THE SLIDES IN THIS ENCLOSURE 2 MAY BE MADE PUBLIC.

ENCLOSURE 2

REDACTED PRESENTATION SLIDES
CASTOR® geo69

Organization and content of the upcoming 10 CFR Part 71 application for package approval

GNS Gesellschaft für Nuklear-Service mbH

GNS Corporate Information
GNS Gesellschaft für Nuklear-Service mbH

Competence for Nuclear Services

A medium-sized company founded in 1974, based in Essen/Germany.

- Competence Centre of the German utilities for the management of spent fuel and all nuclear wastes (HLW/ILW/LLW) from the operation and the dismantling of the German power plants

- Worldwide operations:
  - as one of the leading manufacturers of casks for ILW (MOSAIK®) and spent fuel/HLW (CASTOR®, CONSTOR®)
  - for processing of every kind of radioactive waste, decommissioning and related engineering services

Organisation

Dr. Hannes Wimmer
Chairman of the Executive Board

Dr. Jens Schröder
Member of the Management Board

Georg Büth
Member of the Management Board

CEO
CTO
CFO

Strategy, Sales, Communications
Waste Management
Waste Management Projects LLW / ILW / HLW
WITI

Casks for HLW and Spent Fuel
Casks for LLW / ILW
Cask Loading and Service
Equipment and Systems Engineering

Controlling
Finance, Taxes, Procurement
IT Systems, General Administration
Human Resources, Legal
The Company

- Headquarters Essen
  - Corporate Functions
  - Project Planning and Controlling
  - Development of Casks and Equipment

- Jülich
  - Conditioning and packaging of solid LLW

- Mülheim
  - Cask assembly (SF, HLW, ILW)
  - Training and Test Facility

Turn over > 250 Mio. Euro
Employees about 450

Shareholders

Subsidiary

Competence Areas of GNS

- **Management of nuclear waste** from operations and dismantling of nuclear power plants (ILW/LLW)

- **Management of spent fuel** as well as ILW and HLW from the reprocessing of German spent fuel abroad

- **Casks for transport and storage** of spent fuel and nuclear waste (HLW/ILW)

- Consulting, engineering and equipment

- Preparations for final disposal

- **Operation of Storage Facilities** (until mid 2017 part of GNS, now part of government owned BGZ)
Further international Development

- Germany is phasing out of Nuclear Energy
  - Last spent fuel cask to be delivered for German market in 2025
  - Last casks for waste of reprocessing to be delivered ca. 2035

- Focus on international customer
  - Almost 100 CASTOR cask for dry storage of spent fuel contracted for customers outside Germany in the past three years

- Target Markets
  - Europe: Belgium, Switzerland, Spain, Czech Republic
  - Asia: Japan, Korea, Taiwan, (China)
  - Rest of the World: South Africa, (USA)
CASTOR® Casks by GNS

- Since the very first dry storage cask loading in 1983 the design principle of CASTOR® casks remains unchanged
- CASTOR® casks by GNS are Dual-Purpose Casks
  - No overpack required for transportation and storage
  - Shielding is performed by the cask itself
  - "Load & Go" / "Store & Go"
- CASTOR® casks consist of a monolithic DCI cask body and metal sealings in all lids of the containment
  - No welding seams
  - Suitable for long-term storage
  - Major cost savings compared to forged steel
- CASTOR® casks features continuous pressure monitoring
  - 24/7 monitoring for any possible leakage

The CASTOR® Concept

Dual-purpose casks of GNS fulfil all protection goals during transport and dry interim storage:

- Safe enclosure of the radioactive contents
  - Monolithic cask body (ductile cast iron)
  - Double barrier lid system (forged steel)
  - Lid system permanently monitored for leak-tightness during interim storage
- Shielding of radiation
  - Thick-walled cask body (about 350 to 400 mm)
  - Polyethylene rods inside the cask wall and PE plates at both ends
- Dissipation of decay heat
  - Radial cooling fins machined into the cask wall enlarge the surface of the cask
- Guarantee of subcriticality
  - The design of the cask and its components (lids, basket, impact limiters) guarantee subcriticality under standard and accident conditions.
CASTOR® Variety

- Customized to a variety of reactor types including: PWR, BWR, VVER 440, VVER 1000, MTR, etc.
- Type B(U)F package design approval certificates (incl. validations) including:
  - Germany,
  - Belgium,
  - Czech Republic,
  - Netherlands,
  - Switzerland,
  - France,
  - UK,
  - USA.
- Storage licenses in many countries worldwide

GNS Casks Worldwide

GNS has already developed and manufactured almost 1700 casks for High Level Waste and Spent Fuel.

Casks loaded and in interim storage:
- Germany 1266
- Lithuania (Ignalina) 203
- Czech Republic (Dukovany, Temelin) 124
- USA (e.g. Surry) 35
- Switzerland 14
- Bulgaria (Kozloduy) 13
- Belgium 7
- South Africa 4

Additional casks delivered to:
- Finland, France, the Netherlands, Russia, Korea

As of December 2018

This document may not be cited, reproduced in whole or in part, or made available to third parties without the prior written consent of GNS Gesellschaft für Nuklear-Service mbH, Essen. All rights reserved by GNS. This document contains business and trade secrets of GNS.
Manufacturing of the CASTOR® Cask Body

Assembly of CASTOR® Cask
GNS Cask Assembly at Mülheim

- Up to 80 Spent Fuel/HLW casks per year
- Assembly of ILW casks
- Training and testing facilities

CASTOR® geo and CLU
"German Fuel" vs. Rest of the World

- German PWR fuel features larger diameters compared to international established PWR fuel
  - KWU: \( \varnothing = 230 \text{ mm} \)
  - Areva: \( \varnothing = 214 \text{ mm} \)
  - Westinghouse: \( \varnothing = 197 / 214 \text{ mm} \)
  - CE-Type: \( \varnothing = 207 \text{ mm} \)

  \( \Rightarrow \) Baskets optimized for fuel with largest diameters result in smaller amounts of FA per cask

- German NPPs run larger burn-ups compared to most other countries in the world
- German NPPs have a demand for shorter cooling times compared to most other countries

  \( \Rightarrow \) Baskets optimized for rather hot fuel result in smaller amounts of FA per cask

The CASTOR® geo Family

- Customized basket design
  - Optimized for high fuel capacity

- Established design principles incl. DCI cask body
  - Major cost advantages compared to forged steel cask bodies

- Based on standardized modules and components
  - Saves time and funds for licensing

- Standardized handling and dispatch of the casks
  - Savings in equipment due to standardizations
First Customers for New Casks

- **Belgium:**
  - 30 CASTOR® geo contracted in 2016
  - Delivery from 2021 onwards
    - Units 1-3 of Tihange NPP
    - Units 3-4 of Doel NPP

- **Switzerland:**
  - 51 CASTOR® geo contracted in 2016
  - Delivery from 2024 onwards
    - Gösgen NPP

The CASTOR® CLU System

Next Challenge for GNS:
Complete defueling of dated US-type NPPs prior to decommissioning

**Boundaries**

- Crane Capacity often around 100 US-tons (90.7 Mg) with no option to upgrade
- Reasonable spent fuel specifications in terms of burn-up, cooling times etc.
- Demand for accelerated defueling as many of the old plants retire with immediate decommissioning.
The CASTOR® CLU System

CLU → Cask Loading Unit

- Canister based system for internal transfer increases FA capacity with given pool crane
- Dual Purpose Cask with bolted double lid system for storage and public transport
- Smooth licensing expected since majority of the existing reviewed safety cases of the CASTOR® cask might be re-used for the CLU system

CASTOR® CLU System – Glossary

CLU → Cask Loading Unit

- Canister is loaded under water and dispatched next to the pool while placed in the CLU
- Canister is closed by a dedicated lid with a bayonet locking system
- Canister handling inside plant within the CLU
- Bottom of CLU removable into the lock in order to lower the canister from the CLU into the CASTOR® cask
- Transports and storage inside the established CASTOR® casks with standard lid / sealing system
GNS Integrated Management System is based on ISO 9001:2015.

Meets the requirements for quality management (QM) in accordance with IAEA SSR-6 and with the German regulation BAM-GGR 011 "Quality Assurance Measures of Packagings for Competent Authority Approved Package Designs for the Transport of Radioactive Material"

Scope includes the development, manufacturing and operation of packagings of approved packages for the transport of radioactive material.
Quality Assurance

- Quality Assurance Program (QAP) acc. to ASME Section III Division 3 is implemented separately to the Integrated Management System (IMS) of GNS
- The Quality Assurance Manual (ASME-QAM) is in compliance with NQA-1 Part I
- QAP implemented and established at GNS in year 2018
- ASME Survey scheduled for April 8-11, 2019
- GNS intends to become N3 stamp holder

---

Quality Assurance

- The 10 CFR Part 71 Subpart H requirements are implemented in a Quality Assurance Manual (QAM II) which refers to the ASME-QAM
- Description of the Quality Assurance Program will be part of the Subpart D application
- Procedure of acceptance of QA Program by NRC to be defined
- Quality Project Manual (QPM) serve project-specifically as interface to regulatory, codes & standards, and customer requirements
Project Introduction

Project Objectives

- Package approval of CASTOR® geo69 as Type B(U)F package according to 10 CFR Part 71

- Challenges
  - Design of a class TC transport containment according to ASME BPVC Edition 2017, Section III, Division 3, part WB
  - Conversion of design and manufacturing specifications to US-compliant standards
  - Adoption of US-compliant standards of safety-proofs and licensing applications
Licensing Procedure

- **Applicant:**
  - GNS Gesellschaft für Nuklear-Service mbH,
    Frohnhauser Straße 67, 45127 Essen, Germany

- **Contents of application:**
  - Package description in accordance with §71.33
  - Package evaluation in accordance with §71.35
  - Quality assurance description in accordance with §71.37

- **Time schedule:**
  - Submission of SAR and QA description in December 2019

- URENCO USA Inc. will support GNS
Technical Description of the Cask Concept
Package Overview – Main Components

- Lid Side Shock Absorber
- Cask Lid with axial Moderator, Bolts and Gaskets
- Thread Ring
- Tightening Ring with Bolts, Seals and Gasket
- Canister Lid
- Basket for 69 BWR-FAs
- Canister
- Trunnion
- Radial Moderator
- DCI Cask Body
- Name Plate
- Tilting Stud
- Bottom Side Shock Absorber

Applied Radioactive Content

- BWR Fuel Assemblies with or w/o Fuel Channel

  Dimensions (nominal)

  - Cross Section \( \leq 140 \text{ mm} \)
  - Overall length \( \leq 4450 \text{ mm} \)
  - Total weight \( \leq 322 \text{ kg} \)

- Data of Fresh Fuel

  - Fuel Type \( \text{UO}_2 \)
  - Weight HM \( \leq 185 \text{ kg} \)
  - Length active zone \( \leq 3810 \text{ mm} \)
  - Enrichment \( 3.0 \ldots 4.6 \text{ wt-\%} \)

- Irradiation

  - Burnup \( 20 \ldots 60 \text{ GWd/MgHM} \)
  - Cooling Time \( \geq 10 \text{ years} \ldots 40 \)
Description of cask concept - Basket

Proprietary Information withheld per 10CFR2.390

- Outer sheet: Aluminium Alloy
- \( \text{B}_4\text{C} \) Filling for \( n \) shielding
- Structural sheets for FA positioning:
  - Boronated Aluminium angle for shielding: Al-\( \text{B}_4\text{C} \)-MMC-10
  - Housing for filling: Aluminium Alloy
  - Aluminium segments for heat transfer: Aluminium Alloy
- Capacity for 69 BWR-FAs

Description of cask concept - Canister

Proprietary Information withheld per 10CFR2.390

- Supplement Containment boundary for Burnup > 45 GWD/MgHM
- Welded stainless Steel Liner and Bottom
- Bolted lid, sealed by metal gaskets
- Geometry (Lo/li, Do/di)
- Able for Handling of loaded Canister
Description of cask concept - Cask Containment

Proprietary Information withheld per 10CFR2.390

- Containment boundary for Burnup < 45 GWD/MgHM
- DCI CASTOR® cask → Excellent Experience in Germany
  - Monolithic cast Cask Body
  - Accordance with ASME Sec. II (DCI SA-874M) → Qualification
  - Geometry (L, D, D_o/d_i)

- Bolted Cask Lid with double metal Gasket → Excellent Experience, experimental investigation

- Integrated Moderator Rods in the Cask Wall → Qualification necessary?
- Handling via Lid Side Trunnions
- Tilting via Bottom Side Tilting Studs

Description of cask concept - Transport Configuration

- Lid and Bottom Side Shock Absorbers → Sufficient for Load protection for ACT, worst case 9 m Drop orientation
- Shock absorbing Material (PU) → NRC acceptance for other designs
- Transport Frame
  → Interface with Transport Vehicle
- No load application on Trunnions during Transport
  → Weight load directly on Cask body
## Safety related Function of Main Components

<table>
<thead>
<tr>
<th>Safety Related Function</th>
<th>Containment</th>
<th>Subcriticality</th>
<th>Shielding</th>
<th>Heat Transfer</th>
<th>Cask Handling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basket</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Canister</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canister Lid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tightening Ring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCI Cask Body</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderator rods inside Cask Body</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cask Lid</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cask Lid Bolting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderator Plate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention Ring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lidside Trunnion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

- x - Main Function

(1) - Supplement Containment, if Burnup > 45 Gwd/t

## Materials of Main Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Raw Product</th>
<th>Material Group</th>
<th>Construction Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basket</td>
<td>rolled Plate</td>
<td>boronated Alum</td>
<td>ASME Section II and Section III, Div.3 Subsection WD (1)</td>
</tr>
<tr>
<td>Basket</td>
<td>Extrusions</td>
<td>Aluminium</td>
<td>ASME Section II and Section III, Div.3 Subsection WD</td>
</tr>
<tr>
<td>Canister</td>
<td>rolled Plate</td>
<td>Stainless Steel</td>
<td>ASME Section II and Section III, Div.3 Subsection WB</td>
</tr>
<tr>
<td>Canister Lid</td>
<td>Forging</td>
<td>Stainless Steel</td>
<td>ANSI N14.6</td>
</tr>
<tr>
<td>Tightening Ring</td>
<td>Forging / Plate</td>
<td>Stainless Steel</td>
<td>ASME Section II and Section III, Div.3 Subsection WB</td>
</tr>
<tr>
<td>Metallic Gasket - Typ Helioccox HN20C</td>
<td>Commercial Product</td>
<td>Silver/Stainless Steel</td>
<td>ANSI N14.5</td>
</tr>
<tr>
<td>DCI Cask Body</td>
<td>Casting</td>
<td>Ductile Cast Iron</td>
<td>ASME Section II and Section III, Div.3 Subsection WB</td>
</tr>
<tr>
<td>Moderator rods inside Cask Body</td>
<td>Plate</td>
<td>Polyethylene</td>
<td>(2)</td>
</tr>
<tr>
<td>Cask Lid</td>
<td>Forging</td>
<td>Stainless Steel</td>
<td>ASME Section II and Section III, Div.3 Subsection WB</td>
</tr>
<tr>
<td>Cask Lid Bolting</td>
<td>Forging</td>
<td>Stainless Steel</td>
<td>ASME Section II and Section III, Div.3 Subsection WB</td>
</tr>
<tr>
<td>Metallic Gasket - Typ Helioccox HN20C</td>
<td>Commercial Product</td>
<td>Silver/Stainless Steel</td>
<td>ANSI N14.5</td>
</tr>
<tr>
<td>Moderator Plate</td>
<td>Plate</td>
<td>Polyethylene</td>
<td>(2)</td>
</tr>
<tr>
<td>Retention Ring</td>
<td>Forging / Plate</td>
<td>Stainless Steel</td>
<td>ANSI N14.6</td>
</tr>
<tr>
<td>Lidside Trunnion</td>
<td>Forging</td>
<td>Stainless Steel</td>
<td>ANSI N14.6</td>
</tr>
<tr>
<td>Impact limiter</td>
<td>Foam</td>
<td>Polyurethan</td>
<td>(2)</td>
</tr>
</tbody>
</table>

(1) - Alternative Material not within the Code
(2) - No Code requirement
Safety Proofs

Safety Requirements (10 CFR 71 et al.)

- Criticality safety → Verification of max. $k_{\text{eff}}$
- Activity retention → Verification of max. leak rate
- Radiation shielding → Verification of max. dose rate
- Structural integrity → Verification of stress tests (NCT, ACT)
- Passive heat dissipation → Verification of thermal loads
  - 10 CFR 71, e.g. §§ 71.55, 71.59, 71.71/.73, 71.107
  - NRC Reg. Guide 7.4 → Leakage test requirements
  - NRC Reg. Guide 7.6 → Mechanical load criteria
  - NRC Reg. Guide 7.8 → Load combinations
  - NRC Reg. Guide 7.9, Ch. 6
  - Further cited standards, e.g. ASME Sec. III; ANSI N14.5, N14.6
Design Methodology

The effects on a package ..., must be evaluated by subjecting a specimen or scale model to a specific test, or by another method of demonstration acceptable to the Commission, as appropriate for the particular feature being considered.

Demonstration of compliance

Tests with prototypes or samples
Reference to previous demonstrations
Tests with models of appropriate scale
Calculation, or reasoned argument

Verification basis

The safety analyses of the CASTOR® geo69 will be carried out by means of calculations which are verified by various tests with samples and scaled models.

Approach to Demonstrate Safety

- Safety Case of CASTOR® geo69 for transport and storage licensing applications
- Design methodology verified by numerous experiments and approved within several licensing processes of CASTOR® casks

The applied cask type is based on the established CASTOR® concept, which relies on the long-term tested and continuously licensed, fabricated and applied cask design.
### Drop Tests with a Half Scale Cask

- **Instrumented drop tests sequences (2005 – 2006)**
  - according to Type B(U)F accident conditions

#### Codes & Standards – Mechanics

**Design Calculations**
- Numerical FE-codes
  - LS DYNA® (dynamic), ANSYS® (quasi-static)
- Analytical calculations
- International standards like FKM-Guideline, VDI etc.

#### Experimental base, e.g.
- GNS has executed more than 100 drop tests (9 m, pin drop) on unyielding targets
- Drop test program DROPund (2009 – 2012)
  - Validation of numerical calculations for cylindrical impact limiters with German competent authority
- Drop test program CASTOR® HAW/TB2 (2005)
  - 17 drop tests for transport and storage licenses with 1:2 scale model
- Material and component tests, e.g.
  - Wall segments, basket segments, bolts, gaskets
  - Material behaviour (ductile cast iron, stainless steel ...)

All applied codes are verified by several cask and component tests.
Codes & Standards – Thermal

Design Calculations
- ANSYS®-THERMAL, Version 15
- FLUENT from ANSYS®-CFD

Experimental base
- Validation of ANSYS®-THERMAL with examples from SANDIA-Benchmarks
- Validation of CFD-methods
  - Comparison with measured cask surface temperatures in the interim storage facility in Gorleben
  - Heat transfer of casks under a cover - Comparison of analytical methods with CFD and experimental results
- Fire tests under accident conditions performed

Thermal behaviour of CASTOR® concept is tested and approved.

Codes & Standards - Nuclear

Codes
- Nuclide inventory
  - SAS2H and ORIGEN-S from the SCALE 5.1
  - WTI programs OBERON and LOAD-CHECK
- Shielding
  - MCNP6 Ver 1.0
  - ENDF/B-VII continuous energy cross section data
- Criticality
  - KENO-VI from SCALE 5.1 code package
  - 238-group ENDF/B-V cross section data
  - CENTRM/PCM for self shielded resonance cross sections

Validation
- Comparison of the measured and calculated values for CASTOR® V casks with similar design properties
- Benchmark experiments from ICSBEP Handbook
  (International Criticality Safety Benchmark Evaluation Project - ICSBEP)

The applied codes are verified by international benchmarks and measurements on loaded casks.
Criticality Safety – Code and Validation

- Validation by statistical analyses of ICSBEP benchmark experiments
  - 9 LEU-COMP-THERM experiments with 138 critical rod configurations (thermal neutron spectra with uranium fuel)
  - 6 MIX-COMP-THERM experiments with 79 critical rod configurations (thermal neutron spectra with MOX fuel)
- Different absorber materials between the fuel rods

Validation provides uncertainty of the code as a contribution to $\Delta k_U$

Inventory – Methods and Codes

- Main objective
  - Neutron (NSS) and gamma source strength (GSS)
  - Decay heat (DH) and radionuclide activities
- Methods and codes
  - 1D-transport code SCALE/SAS2 from Oak Ridge National Laboratory (ORNL)
  - 2D-transport codes
    - SCALE/TRITON from ORNL
    - HELIOS from Studsvik Scandpower
  - Burnup and Decay
    - SCALE/ORIGEN-S
- Typical fuel parameters
  - Enrichment up to 4.9 wt.-% $^{235}\text{U}$
  - Burnup: typical 60 - 65 GWD/t$_{HM}$ up to 80 GWD/t$_{HM}$
Conclusion

- The CASTOR® design is proven and internationally accepted for transport and storage.
- GNS has more than 35 years of experience with CASTOR® casks and is a reliable partner for long-term future activities.
- The CASTOR® geo69 is based on the established CASTOR® concept.
- The used codes and methodologies are verified by several casks, component tests, benchmarks and measurements on loaded casks.
- A established quality management plan will meet the specific requirements of NRC according to 10CFR71, Subpart H.

Package Components
Cask Body – Ductile Cast Iron

Proprietary Information withheld per 10CFR2.390

Ductile Cast Iron (DCI)

- Referenced at ASME BPVC Section III, Division 3, Subsection WB and WC for use and construction of transport and storage containments
- According Casting Specification
  - Section II - SA-874 (American Standard)
  - Section II - SA/JIS G5504 (Japanese Standard)

Mechanical Properties
- Tensile Strength ≥ 300 MPa
- Yield Strength ≥ 200 MPa
- Elongation ≥ 12 %
- Fracture Toughness ≥ 50 MPa m$^{1/2}$ at -40 °C, rapid-load test

GNS Fabrication Experience
- More than 1200 castings of cask bodies
- More than 10,000 test samples
- Tensile Strength (avg)  
- Yield Strength (avg)  
- Elongation (avg)  

Cask Body – DCI - Material Tests

- Tension tests at IWM Freiburg (2005 – 2008) with specimens made of DCI
- Round specimens with different notch shapes defining the multi-axiality
- Main Result
  - Determination of the failure strain depending on the multi-axiality under tension
Cask Body - DCI - Material Tests

- Determination of the fracture toughness of DCI at -40 °C (since 2004)
  - The dynamic fracture toughness is required for fracture mechanical evaluation
  - Exclusion of unstable crack propagation under dynamic loads

Main Results
- Database of fracture toughness values and correlations between microstructure and strength
- Influence of sample size and establishing of a specific test method
  
  **Verified lower bound value for fracture toughness under dynamic loads at low temperature.**

Lid System - Metallic Gasket

- Commercial Component, which is established as gasket for nuclear applications.
  - Typ B(U) transportation packages
  - storage systems for spent fuel
  - Reactor pressure vessels

- Metallic gasket serves for
  - High degree of tightness (10^{-8} Pa m^3/s)
  - Longterm stability and function
  - Broad range of application experience gained by GNS since 40 years of application with loaded CASTOR® casks

- Material has already been accepted by NRC within 10CFR71 and 10CFR72 licencing cases
  - CASTOR® V/21 stored onsite of NPP Surry / USA
Lid System – Material Test

- Long-term tests at laboratory of CEA/Technetics Pierrelatte, France (2012 – 2018)
- Prognosis about the long-term characteristic of the used metallic gaskets
- Time-dependent behaviour of:
  - Restoring seal force $Y_1$
  - Useful elastic recovery $r_u$

Knowledge of the time evolution of main sealing parameters of the used gaskets over a period of more than 40 years.

Lid System – Component Tests

- Testing of lateral displacement of the lids (2011 – 2014)
- Time-dependent recovery of leakage rate after impact within one week
- Even for extreme lateral movements of the lid up to 5 mm
  - Bolting assures sufficient pre-stress
  - Gasket remains sufficiently tight

Under extreme mechanical conditions the lid system maintains its integrity.
Lid System – Cask Tests

- Examination of the lid system after drop, measuring of the:
  - Leakage rate
  - Remaining pre-stress in the bolts
  - Roughness of the sealing surfaces
  - Lid displacement

Verified leakage rates under accident conditions.

Impact Limiter – Polyurethan Foam

- Commercial Material, which is established as impact absorbing material for Typ B(U) transportation packages.

- Material has already been accepted by NRC within a 10CFR71 licencing case

Example [limited set] of licensed Radioactive Material Packages using LAST-A-FOAM® FR-2700:

- Package Model No.: TRS-115
  - US Certificate No.: USA/775/WUP-85
  - Licensee: U.S. Department of Energy

- Package Model No.: F-26
  - US Certificate No.: USA/543/WUP-85
  - Licensee: NRC, Horon

- Package Model No.: GB-20
  - US Certificate No.: USA/519/BG-85
  - Licensee: Borak

GNS

The document may not be cited, reproduced in whole or in part, or made available in third parties without the prior written consent of GNS Gesellschaft für Nuklear-Service mbH. Essen. All rights reserved by GNS. This document contains business and trade secrets of GNS.

2019-02-21 / Pre-Application Meeting NRC / 59

Impact Limiter - Polyurethan Foam

- LAST-A-FOAM® FR-2700
  - Featurized: Absorbent, foam material
  - Rigid material
  - Meets performance requirements for nuclear transportation packages

GNS RIGID MATERIAL

WHERE GREAT IDEAS TAKE SHAPE
Impact Limiter – Cask Tests

- Drop test programme with cylindrical impact limiter for validation test
  - Drop tests with CASTOR® V/TB1a half scale model based on CASTOR® V/19 and CASTOR® V/52
- 4 drop tests
  - For all relevant orientations
  - At operation temperature range (up to 80 °C)

Experimental database for verification established.

Impact Limiter – Cask Tests

- Comparison between calculation and drop test
  - FEM simulation
  - High-speed picture of the drop test

The applied numerical model is reliable for the simulation of high dynamic impacts with large deformations.
Basket Material – Boronated Aluminium MMC
Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications
2009 Edition

Basket Material serves for
- Geometrical boundary for lodgement carrying the F/A
- Neutron absorption function to maintain subcriticality
- Thermal conductivity
- Structural stability under all conditions of design

Boronated Aluminium Alloy as Matrix Compound (MMC)
- 10 wt-% of B4C
- No degradation during aging due to thermal treatment before use
  - Time-independent structural properties
- Candidate material:

Moderator Material – Polyethylen

Commercial Component, which is established as neutron moderator for nuclear applications.
- Typ B(U) transportation packages
- Storage systems for spent fuel

Polyethylene serves for
- Efficient moderation of neutron within the cask body
  - Highest partial density of hydrogen within a solid material
  - Cylindrical rods in deep bore holes
  - Plates between the lids and in the cask bottom
- Broad range of application experience gained by GNS since 40 years of application with loaded CASTOR® casks
- Material has already been accepted by NRC within 10CFR71 and 10CFR72 licensing cases
  - 72-1000 – CASTOR® V/21 stored onsite of NPP Surry / USA
Discussion