UPGRADING SPENT FUEL SHIPPING CASKS TO MEET HIGHER BURN UP

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1. SCOPE

Two of the main basic characteristics affecting transportation of spent fuel assemblies have recently undergone a significant evolution :

- initial enrichment of uranium,
- burn-up of the spent fuel.

Another data of the regulatory environment is also being modified : the value of the neutron quality factor used for determination of neutron dose rate.

Furthermore, transportation of irradiated mixed-oxide fuel (MOX) will become more and more frequent in Europe.

All these changes may force transport cask owners to purchase new casks.

In order to avoid this expensive solution, the owners of TN casks are now offering a variety of solutions to fulfill the new requirements without having to invest in new equipment.

The purpose of this paper is to present these alternatives and our experience in this field.

2. BASIC FEATURES OF TRANSNUCLEAIRE CASKS

The basic concept of TRANSNUCLEAIRE transport casks is exemplified by the well-known TN 12 developed around 1980.

Let us recall a brief description of this cask :

- the containment vessel consists of a forged carbon steel shell of internal diameter 1220 mm and thickness 300 mm welded to a forged carbon steel bottom of roughly the same thickness.

  This thick forged steel wall also provides the main gamma shielding.

- radial neutron shielding is provided by a 100 mm thick layer of polyester resin poured around the forged steel shell.

- external heat exchange is achieved by means of copper fins welded to the shell and going through the resin layer. Their free extremity allows for heat exchange by convection/radiation in the ambiant air.

- inside the cask cavity is placed either a PWR type basket holding 12 PWR fuel assemblies or a BWR type basket holding 32 BWR fuel assemblies.

  The different functions of this basket are :

  - mechanical (keeping the geometry of the arrangement in normal and accident conditions of transport)

  - thermal (conduction of the heat from the spent fuel assemblies to the shell of the cask)

  - neutronic (to ensure the subcriticality of the content in all transport conditions)

A similar description applies for TN17 cask (cavity diameter : 800 mm, 7 PWR, 17 BWR) and for TN 13 (cavity diameter : 1220 mm, 12 PWR 1300)

Table 1 summarizes the original performances of TN 12, TN 17 and TN 13 designs obtained in 1980 and sufficient for use until 1990.

3. ADDITIONNAL REQUIREMENTS FOR TRANSPORTATION CASKS

3.1 Increase of initial enrichment

In order to keep the spent fuel assemblies longer in the reactor with a view to improve its global performance, the amount of fissile material per fuel assembly must also be increased. The uranium enrichment must therefore be raised.

In the beginning of the 1980's, the initial enrichment was generally between 3 and 3.5 % (and consequently the former designs of TN baskets allowed such enrichment values)

According to the type of reactors they operate, the utilities may have different policies in this field but on a worldwide basis the initial enrichment currently ranges from 3.25 % to 4.5 %.

3.2 Increase of burn-up

The values of spent fuel burn-up are increasing along the years, more or less quickly depending upon utilities and reactor type.

In 1980, the burn-up levels were around 33000 MWdj/tU, considered for the design of former TN packagings. In 1992, some transports involve fuel with an average burn-up of 45000 MWd/tU. The cooling time of these spent fuel assemblies is generally between 1 and 2 years and cannot be increased for pool management reasons.

To predict the influence of burn-up increase on dose rate around the cask, we have to keep in mind that neutron source varies like burn-up to the power 3 or 4 and that gamma source varies linearly with burn-up.

This means that the neutron shielding capabilities of the present casks can be reached very quickly.

3. TRANSPORT OF MOX FUEL

The first transportation of spent MOX fuel in Europe occured around 1988 ; the number of transport of this type will increase strongly in the next years.

Besides specific problem of reactivity of this kind of fuel, we are also faced with an increase in the percentage of Pu fissile within the mixed - oxide.

Originally , the average content of Pu fissile was around 4 %, while it is now envisaged that it can reach up to 8 or 10 %. Therefore reactivity is increasing accordingly.

Furthermore, the neutron source of a spent MOX fuel is around 10 times that of a spent U02 fuel for the same burn-up ; incidence on the neutron shielding capability is very high.

4. INCREASE OF NEUTRON QUALITY FACTOR

In the 1990 revision of ICRP recommendations (ICRP 60), there is a substantial modification of the quality factor for neutrons. As it can be seen from figure 1, the quality factor of the previous recommendations ranged from 2 to 11, while the new one ranges from 5 to 20.

This corresponds roughly to multiplying by a factor 2 the neutron dose rate arising from a spent fuel cask.

Full implementation of this recommendation will bear a decisive influence on cask neutron shielding.

5. SOLUTIONS PROPOSED TO MEET THESE NEW REQUIREMENTS

5.1 PHILOSOPHY

The design of TN spent fuel casks allows to bring a progressive answer to the transport of spent fuel assemblies with all these new contingencies.

Therefore, the replacement of the whole cask can be avoided or significantly delayed.

TRANSNUCLEAIRE has developed studies in two directions :

- replacement of the existing internal arrangement in order to accommodate higher enrichment and in order to bring additional gammma shielding.
- increasing the thickness of the neutron shielding outside the cask in order to bring additional neutron shielding.

Combination of these two improvements will upgrade the existing casks in order to meet all the new requirements.

5.2 HIGH PERFORMANCE BASKET

The design of new type of baskets to be used in existing TN casks was guided by the following constraints :

- imposed outside diameter
- imposed g-loads in normal and accident transport conditions
- imposed maximum mass
- thermal capabilities at least equivalent to previous design
- no major changes in loading/unloading procedures

In addition to these existing constraints, we have added :

- allowable initial enrichment as high as possible
- additional gamma shielding as high as possible

The solution was found in the following way :

- use of cast boron aluminium alloy
- optimisation of the geometry of the basket cross-section in order to increase criticality control while keeping sufficient mechanical strength and thermal conduction
- presence of stainless steel inserts in the corner of peripherical lodgments in order to improve gamma shielding.

Comparison between geometry of high performance basket and geometry of previous design basket is presented in figure 2.

Around ten of these baskets are or will be in operation in a few months and their performances have been successfully tested.

The detailed performances are recalled in Table 2. Roughly speaking, this type of basket allows following improvement compared to older basket designs :

- between 0,2 % (TN 13) and 0,8 % (TN 12) improvement of allowable U5 enrichment without burn-up credit.
- around 5000 MWd/tU improvement of allowable burn-up

6. BURN-UP CREDIT

TRANSNUCLEAIRE experienced for more than five years the burn-up credit in criticality control.

This has been done on an industrial basis in the following way :

- the value of burn-up taken into account for criticality is based upon the value of burn-up at the 50 cm extremities of the fuel after 1 cycle irradiation. This value has been evaluated to 3200 MWd/tU
- the utility must guarantee by calculation that one cycle irradiation on a fuel assembly produces a minimum burn-up value of 3200 MWd/tU on the 50 cm at extremities
- the utility must guarantee that all the spent fuel placed in the pool have at least one full irradiation cycle
- before loading the fuel assembly in the cask, a simple gamma control is made under water to make sure that the fuel is irradiated.

With this very conservative method, it is possible to accept for transport spent fuel assemblies with 0.1 % to 0.25 % higher initial enrichment than without burn-up credit.

This method is now currently used in Europe, but for the moment being it is limited to U02 fuel. Application for MOX fuel seems difficult for validation of calculation reasons.

Other methods, using accurate burn-up meters, are now under study in order to allow taking into account higher burn-up values.

7. ADDITION OF NEUTRON SHIELDING

As shown in figure 3, the neutron shielding of TN packaging consists of a resin compound poured around the cooling fins on the outer part of the packaging.

As it can be seen on table 1, the original design of TN packaging was able to dissipate more heat than necessary compare to its shielding capabilities. We took opportunity of this particularity to imagine increasing the thickness of the resin compound. Because, increasing the thickness improves the shielding capability but decreases the heat exchange performance by reducing the height of fins in air.

The determination of the optimal thickness of neutron shielding is explained in figure 4.

We have already experimented addition of resin compound on existing packagings and we will perform this operation on industrial basis on TN 12 and TN 17 packagings end of 1992 and during 1993.

This possibility induces big savings for the customers because they can avoid to invest in a new type of packaging.

8. CONCLUSION

Thanks to the versatility of its original design, TRANSNUCLEAIRE is now proposing to its customers, different cask modifications to accommodate to recent changes in spent fuel transport environment.

Changing the basket, pouring additional layer of resin while remaining compatible with handling equipments and procedures give an appreciated advantage to these solutions rather than replacing of the whole cask.

TABLE 1

ORIGINAL PERFORMANCES OF TN CASKS (PWR ASSEMBLIES, 17 x 17 and 18 x 18)

	TN 12	TN 17	TN 13
Maximum initial enrichment of uranium (%)	3.5*	3.5*	3.2*
Allowable (burn-up - cooling time) (MWd/tU - months)	33000/8 40000/12	35000/2 40000/17	33000/9 40000/13
Thermal power per fuel assembly (kW) corresponding to (burn-up - cooling time)	7.75 40000/9	6.57 40000/10	9.17 40000/9

TABLE 2

PERFORMANCES OF UPGRADED TN CASKS WITH ADDITIONAL NEUTRON SHIELDING AND HIGH PERFORMANCE BASKET (PWR ASSEMBLIES, 17 x 17 and 18 x 18)

	TN 12	TN 17	TN 13
Maximum initial enrichment of uranium (%)	4.3*	3.65*	3.5
Allowable (burn-up - cooling time) (MWd/tU - monthes)	50000/12 55000/18	55000/24	50000/14 55000/20
Thermal power per fuel assembly (kW) corresponding to (burn-up - cooling time)	6.3 50000/12	5.4 55000/<24	7.1 50000/14

* No burn-up credit
** Burn-up credit - 3200 MWd/tU

Note : These values are based on a neutron quality factor of 10

FIGURE 1

VARIATIONS OF NEUTRON QUALITY FACTOR AGAINST NEUTRON ENERGY (ACCORDING TO ICRP 26 AND NEW ICRP 60)

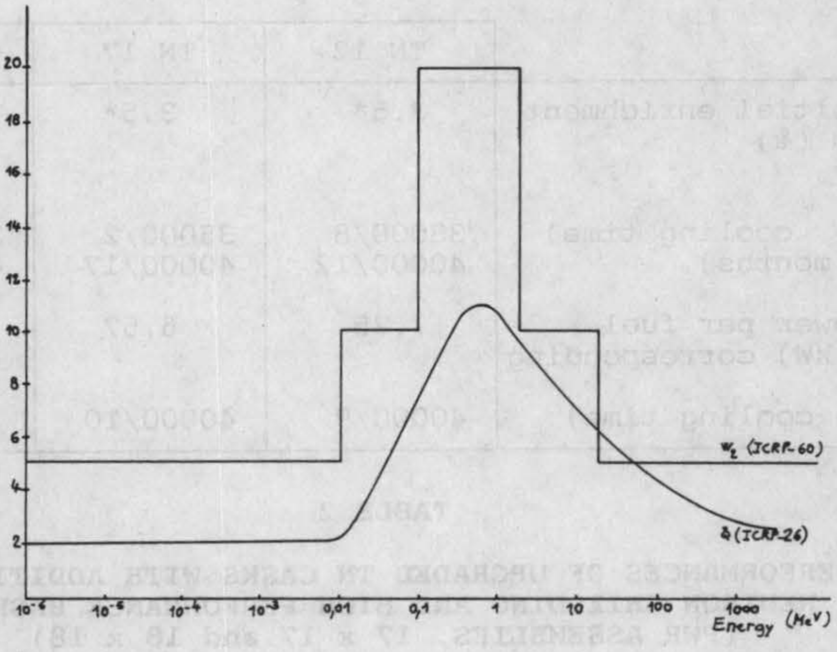

FIGURE 2

COMPARISON OF GEOMETRY OF TN 12

HIGH PERFORMANCE BASKET WITH FORMER BASKET DESIGN

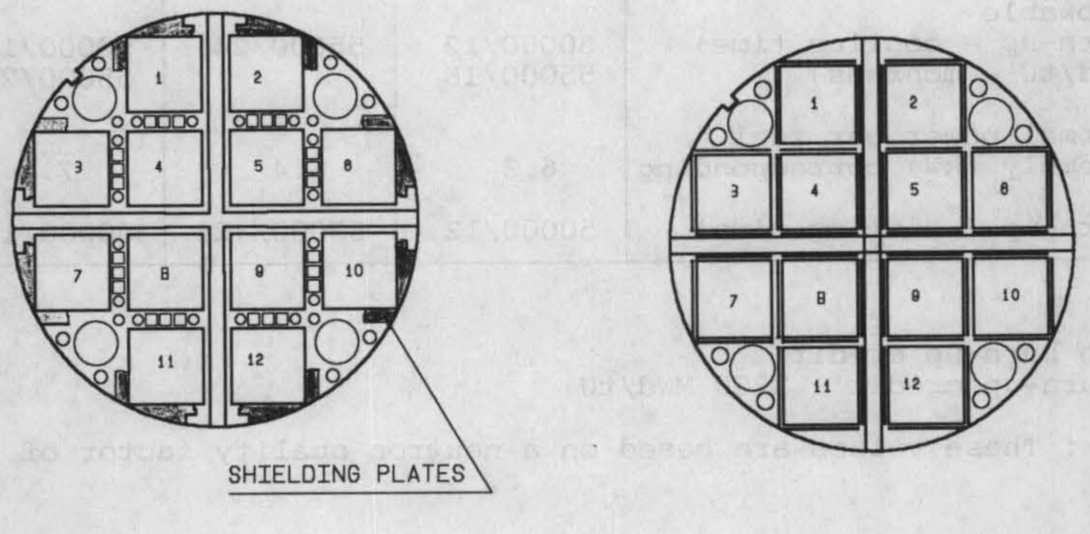

FIGURE 3

NEUTRON SHIELDING OF TN 12 CASK

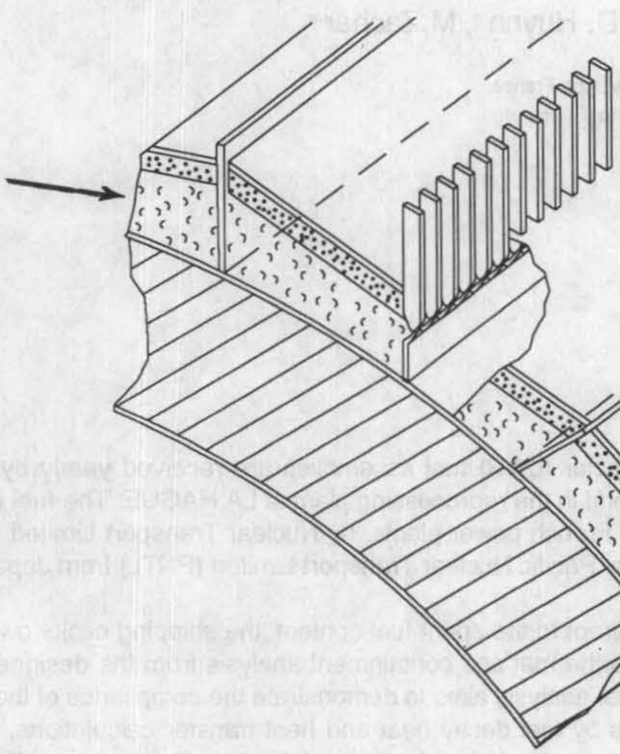

FIGURE 4

OPTIMIZATION CURVES TO DETERMINE RESIN COMPOUND THICKNESS