ON-SITE TRANSFERS

Irradiated fuel-assembly transfer between two spent fuel pools of the same site

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ABSTRACT

Électricité de France (EDF) wishes to be able to transfer fuel assemblies from the pool of a unit to the pool of another unit of the same site. It is valuable to do so, for instance, in the following situations : operational constraints or economic optimisation.

If we want to be able to carry on the irradiation of these fuel assemblies after the transfer, the transfer must allow the fuel assemblies to be as "healthy" as they were initially. To reach this goal the best solution is to perform a “wet” transfer that allows maintaining the fuel rods in unchanged mechanical and thermal state, during and after the transfer.

For that, EDF has used its usual cask, which is a "dry designed" cask having been partially filled with water. The operation being run on a nuclear site, is not ruled by safe transport regulation but by nuclear safety.

The following presentation sums-up the demonstration of the safety of such an operation made by EDF to the French Competent Authority, which lead to an authorization.

Up to now, EDF had effectively carried out on "experimental" and six "industrial" transfers.

1. INTRODUCTION

EDF wishes to be able to transfer fuel assemblies from the pool of a unit to the pool of another unit of the same site. It is valuable to do so in following situations :

<u>Operational constraints :</u>

In the past, it occurred that all the required files showing the compatibility of assemblies from different manufacturers, were not issued. That had been the case in 1995, when EDF wanted to mix assemblies by Fragema and by ANF.

In 1998, EDF had to perform transfers to empty the cooling-pool of Penly-1, before its fixing by changing the racks.

In 1999, EDF had to perform a transfer to carry on the irradiation of lead-assemblies, after their inspection, as far as the refuelling outage of the initial reactor was much longer than initially scheduled and no more compatible with scheduled milestones for these lead-assemblies.

Economic optimisation by reducing the number of incompletely used fuel-assemblies:

In the future, EDF could be lead to reduce the global amount of a site re-usable spent fuel by matching "orphan" assemblies of a pool with orphan" assemblies of an other pool and by doing so, creating quartets that can be burnt more completely. By doing so, in addition to a better economic usage of the fuel, we would also contribute to lower the occupation rate of the pools.

As soon as 1997, EDF had asked the French Competent Authority a generic agreement to perform such transfers in plants with "under the pool" loading system, using a cask partially filled with water.

For that, EDF has used its usual cask : the TN13.2-B by Transnucléaire, which is a "dry designed" cask that has been partially filled with water. To obtain the right of performing the transfer, EDF had to build a safety analysis. Every time it has been possible, this safety analysis had been structured differentially to the transport safety analysis supplied for the B-type approval of the package.

It had been first established that the only incidents to be taken into account are an earthquake, with its consequences or/and uncontrolled radiolyse phenomenon and its consequences.

During the loading or the unloading of the cask, we know that no consequence of neither an earthquake nor radiolyse had to be feared.
During theses phases, the cask is secured while laying on "anti-seismic" supports and the cooling system is operating. The Safety Analysis of the nuclear plant shows that nothing has to be feared.

So, the phase that had to be studied is the path between the two ponds with the cask settled onto a lorry, as shown on following pictures.

During this phase, different from a routine situation, the cask is vertical instead of being horizontal, the shock-absorbers had been removed and the cask is partially filled with water instead of being dry. So the former studies carried on for the transport safety analysis, can't be applied directly. We had made our demonstration partly in an absolute way (seism), partly differentially to the "Transport Safety Analysis" (consequences of a fall and radiolyse), partly using our experience feed-back (radiolyse).

2. CASE OF AN EARTHQUAKE

The seismic safety analysis had been made in successive steps :

1) It had been shown that the seism that could eventually lead to the fall of the cask must be greater than the dimensioning seism for a typical French plant (NRC 0,2g). That guarantee the occurring probability is lower than 10^{-4}. As far as the duration of a transfer (the time where the cask is not laid on the "anti-seismic" supports of the fuel-building) is mastered (typically less than two hours) the probability for a seism of a greater magnitude to occur is lower than 10^{-7}. With this result, we had assumed the seismic risk during a transfer operation is a residual one.

   n.b. To be sure to master the duration, special procedures had been written, and a rescue-tractor waits on site, ready to operate, in case of breakdown of the usual one.

2) Nevertheless, in a defence in depth approach, we were required by the French Safety Authority to study what could happen in case of an earthquake simultaneously to a transfer. With such an assumption, it has been shown that the system composed by the cask set on a trolley neither can fall nor cannot go out of the railway when considering possible earthquake in France.

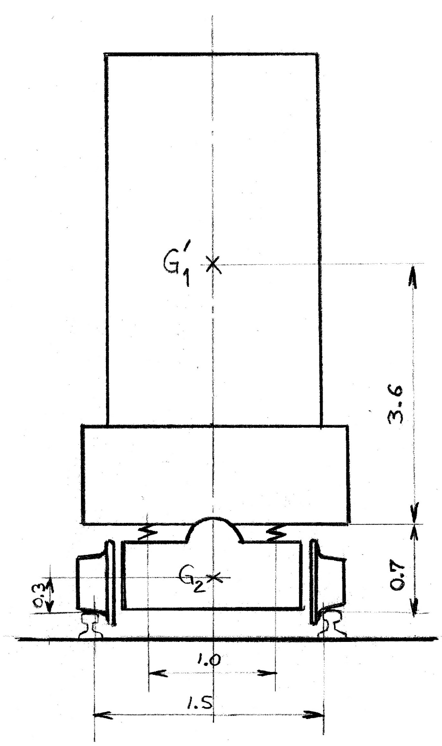
   The structure of the set (a cask settled in a lorry) had been modelled as an oscillating system composed of two mass linked by springs (see below).

   It's easy to check that with a static approach, the set can't fall (the tilt should be about 10°) when the strength amplitude is equal to the seismic one at the infinite (0,2 g).

   For the dynamic approach, the structure of the set had been modelled as an oscillating system composed of two mass linked by springs.

   In this dynamic approach (swinging movement), we had studied the dynamic amplification of longitudinal and transversal oscillations of the system, when we cumulate a seism and the centrifuge force (unimportant) in a curve or when a rude braking occurs simultaneously with the resonance peak of the swinging movement.
   The vertical amplitude due to the seism is assumed being 2/3 of the transversal one.

   The worst case had been found for a seism direction transversal to the railway



With the NRC 0,2g spectrum and with a 1 Hz resonance frequency for the set, the tilt is limited to 0,3° (<<10°) and the rise of a wheel is limited to 8 mm, to be compared to the criterion of 30 mm, height of the edge of the wheel.

So, in any case we could have neither a fall of the cask nor even a derailment.

3) Then another level of defence in depth had been studied :
« *What would happen if the system would swing and fall, after all ?* ».

The studies had been run differentially to the "transport safety studies"

- As the height of the hypothetical fall (the gravity centre is at ≈ 3,9 m) is more than half lower the reference AIEA drop-test one (9 m), and as this fall would arise on a soft floor instead of the rigid one of the reference test, the potential energy variation than can be transferred to the inside structures or components is lower than this ratio.
  So, no superior damage has to be expected.
  Then, in terms of ram-effect towards the screws of the cover, due to water, the overweight-effect is here again largely balanced (< 2%) by the lower drop height.

- It had been check, that during the transfer, there is no strong enough device near the railway that can punch the draining orifices. So the results of the punch test are still usable.

So we can say the mechanical consequences of a hypothetical fall, whatever its origin, are weaker than those taken into account for transport safety analysis.

3. RADIOLYSE

As the cask is partially filled with water during the transfer, we can fear consequences of the radiolyse phenomenon.

This phenomenon can be described as the superposition of two reactions :

✓ Balance between the γ and α radiolyse of the water and the recombination of dissolved hydrogen and dissolved oxygen. **(H_2, O_2) dissolved ⇔ H_2O**

A transfer, to be valuable, has to be performed with perfectly sane fuel-rods, so EDF had made the assumption that α radiation contribution to radiolyse have not to be taken into account.

This assumption as not to be tempered by the eventuality of a fire that could lead to fuel-rods burst. It had been assumed that a fire could not occur during a transfer because this one is performed in a nuclear installation and not in a public area. So every measure preventing from a fire would be taken previously to the transfer. Furthermore, during the transfer, the cask is accompanied by a fire car.

✓ Balance between the dissolved gases (hydrogen and oxygen) and the partial pressure in the gaseous sky of the cask, due to Henry law :

$$(\mathbf{H_2, O_2})\ \textbf{dissolved} \Leftrightarrow (\mathbf{H_2, O_2})\ \textbf{gas}$$

The experience feedback of EDF is up to now, based on one experimental and six industrial transfers :

- Blayais - 1995 : Duration effect

  At that time, every required file showing the compatibility of all assemblies by different manufacturers, had not been issued. As EDF wanted to load new assemblies by Fragema when assemblies by ANF were remaining, it has been decided to transfer these ANF assemblies to another reactor.

  A TN12.2 cask had been used. It had been plunged into the pools for the loading/unloading phases. Although Blayais is not a "under the pound loading system" plant, the results in the radiolyse field remain usable.

  The French Safety Authority took the opportunity of this transfer, to ask EDF to perform numerous experiments and measurements. Specially, the transfer was willingly long (ten days), to evaluate the duration impact upon the radiolyse effects.

  We could see a steady state equilibrium between the water radiolyse, due to γ radiation, and recombination of dissolved hydrogen and oxygen.

  After ten days, H_2 concentration was 0.9% and the partial pressure of the gaseous phase never overtook 10 mbar. We could also see that, in spite of the very long duration of this experiment, we stood far below the explosion threshold (3% for H_2.).

- Penly 1996 : Power effect studied during pseudo-transfer.

  For this experimental pseudo-transfer (the cask did not went outside the fuel building), we wanted to evaluate the power effect. The goal of this experiment was to elaborate a power envelope for the following transfers.

  For that, the cask had been loaded with 12 fuel assemblies which had an average burn-up of 35.5 GWd/t and had been cooled during a year.
  Their power (57 kW) was the maximum possible for transferable assemblies.

  n.b. During a standard dry transport, without any truck-cover, the maximum power allowed for such a cask is 96 kW.

  In addition, to reinforce the power effect, the cooling of the cask had been stopped for ten hours (this duration is a very large envelope for practical transfers) during the experiment.

The physical and chemical characteristics of the gaseous sky had poorly changed during the two first hours. Then the H_2 pressure and concentration had risen but stood largely beyond the critical values.

The steady-state H_2 concentration was about 1.2%, the maximum value having been 1.54%. So, as seen in Blayais in 1995, a real steady-state equilibrium between radiolyse and recombination had been recorded.

During the experiment, a maximum pressure in the cavity of 2.05 bar abs had been recorded. This value is largely compatible with the design of the cask (21 bar).

- Penly 1998 & 1999 : Practical transfer, before and after the renewal of the racks.

The French Competent Authority having required EDF to empty the pond from any fuel assembly to renew the racks, EDF had to transfer twenty-four assemblies from one pool to the other and vice-versa (globally 4 transfers).

As the power of these assemblies was considerably lower than for the 1996 experiment (2.54 and 4.84 kW instead of 57 kW), due to a very long cooling, the results had been confirmed ($[H_2] < 500$ ppm).

More, at the end of the journeys, the inside pressure was always close to the initial pressure, the atmospheric pressure.

- Belleville 1999 : Practical transfer of lead assemblies.

As the refuelling outage of Belleville-1 was much longer than initially scheduled, and as EDF was eager to get the maximum possible feedback about four lead-assemblies made by ENUSA, it had been decided to carry on their irradiation in Belleville-2 reactor.

This transfer had the particularity of having a lower total power (19.4 kW) than in Penly 1996, but nevertheless a similar fuel assembly power, due to a relatively low burn-up (≈30 GWd/t) and a very short cooling for these assemblies.

H_2 concentration varied between 0.1% and 0.3% ; the inside pressure little increased (340 mbar). So, we can still say that a steady-state equilibrium had been recorded.

Radiolyse conclusion.

The experience feedback analysis shows that during a transfer, such as performed by EDF, the influence of water radiolyse is weak and is balanced by recombination of dissolved gases. An equilibrium is always recorded.

The experimental conditions (controlled and limited duration of the transfer, presence of fire-squad) allow EDF to be confident in the practical absence of consequence due to radiolyse.

4. CONCLUSIONS.

After an authorisation-process had been carried out from 1995 to 1999, by EDF and the experts of the French Competent Authority, a generic authorization had been delivered in 1999, allowing EDF to perform transfers on reactors with "under the pond" loading system.

Up to day, EDF had already performed successfully such an operation on one "experimental" and six "industrial" transfers.

The always-growing experience feedback in terms of radiolyse confirms the confidence we have in the assumptions that have been made.

Now, EDF wishes to extend its demonstration to reactors with "in the pond" loading system, so to be able to perform transfer in any kind of reactor.

The objective is to get such an authorization by mid-2002.