BWR Spent Fuel Transport and Storage System for KKL: TN™ 52L, TN™ 97L, TN™ 24 BHL

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Abstract

The LEIBSTADT (KKL) nuclear power plant in Switzerland has opted to ship spent fuel to a central facility called ZWILAG for interim storage. In the mid-nineties, COGEMA LOGISTICS was contracted by KKL for the supply of the TN™ 52L and TN™ 97L transport and storage casks for BWR fuel types. In 2003, KKL also ordered from COGEMA LOGISTICS the supply of six TN™ 24 BHL transport and storage casks. This paper shows how all the three cask designs have responded to the KKL needs to ship and store BWR spent fuel. In addition, it highlights the already significant operational feedback of the TN™ 52L and TN™ 97L casks by the KKL and ZWILAG operators.

TNä 52L

In 1996, KKL decided to purchase the TN™52L cask. This TN™24-type dual-purpose transport and storage cask was designed to respond the needs of KKL, that were: first to perform routine transport of spent fuel from the nuclear power plant to the European reprocessing facilities, and finally to store spent fuel at the ZWILAG interim storage facility.

The TN™52L was designed to comply with all the associated handling, transport and storage requirements. In particular, and although the flask was first to be used for transport, all the requirements for storage at the intermediate storage facility of ZWILAG were included in the design. For instance, the requirement for a double lid system with a permanent monitoring of the pressure in the inter-lid space was incorporated in the flask design features. For illustration, figure 1 gives a view of the TN™52L cask in its storage configuration. The carbon steel primary lid is bolted to the upper end of the cask and ensures the leak tightness of the cavity closure by one inner metallic gasket checkable thanks to one outer elastomer gasket. The secondary lid is also equipped with one metallic gasket checkable thanks to one elastomer gasket. During storage, it is the inter-lid space, which is pressurised with helium and the permanent monitoring of the pressure allows the detection of any decrease in the leak tightness performance.

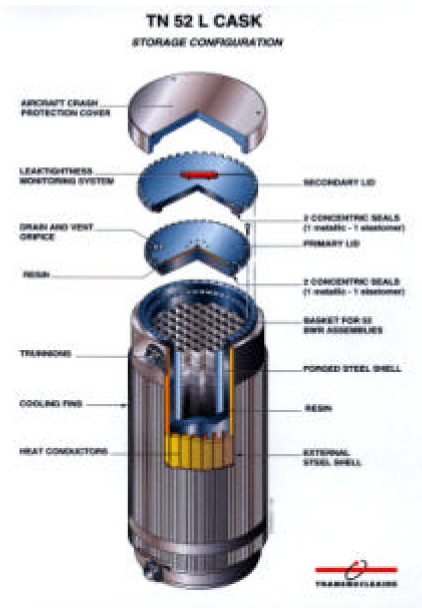

Figure 1

The TN™52L is B(U)F licensed in France with a validation of the packaging approval license in Switzerland. The allowable content is given in table 1.

Table 1

Cask	N° of assemblies	Max Burn up (MWd/tU)	Cooling time (years)	Max Enr. (% U5)
TN™52L	52 BWR	53 000	2.5	4.95

The TN™52L cask was actually the first TN™24-type cask used for routine transport. The cask was delivered in 1999. Cold trials were performed subsequently at COGEMA La Hague reprocessing facility and KKL. To date, five transports have taken place from KKL to the COGEMA La Hague reprocessing facility. The sixth and last transport shall take place, end of year 2004, after the performance of the three-year regulatory basic maintenance in the COGEMA La Hague maintenance shop. In view of facilitating the normal maintenance operations, COGEMA La Hague installations have been adapted in order to allow the withdrawal of the cask basket and the subsequent cleaning of this component with the cask cavity. KKL plans to perform a last cask loading in 2005 and store the cask at ZWILAG. The TN™52L life as a transport cask will then be resumed to enter the next storage phase, thus being the best representative of the true dual-purpose capability of the TN™24 design casks.

The range of operations performed with the TN™52L is the most complete that one can imagine using a dual-purpose cask. As such, it is rather unique and significant operational experience was gained by KKL and COGEMA LOGISTICS from these operations. Table 2 provides a short summary of the challenges this created and the solutions that were developed in order to guarantee the level of performance required from this cask.

Table 2

TNÔ52L Challenges	**Solutions**
In 1998, the “contamination crisis” leads to a temporary ban of spent fuel transports in Europe. The industry had to set up additional measures and precautions in order to guarantee that the level of contamination on the cask surface will not exceed the limits during transport. The TN™52L design features consist of a painted outer surface with a significant number of longitudinal fins and COGEMA LOGISTICS had to be up to the task, in particular to avoid paint peeling.	Tests on painted samples in order to qualify the good performance of the paint with regard to decontamination. Complete review of the cask painting procedure of the cask with the assistance of a Swiss expert named by KKL and implementation of a standard painting procedure for all TN™24-type casks with enhanced technical and QA requirements. Use of a metallic skirt in order to provide efficient protection during the immersion of the cask in the pond. As a result the cask weight during handling is increased and the top trunnions are designed and tested accordingly.
Most dual-purpose casks undergo a very limited number of transport operations, which can be arranged in cold weather or without canopy. When routine transport is concerned, the presence of specific stowing or protection devices such as the wagon canopy has to be taken into account for the thermal evaluation of the cask during transport.	A specific thermal evaluation of the cask under the existing wagon canopy was made and benchmarked by measurement performed during the first cask transport. This measurement enabled the determination of the maximum heat load achievable for the TN™52L under this canopy design.

TNÔ52L Challenges	Solutions
The TN™52L cask has to be compatible with all the following shipping and receiving facility: KKL, ZWILAG and COGEMA La Hague.	Cold trials were performed successfully at KKL and COGEMA La Hague prior to the first cask loading operations. An interface analysis has been performed for the ZWILAG facility and cold trials will take place prior to the cask storage.
During first loading of the TN52L cask at KKL, the first attempts to load some basket positions temporarily failed due to a contact between the KKL fuel grapple and the basket wall. This operation had not been tested during the cold trials in order to avoid cask immersion into the pond and data available on the grapple were not sufficient.	To solve this problem, the orientation of the fuel in their basket position was changed in order to allow their loading. This change of orientation was entered in loading procedures and the KKL grapple was slightly modified in order to eliminate the problem altogether.
During operations at COGEMA La Hague, the secondary lid gasket seat was significantly damaged by shocks. The gasket seat at the level of the secondary lid was not protected during operations on the cask at COGEMA La Hague as the loading operators were not familiar with the need to protect that surface. This seat is important for the leak tightness of the secondary lid during storage but does not contribute to the cask leak tightness during transport, which relies on the primary lid.	Repair by welding and surfacing of the stainless steel overlay and repetition of the leak tightness test will be performed after the last transport to COGEMA La Hague.

In a conclusion, the TN™52L has proved to be an efficient product. Main operating issues were raised during the cask design and procurement phase. The two problems encountered during the operations with the cask have shown the importance of performing interface checks with cold trials prior to all cask operations and of the training of cask operators.

TNä 97L

The TN™52L project being started, KKL subsequently, ordered in 1997, another TN™24 cask design to cover its needs for spent fuel storage at ZWILAG: the TN™97L cask type. Starting from a population of a few hundreds of spent fuel in KKL pond that were available for dry storage, COGEMA LOGISTICS made an optimised design for the given site weight and dimension constraints. The TN™97L is to date the heaviest and largest TN™24 cask constructed by COGEMA LOGISTICS for BWR spent fuel with a total weight of 134.5 tons and a maximum diameter of 2990 mm. The delivery of six casks took place from 1999 to 2001. With a capacity of 97 spent fuel assemblies compared to the capacity of 52 for the TN™52L, the TN™97L offered an impressive payload for the storage of the given fuel assemblies.

As all TN™24 casks designed for Switzerland, the TN™97L is required to be transported to ZWILAG and has a French B(U)F license, with a packaging approval license validation by the Swiss Authorities. The allowable content is given in table 3 below.

Table 3

Cask	N° of assemblies	Max Burn up	Cooling time	Max Enr.

		(MWd/tU)	(years)	(% U5)
TN™97L	97 BWR	Average 26 000	10	3.95

To date, all six TN™97L casks have been delivered and loaded. Five casks have been transported successfully from KKL to ZWILAG and put into storage configuration. The latter cask of this serie will have been transported by end of year 2004. Picture 1 shows the first loaded TN™97L cask on its way from KKL to ZWILAG. The TN™97L was the first cask shipped to ZWILAG so that the interim spent fuel storage facility was successfully put into operation with this cask.

Following the procurement of the six first casks, KKL ordered in early 2003 the supply of three additional TN™97L casks, TN™97L 07 to 09. On the basis of the number of casks already loaded and stored, the operational feedback with the TN™97L cask is significant and worth summarising. Table 4 provides a short resume of the challenges that have been encountered during the cask design and procurement phase together with the solutions that were initiated in order to always guarantee the required level of cask performance.

Table 4

TNÔ 97L Challenges	**Solutions**
To design the highest payload cask adapted to the existing handling capacities of the KKL crane and yoke.	The buoying effect is used during the cask immersion in the pond in order to reduce the actual cask weight lifted by the crane. Prior to lifting the cask out of the pond, the water in the cask cavity is drained, at the level of the pond intermediate step. Once the water in the cavity is drained, the cask weight is compatible with the lifting capacity of the crane and yoke.

TNÔ 97L Challenges	Solutions
To keep in use existing handling equipment considering the distance between the handling arms and the cask top trunnions.	COGEMA LOGISTICS designs and supplies short interface handling arms, between the yoke and the existing handling arms, in order to meet the required distance.
In spite of successful assembly tests at the manufacturing workshop the primary lid of the TN™97L01 cask jammed during the cold trials performed at KKL, The design gap between the lid and its lodgement on the cask is very narrow so that risk of a lid jamming exists if sufficient precautions during handling are not taken.	Removal of the primary lid from the cask by pulling with the crane, after verification of the capability of the load attachment points and the handling means to withstand the load. Definition of tighter machining tolerances for the lid in order to allow the maximum possible gap between the lid and the corresponding positioning lodgement on the cask. Application of the revised machining tolerances on the TN™97L01 primary lid and on the subsequent lids. Definition by the means of “CAD” simulations of the maximum permissible “out of levelness” during the lid handling in order to guarantee no future jamming and implementation by KKL of a specific handling procedure in order to guarantee the required levelness of the lid.

Table 5, next page, concentrates on the issues raised during first operations of the TN™97L cask at KKL and ZWILAG. It is explained how these issues were solved and how improvements were made following the occurrence of such issues.

Table 5

TNÔ 97L Challenges	Solutions

TNÔ 97L Challenges	Solutions
Following the loading of the TN™97L01 cask, dose rate measurements showed that the design dose rate limit of 0.5 mSv/h at any point of the cask surface was exceeded locally at the top level of the cask. A maximum of 0.8 mSv/h was measured. The gamma dose rate due to Cobalt activation was higher than expected. Some older fuel assemblies were loaded for which the initial cobalt content in the top and end fitting was not known precisely. Reasonable assumptions on this initial cobalt content had been made for the cask shielding evaluation but were not borne out by the reality.	An application made by KKL demonstrated to the Swiss Competent Authorities that this situation has no impact on the overall safety of the cask stored within ZWILAG. This application covered the TN™97L01 to 06 series as a similar issue was expected to occur for the subsequent casks. An increase of the thickness of forging was decided for the TN97™L07 to 09 casks in order to improve the cask shielding features with regard to cobalt activation. Following issuance of the latest guideline for the storage of casks (HSK R52) by the Swiss Comptent Authorities, implementation of a procedure determining a dose rate average over the whole cask surface that is compared to the 0.5 mSv/h value. This procedure facilitates implementation without compromising safety.
To meet at the first attempt the leak tightness criteria at the level of the monitoring system connection on the secondary lid. The bolts for the connection are M6 type and the associated uncertainty on the bolt tightening torque with standard tightening tools is such that the needed pressure applied effort on the metallic seal may not reach the required tightness.	To increase the torque to a certain limit in order to achieve the leak rate criteria. Modification of the design of the monitoring system connection for the additional TN™97L 07 to 09 to reduce the time spent for this leak tightness test.
During preparation for storage of the TN™97L01 cask at ZWILAG, the cask was handled with the anti aircraft crash cover whereas this handling configuration was not anticipated by the safety analysis.	Taking into account the actual mechanical characteristics of the trunnions, calculations were performed to demonstrate that the trunnions have suffered no damage following this handling. The site handling procedures were modified to precise the cask allowable configuration during handling.

TNÔ 97L Challenges	Solutions
During the preparation of the TN™97L02 cask for storage, the operators did not achieve at first attempt the leak tightness criteria following the test of the secondary lid inner metallic seal. Upon arrival of the cask, the secondary lid was actually removed without balancing the under-pressure in the inter-lid space. As a result, the gasket seat was slightly damaged and a repair of the scratches was organised by the operators.	More detailed inspections of the gasket seat were organised in presence of COGEMA LOGISTICS and any defaults were corrected. A new leak tightness test showed that the leak rate was still not complying with the criteria even though it was very close. After approval of the Swiss Competent Authorities, the cask was temporarily stored, allowing time for KKL and COGEMA LOGISTICS to set up a repair scenario. The repair scenario included a replacement of the lid and a complete 3-D dimensional control of the top flange of the cask in order to ensure that the cask configuration was compliant with the requirements of the metallic seal assembly specification. This repair scenario was actually not implemented as a new leak tightness test was performed just before. This test showed that the leak rate of the cask was in compliance with the criteria. Site handling procedures were reviewed in order to avoid another occurrence of this event.
Following loading of the TN™97L04 cask, the leak tightness test of the inner metallic seal of the primary lid could not be checked by KKL due to a high level of helium pollution associated with the outer elastomer seal. The same issue also occurs on this cask at ZWILAG during the leak tightness test of the inner metallic seal of the secondary lid, even though a brand new elastomer seal has been mounted prior to the secondary lid assembly. The investigations to identify the root cause of this issue remained inconclusive.	Use of a specific vacuum pumping equipment by KKL to obtain a faster rate of helium evacuation in comparison to the helium release rate from the seal. However, two weeks were required to obtain an acceptable helium concentration in the inter-seal for the performance of the leak tightness test. A modification of the cask preparation procedure was implemented by KKL and COGEMA LOGISTICS to avoid any new occurrence of this event: systematic replacement of the elastomer seals mounted on the delivered cask by a brand new seal, control of the helium pollution in the inter-seal prior to the loading or preparation operations.

As a conclusion, a limited number of challenges were faced during the TN™97L cask design and procurement phase. The first cask operations at KKL and ZWILAG lead to the occurrence of a few specific issues. These were solved in a smooth manner thanks to the full co-operation between the KKL, ZWILAG and COGEMA LOGISTICS teams. The TN™97L cask was the first cask to be stored at ZWILAG and each event was used to gain experience of the product and improve the instructions for the use of the cask. The latter loading and storage operations for these casks have consequently become routine. Some design and fabrication adaptations have also been implemented on the subsequent casks that were procured so that feedback was optimised for this project.

TNä 24BHL

In 2002, KKL initiated a bidding process for the procurement of the transport and storage casks that will allow the shipment to ZWILAG of fuel assemblies with higher enrichment or lower cooling times than those acceptable for loading in the TN™97L cask. There was the opportunity for COGEMA LOGISTICS to propose the TN™24 BH cask and renamed it TN™24 BHL for the occasion. This cask is the last TN™24-type cask developed by COGEMA LOGISTICS for the transport and storage of BWR fuel type in Switzerland. The design was initially launched in 1999 to meet the requirements of the Swiss MÜHLEBERG nuclear power plant (KKM). To date, two units for KKM have been delivered. One has been loaded and stored at ZWILAG in 2003 and one in 2004. The loading of the cask for KKM is rather unique as it is performed in the ZWILAG hot cell, using the fuel assemblies shipped from KKM with the TN™9/4 transport cask. Picture 2 shows a TN™24 BH cask during handling in the ZWILAG storage hall together with the TN™9/4 transport cask. The TN™24 BH has a french B(U)F licensed with a validation of the packaging approval license by the Swiss competent Authorities. The allowale content is given in table 6.

Cask	N° of assemblies	Max Burn up (MWd/tU)	Cooling time (years)	Max Enr. (% U5)
TN™24 BHL	69 BWR	50 000	6	3.9 to 4.2

Table 6

Following the completion of the bidding process, KKL ordered in 2003 six TN™24 BHL casks. The existing B(U)F license shall be extended to the KKL fuel characteristics by end of 2005 and the first cask units are to be delivered in 2006.

The operational experience developed from the use of the TN™52L and TN™97L casks will be fully transferable to the use of this other TN™24 design cask. The bulk of the equipment used for the loading of TN™52L and TN™97L at KKL is standard equipment for a TN™24 design cask so that only minor adaptations are needed. The main adaptation consists of the procurement of a specific skirt for contamination protection during pond immersion. In the same way, the loading procedures are standard and KKL operators are well trained regarding their implementation. Concerning storage preparation operations at ZWILAG, experience is already available with the units already stored for KKM.

Conclusion

Although the focus of cask designers is often on the licensing and manufacturing aspects, operational feedback remains the key to the success of a design. In fact, operators as final customers are mainly interested in operational reliability, flexibility and efficiency of the casks.

The KKL, ZWILAG and COGEMA LOGISTICS experience with the TN™24 design casks TN™52L and TN™97L shows what kind of learning process can be obtained from the challenges managed during the cask operations. It highlights how important it is to identify the root causes of any event and to find the appropriate solution. Substantial gains in terms of cask operations can then be found by improving the cask design or the cask operating procedures.

By selecting another TN™24 design cask, the TN™24 BHL, for their future shipment of fuel assemblies to ZWILAG, KKL will take full benefit from such gains. In addition, there is no doubt that the operations with the TN™24 BHL will also bring additional experience and this will lead to improved performance of these casks.

Thanks and credit are due to the KKL and ZWILAG operators for their full participation in providing feedback and solution during the various projects as well as during the operating periods.