# GNS Experience of CASTORâ Cask Loading for Storage and Transport of Spent Fuel Assemblies

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## Introduction

With over 25 years of experience in the design, manufacturing, assembly and loading of CASTOR® casks, GNS is one of the worldwide leading suppliers of casks for the transport and storage of spent fuel assemblies as well as for canisters with vitrified high level wastes.

GNS products are used at around 30 sites worldwide for a wide range of inventories from pressurized and boiling water reactor fuels (PWR and BWR), thorium high-temperature reactor fuels (THTR) and research reactor fuels to vitrified high-active wastes (HAW) from reprocessing plants.

On behalf of its shareholders, the major German utilities, GNS assists in the loading and dispatch of CASTOR® casks as well as their storage at interim storage facilities and interim storage areas and performs the operations respectively.

### SAFETY WORLDWIDE

**Loaded GNS casks in storage worldwide**

| Location | Cask Type | No. of Loaded Casks as per July 2004 |
|---|---|---|
| Paul Scherrer Institut (PSI), Switzerland | CASTOR® Ic-Diorit | 1 |
| Department of Energy (DOE), Idaho Falls, USA | CASTOR® V/21 | 1 |
| Surry Power Station, Virginia/USA | CASTOR® V/21<br>CASTOR® X/33 | 25<br>1 |
| Ahaus Storage Facility, Germany | CASTOR® THTR<br>CASTOR® V/19<br>CASTOR® V/52 | 305<br>3<br>3 |
| Jülich Research Center, Germany | CASTOR® THTR | 132 |
| Gorleben Interim Storage Facility, Germany | CASTOR® IIa<br>TS28V<br>CASTOR® Ic<br>CASTOR® V/19<br>CASTOR® HAW 20/28 CG | 1<br>1<br>1<br>3<br>39 |
| Dukovany Power Station, Czech Republic | CASTOR® 440/84 | 52 |
| Department of Energy (DOE) | CASTOR® GSF | 6 |
| Hanford, Washington, (USA) | GNS 12 | 2 |

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## SAFETY WORLDWIDE

**Loaded GNS casks in storage worldwide**

| **Location** | **Cask Type** | **No. of Loaded Casks as per July 2004** |
|---|---|---|
| Energiewerke Nord (EWN), Greifswald, Germany | CASTOR® 440/84<br>CASTOR® KRB-MOX | 36<br>3 |
| Koeberg Nuclear Power Station, South Africa | CASTOR® X/28F | 4 |
| Ignalina Nuclear Power Plant, Lithuania | CASTOR® RBMK<br>CONSTOR® RBMK | 20<br>49 |
| Neckarwestheim NPP, Germany | CASTOR V/19 | 15 |
| Biblis NPP, Germany | CASTOR® V/19 | 22 |
| Philippsburg NPP, Germany | CASTOR® V/19<br>CASTOR® V/52 | 7<br>3 |
| Emsland NPP, Germany | CASTOR® V/19 | 9 |
| ZWILAG, Switzerland | CASTOR® HAW 20/28 CG | 4 |
| La Hague, France (to be transported to Gorleben) | CASTOR® HAW 20/28 CG | 10 |
| Rossendorf Research Center, Germany | CASTOR® MTR 2 | 18 |
| Belgoprocess-Mol, Belgium | CASTOR® BR3 | 7 |
| **Total** | | **783** |

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By the end of July 2004, more than 1100 transport and storage casks for spent fuels and vitrified wastes have been contracted, of which more than 920 casks have been delivered and over 780 casks have been loaded.

In Germany, 67 casks have been loaded with spent fuel assemblies from PWRs and BWRs, one the so-called CASTOR® V/19-casks, designed for 19 PWR fuel elements and the other, the CASTOR® V/52-cask for 52 BWR fuel assemblies, respectively.

## 2. Transport and Storage Casks for Spent Nuclear Fuels

The CASTOR® V/19 casks from GNS, for instance, can store 19 PWR fuel assemblies with a total maximum heat load of 39 kW.

The typical design of this cask type is the ductile cast iron body with heat removal fins and embedded neutron moderator material, a fuel assembly basket for 19 PWR fuels and a double lid system for leak-tight closure. Both lids, the so-called primary and secondary lid, are stepwise assembled and bolted to the cask body. Gap measurements on the lids are performed to verify the correct assembly of the metallic seals and their compression.

The primary lid has shielding and leak-tightness functions, forming the containment boundary for the transport configuration of the cask. In this configuration the cask is provided with shock absorbers after the secondary lid has been mounted.

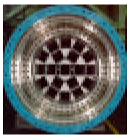
The secondary lid is the leak-tightness barrier of the confinement boundary for the storage configuration of the cask. For this configuration, a protective plate, a cable conduit and a cable for the connection of the pressure switch with the cask monitoring system are assembled to the cask as well.

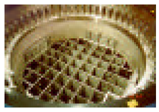
## SAFETY WORLDWIDE

### The Second Cask Generation

**This generation of casks was designed for larger capacities, higher enrichments and higher mean burnups, for example:**

| | CASTOR® V/19 | CASTOR® V/52 |
|---|---|---|
| Fuel Type | 19 PWR F/A, up to 4 MOX | 52 BWR F/A, up to 16 MOX |
| Max. length | 4950 mm | 4485 mm |
| Max. enrichment | 4.45 % U-235 | 4.65 % U-235 |
| Max. mean burnup | 65 GWd/MTU | 65 GWd/MTU |
| Min. cooling time | 5 years | 5 years |
| Heat load | 39 kW | 40 kW |
| Casks deployed | 59 | 8 |





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Both lids are equipped with one metallic and one elastomer seal, forming the lid barriers. The requirements for the leak-tightness of the primary- and secondary lid barrier result in a standard-helium leakage rate equal to $1 \times 10^{-8}$ Pa$m^3s^{-1}$ per barrier or less.

However, before assembling the lids and compressing the seals, numerous work steps have to be performed to prepare the cask for loading.

## 3. Important and Typical Work Steps for a CASTOR® V Cask Loading

Usually the newly fabricated CASTOR® V casks are delivered just-in-time to the site where they will be loaded. The cleanliness, the conservation condition and the intactness of the special cask painting is checked before the cask is transferred through the air-lock into the reactor building.

Furthermore, inspections of the cask condition are performed after both lids have been dismantled, to ensure that the seal-bearing surfaces have no damages which could possibly affect the leak-tightness of the cask. Before the cask is being transported to its loading position in the spent fuel storage pond, a contamination protection skirt (CPS) is assembled at the cask. The CPS protects the cask surface against contamination from within the pond and eases decontamination work to be performed after loading.

In this respect, GNS has made good experience by using warm de-mineralized water (RO/DI water) to decontaminate the CPS and its joints.

The loading of a CASTOR® V/19 cask is completed after an average time of 6 to 8 hours depending on site-specific conditions.

GNS has made a lot of experience with several techniques to close the cask with the primary lid under wet conditions in the pond, as well as under dry conditions at the cask handling platform.
At the beginning of cask loading in the year 1981, GNS directly compressed the licensed silver- and/or aluminum-coated seals under wet conditions.

A few years ago, due to tests with the enclosure of residual moisture in aluminum seals and for avoidance of potential seal corrosion, the aluminum-coated seal was dryly compressed, there after.
GNS designed distance bolts and a special drying plate for the primary lid to fulfil the new requirements for the aluminum gasket.

However, at NPPs with boron-treated pond water, boric depositions at the seal-bearing surfaces are possible. Inspections of the pre-dried seals and seal-grooves detected boric depositions which had crystallized out of the water.
Furthermore, the passivation layer of the aluminum gasket may change under the influence of heat, the air/water mixture and times longer than 10 hours.
Both effects can be the reason that the permitted leakage rate is not reached in any case.

Actually, a few casks were affected by one of these effects, which necessitated subsequent re-cooling of the casks and the renewal of the primary lid seals.

Although further investigations had verified that the passivation layer of aluminum gaskets is unsusceptible to residual moisture, GNS changed, as a precaution, to the permanent usage of silver gaskets as primary lid leak-tightness barriers, since the metal silver is much more corrosion-resistant than the metal aluminum.

After several tests GNS was able to re-confirm that a directly wet compression of the silver gasket within the spent fuel pond results in very good leak-tightness rates. This technique again became GNS standard in PWR as well as BWR, and consequently reduced the cask operation time.

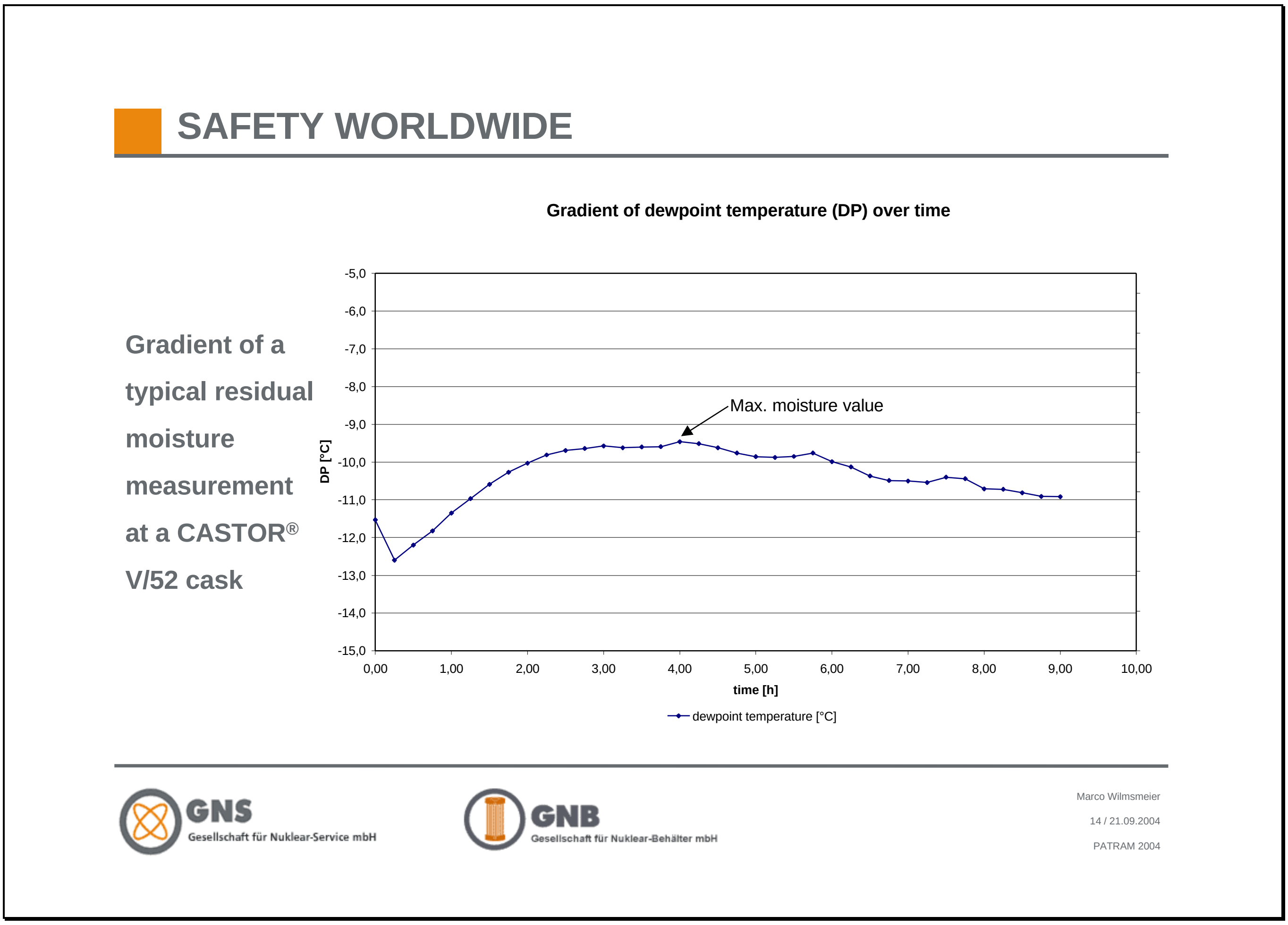
In the meantime, the aluminum-coated seal has been re-accepted.

When the primary lid has been set, the cask is lifted out of the storage pond while partly drained to reduce handling weight.
Decontamination works and contamination measurements at the CPS and the cask head are performed during the transfer to as well as at the cask handling area. The CPS is dismantled before the de-watering of the cask is started.
The de-watering of a CASTOR® casks takes about an average of three to four hours depending on the pump capacity of the compressed-air diaphragm pump, the heat capacity and the type of cask loaded.
When the free cask volume of about 5 $m^3$ is nearly drained, GNS temporarily stops the suction for at least an hour to let adhesive water run off from the fuel assemblies. GNS has made the experience that about one liter of free water amounts per fuel assembly.
Thus, the more water can be drained, the less amount of water has to be extracted by vacuum drying, saving operation time.

Vacuum drying is the appropriate procedure to reach the required degree of dryness within an acceptable timeframe of 30 to 60 hours.

GNS vacuum dries CASTOR® casks in three phases at a pressure of 10 hPa, whereas pressure increase measurements define the end of each phase. Vacuum drying above steam partial pressure is a precaution to avoid the freezing of the water.
When drying casks with heat capacities of 20 kW or more, helium is permanently inserted during drying phase II and III, to ensure sufficient cooling of the fuel assemblies.

To verify the residual moisture in the cask cavity after vacuum drying, GNS uses chilled mirror hygrometers. According to the specific procedure for residual moisture measurement at CASTOR® casks, the measuring period must be at least 9 hours.




After showing a maximum value, the moisture gradient must have a downward drift for at least 3 hours to finish the measurement.

Due to the fact that chilled mirror hygrometers are very sensitive to impurities, which cannot be totally excluded on loaded casks, the measuring periods for the verification of the residual moisture can take longer than required.

Since fuel assemblies, heat capacity, convection and pond water quality are one-of-a-kind at each loaded cask, the measuring periods are not reproducible everytime.

Thus, GNS decided to change the measuring method to determine the residual moisture via pressure increase.

Currently, the new specification for the verification of the residual moisture content in the cask interior is being assessed by the German Authority.
The measuring method will be a major improvement for future GNS cask loading operations because this particular part comprises the maximum optimization potential for effective cask loading.
The verification of the residual moisture in the cask cavity will be provided during vacuum drying at the end of phase II, saving a vast amount of operation time that has been necessary for additional measuring works afore.

Further, GNS will optimize its cask loading potential by permanent improvement of the loading equipment as well as regular training of the staff at GNS' CASTOR® full-scale training and test stand.
At this stand all CASTOR® cask operations can be performed, and the training is almost comparable to the work in German NPPs.

The test stand is equipped with:

- a cask pit,
- a CASTOR® V/19 cask for training purposes,
- cask auxiliary equipment (Multi-Equipment),
- a vacuum pump stand for drying, similar to the ones used in nuclear power plants during the cask loading,
- a humidity measuring system,
- a water container for "wet" lid handling; here, work with boric water can also be carried out,
- an external cask heating system in order to heat up the cask to 100°C,
- leak testing equipment,
- lifting equipment for handling the cask and lids.

Almost any cask operation can be simulated with the test stand equipment, for instance, temperature impacts with the external cask heating system.

## 4. Conclusion

Based on its long-lasting experience in the design, manufacturing, assembly and loading of CASTOR® casks, GNS will, with great efforts, stay inventive in the permanent improvement of its performance and will keep pace with the increasing demand for CASTOR® cask loading.

GNS will achieve these objectives by the assignment of permanently trained staff and the application of state-of-the-art equipment as well as regularly revised specifications.