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COGEMA/TRANSNUCLEAIRE's EXPERIENCE WITH BURNUP CREDIT

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Abstract

Facing a continuous increase in the fuel enrichments, COGEMA and TRANSNUCLEAIRE have implemented step by step a burnup credit programme to improve the capacity of their equipment without major physical modification. Many authorizations have been granted by the French competent authority in wet storage, reprocessing and transport since 1981. As concerns transport, numerous authorizations have been validated by foreign competent authorities. Up to now, those authorizations are restricted to PWR Fuel type assemblies made of enriched uranium. The characterization of the irradiated fuel and the reactivity of the systems are evaluated by calculations performed with well qualified French codes developed by the CEA (French Atomic Energy Commission) : CESAR as a depletion code and APPOLO-MORET as a criticality code. The authorizations are based on the assurance that the burnup considered is met on the least irradiated part of the fuel assemblies. Besides, the most reactive configuration is calculated and the burnup credit is restricted to major actinides only. This conservative approach allows not to take credit for any axial profile.

On the operational side, the procedures have been reevaluated to avoid misloadings and a burnup verification is made before transport, storage and reprocessing. Depending on the level of burnup credit, it consists of a qualitative (go/no-go) verification or of a quantitative measurement. Thus the use of burnup credit is now a common practice in France and Germany and new improvements are still in progress: extended qualifications of the codes are made to enable the use of six selected fission products in the criticality evaluations.

BACKGROUND

For years, France has developed a policy of reprocessing its spent fuels from nuclear power reactors. Today, the facilities located in La Hague (North-West of France), and operated by COGEMA, reprocess the fuel assemblies from the French light water reactors operated by EDF (Electricité de France) and also fuel assemblies from numerous European and Japanese reactors. To support this policy, TRANSNUCLEAIRE is in charge, on behalf of COGEMA, of most of the transports of irradiated fuels to the La Hague reprocessing plant.

TRANSNUCLEAIRE operates a wide range of transport packages with capacities from 3 PWR up to 12 PWR or 32 BWR fuel assemblies. These capacities are achieved for short cooled fuels with high heat load. The cooling time depends on the burnup but, most often, is close to one year. Figure 1 shows the TN 12/2 cask utilized for the transport of 12 PWR or 32 BWR fuel assemblies with a maximum allowed heat content of 76 kW. For longer cooling times, capacities of 37 PWR and 97 BWR fuel assemblies have been achieved for transport/interim storage casks.

Today, TRANSNUCLEAIRE carries out roughly 300 transports of spent fuel casks per year, to the La Hague reprocessing plants. The casks are then unloaded and the fuel assemblies stored into the pools prior to reprocessing. The total reprocessing capability of the two facilities located in La Hague is 1,600 t of heavy metal per year. The two facilities operated are: UP2 and UP3. They have today reprocessed numerous type of fuel assemblies including PWR, BWR, UOX and MOX, and fuels from fast breeder reactors.

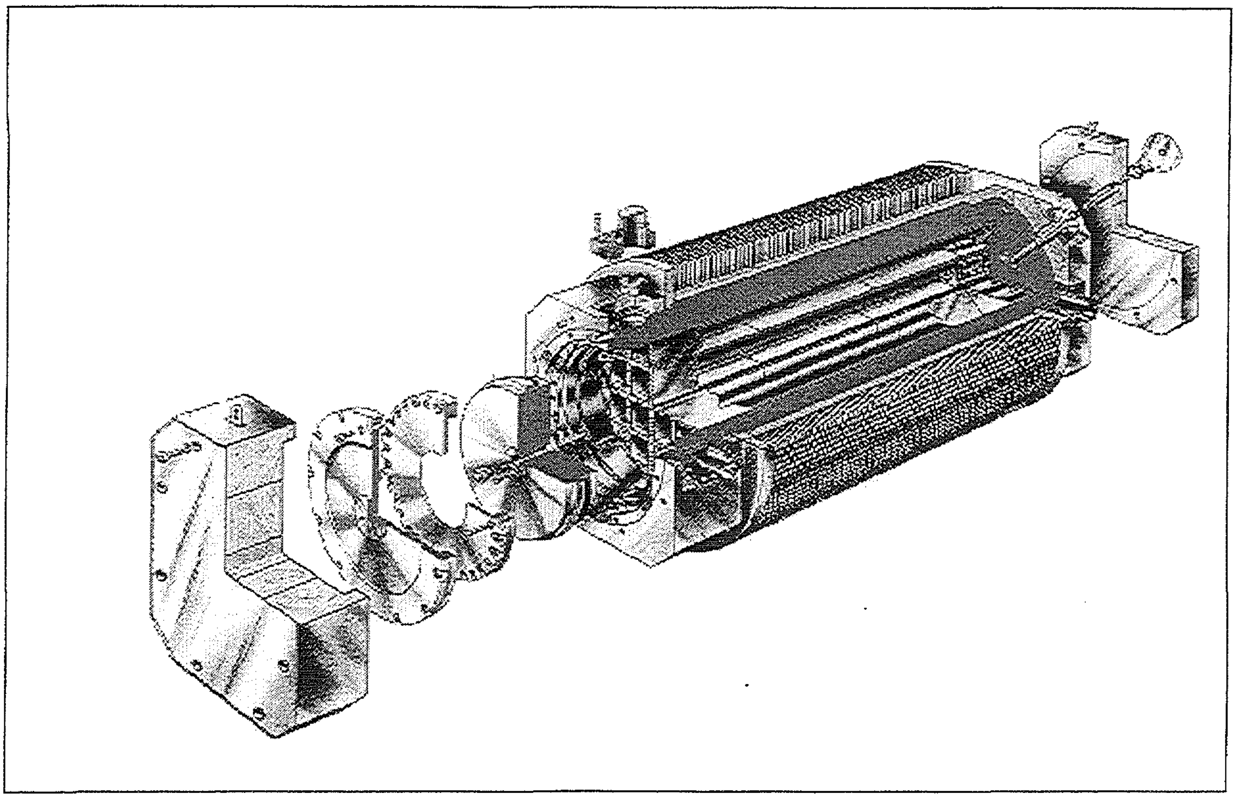

FIG. 1. TN 12/2 Cask

During transport, subcriticality is controlled by the fuel support frame also know as " basket". It is made of materials containing neutron absorbers, usually boronated aluminum or stainless steel and ensures a well defined geometry. The unloading in La Hague takes place in dry or wet conditions. During the unloading operation and the storage in the pool, the fuel assemblies are placed into a special designed basket with boronated stainless steel shrouds. The water of the pool is not boronated.

UTILIZATION OF BURNUP CREDIT

Facing a continuous increase in the enrichment of the fuel assemblies, COGEMA and TRANSNUCLEAIRE has been interested in the use of burnup credit. The experience acquired now is more than 15 years. Shown in the Table I are the different authorizations that have been granted by the French competent authority to COGEMA, for using burnup credit in wet storage and reprocessing. For transport casks, numerous authorizations have been granted in France and validated in foreign countries since the first approval which was obtained in 1987 for 16x16 PWR fuel assemblies loaded in TN 13/1 or TN 13/2 casks.

TABLE I. CRITICALITY SAFETY AND BURNUP CREDIT

Year	Facility	Initial enrichment E_i of the fuel assemblies
1981	Reprocessing UP2 400 :	$E_i < 4.20\ \%\ ^{235}U$
1987	Storage UP2 :	$E_i < 3.55\ \%\ ^{235}U$
1990	Reprocessing UP3 :	$E_i < 3.70\ \%\ ^{235}U$
1993	Storage UP2 :	$E_i < 4.00\ \%\ ^{235}U$

The different authorizations granted in France, for wet storage (in La Hague), reprocessing and transportation, are up to now limited to PWR fuel assemblies consisting of enriched uranium oxide. The acceptance of burnup credit is subject to the verification by the reactor operator that the burnup assumed is effectively met.

Depending on the results of the criticality analyses, two levels of requirements have been accepted. If the burnup required is less than the minimum burnup that the reactor operator can guarantee after one cycle of irradiation, a qualitative (go/no-go) measurement is sufficient to prove that the fuel has really been irradiated. Else, a quantitative measurement is required. The measurement has to be made on the last 50 cm of the active fuel length which is the least irradiated. As an example, the Table II illustrates the different authorizations that have been granted to transport 16x16 PWR fuel type in the TN 13/2 cask.

TABLE II. GRANTED AUTHORIZATIONS

TRANSPORT CASK	FUEL ASSEMBLY TYPE	FUEL ENRICHMENT	BURNUP CREDIT	BURNUP VERIFICATION
TN 13/2	UO2 16x16	3.30 %	0 MW·d/tU	NONE
TN 13/2	UO2 16x16	3.3 < E < 3.55 %	3,200 MW·d/tU (<1 cycle)	QUALITATIVE (GO/NO-GO) BURNUP VERIFICATION
TN 13/2	UO2 16x16	3.5 < E < 4 %	12,000 MW·d/tU	QUANTITATIVE BURNUP MEASUREMENT

For storage the same policy applies: enrichment limits are defined for three fuel assembly types, characterized by the dimensions of the cross section (BWR, PWR 214 x 214, PWR 230 x 230).

For reprocessing, only one enrichment limit is given. If the fuel assembly's enrichment is less than this value, no mass limit is required in the dissolver. Else, two cases are possible: either a mass limit is required, depending on the burnup and of the fuel enrichment, or no mass limit is required but then a burnup verification has to be made.

In any case, the same methodology is used to determine the burnup limits depending on the enrichment. The calculations are performed with qualified codes developed in France by the CEA (French Atomic Energy Commission). No burnup profile is taken into account to calculate the composition of the fuel after irradiation. The conservatism of this assumption relies on the fact that the burnup is measured on the least irradiated part of the fuel assembly, i.e. the last 50 cm. The depletion code used is CESAR, while criticality calculations are performed with APOLLO-MORET.

CESAR [1]

CESAR is a depletion code dedicated to the characterization of spent fuels UOX (PWR and BWR) and MOX. For a given fuel assembly and based on its initial composition, the reactor type and the history of irradiation, it provides the masses of isotopes, activities, heat power and neutrons sources. It enables to evaluate 40 heavy nuclides, 204 fission products and 2 activation products. It uses a Runge-

Kutta method for calculations during irradiation and a matrix type method for calculations between cycles and during cooling time.

APOLLO-MORET [2,3]
APOLLO 1 is a 99 group deterministic criticality code with CEA 86 library. MORET III is a Monte Carlo code with 16 groups. For actinide only burnup credit, these codes are qualified with 102 benchmark experiments. These experiments use fuel composition equivalent to a fuel enriched to 4.5 % and 37.5 GWd/t burnup without fission products. These experiments simulate transport, storage and dissolution configurations.

For the criticality calculation, only major actinides are considered (^{235}U, ^{236}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu). The fission products are neglected. The most reactive configuration is described and considers fuel assemblies with no or a few missing pins. Based on the results of calculation performed in accordance with these principles, the use of burnup has been implemented in two steps, as concerns transport.

FIRST STEP: QUALITATIVE (GO/NO-GO) BURNUP CHECK

The approval has been obtained with the following requirements:

- In order to ensure a safety margin on the irradiation, the allowed burnup credit must be reached on the least irradiated part (i.e. the last 50 cm) of the active fuel length instead of an average value over the total active length.
- On the basis of the fuel management and in-core measurement, the operator of the power plant must guarantee that after one cycle the minimum burnup on the least irradiated part (i.e. the last 50 cm) of the active fuel length exceeds the allowed burnup credit, and that each fuel to be loaded in the cask has been irradiated during at least on cycle.
- The irradiation status of each fuel assembly must be checked by a qualitative go/no go physical measurement in the reactor pool just before cask loading. These measurement have to be in accordance with the plant quality assurance policy.
- In addition, safety authorities require COGEMA and TRANSNUCLEAIRE to demonstrate the reliability of their fuel identification procedures.

SECOND STEP: QUANTITATIVE BURNUP MEASUREMENT

For increased burnup credit, a new requirement has been introduced, which consists of replacing the qualitative irradiation go/no-go checking as previously performed, by an independent quantitative measurement at the reactor storage pools performed with one of the two following devices :

- The PYTHON device, developed by CEA-CADARACHE, evaluates the burnup of the fuel assembly on the basis of a passive neutron measurement and of a total gamma irradiation profile measurement. The whole active length of the fuel is measured. This device has been validated by the French competent authority.
- The FORK detector, developed by Los Alamos, uses the Cm 244 neutron emissions to measure the fluence observed by the fuel. By use of the enrichment, this measure can be converted to burnup. This detector has been adapted by the CEN-MOL laboratory (Belgium), and validated by the French competent authority.

For storage and reprocessing the same principle applies. Besides, a verification of the data sent by the reactor is performed.

OPERATIONAL PROCEDURES

On the operational side it appears that the safety depends on the reliability of the fuel identification procedures. Thus, study of the most likely failure scenario enables an optimization in the procedures by focusing on the prevention of misloading and increasing the possibility of recovering errors prior to shipment. This has led to the definition of the following principles to set up the operational procedures:

- Segregation of fresh or low irradiated fuel assemblies in the pool.
- Fuel element pre-loading positions. The fuel assemblies selected for a given transport are set apart from the bulk of the stored fuel in the reactor pool.
- Training of the TRANSNUCLEAIRE's operators in charge of the fuel identification on behalf of COGEMA.
- Increasing the awareness of the reactor fuel handling staff to fuel identification prior to transport.
- Introduction of redundancy on fuel identification with low dependence level between operators.
- Written records of the checks carried out on each action.

NEW DEVELOPMENT

Thus, the use of burnup credit has become a common practice well mastered by the different organizations involved, from the reactor to the reprocessing in La Hague. However, there is still a need to improve the scope of burnup credit. One need is to take account of the fission products in the criticality calculations. That is why IPSN and COGEMA are currently implementing an experimental programme on actinides (U, Pu) and fission products. The aim is to perform criticality experiments in order to extend the scope of qualification of the French criticality codes used.

The HTC (HTC means high burnup) Programme, which started in 1988 and ended in 1992, was the first step in the experimental programme. The fuel composition considered was equivalent to 4.5 % ^{235}U enrichment with a 37.5 GWd/tU burnup without fission products. The actinides involved where U, Pu, Am.

The second step, which started in 1996 and is due to end in 2001, is the FPs (Fission Products) Programme. The intend is to qualify in the criticality codes, the use of six selected fission products: ^{103}Rh, ^{133}Cs, ^{243}Nd, ^{149}Sm, ^{152}Sm, ^{155}Gd. This will enable COGEMA and TRANSNUCLEAIRE to take credit for these fission products in their criticality evaluations and thus improve the evaluation of the reactivity of the spent fuels.

CONCLUSION

Facing a continuous increase in the fuel enrichments, COGEMA and TRANSNUCLEAIRE have implemented step by step a burnup credit programme to improve the capacity of their equipment without major physical modification. Many authorizations have been granted by the French competent authority in wet storage, reprocessing and transport since 1981. Thus the use of burnup credit is now a common practice in France and new improvements are still in progress: extended qualification of the codes is made to enable, in a first step, the use of six selected fission products in the criticality evaluations.

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