PRACTICES AND TRENDS IN MOX FUEL LICENSING IN FRANCE

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Abstract

The French programme aiming at recycling plutonium in pressurized water reactors (PWRs) was initiated in 1985 by Electricite de France (EDF) in close cooperation with the Commission for atomic energy (CEA), Cogema and Fragema. At the request of the French safety authority (DSIN), the programme proposed by EDF was submitted in 1986 to a preliminary safety examination, concerning the different stages of the plutonium and uranium mixed oxides (MOX) fuel cycle: manufacturing, transport, use in reactors, reprocessing and wastes management. The first load of MOX fuel was introduced in the reactor of Saint-Laurent B1 in 1987. So far, seven 900 MWe PWRs have already been loaded with MOX fuel and operated under specific conditions, dedicated to ensure the safety of their operation.

1. CURRENT PROGRAMME OF PLUTONIUM RECYCLING IN THE 900 MWE PWRS

At the present time, the seven reactors, which have already been loaded with MOX fuel, are the following: Saint-Laurent B1 and B2, Gravelines 3 and 4, Dampierre 1 and 2 and Blayais 2.

The MOX fuel loaded in these reactors consists of a mix of plutonium and uranium oxides, at the rate of 5.3 percent of Pu02 for 94.7 percent of U02 in assembly average. Actually, the MOX fuel assembly is made of fuel rods whose plutonium concentration varies from the center of the assembly to the periphery (3 zones from 6.75 to 3.35 percent of Pu02). Thus, this assembly is the neutronic equivalent of the standard 3.25 percent U235 enriched assembly, in terms of power and irradiation time. The structure of the MOX fuel assemblies is also similar to the one of the standard Fragema U02 fuel assemblies.

At the present time, MOX fuel assemblies are manufactured partly by Cogema in the CFCa plant (Cadarache, France) and partly by Belgonucleaire (Dessel, Belgium). In August 1994, the safety authority authorized Cogema to put in operation the Melox plant located in Marcoule (France). This new plant is dedicated to manufacture MOX fuel rods and assemblies. At present, the qualification of the manufacturing process is in progress.

In the core of the 900 MWe PWRs loaded with MOX fuel, there are 48 MOX fuel assemblies, coming from three reloads of 16 assemblies each. Each MOX fuel assembly is irradiated during 3 annual cycles. The remainder of the core consists in 109 U02 fuel assemblies : 3.7 percent U235 enriched assemblies for reactors under "hybrid" refueling or 3.25 percent U235 enriched assemblies under "third-core" refueling. Thus, the plutonium recycling rate of so-loaded reactors, i.e. the ratio between the number of MOX fuel assemblies and the total number of assemblies in the core, is 30 percent.

2. SAFETY REQUIREMENTS RELATED TO THE USE OF MOX FUEL IN PWRS

A preliminary safety examination of the programme proposed by EDF was carried out in 1986. The French safety authority, assisted by the Institute for nuclear protection and safety (IPSN) within the

CEA and the standing group for nuclear reactors ("Groupe permanent reacteurs" or GPR), authorized in 1987 the recycling of plutonium in the 900 MWe PWRs under the following conditions which were judged necessary to ensure the safety of the handling and the storage of MOX fuel and the safety of the operation of reactors loaded with such fuel.

Fuel handling and storage

Fresh fuel assemblies containing plutonium have a higher dose rate as the one of standard fuel assemblies, due to neutrons and gamma rays. This entails special radiological protection measures during handling. In-plant handling requires the use of a dedicated examination ring.

For radiological protection reasons as well, it is better not to store MOX fuel assemblies, as plutonium progressively turns into americium. Experience shows that consequences on the composition of MOX reloads are acceptable. However, the number of MOX loaded reactors in operation exceeds the strictly necessary one, according to the capacity of production. Used MOX fuel requires a longer cooling-down period than U02 fuel, before it may be transported.

Reactor operation

At the request of the French safety authority, EDF examined the consequences of the presence of MOX fuel on the behaviour of the core in normal operation, as well as in accidental situations. Adjustments and limitations were required, in order to ensure that the safety criteria, which were applied to U02 fuel, would be fulfilled with MOX fuel. These requirements were grounded on the neutronic properties of MOX fuel and the available knowledge on its behaviour in reactor :

The higher neutron absorption of MOX fuel requires a greater neutron flux, in order to generate the same energy quantity; thus, in the MOX fuel assembly, the concentration of plutonium decreases from the center to the periphery (6.75 percent to 3.35 percent), in order to avoid the local power peaks which would, otherwise, appear at the interfaces between MOX fuel assemblies and U02 fuel assemblies.

The higher temperature coefficients (moderator and Doppler), in absolute value, induce a lower worth of the neutron absorbers; in other respects, the lower proportion of delayed neutrons has some effects on the reactor kinetics, in particular during accidents resulting in a reactivity excursion in the core; an increase of the control rod number (4 additional control rods) and a slight increase of the boron concentration make up for these characteristics.

On the basis of the neutronic analyses and experiments carried out in the past, the proportion of MOX fuel in the core has been limited to 30 percent.

Further limitations were required at the beginning of the programme: restriction to operation at constant power and limitation of the irradiation to 3 annual cycles (around 36000 MWday/t), in bundle average; these wise provisions were motivated by the insufficient guarantees about the reliability of MOX fuel behaviour under load-follow conditions and at high burn-up levels.

3. LICENSING ISSUES RELATED TO THE USE OF MOX FUEL IN PWRS

Licensing procedures

In France, the use of MOX fuel in the 900 MWe PWRs is submitted to special licensing procedures. MOX fuel can be used in reactor only under the following conditions:

- The construction license decree, signed by the Prime Minister and countersigned by the ministers in charge of the environment and industry must make provision for the use of MOX fuel. This decree defines the perimeter of the nuclear plant and the requirements which must be met by the operator,

- The use of MOX fuel is subject to the approval of the ministers in charge of industry and environment, after advice of the minister in charge of health. The DSIN, acting on the authority of the ministers in charge of environment and industry, authorizes the delivery and the storage within the perimeter of the concerned nuclear installation of each reload of MOX fuel assemblies, its introduction in the reactor as well as the operation of the so-loaded reactor.

In other respects, on the occasion of these authorizations issued for each MOX fuel reload, the operator is asked to bring to the notice of the DSIN and the Office for protection against ionizing radiations (OPRI) which assists the ministry in charge of health, a quarterly evaluation including, among others results, those about the production of wastes and the activity levels of alpha emitters in the reactor coolant.

At the present time, sixteen 900 MWe PWRs have a construction license decree which provides for the use of MOX fuel: Blayais 1 and 2, Dampierre 1 to 4, Gravelines 1 to 4, Saint-Laurent B1 and B2 and Tricastin 1 to 4.

Examination of the licensing requests

The main bodies involved in the examination of the licensing requests of the French operator, aiming at using MOX fuel in one of its 900 MWe PWRs, or more generally, aiming at modifying the conditions of such use, are the following :

- The DSIN examines the licensing requests of EDF, with respect to technical safety. It is assisted by the IPSN which carries out the technical safety analyses of the provisions made by the operator.

- The service for the radiological protection ("Bureau de la radioprotection") within the ministry in charge of health examines these requests, with respect to radiological protection. It is assisted by the OPRI.

Information

Since the beginning of the programme, the French safety authority has made available information to the public on safety problems related to the recycling of plutonium in the 900 PWRs. The high council for nuclear safety and information (CSSIN) has played a major role in the process of informing the public; this council issued recommendations on the subject in 1989.

4. SHORT TERM AND MID TERM PROSPECTS

Experience of plutonium recycling

Since 1987, experience has been gained far more than 20 reactor.years : around 350 MOX fuel assemblies have been loaded, of which around 150 have been unloaded. The results of this experience are now available.

The behaviour of MOX fuel irradiated in reactor seems similar to the one of U02 fuel. Up to now, burn-up reached by MOX assemblies has averaged 38000 Mwday/t. The fission gas release within the rod is greater with MOX fuel than with U02 fuel but internal pressure is kept within the specified limits, thanks to the physical characteristics of the MOX pellet.
Technical specifications for reactor coolant activity are the same as those applied to U02 assemblies. So far, only one MOX rod showed a slight leaktightness fault below the threshold for unloading set by the French operator. Having been reloaded and closely observed, its behaviour appeared identical to the one of U02 assemblies having a similar defect. So far, no alpha contamination has been observed in the reactors using MOX fuel.

Reinforced by this experience, the French operator intends to pursue and extend its recycling policy. Thus, EDF has demanded the authorization of the DSIN on several purposes. The requests, which have been recently examined by the safety authority, deal mainly with the extension of the use of MOX fuel to further reactors and modifications of the refueling and operation conditions of the reactors loaded with such fuel.

Starting of Melox production and extension of the use of MOX fuel to further reactors

Melox plant shall be put in industrial operation in 1996. The production capacity will be 115 tons per year (weight of MOX fuel contained in the fuel elements). The plant will be able to supply MOX assemblies for 20 reloads of 900 MWe reactors per year, thus balancing the flow of plutonium produced by reprocessing and the one entering the production of MOX fuel assemblies.

EDF intends to increase the plutonium recycling capacity of its reactors, in accordance with the evolution of MOX assemblies production capacity:

- EDF intends to burn MOX fuel progressively in its sixteen reactors whose construction license decree provides for the use of MOX fuel ; the approval of the DSIN will be required for each reactor concerned ; to date, EDF plans to extend the use of MOX fuel to nine reactors in 1996, fourteen reactors in 1997 and sixteen reactors in 1998.

- EDF intends to prepare progressively the licensing files for further reactors ; besides the sixteen reactors already licensed to receive MOX fuel, twelve additional 900 MWe reactors are technically designed to do so; as the use of MOX fuel is not mentioned in the construction license decree of these reactors, the licensing procedure will require to resume the initial decree and to obtain a ministerial approval; in particular, a public inquiry will have to be carried out, as part of the licensing procedure; the reactors of Chinon B are the first to be examined through this procedure.

Use of a new MOX fuel assembly design

The French safety authority is at present examining the request of EDF concerning the use a new MOX fuel assembly design. The acquired experience has led to advances in the design of fuel assemblies. For MOX fuel, the resulting assembly is the AFA 2G MOX fuel assembly designed by Fragema, which includes the improvements applied to the current AFA 2G U02 fuel assembly: mainly an optimized Zircaloy 4 cladding with enhanced corrosion resistance, mixing grids with higher thermohydraulic performance and a device aiming at retaining debris.

"Hybrid" refueling

"Hybrid" refueling consists in differentiating U02 assemblies from MOX ones, in order to optimize the use of U02 fuel : 3.7 percent U235 enriched U02 assemblies are irradiated for four annual cycles whereas MOX fuel assemblies are irradiated for three annual cycles. Having been experimented on two reactors (Dampierre 2 et Gravelines 4), the extension of this type of refueling to the other reactors loaded with MOX assemblies was authorized in August 1994. This fuel management replaces the former "third-core" refueling under which all the fuel assemblies remain three annual cycles in the core.

Operation under load follow conditions

The possibility to remove the initial limitation to operation at constant power has been recently examined. At the request of the French safety authority, EDF has set up an experimental programme, in order to assess the consequences of load follow operation on the behaviour of MOX fuel, with respect to pellet-cladding mechanical interaction loading. According to the results of the power ramp tests which have been carried out in experimental loops, this operation mode does not seem to raise any particular technical problem linked to the presence of MOX fuel. Its behaviour seems similar to the one of U02 fuel. In other

respects, two reactors (Saint Laurent B1 and B2) have been operated under load follow conditions for a probationary period of two annual cycles. The operation of these reactors has not raised any difficulty for the operators. On the basis of the experimental knowledge as well as the operating experience, the French safety authority has recently authorized EDF to generalize the load-follow operation mode to all its MOX loaded reactors (approval in June, 1995).

5. LONG-TERM PROSPECTS

Concerning the burn-up limit applied to MOX fuel, the DSIN judges that it is not able at present to authorize an increase of this limit. This position applies to MOX fuel as well as standard U02 fuel. In order to get the approval for higher limits, EDF will have to assess the behaviour of highly irradiated fuel, under incidental and accidental conditions, more particularly under design-basis accident conditions. Indeed, these conditions have been judged critical to assess the requests of the operator.

In this respect, the CABRI-REP programme has been set up by EDF since 1992, in order to better understand the effects of irradiation on the fuel behaviour during a reactivity initiated accident. The tests, which have been so far carried out on U02 fuel, will be also performed on MOX fuel (2 tests scheduled in 1996 on MOX fuel irradiated during 2 and 3 cycles). Parallel to the R&D programme, EDF was authorized in 1993 to irradiate during 4 annual cycles (up to 46000 MWday/t) some MOX fuel assemblies in the reactor of Gravelines 4, in order to investigate on highly irradiated MOX fuel. In order to ensure the safety during the operation cycle, the corresponding assemblies were not situated in the core at places where the energy deposition in case of a control rod ejection would be maximal. The experimental investigations will provide one part of the safety demonstration, the other part being grounded on theoretical analyses and code simulations.

With the technical support of the IPSN, the French safety authority carries out a thorough analysis of the experimental and operating data related to the behaviour of MOX fuel under normal and accidental conditions. So far, the reliability of the use of MOX fuel in PWRs, under the present refueling and operation conditions, has been confirmed by the experimental results as well as the operating experience.

The French safety authority is open-minded on possible modifications of these conditions, insofar as they are justified through a satisfactory safety demonstration. As it was said previously, the operation under load follow conditions has been recently authorized, on such basis. In the same way, the technical elements, which will be provided by EDF on the behaviour of highly irradiated MOX fuel, will be thoroughly examined by the DSIN, in order to assess the reliability of the use of MOX fuel at high burn-up levels.