FR8800033

FRADOC--11-2

R1

EXTENDED FUEL CYCLE LENGHT

Bruyere, M.; Vallee, A.; Collette, C.

Framatome, 92-Coubevoie (France)

Communication présentée à : Congress on power station 1986
Strasbourg (France)
2-5 Sep 1986

INTRODUCTION

Extended fuel cycle length and burnup are currently offered by Framatome and Fragema in order to satisfy the needs of the utilities in terms of fuel cycle cost and of overall systems cost optimization.

In view of the diversity of utilities needs, different fuel management strategies have been analyzed. They can be characterized by the following points :

- Fuel cycle length up to 18 month
- Assembly average discharge burnup up to 50000 MWD/T
- Feed region sizes from 36 to 72 assemblies (for 3 loops plants)
- Possible use of gadolinium as burnable poison
- Core loading strategy : out_in type or hybrid type.

Our purpose is not to present the analytical and experimental programs which have been carried out in order to evaluate the impact of extended burnup on the fuel assembly behaviour including poolside examination of the fuel assembly geometry, measurement of the oxyde corrosion thickness and of the fission gaz release.

We intend to point out the consequences of an increased fuel cycle length and burnup on reactor safety, in order to determine whether the bounding safety analyses presented in the Safety Analysis Report are applicable and to evaluate the effect on plant licensing.

This paper presents the results of this examination. The first part indicates the consequences of increased fuel cycle length and burnup on the nuclear data used in the bounding accident analyses.

In the second part of this paper, the required safety reanalyses are presented and the impact on the safety margins of different fuel management strategies is examined. In addition, systems modifications which can be required are indicated.

As an example, the safety analyses which have been performed for the french 3 loops CONTRAT PROGRAMME 1 plants (CP1 plants) and for the TIHANGE plants in Belgium are indicated in more detail.

For the TIHANGE 1 and 2 plants, the fuel cycle length is intended to be progressively increased up to 18 months during the next cycles, which leads to a fuel assembly discharge burnup of 50000 MWD/T. The loading pattern strategy is classical (out-in-in) without use of burnable poisons, with a feed region size of approximately one third, fuel enrichment is close to 4.5 %.

For the CP1 plants, a different fuel management strategy has been already adopted : fuel cycle length of about 14 month (assembly discharge burnup of 42000 MWD/T). The loading pattern strategy is also classical (out-in-in type) with a feed region size of one third. However gadolinium burnable absorbers are used. The initial fuel enrichment is 3.7 %.

PHYSICS CONSIDERATIONS

Extended fuel cycle length can be achieved in PWR plants by increasing the number of fresh fuel assemblies at each reload or the discharged burn-up of the assemblies, or by a mixing of the two.

Figure 1 shows the different possibilities connected to the problem. Two parameters are sufficient to define the main characteristics of the reload : the fuel cycle length and the maximum achievable batch burn-up. The figure is plotted from out-in-in fuel management pattern ; a low leakage pattern does not change anything but the initial enrichment by less than 0,10 %.

Before going further, it may be interesting to have a look on the Economy. Fuel cycle length optimization is the result of considerations which are specific of the utility needs (part of the Nuclear production, plant operating in base load or not, number of units on site, and so on...) and not only the fuel cycle cost. But at least, we can assume that for a given cycle length the cost must be as low as possible.

Moreover, figure 1 indicates tendencies on fuel cycle cost. Because of the different ways and data for approaching such a cost, these tendencies are only indicative. What is interesting to note is the saturation of the gain with discharged burn-up which is more sensitive in annual length than in longer ones. Typically, a 5 % gain can be obtained for a 12 months period by increasing the burnup from 33 GWD/T to 47. For a 18 months period, that is achievable with 41 GWD/T.

We can now go through the consequences of high burn-up and/or cycle length. The first impact is on the reactivity of the core at beginning of life : the enrichment and/or the number of fresh fuel assemblies have to be increased. So, the needs of soluble boron or burnable poison during reloads and power operations are higher. The capacity of increasing boron concentration is limitated by the basic design Auxiliary System and by the temperature coefficient which may become progressively positive.

Another important consequence comes directly from the initial enrichment : as it increases, the spectrum hardens, that not only at the beginning of life but all the cycle through. Problems may occur at the end of cycle, because of the consequently reduced worth of the shutdown rods, at the time when the Reactivity Inventory is the lowest. Low leakage pattern are generally a good way to minimize this concern.

Last but not least, are the problems related to core power capacity. On one hand, high burn-up has very favourable consequences on the core stability ; on the other, it widens the reactivity dispersion among the fuel assemblies in the core and so increases the radial peaking factors. They can be reduced during part of the cycle by burnable poisons such as gadolinia, but a too extensive use of them gives the same kind of reactivity dispersion and consequent problems at the end of the cycle when they are burned.

These considerations show that no general solution is possible for extended fuel cycle length, but that only a case by case approach is possible.

REQUIRED SAFETY ANALYSES AND SYSTEMS MODIFICATIONS

The main consequences of extended cycle length and burnup on the bounding nuclear values used in the safety analyses (which where based on standard annual 33000 MWD/T fuel cycles) can be summarized as follows :

- Increase in the soluble boron concentration.

As an example, for the 18 month cycles envisaged for the TIHANGE 2 plant, soluble boron concentration of up to 2100 ppm at full power conditions and of up to 2600 ppm at cold shutdown conditions are planned. When compared to standard annual cycles, the increase in the boron concentration is of about 700 ppm.

- Decrease in the rod worth and in the shutdown margin.

For the present 14 month fuel cycles of the French CP1 plants, the decrease in shutdown margin has been evaluated to approximately 500 pcm when compared to the value obtained for the standard annual cycles.

- Increase in the radial peaking factors.

The magnitude of the increase strongly depends on the type of fuel management. Only small increases : less than 5 % have been observed for the CP1 plants.

- Positive moderator temperature coefficient.

The previous accident analyses presented in the Safety Analysis Report were performed assuming a negative value for the moderator temperature coefficient. Resulting from the increased soluble boron concentration, this coefficient can become positive, which requires some amount of accident reanalysis.

A Review of the safety analyses which have been performed in order to take into account the modified nuclear data is indicated in the following.

1 . **Increased soluble boron concentration**

- The first point which has to be examined is the ability of the plant fluid systems to supply the required boron concentration. The systems which are involved are mainly the CVCS (chemical and volumetric control system) and the refueling water storage tank. Additional capacity of the CVCS boric acid tanks may be required in order to still meet the safety requirement : $K_{eff} \leqslant 0.99$ at cold shutdown conditions with shutdown banks out of the core.

  On the other hand, the boron concentration of the refueling water storage tank and of the safety injection accumulators has to be increased in order to satisfy the subcriticality Safety criteria at refueling conditions : $K_{eff} \leqslant 0.95$.

- The second point is the reanalysis of the accidents which are penalized by high boron concentration. The inadvertent boron dilution accident was reanalyzed as a consequence of the increased reactivity insertion rate, the results of the analysis indicate that adequate time for operator action after the initiation of the accident is still ensured. Another reanalysis concerned the loss of coolant accident (LOCA) : long term calculation. The boron cristallization risk in the core for a cold leg break is increased and therefore a shortened time for the operator action (safety injection switch from the cold leg to the hot leg) was specified.

2 . Decreased shutdown margin

Reanalysis of the steamline break and of the inadvertent opening of a secondary safety valve accidents was required for the CP1 and for the TIHANGE 1-2 plants. In addition to the decreased shutdown margin, the analyses included changes in the moderator temperature coefficient and in the Doppler coefficient. For the CP1 plants, a modification of the shutdown rods pattern (location changed for 4 rods) was found necessary in order to meet the Safety criteria. For some other plants, additional shutdown rods may be required. Modifications in the Safety Injection system may also be useful.

3 . Increased radial peaking factors

The amount of increase being very sensitive to the type of fuel management, an effort has been found useful in order to relax the Safety limits on the hot spot factor (Fq) and on the hot channel factor (FΔh).

As an example, for the RINGHALS 3-4 plants (Sweden), recent LOCA analyses have been performed which indicate that limited changes in the ECCS models and assumptions lead to an increase in the Fq limit value of more than 10 %.

Another example can be found in the TIHANGE 1 reanalysis of DNB limiting accidents in order to get licensing of an increase of 6 % of the FΔh limit (from 1.55 to 1.65). The accidents mainly involved were the uncontrolled bank and rod withdrawal at power accidents, the rod drop / misalignment accident, the loss of primary flow and the locked rotor of a primary pump accidents.

4 . Positive moderator temperature coefficient

Operation with a positive moderator temperature coefficient (MTC) is presently not authorized in France.

Plants must operate with a negative or near zero MTC.
Safety reanalysis is planned in a next future with positive MTC of + 9 pcm/oc. Accidents to be reanalysed are the one which cause reactor coolant temperature to increase and for which an immediate trip of the reactor is not initiated (as for example the total loss of load accident, the uncontrolled bank withdrawal at power accident). For these accidents, positive MTC will add additional reactivity and increase the severity of the transient.

In addition to these accident analyses, attention will be paid to the operational impact of a positive MTC (rod stepping, operation stability, effect on normal transients such as rapid load changes...).

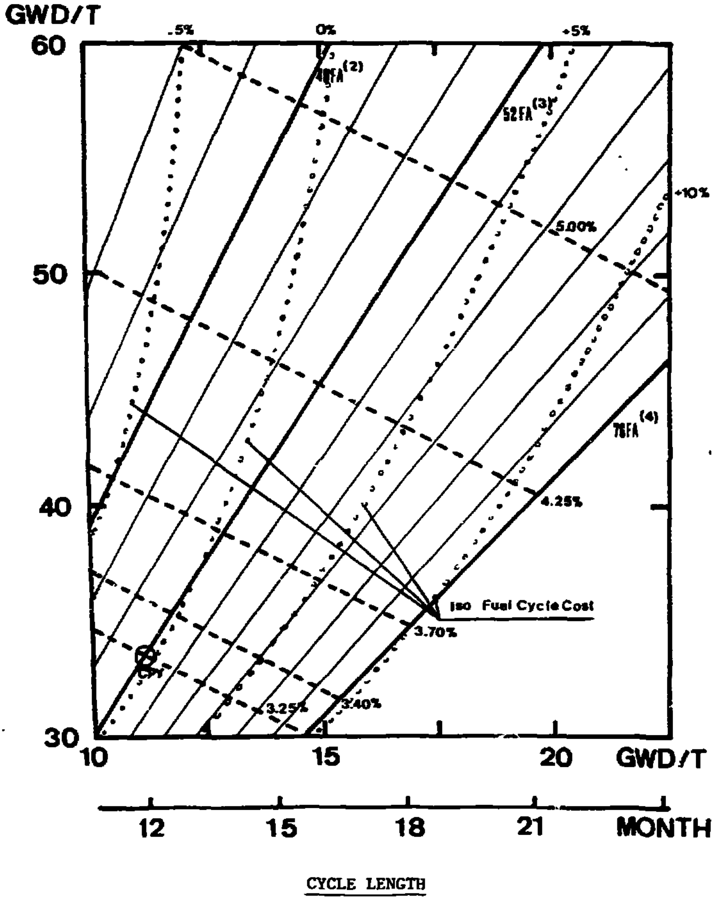
CONCLUSION

A multifaceted fuel management can be proposed by Framatome and Fragema in order to satisfy the diverse needs of the utilities.

In addition to some design improvements of the fuel assembly to allow operation at high burnups, such a diversity required to develop new analytical methods in order to change some licensing bases.
These improvements are helpfull in order to assist the utilities in minimizing system power costs and maximizing plant availability.

FIGURE 1 : FUEL MANAGEMENT

Typical Diagram - French Standard Series



(1) With a load factor of 80 %

(2) Reload per quarter

(3) Reload per third

(4) Reload per half.