French plutonium management program

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Abstract. The French plutonium management program is summarized in this paper. The program considers nuclear generation as a major component of national electric power supply and includes the reprocessing of the spent fuel.

SUMMARY

French nuclear energy policy, set up and confirmed by various governments from the beginning of this industry, considers nuclear generation as a major component of national electric power supply and includes the reprocessing of the spent fuel.

The French Government and the Parliament are involved in the nuclear policy mainly through the action of Ministry of Industry and Ministry of Environment for the former and Parliamentary Office for Assessment of Scientific and Technological Options for the latter.

The main actors of the nuclear industry are the Commissariat à l'Energie Atomique (CEA), national agency in charge of basic research and tests, Electricité de France (EDF), national utility operating the power plants, COGEMA in charge of the nuclear fuel cycle, FRAMATOME designer and manufacturer of nuclear reactors and ANDRA, national agency for waste management.

The Reprocessing-Recycling strategy pursued in the last thirty years has allowed the development of a fully mature industry in the field of spent fuel management, with a world-wide international business development. At present in France 955 tons of enriched uranium fuel are loaded each year, among which 850 tons of spent fuel are reprocessed allowing the recovery of 8 tons of plutonium used in MOX fuel fabrication. This MOX fuel is loaded in 900 MWe PWRs. Already part of the reprocessed uranium is reenriched and recycled.

At present 18 reactors in France are loaded with MOX fuel and the whole set of 900 MW-class reactors (28) are expected to be loaded with MOX in the future.

In Europe, COGEMA controls 97 % of the MOX fuel manufacturing which is processed in three facilities: DESSEL in Belgium, CADARACHE and MELOX in France.

The Reprocessing-Recycling strategy is considered as presenting many advantages in various fields, such as recovery of valuable materials, conditioning of final non reusable waste, reduction in waste radiotoxicity. Moreover it leads to a significant reduction in the volume of final waste. This reduction has been given the benefits of strong improvements obtained through the completion of large research and development actions along the years. Several economical studies have not found any significant difference in costs between this option and the direct disposal option.

Beyond the present status of the recycling industry, Research and Development actions regarding the back-end of the fuel cycle are in progress in various directions: widening of the field of MOX use (BWR, EPR, etc.), higher burnups (70 GWd/t), plutonium multiple recycling, etc.

1. ORGANIZATION: GOVERNMENT AND INDUSTRY

French Nuclear Energy Policy and Reprocessing-Recycling

French energy policy from the very beginning has placed the generation of electric nuclear power as a major component of the supply of energy. This policy included the reprocessing of spent fuel, considered as not questionable due to the risk of uranium shortage and the development of breeders reactors. All governments that succeeded one another in France have regularly approved the options taken in the 1970s. The French Parliament has also regularly confirmed its support of the strategy for energy proposed by the Government. When it became clear that the breeder reactors policy had to be interrupted, reprocessing was questioned, but accounting for several major factors, feasibility of recycling of plutonium in PWR reactors, favourable outlooks of a back-end strategy for final waste, and economical aspects, the Reprocessing-Recycling strategy was confirmed and adopted by all main actors of the French Nuclear Industry.

Main actors

The French organisation in the field of Nuclear Energy is based on the following actors: the CEA, Commissariat à l'Energie Atomique, national research centre, ANDRA, national nuclear waste agency, Electricité de France, the national utility in charge of electric energy supply, which operates electric power generating plants (58 PWR reactors), FRAMATOME, the nuclear reactors manufacturer, and COGEMA in charge of the nuclear fuel cycle, starting from uranium mining, enrichment, fuel manufacturing, reprocessing and final waste conditioning.

Government and Parliament bodies

Concerning political and administrative entities and technical and safety aspects, the main body is the DSIN (Direction de la Sûreté des Installations Nucléaires, Directorate for Nuclear Installations Safety) which is directly responsible both to the Ministries of Environment and Industry. This Directorate is in charge of all safety matters in relation with nuclear energy, including transportation of nuclear material and waste management. DSIN uses as main technical advisor the IPSN (Institut de Protection et de Sûreté Nucléaire).

The DSIN role includes the assessment of the consistency of the choices made for the back-end fuel cycle options, particularly the **plutonium management.**

Parliamentary Office for Assessment of Scientific and Technological Options

The Government and the Parliament are acting through various bodies. On the parliamentary side we find the **Parliamentary Office for Assessment of Scientific and Technological Options**, composed of Members of Parliament, whose missions are:

- to inform the Parliament about the consequences of the scientific and technological choices in order to make all important decisions clear,
- to facilitate the legislative function by working upstream of the bill and law drafting process,
- to enforce the parliamentary control over the executive.

This Office issues information and guideline reports in order to inform and guide the Government as well as the Members of Parliament about the French energy policy. Two lately issued reports illustrate this important role of the Office:

- the Bataille-Galley report on development in research on wastes of March 1996,
- the Bataille-Galley report on fuel cycle back-end dated 11th of March 1999,

whose main conclusions were that the fundamental options implemented in France regarding the back-end fuel cycle, namely spent fuel reprocessing and fissile material (plutonium and uranium) recycling should be maintained.

National Assessment Committee

Another important component of the French Organisation is the National Assessment Committee (Commission Nationale d'Evaluation), composed of 12 independent French and international experts named by the Government, the Parliament and the High Council for Nuclear Safety and Information. This Committee was stipulated in the 1991 law on high-level long-lived radioactive waste and formally created in 1993. The main task of the Committee is to organize regularly deep audits of all nuclear actors and issue a yearly synthesis report on high-level waste management. Its missions are in fact extended to the overall back-end fuel cycle which includes plutonium management.

Broad consensus and late political decisions

As explained here above, the policy towards nuclear energy has always been confirmed democratically and the last decisions made by Mr. Lionel Jospin's Government do not diverge from this line in confirming that « *the choice of nuclear energy as a major component of the national electric power supply will be maintained* », as stated at the highest level in 1998 on the occasion of the 9th December meeting of an interministerial committee. One may also note the conclusions of the parliamentary debate on energy on the 21th January 1999. With the exception of the « Green Party », which is no surprise, the French commitment to the nuclear options meets a very broad consensus amongst the French political staff.

2. PANORAMA OF THE BACK-END FUEL CYCLE

General

As stated in the general overview of political and administrative aspects of the nuclear energy framework in France, spent fuel has been continuously reprocessed in France since the beginning of the nuclear program. Despite some noticeable changes in the nuclear policy, as either the shift from Gas Cooled Reactors to Light Water Reactors as basic generators of electric power, in the late sixties, or the more recent phasing-out of Superphenix breeder reactor, all actors of the nuclear industry consider spent fuel reprocessing and valuable fissile material recycling as the only satisfactory solution for the back-end problem. At present the recycling of plutonium in MOX fuel to be loaded in the core of PWR reactors, whose decision was taken in 1984, is the current policy. The feasibility of plutonium recycling in PWRs had long since been demonstrated through various programs and experimentation, and in 1987 actual loading of reactors with MOX fuel began.

So France has acquired a very large experience in all technologies related to Reprocessing-Recycling, spanning over 30 years. This strategy has reached an unquestionable industrial reality, and has allowed the development of a mature industry as well as an international business development.

3. REPROCESSING

COGEMA operates at La Hague two large reprocessing facilities, UP2 and UP3. They have been designed with a nominal capacity of 800 tons of fuel each and their combined production has reached this target since five years. These plants basically deal with LWR fuel, but they are capable of other fuel, as Fast Breeder Reactor fuel, and MOX fuel and such operations have already been made.

The waste generated by the process has been drastically reduced in volume during the last years. Through improvement of the existing technologies and the adoption of new concepts, the specific volume of the ultimate residues has been reduced from 3 cubic meters per ton of uranium in the 80s to the present figure of less than half a cubic meter, with a content in plutonium less than 0.1 % of the original, whereas the forecasted figure for the direct disposal option is about 2 cubic meters.

4. RECYCLING

MOX fabrication plants

As concerning the MOX fuel designed for LWR reactors, the COGEMA Group supplies the production of three plants:

- two of them, CADARACHE and MELOX are operated by COGEMA and are located in France;
- the third, located at DESSEL in Belgium is operated by BELGONUCLEAIRE.

The MOX platform, with this set of these three plants, delivers 97 % of the MOX consumption in Europe, corresponding to 31 reactors (32 European reactors are currently loaded with MOX fuel). The COGEMA Group will be able in the future to supply all recycling needs of its back-end customers.

COGEMA has also started the production of MOX fuel for several Japanese utilities.

The process used in these plants is called the MIMAS process and has become a world-wide reference. The Department of Energy of the United States has selected MIMAS for its program of elimination of weapon-grade plutonium into MOX fuel (which demonstrates another benefit of the Reprocessing-Recycling strategy: getting rid of non civilian plutonium).

Reactors served

In France, with the 58 PWR reactors of EDF under operation, 955 tons of uranium fuel are loaded each year. Out of them, 850 tons are reprocessed in order to recover about 8 tons of plutonium that are needed for the manufacturing of MOX fuel elements. At present 18 PWR reactors receive and use MOX fuel elements and 28 are planned to be loaded with MOX fuel in the future.

Uranium recycling

It is important to note that the reprocessing technology allows also the recovery of slightly enriched uranium, which is a valuable material that may be further reenriched and reused in cores. The COMHUREX plant in southern France is one of the world few units to convert the uranium coming from the reprocessing plant under the form of uranyl nitrate into uranium

hexafluoride (UF6) so as to be reenriched and thus allows the fabrication of URE (Enriched Reprocessed Uranium fuel). This is currently done at the FBFC-Romans plant which produces two fuel reloads per year. Two reactors in France are authorized to load reprocessed and reenriched uranium, CRUAS 4 was first loaded in 1987 and since 1995 CRUAS 3 and 4 burn URE exclusively.

5. ADVANTAGES OF REPROCESSING-CONDITIONING-RECYCLING (RCR)

The advantages of the Reprocessing-Conditioning-Recycling strategy have been placed in a prominent position through many studies, and large industrial experience feedback.

Overall economy

On the economical and strategic point of view, it appears that this option is a guarantee for a supply of nuclear fuel at stable conditions in the long term, not subject to fluctuation as are other energy resources such as fossil fuel.

Furthermore, in terms of costs, though the economy of the RCR option has often been questioned - and mainly by nuclear opponents...-, many studies have compared the once-through option (direct disposal of spent fuel) to the RCR and no significant difference appears between them. The OECD launched a thorough study of the overall costs and its result was that the difference is lower than 10 %. It must be stressed that the main investments have been made, whereas no remarquable installation for direct disposal exists nor has really proven its feasibility, and the cost of this option is still speculative. Moreover, the trend towards an increase of fuel discharge burnups will clearly improve the competitiveness of the MOX fuel and thus enforce the RCR option.

Though the RCR industry has proven to be mature under several major aspects, it is still a young moving forward industry and many improvements are expected from R & D in the near future, that will enhance both safety and productivity so as to make it more and more competitive.

On the utility point of view, it is also clear that all supplementary investment in spent fuel pool capacity via reracking or pool extension at the reactor are avoided, as in and out flows of spent fuel are permanently adjusted.

Final waste

As regarding the final waste, the reprocessing technology leads to small volumes of non-reusable materials, which are sorted and separated from the valuable ones and may be safely conditioned. Many improvements to this process have been performed during the late years.

The overall radiological balance is improved by plutonium recycling in MOX fuel. A very small quantity of plutonium is present in the final waste and the radiotoxicity of the irradiated MOX fuel is on the long-term lower than the radiotoxicity of the plutonium that would have not been used in MOX plus the uranium fuel which would have been used in place of MOX.

6. FUEL CYCLE BACK-END IN FRANCE - THE FUTURE

Research and development

As already stated above, the RCR industry in France devotes strong efforts in R&D studies so as to improve the back-end fuel cycle advantages in various fields. These efforts bear on the

optimisation and adaptation of MOX fuel fabrication processes, the increase of discharge burnups, the increase of the in-core MOX fuel ratio, the multiple recycling of plutonium.

Concerning the MOX fuel fabrication, studies have been launched within the Russian-and-US program of elimination of weapon grade plutonium, by way of making it usable for burning in reactors.

Technological developments are in course with the aim of the improvement of MOX fabrication plants operation and efficiency, through upgrading and renewal in the mid-term.

A large and very promising R & D program is at present also under progress regarding the increase of burnups. This increase as said above shall make the MOX more competitive. A new type of fuel assembly is under study that will be capable of reaching 70 GWd/t by the year 2010.

At present at MOX using reactors, the reload includes only a third of a core in MOX fuel assemblies. Studies for the increase of the in-core MOX fuel ratio up to 100 % are undertaken. It is also intended to assess the increase of MOX fuel content in BWR and EPR.

A very important topic, which shall give an answer to some questions, lies in the multiple recycling of plutonium. At present it can clearly be stated that the feasibility of MOX fuel reprocessing has been proven, as La Hague plant has already reprocessed at an industrial scale spent MOX fuel on the occasions of the 1992 and 1998 reprocessing campaign. Moreover, several other components of the MOX strategy, such as spent MOX fuel transportation have already been given a confirmation.

The next step will be the second recycling of plutonium in a light water reactor core.

Scenario studies

Within the framework of R & D programs described above, an industrial working group in which participate ANDRA, CEA, COGEMA and FRAMATOME has been set up in order to overview the strategic options for the fuel cycle back-end.

This group works on the following scheme: a set of basic scenarios that can be envisaged for the future have been selected, based on the following points:

- are large quantities of plutonium acceptable or not in deep geological disposal,
- the best concept for deep geological repositories, and comparison with other ways of managing waste,
- authorized burnups,
- available techniques (RNR, purger laser, actinides partitioning).

In line with the ideas developed, CEA and COGEMA have undertaken a specific study aiming at the assessment of what should be in the mid and long term the total plutonium inventory according to six different scenarios, which account for different concepts. Among these concepts one finds CAPRA and MIX.

CAPRA (Consommation Accrue de Plutonium en Réacteur) is a research program, initially based upon the use of Fast Neutron Reactors with the aim of increasing the consumption of plutonium in reactors, at present the studies made on a multinational basis keep the same objective with other reactors. The goal lies in designing and operating high plutonium content reactors.

MIX is a new concept of nuclear fuel based upon the use of a mix composed of enriched uranium and plutonium. This fuel should be well adapted to multi-recycling use.

At present it is possible to give a partial information regarding assessment of future plutonium inventory via the outcome the study of six following scenarios:

- open cycle,
- a single recycling of plutonium in MOX fuel,
- multi-recycling of plutonium in MOX fuel,
- implementation of CAPRA,
- use partial MIX fuel elements,
- use of 100 % MIX fuel elements.

According to the result of this study, the plutonium inventory should:

- increase in the case of open cycle or a single recycling,
- remain stable in the case of CAPRA processing or multi-recycling of plutonium in MOX fuel,
- decrease in the case of implementation of a MIX strategy.

Another noticeable outcome of the study of these scenario concerns the radiotoxicity of the final waste. When comparing the five latter options to the open cycle in terms of radiotoxicity (through the ingestion exposure pathway) of the final waste, it appears clearly that, taking the open cycle as reference, the ratios are far in favour of all options based upon the reprocessing-recycling strategy, in the mid term and particularly in the very long term, with a factor of 10 after 10 000 years.

7. CONCLUSION

The Reprocessing-Conditioning-Recycling policy, at its current status has widely sustained the nuclear development in France. It relies on improved and well-mastered processes implemented on an industrial scale. It provides a steady solution to the back-end fuel cycle: low volume and lower toxicity of High Level Waste. Thus on account of the numerous advantages offered, the fundamental option for dealing with spent fuel in France is well justified.

As no irreversible option has yet been taken, this back-end solution keeps fully open the future. The disposal solution for the high level waste is to be taken by the Parliament in 2006, so the Fuel Cycle completion will be reached.

Thanks to a substantial investment on R & D, in order to improve and optimize the production capability, to develop and check new concepts, new products and new services, the RCR industry, though mature, has an enormous potential for further development.