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French Nuclear Reactor Fuel Reprocessing Program

An Intelligence Assessment

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September 1984
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French Nuclear Reactor Fuel Reprocessing Program

An Intelligence Assessment

This report was prepared by [redacted] Office of Scientific and Weapons Research. Contributions were made by the Office of Imagery Analysis and the Office of Global Issues. [redacted]

Comments and queries are welcome and may be directed to the [redacted] OSWR, [redacted]

Secret
SW 84-10057
September 1984

French Nuclear Reactor Fuel Reprocessing Program

Key Judgments

Information available as of 15 August 1984 was used in this report.

France is committed to developing an economy in which nuclear energy is the major source of electrical power. This commitment has led France to develop a large-scale program for commercial reprocessing of domestic-origin spent nuclear fuel. This program is conducted by a subsidiary of the French atomic energy agency. The reprocessing effort reduces the requirements for uranium while providing a source of plutonium. The plutonium is needed for fuel for fast-breeder reactors, a key part of France's future energy developments.

France's desire to obtain the maximum benefit from its nuclear technology, combined with its position as the most technologically advanced Western nation in commercial reprocessing, has led it to seek contracts for reprocessing foreign-origin nuclear fuel. Until the 1990s when the United Kingdom is scheduled to start a large commercial reprocessing plant, France will virtually control commercial reprocessing in the West.

France's commitment to reprocessing will continue to result in a series of conflicts with the United States because France (as well as other West European nations and Japan) wants recovered plutonium for fast-breeder reactors. This, in turn, will almost certainly lead to US questions about the adequacy of security of the plutonium against theft or diversion during transport, storage, and fabrication. The United States can prohibit the transfer of any plutonium recovered from US-origin fuel. (Most foreign-origin fuel reprocessed in France has been of US origin.) A shipment of plutonium from France to Japan has been delayed significantly because of US concerns about the security of sea shipment.

France's overall commitment to nuclear energy has important benefits. France is widely seen, at least by Europeans, as the only country with a long-term commitment to nuclear power. This is a critical factor in the sale of nuclear power plants, which require 10 years to build and have a 20-year operating life.

We believe that by the end of 1985 France will be using civilian gas-cooled reactors to meet most of its military requirements for plutonium. (France's last large dedicated military production reactor will be retired that year.) The potential production capacity of France's civilian reactors far exceeds any likely military requirement.

France's official policy prohibiting construction of reprocessing plants for foreign countries and/or transfer of reprocessing technology is not likely to change. We believe, however, that some French suppliers will continue to circumvent the official government policy and attempt to sell prohibited pieces of equipment.

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French Nuclear Reactor Fuel Reprocessing Program

Technical Foreword—Reprocessing

In an ideal nuclear power reactor the nuclear fuel would remain in the core until all fissile isotopes were completely consumed. However, practical considerations force removal of the fuel long before this happens. Limiting factors include the buildup of neutron-absorbing fission products and the degradation of the fuel and cladding from heat, pressure, and radiation. Relatively large quantities of nuclear fuel must be replaced annually. For example, about 26 tons of irradiated fuel are replaced each year in a 900-megawatt electrical (MWe) pressurized water reactor. The fuel used in the reactor is zirconium-clad uranium oxide enriched to about 3.2 percent in the uranium-235 isotope. The irradiated fuel is still mostly (about 96 percent) uranium oxide, but the uranium-235 content is reduced to about 0.9 percent. (Natural uranium contains 0.72 percent uranium-235.) Each ton of the discharged fuel also contains about 9 kilograms of reactor-grade plutonium, created by neutron absorption in uranium-238, and about 100 million curies of radioactive fission products.

Reprocessing the irradiated fuel allows the uranium to be recycled, reducing natural uranium consumption by 20 percent, and recovers the plutonium. Plutonium is fissile and is the fuel of choice for use in fast-breeder reactors where it is used to produce both electric power and more plutonium. Reprocessing also reduces the volume of high activity and long-lived fission products, a potential benefit in radioactive waste management.

Introduction

The French Government has enormous influence over the French nuclear industry. As is shown in figure 7, at back, the government, through the Commissariat a l'Energie Atomique (CEA) and Electricite de France, owns a significant part of all the companies involved in the French nuclear program. Compagnie Generale des Matieres Nucleairs (Cogema), which conducts all reprocessing, is a subsidiary of the CEA. The commitment of France to developing an economy in which nuclear energy is the major source of electrical power appears to transcend politics. Although President Francois Mitterrand pledged to scale down the nuclear program during the campaign that gave France its first Socialist government in more than two decades, developments since May 1981 make it clear that there will be no significant changes in the ambitious domestic nuclear program. Mitterrand quickly concluded that the political and economic costs of a major reduction would be far too high and is proceeding with the program formulated under former President Giscard. Opposition to France's nuclear program comes from environmentalists and a few other antinuclear groups, but these groups are so few in number as to have essentially no impact on France's centralized decisionmaking process.

France plans to meet its nuclear power goal with a combination of natural uranium fueled gas-cooled reactors, reactors fueled with low enriched uranium, and plutonium fueled fast-breeder reactors. The possibility of reducing uranium requirements coupled with the necessity of obtaining plutonium for fast-breeder reactors has made spent fuel reprocessing a key element in the French nuclear energy program. Because of France's long-term commitment to reprocessing, it has surpassed all other Western nations in the application of reprocessing technology. This success, combined with France's desires to obtain the maximum benefit from its nuclear technology, has led France to actively promote and market nuclear fuel reprocessing, an activity that the United States is trying to discourage because of its proliferation potential.

In France, military and civilian reprocessing operations are fully integrated (figure 1). Activities at the reprocessing centers at Marcoule and Cap de la Hague can be divided into three basic activities:

- Recovery of weapons-grade [1] plutonium from fuel irradiated in dedicated military production reactors for the French nuclear weapons program.
- Recovery of reactor-grade [1] plutonium from fuel irradiated in French power reactors for the French fast-breeder reactor program.
- Reprocessing foreign-origin fuel under contract for other European countries and Japan.

Production of Plutonium for Weapons Use

France's experience in nuclear reactor fuel reprocessing began with its plutonium production program for nuclear weapons at Marcoule under the military arm of the Commissariat a l'Energie Atomique (CEA). The French constructed three gas-cooled production reactors (G-1, G-2, and G-3) at Marcoule. These reactors were dual purpose, producing both plutonium and electricity. Of these reactors, only G-3 remains in operation and it is scheduled to be decommissioned in July 1985. The French also built two heavy water reactors (Celestine 1 and 2) for tritium production. (The French needed tritium in quantity to produce smaller, more efficient weapons with more predictable yields.) With the decommissioning of G-1 and G-2, the Celestine reactors have been converted to plutonium production. (They probably also produce small amounts of tritium.) Since the start of operation in 1958, Marcoule has reprocessed over 10,000 tons of irradiated production reactor fuel and recovered over 2.5 tons of plutonium for weapons use. Retirement of G-1, G-2, and G-3 will reduce France's plutonium production capability by over 50 percent. Further, with the Celestine reactors making plutonium, France has no way to make tritium in quantity.

[1] The presence of the isotope plutonium-240 creates problems for weapons designers. These include possible degradation of nuclear yield, irradiation of personnel, and heating problems that can create undesirable stress in weapon components. As a result, weapons designers limit the amount of plutonium-240 in plutonium used in weapons. The French appear to have selected 7-percent plutonium-240 as an upper limit for weapons use. Normal irradiated power reactor fuel contains over 20 percent plutonium-240. It is impractical to remove the plutonium-240 using any isotope separation process currently available. To achieve 7-percent plutonium-240, the French must limit the irradiation level of the fuel. This, in turn, requires much more frequent refueling and much more uranium fuel than an operation in which plutonium-240 content is not a concern.

State Department reporting indicates that the French are retaining the option to use civilian natural-uranium fueled or fast-breeder reactors to meet their requirements for weapons-grade plutonium. The French will need additional plutonium for weapons if they decide to produce more nuclear warheads and/or to modernize existing nuclear weapon systems. The French have already used the Phoenix prototype fast-breeder reactor to produce some weapons-grade plutonium. In addition, they may shift the power reactors Chinon-2 and/or Chinon-3 to plutonium production and could also adapt the St. Laurent-1 and St. Laurent-2 reactors to produce weapons-grade plutonium.

Reprocessing Power Reactor Fuel

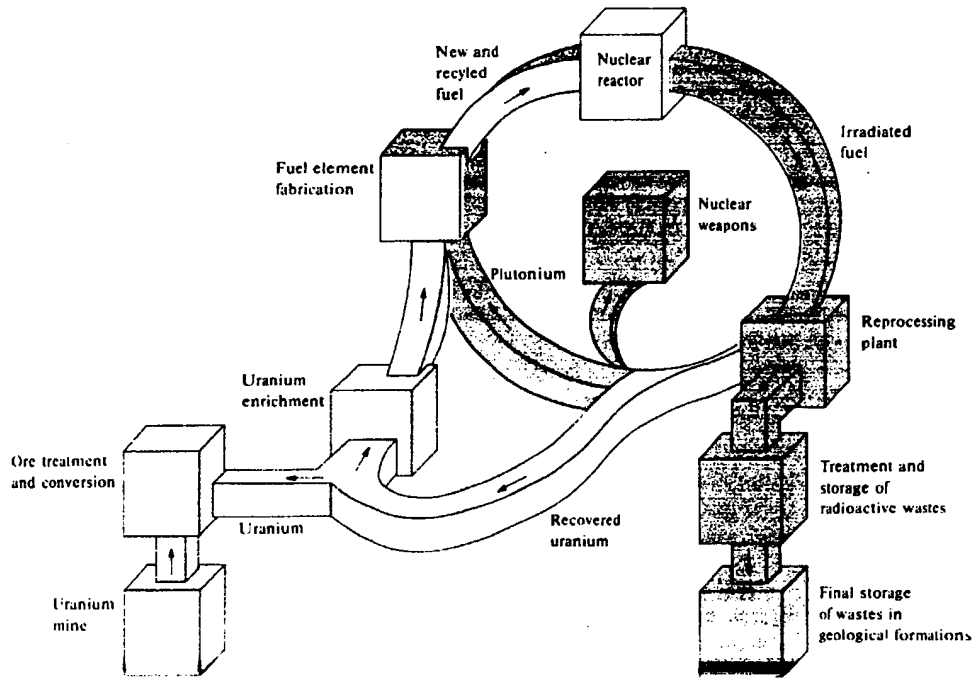
Gas-Cooled Reactor Fuel

The CEA used the Purex process in its first commercial-scale plant, the Usine Plutonium Plant No. 1 (UP1) at Marcoule (figure 2) and have continued to develop and refine this process in all subsequent French reprocessing facilities. The Purex process recovers separate streams of plutonium and unburned uranium from irradiated material (figure 3). Early modifications to the UP1 plant allowed it to reprocess spent fuel from gas-cooled power reactors (GCR),[2] as well as material from the earlier plutonium production reactors developed for the weapons program.

The UP1 plant, nevertheless, was unable to handle the increasing volume of GCR fuel that was being discharged in the 1960s. The CEA, therefore, constructed an additional plant, the UP2, at Cap de la Hague near Cherbourg. With a nominal capacity of 800 metric tons per year (mt/y), UP2 began operations in 1967 and by 1983 had reprocessed over 4,300 mt of gas graphite fuel, according to statements by French officials. In total, UP1 and UP2 have reprocessed about 6,000 mt of GCR. (This is in addition to the 10,000 mt of gas-cooled production reactor fuel reprocessed at UP1.) The plutonium recovered from the power reactor fuel, almost 9 mt, is allocated for use as fast-breeder reactor fuel.

[2] Gas-cooled, graphite-moderated reactors were an early choice as power reactors in France and elsewhere. They use natural uranium metal fuel rods with a magnesium alloy cladding known as GCR fuel.

Figure 1
The Nuclear Fuel Cycle



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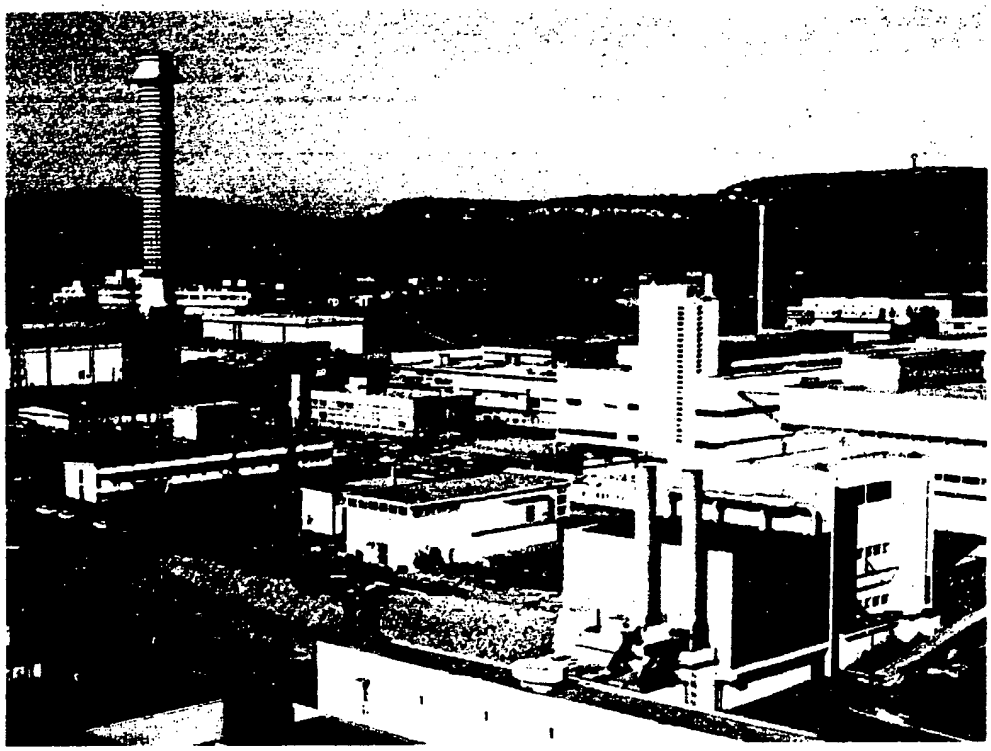

Figure 2. UP1 Reprocessing Plant, Marcoule

Light-Water-Power Reactor Fuel

In 1969 the government-controlled utility, Electricite de France (EDF), switched from gas-cooled power reactors to a Westinghouse-designed pressurized water reactor (PWR) for all future power reactor construction, and new reprocessing procedures had to be introduced to handle the spent fuel. The CEA accomplished this by adding a special head-end onto the existing UP2 plant at La Hague (figure 4) between 1972 and 1976 and modifying some of its equipment. Known as the high-activity oxide (HAO) facility, the head-end included new unloading, storage, shearing, and dissolving units designed to handle light-water-reactor (LWR) fuel. After 10 months of operation, the French openly stated that the nominal capacity for the plant was 400 mt/y of uranium.

When HAO began operations in 1976, the UP2 plant became a dual-use facility capable of reprocessing either gas-cooled or light-water-power reactor fuel. At that time, the CEA transferred ownership of the La Hague site to the newly formed Compagnie Generale des Matieres Nucleaires (Cogema).

As figure 5 indicates, the HAO/UP2 plant has yet to reach 50 percent of its rated capacity for LWR fuel (400 mt/y). According to published reports, the poor performance was attributed to a number of problems related to the physical characteristics and high radioactivity of LWR fuel, including numerous equipment

failures and accidents. Scheduling problems also cut into the time available for reprocessing LWR fuel at La Hague; spent GCR fuel received first priority because of its tendency to corrode quickly. In 1980, for example, the UP1 at Marcoule and the UP2 at La Hague each were reprocessing about 250 mt/y of this type of fuel. After the period 1984-85, a new plant now under construction at Marcoule, the MAR-400, is scheduled to reprocess all the GCR fuel, freeing La Hague to reprocess LWR fuel exclusively.

The performance of the HAO/UP2 plant has improved significantly as the French learned to handle LWR fuel. By mid-1983, the plant had reprocessed over 700 mt of fuel and was reportedly operating at rated capacity. The French boast that more LWR spent fuel has been processed successfully at their plants than at a combination of all Western plants ever operated. They are likewise proud that they have the only plant now operating in the West that is capable of reprocessing LWR fuel.

New Plant Construction

Open-source reporting indicates that the French realized in the mid-1970s that they would need additional plant capacity to reprocess spent fuel resulting from their rapidly expanding nuclear power program. A Cogema report acquired from a third party indicated that engineering studies completed in 1979 showed that two 800-mt/y plants should be built at La Hague. By that time the French were also under contract to reprocess foreign fuel. According to published information, the HAO/UP2 plant in fact already was reprocessing foreign fuel and by mid-1983 had reprocessed fuel from 12 European and Japanese power reactors.

Expansion at La Hague is well under way. The HAO/UP2 plant is being enlarged and will be known as the UP2-800. It will be devoted entirely to reprocessing domestic-origin spent PWR fuel. Scheduled for startup in 1988, the UP2-800 plant probably will be about six months to a year late. At that time the HAO facility will be closed down permanently.

The other new plant will be a completely new installation, known as the UP3, also an 800-mt/y plant. It is targeted for completion by 1987, but based on past experience we estimate it also will be about six months to a year late. The UP3 plant will reprocess foreign fuel under contracts with Cogema. After 1997 or 10 years after startup, the plant will revert to reprocessing French-origin fuel. At present, the French have no plans to construct future new plant capacity for foreign fuel.

Commercial Spent Fuel Reprocessing Contracts

A considerable amount of information on the French domestic and foreign reprocessing contracts was obtained from an acquired Cogema report. Other data were obtained primarily from open sources. The contracts have evolved over the years, reflecting changes in French economic, political, and technological perceptions regarding nuclear fuel reprocessing.

Domestic Contracts

The first contracts were fixed-price, continuing contracts written in the 1960s between Electricite de France (EDF) and the CEA to reprocess GCR fuel. The contracts were taken over by Cogema in 1976 and are updated every three years to reflect cost increases. EDF retains ownership of the waste. About 500 mt/y of GCR fuel from the Chinon-2 and Chinon-3, the St. Laurent-1 and St. Laurent-2, and the Bugey-1 GCRs are reprocessed. A similar contract provides for reprocessing GCR fuel from the Spanish Vandellos reactor supplied by the French in 1972.

After the switch to pressurized-water-power reactors, Cogema contracted to reprocess all the PWR spent fuel from EDF light-water-power reactors under a cost-plus contract. Included is fuel from the Chooz PWR owned by the Ardennes Nuclear Energy Company. All other light-water-power reactors in France are owned by EDF.

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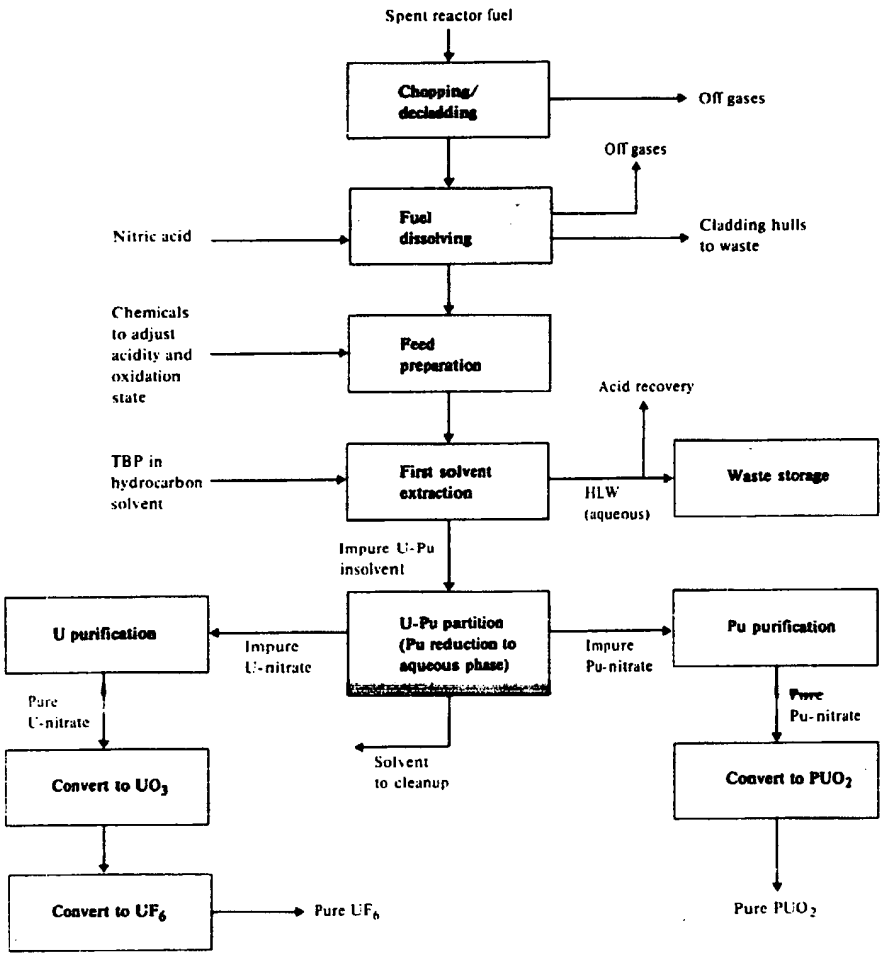
Figure 3
The Purex Process[a]



[a] Purex is an acronym for plutonium-uranium-extraction

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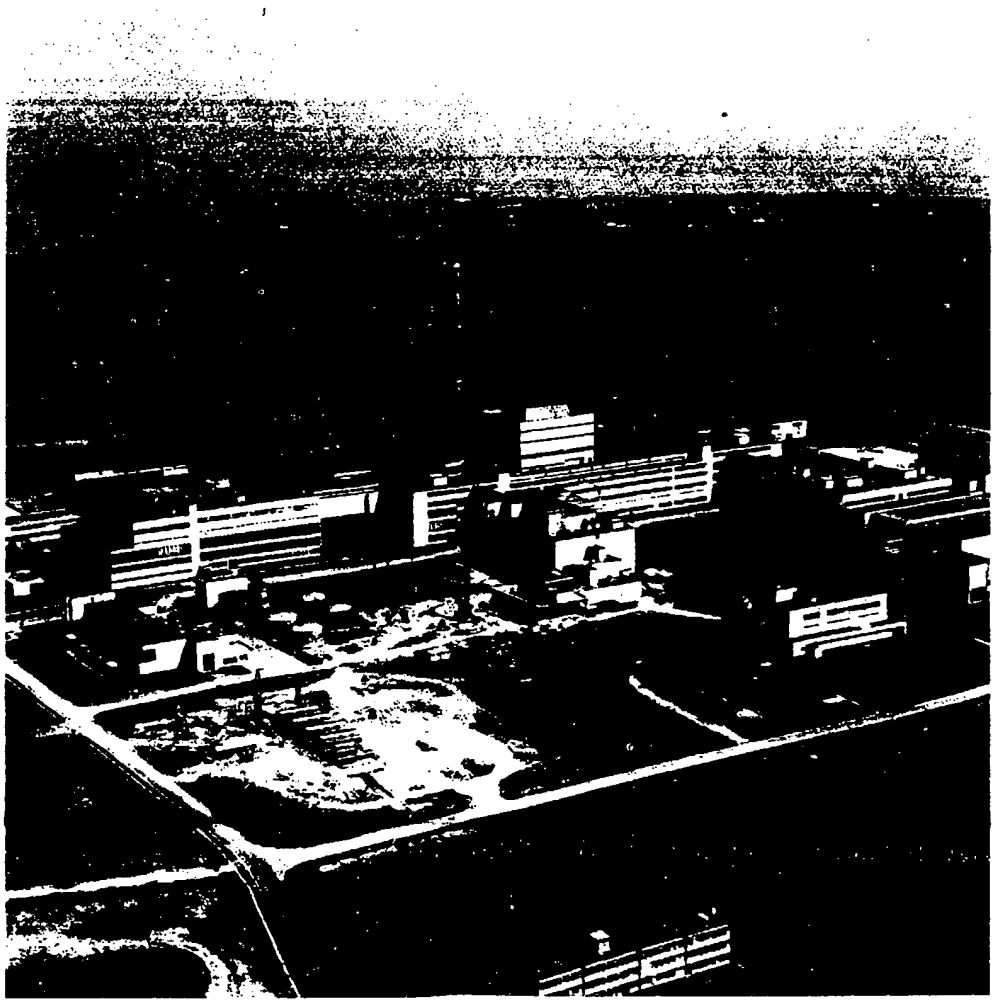

Figure 4. UP2 Reprocessing Plant, Cap de la Hague

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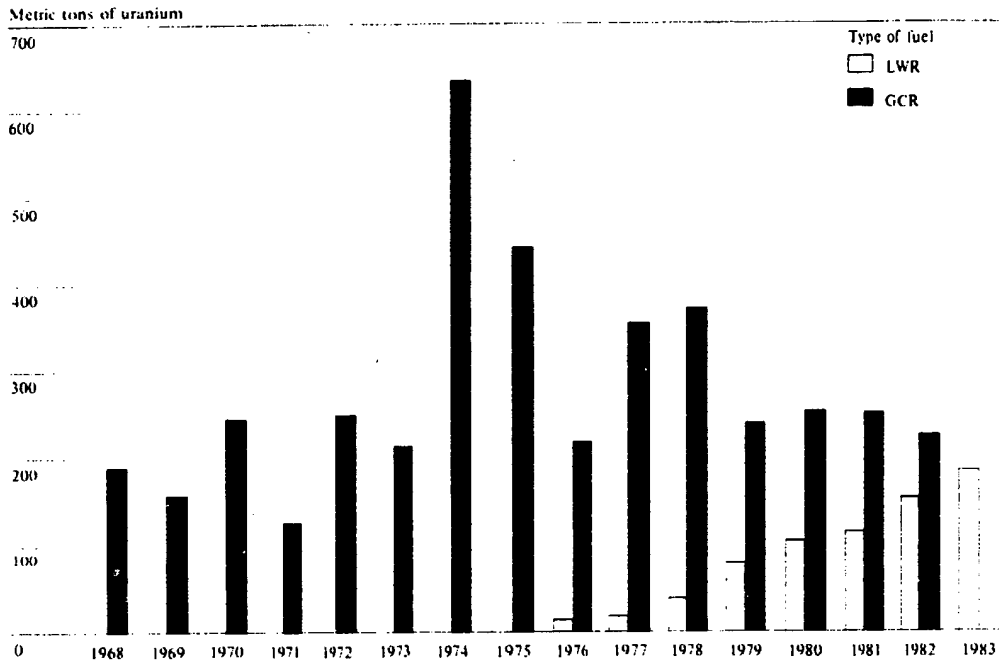
Figure 5
Cap de la Hague Reprocessing Plant
Record of Production Since 1968



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These contracts allow Cogema to recover operating costs but not to finance plant construction. The Cogema report states that the contract with EDF calls for a total of 5,344 mt of PWR fuel to be delivered to the UP2/UP2-800 plant through 1989. The price charged per kilogram of uranium reprocessed is revised each year. EDF pays a fixed installment when the spent fuel is delivered into the reprocessing plant and a final installment when the recovered uranium and plutonium are made available by Cogema.

Foreign Contracts

In the period 1971 to 1974, the United Reprocessors GmbH [1] negotiated spent power reactor fuel reprocessing contracts with foreign utilities on behalf of the

[1] United Reprocessors GmbH was formed in 1971 under West German law with joint ownership by the French CEA, British Nuclear Fuels Ltd (BNFL), and a West German consortium—Kernbrennstoff-Wiederaufarbeitungs-Gesellschaft mbH (KEWA). Its purpose was to market spent power reactor fuel services on behalf of the plants then expected to be built in each country.

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French CEA. These contracts covered a total of 514 mt of fuel from 15 light-water-power reactors owned by 10 foreign utility companies. They were fixed-price, guaranteed-delivery contracts and provided that the reprocessor would retain the waste at no cost, because at that time the French believed that commercially valuable radioactive isotopes might be recovered. Later the CEA was able to revise two contracts to provide the return of the wastes to the customer, thus reducing French obligations to retain the wastes from only 297 mt of spent fuel (about 9 mt of actual waste).

After 1976 Cogema assumed responsibility for all French reprocessing contracts with foreign customers. A new standard contract in the 1977 to 1979 time frame covered the reprocessing of 713 mt of foreign LWR fuel for 12 utilities representing 20 power reactors. These contracts call for higher prices to finance about 20 percent of the construction costs of the UP2-800 plant and no guaranteed delivery date. The customer retains ownership of the waste and must take it back after 1990 or pay a penalty for further storage.

Current contracts covering foreign LWR fuel to be reprocessed in the UP3 plant cover 6,000 mt of fuel from 70 power reactors owned by 30 utilities in six foreign countries (figure 6). According to plan, spent fuel began arriving in France in 1981 and will continue until 1990. The customers are paying, partly in advance, for the construction of the UP3 plant in return for 10 years of its use. Cogema, nevertheless, retains sole ownership. The customer also pays for plant operating costs including spent fuel storage costs and waste treatment in proportion to the amount of fuel reprocessed. Japanese utilities loaned Cogema 600 million French francs ($141 million) in 1979 toward construction of the second of two waste vitrification plants on the site. Repayment is to be in the form of reprocessing services. As the UP2-UP3 complex at Cap de la Hague will be the only commercial-sized reprocessing plant in Western Europe until the 1990s, France virtually will control commercial reprocessing in the West for at least the next 10 years.

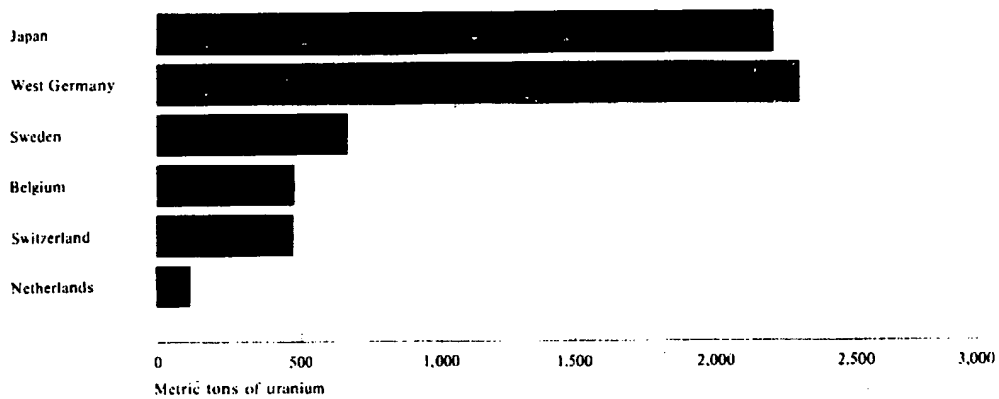
All of the uranium and plutonium recovered from reprocessing foreign fuel is stored in France until required by the customer for recycling. In the case of plutonium, however, the customer's government must show an immediate need and guarantee its use for peaceful purposes under IAEA or EURATOM safeguards.

Another provision of the foreign contracts specifies that Cogema will convert the radioactive wastes to a form suitable for safe transport and storage in conformance with agreed specification or international regulations if in force. The customer had two years or up to 1 January 1984 to accept, after which Cogema may convert the contract to a fuel storage contract and refuse to reprocess the fuel. In that situation, Cogema agrees to store the spent fuel until 1995 and then return it to the customer. In our judgment, this provision, if enforced, is intended to prevent a customer from refusing to accept the waste treatment packaging specifications as a way of backing out of the reprocessing of shipped fuel or refusing to accept the waste.

At the March 1983 Atomic Industrial Forum Fuel Cycle Conference, a Cogema spokesman explained that waste from reprocessing foreign fuel will not be shipped back to the customer prior to 1990, and, indeed, storage could be extended over the following 25 years. He implied that Cogema must be reasonably sure that the country of origin will be capable of accepting the wastes and storing them safely. A trade journal has reported that the French have agreed to hold Japan's waste indefinitely. The table summarizes all the French spent fuel reprocessing contracts.

Cogema's contracts for reprocessing foreign power reactor fuel call for return of the recovered uranium, plutonium, and wastes to the customer as discussed in detail elsewhere in this report. Some uranium and small amounts of plutonium have been shipped out so far. Belgium and West Germany have obtained plutonium and uranium oxides from Cogema for use in fabricating mixed oxide fuel for breeder reactors and experimental purposes.

Figure 6
Cogema Contracts for Reprocessing Foreign Light-Water-Reactor Fuel in UP-3 Plant



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At the Belgonucleaire plant at Mol, Belgium produces experimental fuel for the French Phoenix reactor and other European experimental fast reactors. Nukem GmbH of Hanau, West Germany, fabricates fuel for future use in the SNR-300 fast breeder under construction at Kalkar. No problems have been encountered in shipping plutonium or uranium by rail or truck from France to these destinations, and the material is stored under IAEA safeguards.

A shipment of 135 kilograms of plutonium from France to Japan by air or sea is under negotiation and is proving troublesome. Kansai Electric Power Company Ltd. (KEPCO) wants the plutonium returned for fabrication into mixed oxide fuel for the experimental JOYO breeder reactor. The plutonium was recovered from 20 mt of spent power reactor fuel reprocessed under contract at La Hague. However, because the fuel was made from US-origin uranium, in April 1982 Japan submitted an application for approval of transfer of special nuclear material required by the US Department of Energy. As of early August 1984, the method of packaging, the route and mode of transport, and the means of physical security while in transit had been decided and approved and the shipment was expected to occur in the near future. The Japanese want the plutonium as soon as possible so they can begin fabricating the fuel by the winter of 1984.

According to US State Department reporting, Switzerland wants Cogema to return about 200 kilograms of plutonium that was obtained from reprocessing Swiss power reactor fuel. As in the Japanese case, the fuel was fabricated from US-origin uranium. The Swiss intend 80 kilograms for experimental use in a research reactor and 120 kilograms for fabrication into mixed oxide fuel to be recycled in their Beznau pressurized-water-power reactors. In September the US State Department promised the Swiss that although it was willing to proceed with the MB-10 for the retransfer of the plutonium, State is obligated by the US Congress to seek to renegotiate existing nuclear cooperation agreements in cases of this kind so as to conform with the provisions of the Nuclear Non-Proliferation Act of 1978. According to State Department reporting, the Swiss viewed renegotiation as a long, drawn-out process not easily accepted by their government.

Summary of French Spent Reactor Fuel Reprocessing Contracts

Contractor	Customer		Type of Fuel	Reprocessing Plant	Comment
	Domestic	Foreign			
CEA (until 1976)	EDF		GCR	Marcoule UP1 La Hague UP2	Fixed-price contracts updated every three years; all fuel to be reprocessed at Marcoule after 1985 in MAR 400 plant.
United Reprocessors (for CEA) 1971-76		Japanese/ European utilities	PWR and BWR	La Hague UP2/HAO	Contracts signed in the period 1971-74 to reprocess 514 metric tons of LWR fuel.
Cogema (since 1976)	EDF		GCR and PWR	La Hague UP2 Marcoule UP1 La Hague UP2/HAO	Contracts signed for reprocessing 713 metric tons of fuel in the UP3/HAO plant until UP3 is in operation.
Cogema		Japanese/ European utilities	PWR and BWR	La Hague UP3	Contracts totaling 6,000 metric tons to be reprocessed over 10-year period; no more contracts except for fuel from reactors exported by France.
Cogema	EDF Ardennes Nuclear Energy Company (Chooz Reactor)		PWR	La Hague UP2-800	All French PWR fuel to be reprocessed until UP3 converts from foreign to domestic about 1995.
Cogema (future)	CEA Super Phoenix (nersa)		FBR	Marcoule TOR plant	Plant capacity to be 5 to 6 metric tons per year of fast-breeder fuel.
Cogema (future)	Super Phoenix and future LMFBRs		FBR	MAR-600	Plant capacity to be about 50 metric tons per year (now in design stage).

The French have no objections to shipping plutonium as long as the customer can show a peaceful-purpose need. Delays in approval for the Japanese and Swiss plutonium transfers probably will increase the concerns of these and other countries about the impact of extraterritorial US nonnuclear proliferation policies on their nuclear development programs.

Potential for Export of Reprocessing Technology

The French guard their advanced reprocessing and related technology as proprietary information because they hope to gain economic benefits not only from reprocessing contracts but also in sales of the technology including radioactive waste treatment technology. Cogema's foreign customers are denied specifically any access to French reprocessing technology in connection with their contracts. Also, the French want to impress foreigners with their leadership in reprocessing as an incentive for sales of French nuclear power reactors to developing countries that are concerned about disposition of spent fuel.

A delegation from the Taiwanese electric utility, Taipower, visited French nuclear facilities in June 1983, including the La Hague reprocessing plant. Because of the perceived political sensitivity of the visit, Taipower did not include nuclear scientists in its delegation. Thus, the French are keeping the door

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open to possible future sales to Taiwan of waste treatment, disposal, and even reprocessing technology should it become politically acceptable.

Government Policy on Proliferation Aspects of Reprocessing

The French Government has not changed its official policy on exports of reprocessing technology to countries of proliferation concern since 1976 when it decided not to construct any more reprocessing plants for foreign countries. The present administration openly supports an earlier government decision in 1978 to terminate aid to Pakistan in building a commercial-scale reprocessing plant. Mitterrand's Socialist Party has also recommended that France sign the Nuclear Non-Proliferation Treaty, but President Mitterrand has not chosen to follow this policy. He apparently believes that to do so would constrain France's political and commercial interests. France is a member of the London Suppliers Group but is not obligated to require and does not demand comprehensive safeguards on sales of nuclear energy materials or technology to foreign nonnuclear weapon states.

According to State Department reporting, France participated in the seven-country IAEA Reprocessing Working Group meetings in Vienna in 1983 to discuss controls on exports relating to reprocessing nuclear materials. Also the French reprocessing facilities at La Hague were under EURATOM safeguards prior to 1977 and a trilateral IAEA-French-EURATOM safeguards agreement was signed in July 1977 bringing the facilities under IAEA safeguards.

Some French suppliers of equipment used in reprocessing apparently are willing to circumvent government nonproliferation policies, however. A manufacturer of remote manipulators who had supplied Pakistan's New Laboratories in 1977 planned a visit in June 1983 with the intent to sell more. This sale was stopped in July by the French Government as a result of a US State Department demarche.

Figure 7
French Nuclear Industry

Legend

Nuclear Fuel

Cogema -complete fuel-cycle services
EURODIF-uranium enrichment
SGN-reprocessing technology
COMURHEX-uranium conversion
SIMO-uranium conversion
Uranium P.U.K.-uranium conversion
Minatom-uranium prospecting
CERCA-fuel fabrication
EUROFUELS-fuel fabrication
STEC-engineering firm
TECHNIP-engineering firm

ENUSA (Spain)
SOBEN (Belgium)
CNEN (Italy)
AGIP NUCLEARE (Italy)
SOFIDIF (Iran-France)
shareholders in EURODIF

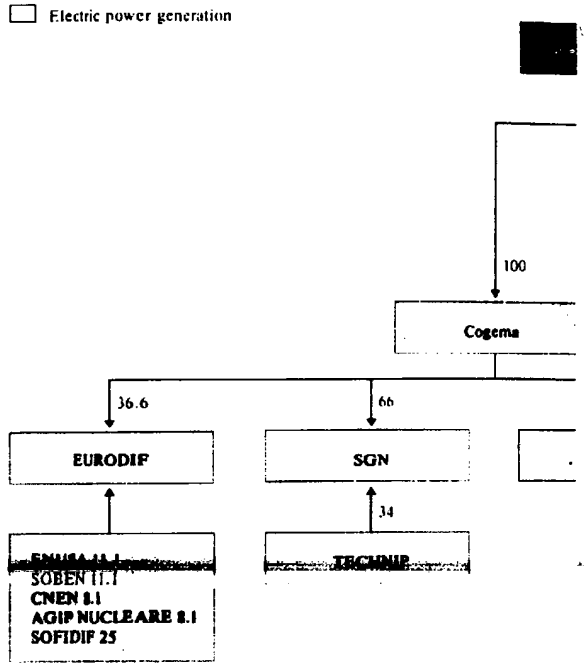
Reactors

Framatome-light water reactors
NERSA-fast breeder reactors
SOFINEL-engineering firm
Novatome-generators and components, especially for fast breeders
Sofratome-consulting firm, assists buyers of French technology
Technicatome-reactor designs and marketing services
Framatea-engineering firm, manages overseas contracts

ENEL (Italy)
SBK (West Germany)
participants in fast breeder research program

Creusot-Loire-steel manufacturer
Alsthom-Atlantique-generators
Electricite de France-national utility
US Westinghouse Europe

French government
Nuclear fuels fabrication
Electric power generation



Note Numbers indicate percent of ownership

[a] Chaired by French Prime Minister
[b] Numbers do not reflect total shareholder percentages

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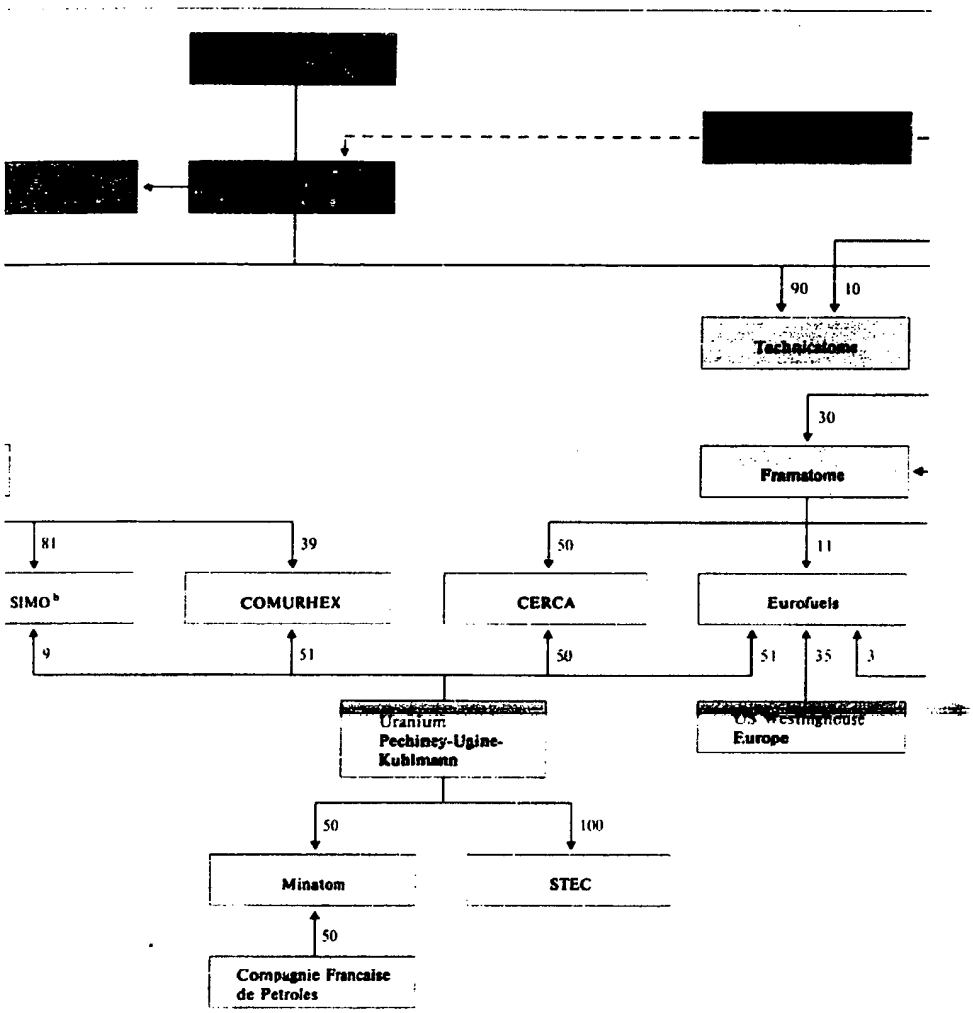
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10
Technicatome
30
Framatome
81
39
50
11
SIMO[b]
COMURHEX
CERCA
Eurofuels
9
51
50
51
35
3
Uranium
Pechiney-Ugine-Kuhlmann
US Westinghouse
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Coger
EURC
SGN-
COM
SIMO
Urani
Minat
CERC
EURC
STEC
TECH

ENUS
SOBE
CNEI
AGIP
SOFI

React

Fram
NERS
SOFI
Nova

Sofra

Techr

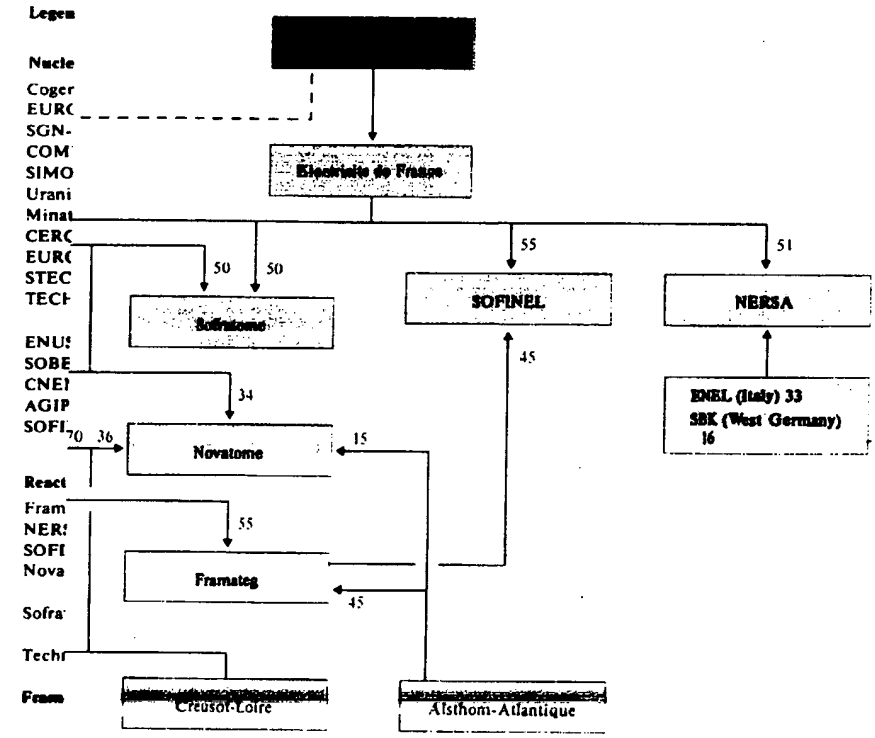
Fram

ENEI
SBK

Creus
Alsth
Elect
US W

Note:

[a] Cha
[b] Nu



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