# Inerting of Casks Cavity Atmospheres - The GNS Approach to Treat Hydrogen Generation in Sealed ILW Packages – 16043

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## ABSTRACT

A new approach to deal with the issue of hydrogen generation in sealed packages for radioactive waste with organic content is presented. The so-called “inerting” of the cask cavity atmosphere can be either executed after loading or after interim storage via a new facility introduced by GNS. This new approach is approved by the German competent authority and yield to the recent prolongation of the Type B(U) certificate of approval of the GNS MOSAIK® cask.

## INTRODUCTION

Hydrogen generation in radioactive wastes with organic content or significant amounts of residual water is a long and widely known issue throughout the nuclear industry. It becomes even more challenging in the context of packaging and transportation of radioactive wastes.

Traditionally the issue of hydrogen generation during storage is resolved by constant venting of the packages through filters and rather short transportation times. This effective strategy is a well proven practice in most of the countries dealing with radioactive wastes.

Although hydrogen is commonly excluded by means of short transportation times with subsequent venting of the packages respectively, this approach is -unfortunately- not generally applicable. At least in Germany a hypothetical minimum transportation time of one year has to be taken into account licensing wise for a Type B(U) certificate of approval. For a given hydrogen production rate this minimum transportation time of one year might not be sufficient to exclude the amount of hydrogen necessary for a flammable atmosphere with the presumption of the presence of sufficient amount of oxygen.

Therefore, the presence of hydrogen during transport has to be taken into account as an affiliated risk in addition to the main risk of radioactivity in terms of the respective laws covering hazardous goods. The affiliated risk has to be taken into account for the safety case of the package.

From a technical point of view, the presence of hydrogen in a sealed cask is tolerable with respect to internal pressure, since thick-walled casks like the GNS Yellow Box®[i], the MOSAIK®[ii] and the SBoX®[iii] withstand very high internal pressure and it is also tolerable with respect to a supposed flammable atmosphere. For a presumed ignition, the relevant gases both hydrogen and oxygen have to exceed a certain percentage in the atmosphere, about 5 percent.

Even though the chemical and radiolytical processes of gas generation and consumption and in particular the multiplicity of intermediate steps during these processes are very complex, it is fair to state that the amount of oxygen is simultaneously very low at large radiolytic hydrogen production rates due to parallel radiolytic processes that consume the oxygen. However, this simple statement has to be demonstrated for the safety case of the package, which is rather complicated by calculation due to the mentioned complex processes with many intermediate steps.

GNS is introducing a new approach for the hydrogen issue for extended transportation times or cases in which longer minimum transportation times have to be taken into account for the safety case. “Inerting” of the cask cavity atmosphere with nitrogen prohibits the formation of flammable atmospheres inside the casks and in any handling cases including lid opening after long-term interim storage. Furthermore, it is a easy to use and cost effective method, which is practicable in virtually all operating conditions. It is worth noting that this new approach yield to the recent prolongation of the longtime Type B(U) certificate of approval for the MOSAIK® cask made from ductile cast iron.

## INNERTING OF CASK CAVITY ATMOSPHERE

GNS introduced a new approach to solve the issue of potentially flammable gas mixtures by excluding oxygen in the cask cavity atmosphere, rather than minimizing the amount of hydrogen. The existing oxygen is replaced by nitrogen, a process we refer as “inerting” of the cavity atmosphere. The inerting can be performed after loading of the cask and if necessary before transportation, respectively. Since the generation of hydrogen is not controllable in casks with organic content and considerable activity, the main advantage of this approach is the provision of maximum sealing times without any venting.

The permanency of the replacement of the oxygen by nitrogen is influenced especially by the permeation of atmospheric oxygen through the elastomeric seals into the cask. In the case of non-consideration of radiolytically consumed oxygen inside the cask (see “considered alternatives”), the permeated oxygen restricts the maximum sealing time before a formation of a flammable gas mixtures would have to be presumed. This maximum sealing time therefore restricts the time after an initial inerting in which the foreseen transport has to take place. It is worth noting, that the maximum sealing time is highly dependent on the content.

For the most common contents/wastes this technique provides an adequate timeframe after the initial inerting (directly after loading) before the transportation actually has to be performed. In this context one has to consider different inert gases which provide slightly different timeframes with respect to the permanency of the oxygen replacement. Nitrogen is favored over other inert gases since its easy available and manageable as well as reasonable priced. Even though other inert gases, especially noble gases, offer slightly longer sealing times, the content-dependent sealing times achieved by inerting with nitrogen are more than sufficient for the presumed transportation time of one year (see introduction) and also for an additional short interim storage before the transport actually has to be executed.

## Inerting subsequent to loading

Typically loading of self-shielded casks like the GNS Yellow Box® and the MOSAIK® is executed for instance via the GNS loading and drying facilities KETRA for core components, FAVORIT for sludges, concentrates and resins and FAFNIR for resins. All these facilities can easily be upgraded to inerting facilities that can be used directly after loading of the cask.

After the drying of the casks content below the required residual moisture level a vacuum is generated inside the cask. Via the venting port nitrogen can be easily injected into the cask cavity. Depending on the free volume inside the cask the amount of nitrogen necessary for the inerting is adjusted and generates a pressure inside the cask that corresponds to the ambient pressure.

This effective and time saving procedure does not require any extra equipment. Therefore, the total cost for a campaign with additional inerting of the cask does not significantly differ from a traditional campaign without inerting.

GNS already gained extensive experience with this procedure during campaigns for spent resins in a German NPP. The inerting was performed with the standard GNS drying facility FAFNIR and provided dried and inerted casks, ready for transportation.

## Inerting after interim storage

In the case of the necessity of inerting after interim storage another challenge has to be solved. Hydrogen that was generated during interim storage inside the cask must not form a flammable atmosphere with the oxygen flowing onto the casks when the lid is opened. This might especially occur when a negative pressure was created inside the cask due to the consumption of oxygen during interim storage (see considered alternatives).

Therefore, GNS invented a new inerting facility, which is currently under construction. This facility will allow direct inerting of different types of self-shielded casks, even when hydrogen was generated inside the cask above the flammability limit. Figure 3 shows a rendering of the facility with a MOSAIK® cask on the working position.

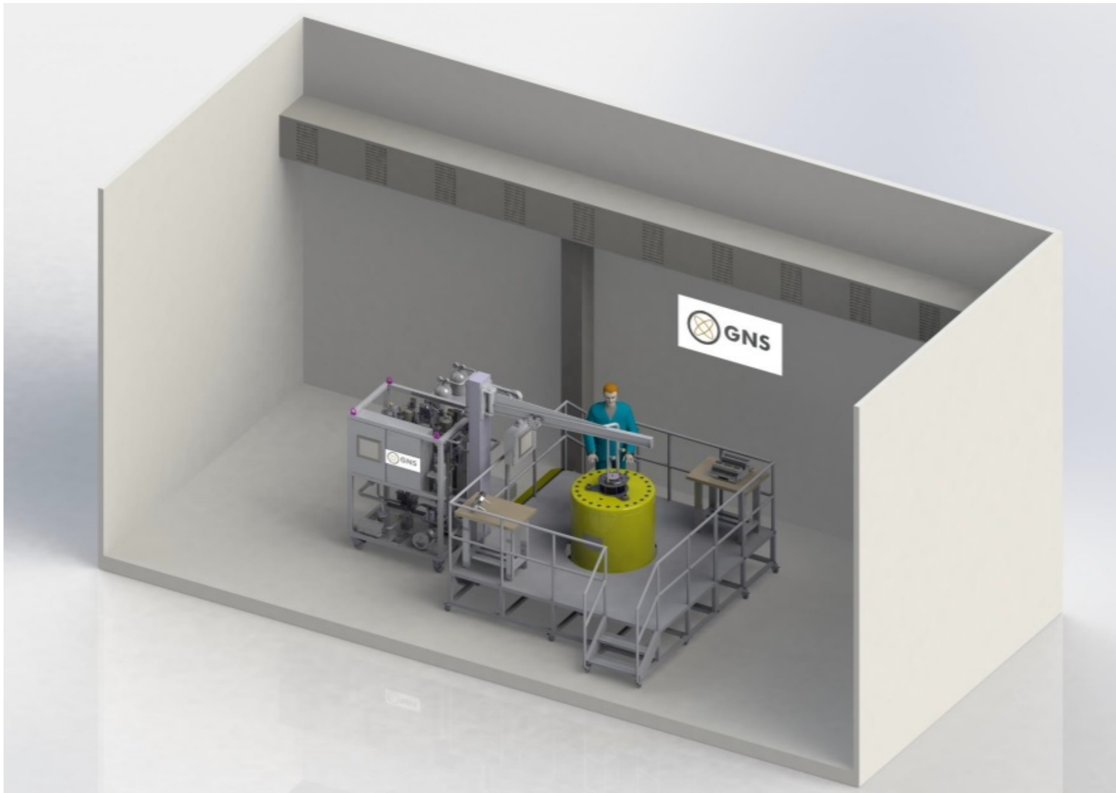


**Figure 1: Sketch of the new GNS inerting facility with a MOSAIK® cask in working position.**

After placing the cask into the facility, a handling box is attached to the closure lid of the cask. The handling box is filled with nitrogen and the closure lid is opened using a special tool inside of the handling box. This process covers both possible options of pressure inside the cask, over and under pressurization. Afterwards the newly formed gas mixture is deduced by the facility. Now the casks can be either directly inerted or necessary maintenance work which requires an open closure lid can take place. Before sealing the closure lid the cask is filled again with nitrogen. Depending on the free volume inside the cask the amount of nitrogen necessary for the inerting is injected into the cask. After this process the pressure inside the cask corresponds to a predefined pressure, preferably ambient pressure. Finally, the pressure box is disconnected and the cask can be removed from the facility.

Typically, the process will take place during the periodic inspection before transportation and is therefore not particularly interfering with the normal procedures after interim storage. Especially in old casks that require some maintenance work before transort, this process creates standardized conditions while working on the casks components.

## Considered alternatives

We have evaluated a number of alternative measures to exclude the generation of a flammable atmosphere inside the cask during long transportation times in order to avoid the inerting of the cavity atmosphere. It turned out that all commonly known alternatives have either not been qualified by regulators in Germany for this purpose in Type B(U) transport casks or not to be fully designed for use. Resolving these issues for the alternatives would have cost both money and time as described briefly below.

The most common alternative to the presented approach is the time restricted transport of radioactive wastes. Commonly used transportation times below ten days for LSA material (low specific activity due to IAEA SSR-6) exlude the generated amount of hydrogen by magnitudes below the necessary amount for the formation of a flammable atmosphere. With this approach the consideration of the amount of oxygen is obviously obsolete, since the anticipated amount of hydrogen is already not sufficient for the formation. As mentioned in the introduction, this alternative approach is practically impossible for Germany, since a transportation time of one year as a minimum has to be anticipated.

Another alternative would have been to quantitatively consider the radiolytically consumed oxygen (cp. radiolytic oxydation), as described in the introduction. The general statement, that in cases of high radiolytic hydrogen production rates the radiolytical consumption of oxygen in simultaneously high, is indeed true, though the detailed reaction mechanisms to be considered are very complex. For transport licensing purposes it is certainly required to have a full quantitative analysis of the generated and consumed fractions of gases in order to use this argumentation for the safety case of the package. Unfortunately, this is not possible or would require a fair amount of fundamental research and development.

A further considered measure includes the usage of catalytic recombiners, which have to be included in the packages or added to the waste. Unfortunately, this technically elegant approach has the same striking disadvantage as the quantitative calculation of fractions of the different gases in the casks atmosphere. It is not yet established with the German regulators. Doing so would also require considerable research and development. Additionally, depending of the chosen recombiner, this approach might create a considerable increase in costs.

## CONCLUSION

GNS has invented a user-friendly approach to deal with the hydrogen issue in sealed packages for organic radioactive waste in cases of longer transportation times. The selected technique for exclusion of flammability is technically simple and therefore easy to approve by the regulators, as demonstrated by the recent prolongation of the Type B(U) certificate of approval for the MOSAIK® cask by the German competent authorities. Since the inerting technique is adaptable to existing drying facilities like the GNS FAFNIR (in case of inerting after loading) it is rather convenient to use during the existing process for waste management and transportation.

The new inerting facility which is currently under construction will complementary allow to handle casks after interim storage. As a benefit, it is fair to state that no complicated additional infrastructure is required for the use this facility.

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[i] GNS Yellow Box is a registered trademark of GNS Gesellschaft für Nuklear-Service mbH (Frohnhauserstraße 67, 45127 Essen, Germany)
[ii] MOSAIK is a registered trademark of GNS Gesellschaft für Nuklear-Service mbH (Frohnhauserstraße 67, 45127 Essen, Germany)
[iii] SBoX is a registered trademark of GNS Gesellschaft für Nuklear-Service mbH (Frohnhauserstraße 67, 45127 Essen, Germany)