CLOSING THE FUEL CYCLE : THE INDUSTRIAL DEMONSTRATION

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ABSTRACT

The progressive implementation of some key nuclear fuel cycle capacities in a country corresponds to a strategy for the acquisition of an independant energy source. France, Japan, and some European countries are engaged in such strategic programs.

In France, COGEMA, the nuclear fuel company, has now completed the industrial demonstration of the closed fuel cycle. Its experience covers every step of the front-end and of the back-end : transportation of spent fuels, storage, reprocessing, wastes conditioning. The La Hague reprocessing plant smooth operation, as well as the large investment program under active progress can testify of full mastering of this industry. Together with other French and European companies, COGEMA is engaged in the recycling industry, both for uranium through conversion of uranyl nitrate for its further reenrichment, and for plutonium through MOX fuel fabrication.

Reprocessing and recycling offer the optimum solution for a complete, economic, safe and future-oriented fuel cycle, hence contributing to the necessary development of nuclear energy.

1 - A strategy in the nuclear fuel cycle

In the course of development of a comprehensive nuclear power industry, it is necessary to follow a lengthy and steady time schedule, devised to master progressively the industrial steps, starting with the nuclear reactor itself, and followed by the fuel cycle capacities.

To make nuclear energy as independant as possible from external forces and constraints, the fuel supply for the reactors must be insured first through the diversification of overseas sources, and a progressive local establishment of some key segments of the fuel cycle. We will have spent 25 years in France between 1965 and 1990 to cover the whole cycle on an industrial and commercially competitive scale. Last but not least the back-end capacities are currently achieving their industrial break through.

Other European countries relying strongly upon nuclear energy, such as United Kingdom, Belgium and the Federal Republic of Germany, have been and are actively engaged in some key steps of the fuel cycle, particularly in reprocessing and recycling industry.
In fact, closing the fuel cycle through recycling is specially important for the countries, poor in natural energy sources and developing an important nuclear energy program, which cannot afford to waste their spent fuel, still valuable in fissile materials.
France, as well as Japan are strongly convinced of the necessity for recovering both uranium and plutonium which have been separated by reprocessing.

2 - The reprocessing industrial operations in France

Mastering a new technology, from fundamental research to full-scale industry including commercial demonstration is a time and money consuming activity. We have spent time and money in CEA and in COGEMA on the reprocessing activities to answer that question : is reprocessing like enrichment or fuel fabrication, a commercially proven activity ?

The answer is clearly positive, as we have now evidenced that :
- the reprocessing plant UP2 at La Hague has a regular production for more than 3 years, in accordance with the design capacity ;
- the finished products show a guaranteed quality ;
- safety levels comply with high standards.

The back-end "package" services provided to nuclear utilities by our industry include :
- spent fuel transportation
- pool storage ;
- reprocessing and waste conditioning for final disposal ;
- plutonium and uranium recycling.

Spent fuel transportation

Over 1700 transportation casks carrying more than 5000 tonnes of spent fuel from 60 Western European and Japanese light water reactors have been received at La Hague since 1975. Whether by truck, by rail or by sea, these shipments have occurred without any incident

Spent fuel receiving and storage

La Hague's present pool storage capacity of 6300 tonnes will be increased to more than 10,000 tonnes by 1988 with the start-up of a new pool. An important safety feature of the pools lies in the use of innovative in-pool units for water cooling and purification.

Reprocessing

By the end of 1986, the La Hague plant had reprocessed more than 1600 tonnes of light water reactor fuel. The UP2 400 plant now on line, operates at its nominal capacity of 40 tonnes per month.

The figure 1 shows the cumulative tonnage reprocessed at La Hague by the end of 1986.

Under construction are the facility UP3 scheduled for by the beginning of 1989 and the facility UP2 800 which is an extension and modernization of the UP2 400 plant and will be on stream in 1992. The total capacity of La Hague plant will then be 1600 t/a.
The financing of UP2 is shared between COGEMA and EDF while UP3 is totally financed by foreign customers, to which the first productions of the plant will be dedicated.

High level activity wastes

With respect to waste processing, the most difficult challenge is to solidify separated fission products in a liquid state that contain over 99 % of the activity of the spent fuel upon arrival at the reprocessing plant. The selection of borosilicate glass as a containment matrix has been unanimous among nuclear nations. The continuous operations of the AVM vitrification facility in Marcoule since 1978 have thoroughly demonstrated the French process, which has vitrified more than 1000 m^3 of high level liquid waste into 1400 canisters.

After a cooling period of 3 years at the vitrification site the canisters will be stored 30 to 40 years in an interim storage before final disposal.

Low and medium level activity waste

For the low and medium level activity wastes, the cumulative productions of the French utility EDF from 1960 to 2000 are respectively 800,000 m^3 for short-lived wastes and 45,000 m^3 for long-lived wastes.

Final storage is achieved by shallow-land disposal, such as ANDRA's "Centre de la Manche", while long-lived wastes will be disposed in deep geological formations, currently on design.

* Short-lived wastes are :

. either embedded in cement inside concrete containers on the production site, then transported to the final disposal center ;
. or simply placed in metal drums before being compacted, mixed with an embedding material, packed in concrete containers, and permanently stored at the shallow-land disposal.

* Long-lived wastes are :

. either encapsulated in cement : so are hulls fuel fabrication and technological wastes ;
. or encapsulated in bitumen : so are concentrates from liquid treatment stations.

Safety

Production and productivity of reprocessing and waste management plants cannot be achieved at the expense of high safety standards. In the absence of any significant incident, safety performance can be evaluated by analyzing personnel exposure statistics. The annual average individual dose rate of La Hague personnel decreased from a maximum of 509 mrem in 1975 to 156 mrem in 1986, compared to a maximum allowable dose rate of 5000 mrems.

The specific dose rate, which is the ratio of the collective dose rate to the amount of electricity produced by the reprocessed fuel, decreased also to a level of 0.08 man rem/MWe year in 1986. This figure is noteworthy in that it illustrates that, contrary to a common misconception, reprocessing is not the area of the fuel cycle with the highest personnel exposure. In fact, the corresponding figure for uranium mining is 0.25 man rem/MWe year and light water reactor operation generates specific doses of at least the same order of magnitude as uranium mining.

The figure 2 shows the specific close rate evolution at the reprocessing plant.

3 - Plutonium and uranium recycling

The French experience in plutonium fuels dates back to 1962. The CEA/COGEMA Caradache fabrication facility supplied fuel for the fast breeder reactors RAPSODIE, PHENIX and recently SUPER-PHENIX the 1200 MWe FBR at Creys-Malville.
An extension of this facility for thermal mixed-oxyde Uranium-plutonium fuel is in the commissionning phase.
COGEMA is associated with BELGONUCLEAIRE (Belgium) in a joint venture, the COMMOX Company, which sells MOX fuel rods. Such MOX products have been delivered so far to 16 customers in 11 different countries.

BELGONUCLEAIRE has a 25 years experience in plutonium recycling both for fast breeder and thermal reactors. Its Dessel located plant fabricated the first MOX assembly in 1962. This plant has a present capacity of 35 t/a.
Both partners in the COMMOX venture have plans for production capacity extension: A 100 t/a plant called MELOX will start production in France in the early nineties and a following unit, DEMOX, will further increases the Dessel capacity.
In the meantime close cooperation has been established with the british company, BNFL in this mixed-oxyde fuels.
Pressurized-water reactors reloads are currently designed and manufactured by FRAGEMA which incorporates in the bundles the mixed-oxyde rods supplied by COMMOX.
Two nuclear units in France are to be loaded in 1987 with MOX assemblies and EDF has plans to introduce such fuel materials in 12 units in the frame of a progressive program.

The same policy has been adopted by other utilities in EUROPE, namely in Federal Republic of Germany and Switzerland were MOX reloading has become a reality.

Recycling Uranium obtained from reprocessing implies reenrichment of this material in order to raise its ^{235}U assay from the residual value around 1 % to the usual 3-4 % range requested by LWR.

Prior to reenrichment, the conversion of the Uranyl nitrate produced by the reprocessing plant has to be carried out in special dedicated facilities, due to radio chemical activity of the product.
The conversion into UF6 started at COMURHEX ten years ago and the present cumulative amount converted at the COMURHEX Pierrelatte plant is more than 1500 tonnes, the uranyl nitrate coming from COGEMA La Hague as well as from the DWK facilities in the Federal Republic of Germany.
In addition a COGEMA facility, on TRICASTIN Site, is carrying out the transformation of uranyl nitrate into oxides for convenient interim storage before further recycling through fluoration and reenrichment.

Since 1986, COGEMA and COMURHEX are associated in the UREP joint venture to offer those services between reprocessing and reenrichment, thus closing the uranium loops. New large conversion facilities consistent with the La Hague plant output are planned for the early nineties.

The enrichment of reprocessed uranium has then to be carried out with the view of limiting the mixing of this material with fresh feed. Particular operating modes of the enrichment plants have thus to be adopted : either a dedicated production line or a batch-operation program, according to the specific features of the enrichment processes. In large gaseous diffusion plant we use the later operating mode.
By the end of the century advanced enrichment technology using laser isotopic separation process will be available and will offer a great advantage by selecting more efficiently the ^{235}U fissile isotope.

4 - Checking up on economics

Some countries are considering an alternate solution for spent fuel management : instead of reprocessing the fuel and recover the fissile products, they suggest just to store the spent fuel during a more or less long period, and then dispose of it as a waste.

Economic comparisons between these two options have been made in the recent years. An OECD/NEA study published in 1985 focused on a method to calculate fuel cycle costs per kWh (and based on average costs) estimates on each segment of the fuel cycle, showed a slight advantage for the once-through option under 1984 economic conditions.
COGEMA recently analyzed in depth those cost comparisons using the company's strong technical expertise and industrial experience in the closed fuel cycle.
A major parameter of these analyses is of course the cost of reprocessing operations. In this area, COGEMA can now confirm that an appreciable reduction in commercial prices for reprocessing services will be achieved following the execution of the present baseload contracts, from the year 2000 onwards.
This important price reduction measure will be achieved through the following means.

a - Financing of La Hague's new reprocessing UP3 facility will yield a return on investment over 10 years, starting with initial plant productions in 1989. Thus, in 1999, an important component of price will vanish.

b - The cumulative operational experience gained on our facilities will lead to a reduction of the risk provisions that had been incorporated into present baseload prices.

However, maintenance and refurbishing expenses are forecast for that period, as well as provisions for future decommissioning.
On balance, the prices offered will be significantly lower than those paid during the baseload amortization period.
Of course current customers will have priority for these future reprocessing services.
When these trends in reprocessing prices are taken into account, along with the other in-house prices and evolutions for each component of the fuel cycle in particular manufacturing recycled materials, we come to the conclusion that the reprocessing/recycling route offers now a clear advantage over the once-through option in terms of the fuel cycle cost per kWh.

CONCLUSION

This review of the various aspects of the back-end of the nuclear fuel cycle shows the thorough development of each industrial step and demonstrate the consistancy of the overall strategy developed in France and other countries with the view to close the fuel cycle.

The economic advantage results eventually from this smooth development and industrial achievement. Other important considerations such as security of supply, environment protection and public acceptance are additional factors which confirm the positive aspect of reprocessing/recycling route.

Moreover, this route is really future-oriented in the way that it warrants that the nuclear energy will keep available its potential advances : FBRs can rely on Pu fuel supplies when the time comes for their industrial development.

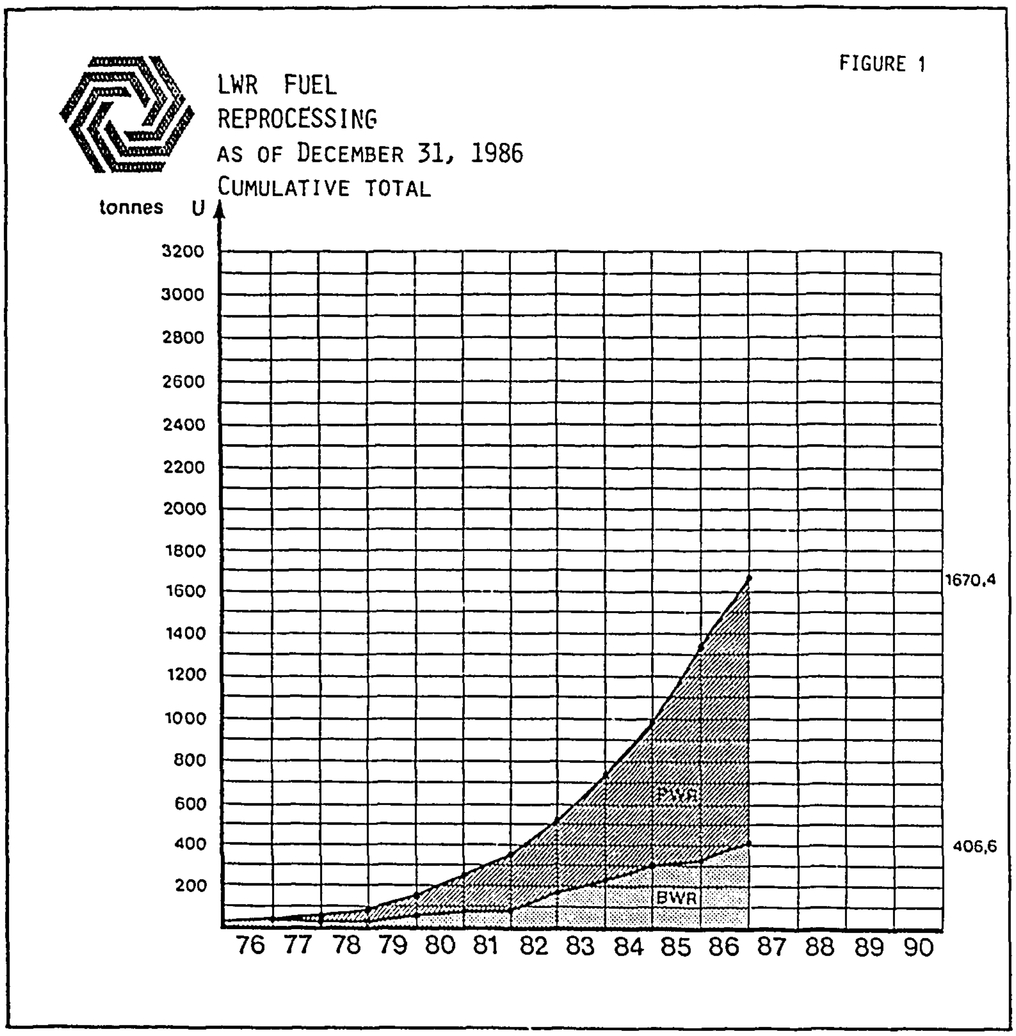
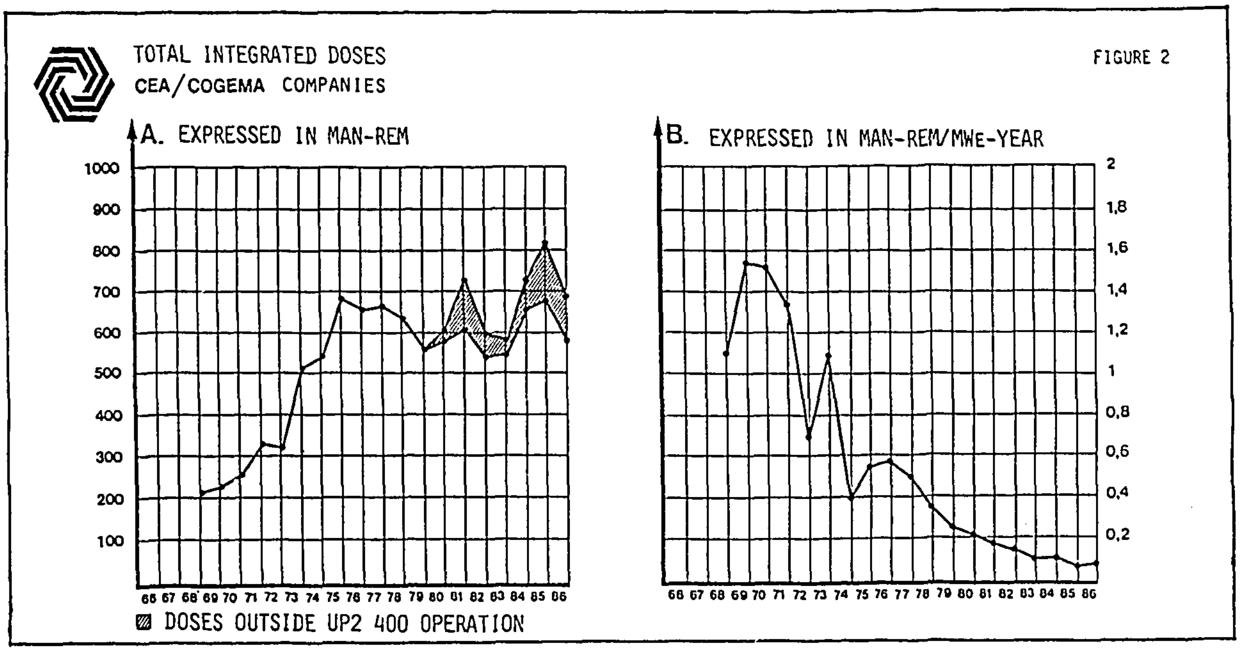


FIGURE 1
LWR FUEL
REPROCESSING
AS OF DECEMBER 31, 1986
CUMULATIVE TOTAL
tonnes U
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
1670,4
406,6
PWR
BWR
76 77 78 79 80 81 82 83 84 85 86 87 88 89 90


TOTAL INTEGRATED DOSES
CEA/COGEMA COMPANIES
FIGURE 2
A. EXPRESSED IN MAN-REM
1000
900
800
700
600
500
400
300
200
100
66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86
DOSES OUTSIDE UP2 400 OPERATION
B. EXPRESSED IN MAN-REM/MWE-YEAR
2
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86