1955 about one gram of plutonium had been extracted from the uranium rods taken from the Zoe reactor.[4]

Apparently the decision was made about 1952 to follow the "plutonium path" and acquire plutonium in quantities sufficient for weapons, since the 5-Year Plan called for the establishment of a large plutonium production center. Preliminary studies were made, and actual construction of the plutonium production facility was begun in 1954 at Marcoule, in the Rhone Valley near Avignon. The major facilities at Marcoule include three natural uranium, graphite moderated, gas-cooled reactors and a chemical separation plant. The reactors are designed primarily to produce plutonium, with electric power being a by-product.

The first of these plutonium producing reactors, G–1, went into operation on 7 January 1956. It has a designed power level of 40 thermal megawatts and is generally similar to the U.S. Brookhaven pile. Since September 1956 the reactor has been running at only about 35 thermal megawatts because of difficulties encountered from fuel element rupture.[5] The annual production of plutonium by the G–1 reactor was expected to be about 15 kilograms, but because it is operating at reduced power levels, it is not expected that this production rate will be achieved. The first set of fuel rods were irradiated in G–1 during 1956–57 and removed in December 1957.[6] An experimental power generator was installed at G–1 by *Electricitie de France* for the production of electricity. The generator has a maximum installed power of about 5 electrical megawatts, and it first produced electricity in the fall of 1956.

[redacted]

[redacted]

The second and third reactors at Marcoule, G–2 and G–3, are of identical design. They are natural uranium reactors, using graphite as a moderator, and are cooled by pressurized carbon dioxide. G–2 went into operation on 21 July 1958 and by April 1959 had attained a power level sufficient to produce 9 megawatts of by-product electricity. At full scale operation, it will have a power level of about 150 thermal megawatts, permitting the production of about 40 kilograms of plutonium per year and 25 to 30 megawatts of by-product electricity. G–3 went into operation in June 1959, and it is expected that the power level will be increased progressively until it is in full scale operation sometime in 1960. When the three reactors at Marcoule are in full operation, the annual plutonium output will probably be about 100 kilograms. In addition, some 65 megawatts of electricity will be generated. The accompanying table shows the estimated plutonium production capacity of the French reactors at Marcoule.

The first French nuclear power station is under construction at Avoine, just north of Chinon. It is scheduled to start operating in 1960. This reactor, called EDF–1, is a graphite moderated, gas-cooled reactor and will have an estimated electrical output of 60 megawatts. Construction of additional power reactors is planned, and current goals call for 850 MW of installed capacity by 1965. All of the nuclear power reactors will produce significant quantities of plutonium as a by-product. Upon completion of the announced nuclear power program, French reactor facilities should have the capacity to produce about 550 kilograms of plutonium per year.

PLUTONIUM EXTRACTION

Construction work on the Chemical Separation Plant at Marcoule was begun in 1955, and the plant was inaugurated in July 1958 by General de Gaulle. It is a Purex-type solvent extraction plant for plutonium and uranium recovery. The overall process employs mixer-settlers and utilizes tributyl phosphate as the solvent and nitric acid as the salting agent. The plutonium product is an oxalate salt that is converted to metal at an adjacent plutonium metal reduction facility. In spite of earlier pilot plant work at Chatillon, considerable delay apparently was encountered in getting the separation plant into operation. The nature of the trouble is unknown, [redacted] Kilogram quantities of plutonium probably did not become available for weapons development purposes until the summer of 1959.

URANIUM ISOTOPE SEPARATION

As the French nuclear program developed, it became clear that the possession of U–235 was essential. Research on isotope separation was initiated at Saclay by 1955, and in 1957 the first of two pilot plant facilities was begun. The first Saclay pilot plant was a 12-stage installation used to test gaseous diffusion barriers. Barriers could be tested in both tubular and flat shapes. The second plant at Saclay was larger and contained 16-stages of prototype cells of a type planned for the first full-scale plant.[8]

In 1957 the CEA also secured an appropriation of 25 billion francs ($71,350,000) * for initial construction work on a full scale gaseous diffusion plant. France attempted to interest the EURATOM partners in joint construction of this full scale gaseous diffusion plant. Only the Italians showed interest; they are reported to have offered tentatively about $20 million toward the project. Finally, France decided in 1958 to incur the expense of building its own plant. Ground was broken for this facility in the fall of 1958 at Pierrelatte, 15 miles south of Montelimar, between two hydroelectric dams on the Rhone River. The total cost of the installation is to be around 55 billion francs ($156,970,000).[9]

Plans call for the plant to be in partial operation in 3 years and to be in full production in 4 years. The plant is expected to treat about 350 tons of natural uranium per year, producing 500 to 700 kilograms of product enriched in U–235 to about 3 percent. This product will be suitable for increasing the efficiency of French reactors but not suffi-

* Conversion rate: 1 franc=$.002854.

[redacted]

[redacted]

[redacted] TABLE

ESTIMATED FRENCH PLUTONIUM PRODUCTION AT MARCOULE *

OPERATING CAPACITY IN THERMAL MEGAWATTS (TMW)

	Design Level	Start-up Date	Calendar Year 1956	1957	1958	1959	1960	1961	1962	1963	1964
G-1 Reactor	40	Jan 56	10 (avg)	34	34	34	34	34	34	34	34
G-2 Reactor	150	Jul 58	—	—	50	150	150	150	150	150	150
G-3 Reactor	150	Mid-59	—	—	—	50	150	150	150	150	150
Total TMW (year end)			10	34	84	234	334	334	334	334	334

PLUTONIUM PRODUCED IN IRRADIATED REACTOR FUEL (in kilograms)

	1956	1957	1958	1959	1960	1961	1962	1963	1964
G-1 Reactor	3	10	10	10	10	10	10	10	10
G-2 Reactor	—	—	15	45	45	45	45	45	45
G-3 Reactor	—	—	—	15	45	45	45	45	45
Total Annual Pu Production	3	10	25	70	100	100	100	100	100
Cumulative Pu Production (year end)	3	13	38	108	208	308	408	508	608

ESTIMATED PLUTONIUM EXTRACTED FROM IRRADIATED FUEL (in kilograms)

	1956	1957	1958	1959	1960	1961	1962	1963	1964
G-1 Reactor	—	—	7	10	10	10	10	10	10
G-2 Reactor	—	—	—	15	45	45	45	45	45
G-3 Reactor	—	—	—	—	15	45	45	45	45
Total Plutonium Extracted	—	—	7	25	70	100	100	100	100
Cumulative Pu Extracted (year end)	—	—	7	32	102	202	302	402	502

* Assumptions:

1. 300-day operating year for each reactor.
2. Irradiation level for G-1 to end of 1957 was at 130 grams of plutonium per ton of fuel, and there was a 50 percent unloading of G-1 at end of 1957.
3. Irradiation level for each reactor after 1957 was at 200 grams of plutonium per ton of fuel.
4. Intake of irradiated slugs at the Chemical Separation Plant was 5 tons per day.
5. U-235 to plutonium conversion ratio was 0.77.

[redacted]

[redacted]

ciently enriched for weapons. Plans are being considered, but no decision has been made as yet, for building additional stages to secure a product of higher enrichment suitable for weapons purposes. Papers presented by the French at the Second U.N. Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958, and reports by U.S. scientists who have visited the Saclay pilot plant indicate that the development work on gaseous diffusion has been very sound. Three types of barrier (alumina, nickel, and teflon) have been developed by the French, but it is not known which of these will be used in their full-scale plant.

WEAPONS RESEARCH AND DEVELOPMENT

Nuclear weapons research has been carried on in France for the past 4 to 5 years.[10] [redacted] Officially, the DTN is organizationally subordinate to the French *Commissariat a l'Energie Atomique* (CEA) and has the responsibility for the development of nuclear weapons, yet it appears in fact to be a joint CEA-National Defense organization with policy direction given by a special nuclear committee within the French Government. The following organizations are probably doing research and development on nuclear weapons under or for the DTN.

a. Research Center of Bruyere-le-Chatel (*Centre d'Etudes de Bruyere-le-Chatel*), located near Arpajon (Seine-et-Oise), was created in 1955 and is directed by Mr. (fnu) Laurent.[11] It has been reported that this center does theoretical and applied studies of the critical mass of nuclear explosions and prepares models of weapons.[12]

b. Armament Research and Manufacturing Directorate (*Direction des Etudes et Fabrications d'Armament*), DEFA, is a French Army organization which in collaboration with the Powder Service (*Services de Poudres*) is reported to have done research and development of detonators.[13 14] The electronic laboratories of DEFA are located at Fort d'Issy, and the headquarters of the chemical section of DEFA are located at St. Cloud. The DEFA also has an atomic section, which is headed by Professor Paul Chanson, reported to be one of the guiding lights for the construction of an atomic bomb.[15]

c. Nuclear Research Center at Saclay is reported to conduct theoretical studies on critical masses and studies of neutron reflectors.[12] Saclay is the largest research center in the French nuclear program.

d. Research Center at Vaujours (*Centre d'Etudes a Vaujours*), is located at the military fort of Vaujours, east of Paris, and is directed by Engineer-in-Chief Barguillet.[11] It began to function in 1956 [redacted]

NUCLEAR WEAPONS TESTING

After assuming power in 1958, General de Gaulle made it known that he was anxious for France to conduct a nuclear test as soon as possible,[17] but technical difficulties apparently caused significant delays in the acquisition of plutonium suitable for weapons purposes. These difficulties were largely with chemical separation and "dirty plutonium." * [redacted][18] Although the Marcoule chemical separation plant was completed in July, 1958, it did not start production scale operation until January 1959 because of unidentified operational difficulties. This time scale indicates that there would not be sufficient plutonium for weapons fabrication before mid-1959.

Because of the limited quantities of plutonium metal available to the French, their first nuclear weapon probably will be of the implosion type. The French nuclear weap-

* "Dirty plutonium" is that considered less suitable for weapons purposes either because of residual contaminants left by the chemical separation process or the presence of too high a percentage of Pu-240 (as opposed to Pu-239).

[redacted]

[redacted]

[redacted]

ons capability will be limited to weapons using plutonium, unless they are provided with fully enriched U–235 by the United States or United Kingdom or decide to enlarge the isotope separation plant presently under construction (now scheduled to produce only slightly enriched uranium). They probably could not have the capability for producing highly enriched U–235 before 1965. Highly enriched U–235 would be necessary to develop composite weapons, including the more advanced types.

The French could conduct a nuclear test by November 1959, [redacted] The French test will probably be a 300-foot tower shot yielding about 20 kilotons.[19] Possibly more than one test will be conducted.

[redacted]

[redacted] The French probably desire to make their first test as sophisticated as possible in order to meet the legal requirements for securing an exchange of weapons information from the United States.

Reggane in the Sahara (26°42′N; 01°10′E) is the headquarters for French test operations.[21] A new interservice test center was scheduled for completion near Reggane in the fall of 1958.[22] The commander of this center was to be a French Air Force colonel, whose superior was Army Brigadier General Charles Ailleret, Chief of Special Arms of the French Armed Forces. An airstrip constructed at Reggane and a major airfield at Aoulef, some 50 miles northnortheast, make the airlift of supplies and personnel feasible.[23] The test range is believed to be 60 miles almost due south of Reggane in a remote part of the Sahara.

[redacted]