Operational and Safety Aspects of Vitrified Waste Casks

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For the countries which have chosen reprocessing, closing the fuel cycle implies in particular to take back the resulting vitrified high active waste (HAW).

The final solution envisaged worldwide for HAW is the burying into deep geological layers. But because of the high residual heat power, it is generally considered that this operation should not take place before a long cooling period. Therefore, an intermediate storage of long duration will be necessary.

For the time being, two technical solutions have been developed for the interim storage:

- one is based on forced air cooled pits set out in a concrete structure, similar to that presently provided as buffer storage adjacent to the Vitrification Facilities on reprocessing sites;
- the other relies upon transportable storage casks standing vertically on a storage pad, following principles similar to those already implemented with spent fuel storage casks.

Considering these two solutions for interim storage, TRANSNUCLEAIRE has developed two main types of transportable casks for vitrified HAW; one is a routine transport cask called hereafter "transport cask"; the other is a transportable storage cask called "storage cask". Both are covered by the generic name TN28V and have been already described in previous papers.

This paper is devoted to the major aspects related to the safety and operation of the casks under both transport and storage conditions.

1. TRANSPORT CONDITIONS

To cover all cases involved for both transport and storage casks, three main cask configurations have to be considered:

- transport of either cask type from reprocessing plant to interim storage site, called "initial transport",

- transport of a standard storage cask after completion of the storage period (general case), called "final transport"

- transport of an assumed defective storage cask from interim storage site, called "special transport"

For these three cask transport configurations, a full justification against IAEA requirements for Type B(U)F packages has been provided, covering both regulatory normal transport and accident conditions while meeting the additional criteria imposed for the contents, especially the maximum allowable temperature of glass.

In all cases, transportation will be carried out with the cask in the dry condition and in the horizontal position, tied-down on a transport frame or on trunnion supports attached to the vehicle.

1.1 Initial Transport from Reprocessing Site (see Fig.1)

Whichever type of cask is considered (transport cask or storage cask) the configuration for transport after loading the glass canisters at reprocessing plant is basically the same: the cask body is equipped with its basket, a thick lid (the primary lid for a storage cask), and end shock absorbers. The other conditions are as follows:

. Upon arrival at the reprocessing site for loading the glass, a storage cask will normally be new, just delivered by the manufacturer, and therefore not contaminated; on the contrary a transport cask will generally be in routine use, coming from the interim storage site after delivery of its previous load; nevertheless, as the outer surfaces of all glass canisters have been checked for non-contamination before loading, the cask inner and outer surfaces should in all cases be free from any contamination.

. The transport cask has been designed with an integral bottom shock absorbing structure, while the storage cask is fitted at its lower end with a removable shock absorbing cover. Nevertheless, from an operational point of view there is no difference, since the removable shock absorber has been designed to bear the cask weight. It is therefore not necessary to remove it at the reprocessing plant, thus saving time and personnel exposure during glass loading operation.

. The major difference between both types of cask concerns the sealing arrangement of the main lid which consists of an elastomer O-ring for the transport cask and of a metallic gasket for the storage cask. Accordingly, the cavity gas will be Helium and the leaktightness test method will be an Helium leak test (criterion: 10^{-7} atm.cm^3/s) for the storage cask, while it may be a simple pressure rise test (criterion : 10^{-2}atm.cm^3/s) for the transport cask whose cavity may be filled with air or nitrogen.

All other components are very similar, including the basket and the lid Shock Absorbing Cover (SAC).

Upon arrival at the cask loading facility, the cask will be first cleared of the lid SAC, then tilted to the vertical position and put down on the cask preparation area where the lid will be removed, the lid gaskets inspected and replaced when necessary, the gasket seats checked for good condition and cleanliness, and the contamination check performed where needed and using the appropriate method (smear test, gas sampling). In case of necessity, a change of basket would take place at this step.

Then, through a series of remote control operations, the open cask in the vertical position is transferred and installed with interposition of an inflatable gasket under the orifice of the adjacent loading cell where the inner pressure is maintained a few tens mbar below the ambient pressure. The cell plug is lifted open and the glass canisters are lowered into the basket lodgements according to a pre-established loading plan. Subsequently, the cell plug is closed and the cask is transferred back to the preparation area where the lid is replaced.

Then, cask preparation and inspection before shipment will take place according to the applicable procedure:

. tightening of lid bolts to the specified torque
. leak test of the lid main gasket
. filling the cavity with the appropriate gas at the specified pressure through the lid orifice
. tightening of lid orifice plug and associated leak test
. fitting the other components of lid orifice closure

Finally, the cask is transferred and tilted down to the horizontal position on the transport vehicle where the last operations and checks are performed:

. tying down on trunnion supports
. installation of the lid SAC and security seals
. check of outer temperatures and installation of thermal barrier when necessary
. check of gamma and neutron dose rates around the cask
. check for non-contamination
. verification of QA documentation
. fixation of regulatory labels

If confirmed as meeting all requirements of the transport regulations, the loaded cask is released for shipment.

1.2 <u>Final Transport after Long Term Storage</u> (see Fig.2)

This case of course concerns the storage cask type only. It may take place after a storage period of several decades or even more than 50 years.

The normal cask configuration planned for final transport is with its secondary lid, plus the appropriate end shock absorbers (i.e. the bottom SAC and the secondary lid SAC). Nevertheless, as anyway the primary lid has been proved leaktight at the time of shipment, a final transport with the loaded cask only equipped with its primary lid, protected by the primary lid SAC, would be fully acceptable and in compliance with the transport licence.

In both cases, the cask preparation before shipment will be very simple when no leakage has been detected (normal case) by the monitoring system providing a continuous recording of the pressure (around 6 bar Helium) in the interspace between the two lids. Since this monitoring applies to storage conditions, and especially to the storage leaktightness criterion (10^{-7}atm.cm^3/s), it will demonstrate that both lids fully comply with the transport leaktightness criterion (10^{-2}atm.cm^3/s).

Therefore, after disconnecting the monitoring system, the cask will be transferred from the storage pad to the cask preparation area, mainly for visual inspection with particular attention to the condition of trunnion bolts.

If the trunnions have been left in place during a long storage period, some bolts will have to be unscrewed and checked for corrosion. According to the result of this check, corrective actions may be decided in order to guarantee that the cask will comply with the licensed package design.

If trunnions had been removed at the beginning of the storage period, they will have to be replaced, after checking the good condition of the threaded holes.

Thereafter, the cask will be cleared from any additional protection (such as aircraft crash protective cover, if any), transferred and tilted down onto the transport vehicle where the last operations and checks will be performed like for the initial transport (tying down, installation of appropriate SAC, verification of temperatures, dose rates, non-contamination, etc.)

1.3 Special Transport of a Cask Assumed Defective (Fig.3)

We assume that at any time during storage a leak might have been detected through the monitoring system of a loaded cask staying on the storage pad. The pressure recorded in the lid interspace has started to decrease.

When it appears that the leak rate is such that the time left for the interlid pressure to decrease from around 6 bar to 1 bar will be in the range of weeks instead of years, the cask will be transferred to the cask preparation area. There, the secondary lid main metallic gasket (inner gasket) will be helium tested.

If the storage criterion (10^{-7}atm.cm^3/s) it not met, the secondary lid will be removed and its gasket replaced. Then the secondary lid will be re-installed.

If the storage criterion is met, it shows that the primary lid is leaking because would it be leaktight, the pressure decrease $\Delta p/\Delta t$ should meet (when ignoring the temperature variations):

$V.\Delta p/\Delta t < 2 \times 10^{-7}$atm.cm^3/s

with V in the range of 10^5cm^3, and therefore:

$\Delta p/\Delta t < 2 \times 10^{-12}$ atm/s ($\approx$ 0.1 mbar/year)

which would be quite imperceptible.

In such a case of a leaking primary lid, one can consider that the primary leaktightness barrier is transferred to the secondary lid which has been tested as leaktight according to the storage criterion, i.e. the cask is transportable as it is. Now it is possible to re-establish a second leaktightness barrier by fitting a ternary lid around the secondary lid. Fixation of the ternary lid to the body is achieved by bolting and welding which provides a high degree of leaktightness complying with the storage criterion as long as accident conditions are not involved. The interspace between the secondary and the ternary lid can be pressurized with Helium and monitored in the same way as before. Thus this configuration meets the storage criteria.

When so equipped with a ternary lid, a cask will also comply with the transport regulations as long as the secondary lid meets the transport leaktightness criterion, which can be proved by the monitoring system. Therefore when shipment is needed, preparation of the cask for transport will follow a procedure very similar to the previous one.

2. INTERIM STORAGE CONDITIONS

The basic concept of any interim storage of HAW aims at three main objectives :

- protection of the populations and environment against irradiation and contamination from the waste
- protection of the waste against external aggressions
- retrieval of the waste at the end of the storage period.

To achieve these objectives, the cask storage concept relies on the following features:

. the waste conditioning, i.e. the glass canister which provides a very effective first containment for the nuclides

. the cask itself under storage conditions, i.e. including any additional protection, for instance against aircraft crash

. the auxiliary building and/or equipment available on the interim storage site, which may provide additional shielding when required by very severe local regulations.

Cask contribution to safety of the interim storage covers all the main aspects involved, in particular:

- mechanical: resistance of the cask body, including its closure system, to accident conditions in storage (not only shock and drop during handling, but also external aggressions like explosion, earthquake, aircraft crash, terrorist attack,etc.) ; for the most severe cases, investigations by calculation model and/or representative tests have been performed to evaluate the consequences of such events for the condition of the HAW and for the environment (nature and human beings)

- thermal: evaluation of the temperatures reached both inside the cask including within the glass and in the neighbourhood of storage casks, both under normal conditions and in case of fire, so as to confirm that the maximum allowable temperature of glass is never exceeded

- shielding: for both gamma and neutron, the major contribution to the shielding is brought by the cask body which has been designed mainly to meet the requirements of transport regulations; nevertheless additional shielding might be easily provided at storage site where necessary

- containment: among all aspects considered, containment certainly corresponds to the major concern of safety authorities; based on the "zero release" principle, the storage cask concept has been developed in associating long term sealing devices (in particular metallic gaskets with elastic properties and limited creep under mechanical and thermal cycling conditions), effective designs (namely the double lid system with pressurized interspace), appropriate atmosphere (e.g. using Helium which provides an efficient protection of gasket material against corrosion on a long term basis, while allowing very easy and precise leaktightness test) and continuous monitoring (using a pressure sensor with permanent recording and alarm when a given threshold is crossed).

Since the metal cask proposed for storage is made from a very strong material for which a limited maintenance programme is enough to guarantee durability for a long period of time, and because the few sensitive components are especially protected from corrosion or damage on a long term basis, the cask storage concept certainly provides a solution with a high level of safety for interim storage of HAW. In addition to economic benefits, its modular nature also offers substantial advantages for safety and security.

Moreover, we have nevertheless assumed that if for an unlikely reason the closure system happened to be defective during the storage period (for instance a leak is detected on one of the two leaktightness barriers), a corrective action has been provided for (see above par. 1.3). It simply consists in re-establishing the double leaktightness barrier with monitored interspace by installing a ternary lid, which allows either to proceed with interim storage under the same safety criteria (see Fig.5), or to ship the cask to an appropriate facility for specific maintenance operations (see Fig.3).

CONCLUSION

For more than 10 years, spent fuel assemblies have been routinely shipped without incidents for safety using transport casks similar to those now proposed for vitrified HAW. A cask maintenance approach including two levels of requirements has proved to be very effective. Therefore a similar maintenance programme applied to the vitrified HAW transport casks will guarantee the same high level of safety.

As far as the storage casks are concerned, the only maintenance will consist of:

- periodical repainting of external surfaces
- verification of trunnions and fixing bolts before moving the cask after a long storage period.

Lastly, it should be noted that from the viewpoint of transport regulations, a cask is allowed to be kept loaded for one year before being shipped and unloaded.

A very safe concept of interim storage for high active waste is therefore provided by the steel cask technology.

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DIFFERENT CASK CONFIGURATIONS
DURING TRANSPORT AND STORAGE