Technical Keynote August 19, 2013

A SURVEY ON 35 YEARS OF PACKAGING, TRANSPORT AND STORAGE OF RADIOACTIVE MATERIALS

Bernhard Droste

BAM Federal Institute for Materials Research and Testing, Berlin, Germany
1. Package Design Testing
- Transport packages
- Transport & storage casks
- Waste disposal containers
- Regulatory
- Extraregulatory
- Experimental, small/full scale
- Computational

2. Research
- Safety margins in accidents
- Fracture safety of DI
- Seals, containment
- Impact limiter materials

3. Regulatory Aspects
- Guidance for testing
- Dual Purpose Cask Safety Case
- Quality and knowledge management

4. Miscellaneous
- Special form radioactive material
- Mont Louis and other accidents
- Transnuklear Germany scandal
- SNF cask contamination issue
- Large NPP components transport
BAM`s first Drop Test Facility
Berlin-Grunewald

CASTOR Ia 1:2 scale Model
9-m Lid Corner Drop without Impact Limiter; -40 °C
1.2 First Drop Tests with a full scale SNF Cask 1978

BAM`s 100-tons Drop Test Facility Lehre

9-m Drop Tests with CASTOR Ia Prototype

Justification for full scale model tests:
No correct “scaling“ of properties of thick-walled Ductile Iron was possible

Before 9-m horizontal Drop onto Trunnions;
- 40 °C; without Impact Limiters

After 9-m horizontal Drop onto Trunnions
1.3.1 Development of Transport & Storage Casks 1979

Design Principles of Dual Purpose Casks developed and used in Germany

Double Barrier Closure of monolithic Cask Body
(right: usual version; left: repaired version with welded Lid)

Monitoring Principle

Interspace Pressure Switch

Bernhard Droste

PATRAM 2013
Main SNF Transport and Storage Cask Design Features used in Germany

- Dual purpose for transport and storage operation
- Monolithic cask body made of ductile cast iron (alternate cask designs made of forged steel cylinder with welded bottom part)
- Dimensions
  - Length: 4.0 to 6.0 m
  - Diameter: 1.5 to 2.5 m
  - Wall thickness: 0.25 to 0.45 m
- Cylindrical holes filled with polyethylene neutron moderator in cask side wall
- Double lid closure system with metal seals and permanently monitored pressure between bolted lids
- Vacuum dried and helium filled (≈800 hPa) cask interior

Example: CASTOR® V Cask Design by GNS, Storage Cask Version
1.4.1 First Drop Tests with Dual Purpose Casks 1980

CASTOR IIa 1:2 scale Model
BAM, Lehre

Leakage measurement at secondary Lid
1.4.2 First Drop and Fire Tests with Dual Purpose Casks 1980

TN 1300 1:3 scale Model

9-m horizontal drop onto trunnions; with artificial "saw-cut" failure, no impact limiters, BAM, Grunewald

30-min Fire test
BAM, Lehre
1.4.3  BAM Fire Test Facilities 1978 - 2013

Propane Gas Fire Test Facility
BAM Lehre 1995

Fuel Oil Pool
BAM Lehre 1978

Propane Gas fire test Facility
BAM TTS 2010
1.5 Drop Tests with second full scale Cask 1982

CASTOR Ic full scale Prototype

BAM, Lehre

Leakage Test

Preparation for 9-m slap-down

1-m Puncture Drop onto Lid; with modified Impact Limiter
1.6  Drop Test with third full scale Cask 1985

9-m horizontal Drop; -40 °C; no impact limiters; max. bending strains; BAM Lehre
1.7 First Expertise for dry spent Fuel Storage in Transport Casks 1982

**Expertise**

Assessment of cask specific aspects of dry storage of spent nuclear fuel in transport cask storage site Ahaus

November 1982

BAM Berlin

---

**Cold Trials in Transport Casks Storage Facility Gorleben**

---

Bernhard Droste

PATRAM 2013
1.8.1 Dry SNF Storage Demonstration & Measurement Programs 1982-1985

**German Dry Spent Fuel Storage Demonstration & Measurement Programs with different SNF Dual Purpose Cask Designs:**

- CASTOR Ib with 4 PWR SNF Assemblies, NPP Stade-WAK Karlsruhe
- CASTOR Ia with 4 PWR SNF Assemblies, NPP Biblis-KFA Juelich
- TN 1300 with 12 PWR SNF Assemblies, NPP Biblis
- CASTOR Ic with 16 BWR SNF Assemblies, NPP Würgassen
- CASTOR AVR with 2 Stainless Steel Canisters, each filled with 950 spherical „Graphite Ball“ AVR Fuel Elements, KFA Jülich
- TN AVR-2 with the same Contents as before, KFA Jülich

**Results:**

Verification of
- Cask handling operations
- Containment function
- Leakage rates and their measurement methods
- Evacuation, drying and gas filling operations
- Shielding efficiency
- Heat removal
- Fuel rod temperatures
- Fuel rod integrity; cavity gas sampling
1.8.2 Dry SNF Storage Demonstration & Measurement Programs 1982-1985

CASTOR lc-02 with 16 BWR SNF Assemblies
1.3.1982-19.4.1984

Cask delivered with protected measurement equipment above orifices through the lids

Primary Lid

Secondary Lid

Cold Trials
1.8.3 Dry SNF Storage Demonstration & Measurement Programs 1982-1985

CASTOR Ic-02 with 16 BWR SNF Assemblies /J. Fleisch et al., DWK, 1982/

**FIGURE 1** DRY STORAGE DEMONSTRATION IN TRANSPORT CASKS: TEST PROGRAM FLOW DIAGRAM AND OVERVIEW

**FIGURE 2** Cask and Fuel Assembly Instrumentation: Axial Thermocouple Locations
CASTOR Ic-02, NPP Würgassen /DWK, 1982/

SNF Assemblies Characteristics and Temperature Measurements inside the Cask
CASTOR Ia with 4 PWR SNF Assemblies
09/1983 – 09/1985

For transportation with a primary lid penetrated by instrumentation orifices the secondary lid needs to be assessed and approved as transport package containment boundary.

...that is the same requirement as for storage casks to have a back-up solution in case of a hypothetical loss of primary lid’s leaktightness.

Loading at NPP Biblis

Transport and Transfer into a Hall at KFA Juelich
1.8.6 Dry SNF Storage Demonstration & Measurement Programs 1982-1985

CASTOR Ia in Storage Test Position KFA Juelich

Thermocouples Penetration through secondary Lid, soldered leaktight in small Lid
CASTOR Ic-Diorit
Loaded 1983 with the inventory of the Research Reactor DIORIT; currently stored at ZWILAG, Switzerland

Courtesy: Paul Scherrer Institute, Switzerland, 2013
1.10 German Cask Designs for foreign Applications

CASTOR WWER 1000 (Soviet Union, 1985)

CASTOR V/21 (VEPCO, Va., USA, 1986)

CASTOR 440/84M (NPP Dukovany, Czech Rep.)

CASTOR X/28 F (NPP Koeberg, South Africa)

CASTOR SPX (Cadarache, France, 1987)

Fotos: GNS
1.11.1 Packages for Transport, Storage & Disposal of LLW, MLW

„MOSAIK“ Casks (GNS)

Drop Tests, BAM Grunewald, 1978

Waste Storage Facility Gorleben, 2013
1.11.2 Packages for Transport, Storage & Disposal of LLW, MLW

Steel Sheet Containers for cemented Waste

Drop of a Ductile Cast Iron Container onto a Target simulating KONRAD Repository Ground (2007)

First Tests BAM Lehre 1990
BAM performed 2009 a series of three 8-m drop tests with a new Japanese waste container design, contracted by Kobe Steel, Ltd. who developed them for Chubu Electric Power Co., Japan.
Drop Test Campaign with 1:3 Model of TS 28V (Cogema Logistics, CEA, France, 1989)

9-m Corner Drops: Strain Measurements at instrumented lid bolts to ensure appropriate function
1.13 CASTOR THTR/AVR Dual Purpose Casks (1992)

305 of these casks in Transport Cask Storage Facility Ahaus (additional 152 stored at Research Center Juelich)
1.14 Transport Casks Storage Facility Gorleben for HLW (and SNF)

Current Inventory:
-108 HLW Casks (1 TS 28V, 74 CASTOR HAW 20/28CG, 11 TN 85, 22 CASTOR HAW28M)
-5 SF Casks (1 CASTOR Ic, 1 CASTOR IIa, 3 CASTOR V/19)

Storage started 1994

Foto: GNS
1.15 Spent Fuel Transport Casks Storage on At-Reactor Sites

ZLN Lubmin, 64 CASTOR 440/84 Casks

200th CASTOR V Cask (GNS) Delivery, Transfer to Interim Storage Facility at NPP Lingen

Foto: EWN
1.16 Drop Test Campaign with a Multi Purpose Cask 1:1 Model (1994)

POLLUX Cask (GNS)
Designed for transport, storage and disposal of spent nuclear fuel
1.17 Most-used Dual Purpose Cask for vitrified HLW (1995)

CASTOR HAW 20/28 CG (GNS)

On-site transport of a cask at Vitrification Plant at WAK (Reprocessing Plant Karlsruhe) before transportation to storage site ZLN, Lubmin (2011)
1.18.1 Drop Test Campaigns with Fresh Fuel Packages (1999)

BAM Drop Tests performed at ENUSA Site, Salamanca, Spain

ENUSA got Permission to use Dummy Fuel Assemblies filled with UO$_2$ (depleted U-235)

RA-3D Package (Trauner) for 2 BWR Fuel Assemblies
1.18.2 Drop Test Campaigns with Fresh Fuel Packages (2000)

The „French“ 1-m Puncture Drop Test

...to maximize penetration through outer shell

(BAM Berlin in-house Drop Test Facility)
ANF-18 (ANF) for 2 PWR fuel assemblies
- Slap-down 9-m drop -
1.19 The third Dual Purpose Cask Design for vitrified HLW

9-m oblique Drop with **1:3 small-scale**

**Model of TN 81** (TN-I)

Drop Test Campaign 2000/2001

---

**TN 85** Cask in Transfer Station Dannenberg (on shipment from La Hague to Gorleben)
1.20.1 Inauguration Tests at the large BAM Drop Test Facility on PATRAM 2004

- Height: 36 m
- 200 ton Hoist, 80 ton Portal Crane
- Test Hall with 24 m x 20 m Area
- Unyielding Target of 2600 Tons
1.20.2 9-m horizontal Drop of the CONSTOR V/TC Cask
CONSTOR V/TC Cask

(GNS)
Total mass: 181 tons

<table>
<thead>
<tr>
<th>The CONSTOR® V/TC (TC = Test Cask): Dimensions and Masses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Overall length of cask with shock absorbers        7 445 mm</td>
</tr>
<tr>
<td>• Outer diameter of cask body                         2 332 mm</td>
</tr>
<tr>
<td>• Outer diameter of shock absorbers                   3 510 mm</td>
</tr>
<tr>
<td>• Outer diameter of overpack                          2 592 mm</td>
</tr>
<tr>
<td>• Mass of loaded cask                                 Approx. 110 metric tons</td>
</tr>
<tr>
<td>• Mass of shock absorbers                             Approx. 20 metric tons/absorber</td>
</tr>
</tbody>
</table>
1.21.1 Drop Test Campaign with full and 1:2.5 scale Models MSF 69 BG

**Full-Scale Model**
- Total Mass: 127,000 kg
- Length with Impact Limiters: 6,800 mm
- External Diameter of Impact Limiters: 3,100 mm

**1:2.5 Scale Model**
- Total Mass: 10,000 kg
- Length with Impact Limiters: 2,700 mm
- External Diameter of Impact Limiters: 1,300 mm

PATRAM 2013
The Problem of Drop Tests with small scale Models

e.g. in this case (9-m oblique, horizontal drop) the small scale model cask body flange bending strain (axial) was 68% lower than the equivalent full scale model value!

/ T. Quercetti et al., PATRAM 2007 /
1.21.3 Drop Test Campaign with full and 1:2.5 scale Models MSF 69 BG

Helium Leakage Testing on full scale Cask’s secondary Lid
Close Range Photogrammetry to support the Assessment of Closure System Behaviour

Measuring the relative lateral lid displacement
1.22.1 The fourth Dual Purpose Cask Design for vitrified HLW

**CASTOR HAW TB2 1:2 scale Model (GNS, 2005)**
- Mass: 14.000 kg
- Length: 3.382 mm
- Outer Diameter: 1.415 mm

**CASTOR HAW 28M (GNS) on Railway Wagon (2010)**
1.22.2  Drop Test Sequences of CASTOR HAW/TB2 (1:2)  2005
1.23.1 Actual Mechanical Package Design Assessment Strategy

Mechanical assessment strategy now includes experimental and computational Methods

1. Drop test

2. Verification of FE model

3. Numerical stress calculation of original cask design with verified FEM model

4. Fracture mechanics safety assessment; calculation of stress intensity or J-integral at points of maximum stress; comparison with relevant fracture toughness values
1.23.2 Actual Mechanical Package Design Assessment Strategy

Finite Element Analysis
(here: 9 m horizontal Drop)

Completely Dynamic

Quasi-Static
with verified
dynamic factor
Consideration of Impact Limiter Modelling in the Safety Case

1. Performance of sample tests
2. Evaluation
3. Material model
   a. Identification, parametrizing
   b. Verification
4. Package modeling
5. Verification by package drop test

Basis for safety case/assessment

1.23.3 Actual Mechanical Package Design Assessment Strategy

Bernhard Droste

[G. Eisenacher et al.]
1.23.4 Actual Thermal Package Design Assessment Strategy

Use of CFD calculations, and control of canopy compliance with the design safety analysis report, handling instructions
Finite Elemente Analyses of Casks in Fire Scenarios

BAM FE-calculation example:
Temperatures of a CASTOR cask with 40 kW spent fuel decay heat

Balanced thermal conditions before fire

- Approx. 80°C
- Approx. 300°C

After 20 minutes fire duration

- >500°C
- Approx. 400°C

2 hours after end of fire

- Approx. 300°C
- Approx. 250°C
- Approx. 350°C

/G. Wieser, BAM-3.43/
1.24.1 Special Spent Fuel Transport Cask Designs

NCS 45 (NCS)

Drop Test 1:3 Model (2005)
1.24.2 Special Spent Fuel Transport Cask Designs

CASTOR KNK Transport and Storage Cask (WTI/GNS)

Cask in Handling/Rotation Frame

Cask in Transport Frame

Lifting without Frame

(2008)
1.24.3 Special Spent Fuel Transport Cask Designs

**ESBB Cask**
for single fresh fuel rods

(NCS, 2001)
1.24.1 Non-Regulatory Tests, Aircraft Crash Simulation Tests

Steel Projectile (1000 kg, 300 m/s) Impact onto the Centre of a CASTOR IIa double Barrier Closure System with 1:1 Diameter (WTD 91 Meppen, 1980)
1.24.2 Non-Regulatory Tests, Aircraft Crash Simulation Tests

Aircraft crash simulation test with a full-scale spent fuel cask TN 1300 (WTD 91, Meppen, 1983)

Central impact onto protection lid

Impact onto cask wall
Post September 11, 2001 computational investigations of large civil aircraft crashes onto interim storage sites

- Side-on engine impact onto standing casks
- Central impact of storage hall roof fragments onto the cask closure system
- Fire
Impact of building roof fragments onto the centre of the closure system; numerical analysis of lids and bolts (G. Wieser et al., PATRAM 2004)
1.24.5 Non-Regulatory Tests, Shaped Charge Attack Experiment

CASTOR IIa Sample with full scale
Wall Thickness and Diameter

Fig. 1: Side view of experimental set-up

CASTOR IIa Sample with full scale
Wall Thickness and Diameter

GRS 1992 /F. Lange et al. PATRAM 2001/
1.24.6 Non-Regulatory Tests, Blast Wave Simulation

Finite element calculation of a spent fuel cask’s response to a blast wave due to a railway wagon (21 t TNT) explosion in 25 m distance (V. Ballheimer et al., PATRAM 2004)
1.24.7 Non-Regulatory Tests, Drops onto real targets

19.5 m-drop of full-scale spent fuel cask CASTOR Ic onto a highway target (BAM, Lehre, 1983)
1.24.8 Non-Regulatory Tests, Drops onto real targets

Drops of packages without their impact limiters; on-site handling accident drops

- Practical tests -

CASTOR lc
13 m, Hexcel

COCON AVR
3.5 m, concrete

POLLUX, 5 m, concrete

TN THTR, 3.5 m, concrete
CASTOR® HAW/TB2: Storage Site Specific Accident Scenario
Test Specimen and BAM Finite Element Model
Code: ABAQUS/Explicit Version 6.5

/H. Voelzke et al., PATRAM 2007/

Cask
219,838 elements
388,775 nodes

Target
110,136 elements
130,012 nodes

surrounding infinite elements
14m drop test with the CASTOR VHLW cask (with a 120 mm deep failure inside the 260 mm ductile iron wall) in comparison with the regulatory 9-m drop test.
2.2 Research in Development of Numerical Calculation Methods

Numerical calculation of horizontal 9-m drop of CASTOR VHLW cask

Finite elemente model of cask with impact limiters

Steel rod
Steel sheet
Polyurethane foam

Cask body
Canister
Lid

Anima02.avi

Dynamical calculation

/L. Qiao, U. Zencker et al., PATRAM 2007/
2.3 Research in Safety of Ductile Iron Casks 1987

BAM drop test with a thick-walled pipe of ductile cast iron

- corresponding to the 1:2.5 scaled model of a large cylindrical CASTOR V cask
- drop height 9 m
- drop onto steel cylinders located on an unyielding IAEA target
- equipped with an artificial crack-like defect (40 mm in 150 mm wall)

No failure by fracture.
2.4 Research in structural Analysis of cubic ductile Iron Containers

Development of dynamic FEA of Container Impacts, Fracture Assessment Methods, and Justification for a Drop Test Target representing the KONRAD Repository Underground

[ U. Zencker et al.]

Drop Test with ductile Iron Container

Model of a semi-elliptical Surface Crack

Drop Test Scenario Model
BAM test setup for metal seal investigations with continuous leakage rate measurements

Characteristic load – deflection curve of a Helicoflex® metal seal (Ag) and correlation with the helium leakage rate

\[ Q_{\text{He/St}} = \leq 10^{-8} \text{ Pa} \cdot \text{m}^3 \cdot \text{s}^{-1} \]

- \( Y_0 \) = Achievement of \( Q_{\text{He/St}} \) during pressing process
- \( Y_1 \) = Exceeding \( Q_{\text{He/St}} \) during load relieving
- \( Y_2 \) = Optimal operation point according to manufacturers specification
- \( r_u \) = usable resilience

[U. Probst, H. Voelzke, D. Wolff et al.]
Experimental results for Wood

- Multiaxial stress state affects softening and hardening behavior

Without lateral constraint:
- High lateral dilation
  - Plastic Poisson’s ratio $> 0$
- Non-continuous structure

Situation inside impact limiter:
- Softening lateral constraint
  - Mixed case
Ageing Effects of Dual Purpose Cask Polymer Components

Neutron shielding components
- Temperatures up to 160 °C (\(\rightarrow\) decrease during storage)
  - Thermal expansion
  - Structural changes from semi-crystalline to amorphous
- Radiation (\(\rightarrow\) decrease during storage)
  - Hydrogen separation by gamma radiation causes structural damages and/or crosslinking
- Mechanical assembling stresses
  - Stress relaxation
- Focus on neutron moderator material

Elastomeric auxiliary seals
- Materials:
  - Viton
  - EPDM (ethylene propylene diene monomer (M-class) rubber)
  - Silicone
- Low temperature and long-term behavior

Ultra-high molecular weight polyethylene (UHMW-PE) [K. von der Ehe et al.]

Low temperature and long-term behavior [M. Jaunich et al.]
Deformation Measurements of Impact Limiters

Optical Surface Digitization Measurements

Sensor arrangement with objects

Deformed shock absorber model merged with cask data

Shape comparison with CAD data

Shock absorber deformation due to drop test damage
2.7.1 Research in Safety Margins

BLEVE impact onto a CASTOR THTR/AVR spent fuel cask

(BAM, Horstwalde, 1999)
2.7.2 Research in Safety Margins

Fire test with a CASTOR THTR/AVR cask placed beside a LPG tank wagon
Similarity and Scaling Laws / Problem: small-scale Model with soft Impact Limiter

Example: „1m puncture drop test“ in accordance to the IAEA regulations

Energy Similarity for Punch Impact onto Containment Boundary

\[ E_O = \lambda^3 \cdot E_M \quad \text{and} \quad \Delta E_O = \lambda^3 \cdot \Delta E_M \]

full-scale (1:1)
CASTOR® lc

scale-model (1:2)
CASTOR® HAW TB2

[ F. Wille et al., PATRAM 2007]
3.2 Regulatory Guidance

BAM GGR 012: Guideline for Calculation and Assessment of Lid and Trunnion Systems for RAM Packages

Adressed Objects:

- Lid system
- Trunnion system

In the Past:
Analytical approaches based on nominal stress limitation concepts

Current Developments:
Numerical approaches based on local stress limitation concepts
3.3 Managing Dual Purpose Cask Ageing

The Problem of Ageing Management (of the Cask, its Content, the Safety Case, the Design Approval Certificates, the Storage License etc.) and Transportation after some Decades of Storage

Design assessment and approval of transport package design and safety evaluation in storage licensing should be linked effectively, ideally in an integrated, holistic approach.

Permanent validity of transport package design approval certificate is the best measure for industry and authorities of constraint towards stable control and the safety case’s state-of-the-art improvement; in case of technical or regulatory changes corrective actions before transport are justified.

International cooperation, experience exchange and joint research is established, e.g. at IAEA, Joint TRANSSC/WASSC Working Group, Coordinated Research Project on extended SNF storage, USA/International, BAM/CRIEPI Collaboration etc.

IAEA-TECDOC-DRAFT
“Guidance for preparation of a safety case for a dual purpose cask containing spent fuel”
4.1 Tankcontainer for Recovery of damaged UF₆ Cylinders

After collision on 25th August 1984 with the ferry "Olau Britannia" the cargo vessel "Mont Louis" sank in the North Sea 10 miles off the Belgian coast. On board: Thirty 48Y containers with depleted and low enriched UF₆.

For the recovery action a brand new tankcontainer from Transnuklear Germany was provided. This tankcontainer design was approved by BAM 1 month before!

The recovery was performed with the containers that had only minor leakages.
4.2 Transnuklear/Nukem Germany Scandal 1987

What happened?
- A new CEO found “dubious“ bills of radioactive waste decommissioning contracts
- Around 100 employees from NPPs and utilities took bribes for providing contracts
- Shipping of large amounts of radwaste to Nuclear Research Center Mol, Belgium, where they were not decommisioned properly; reshipment to German NPP of radwaste different from that which was delivered

What was the Result?
- Withdrawal of the fuel fabrication license of Nukem, Hanau
- Dismiss of Nukem management and involved NPP utility persons
- Convicted Transnulear Germany CEOs and Dpt. heads
- Suicide of two involved persons
- Complete reorganisation of German nuclear backend industry by German Minister for the Environment and Nuclear Safety, Mr. Toepfer („Toepfer Concept“):
  - Sharp split between the three sectors and dedication to separate companies:
    - Waste management ---- Gesellschaft fuer Nuklearservice (GNS)
    - Package development and manufacture ---- Ges. für Nuklearbehaelter (GNB)
    - Transport operations ---- Nuclear Cargo Services (NCS, DB daughter)
- Begin of the complete closure of all Hanau nuclear industries
- Severe damage to public acceptance of nuclear energy in Germany
- 1 year after Chernobyl accident enhanced NPP phase out discussion in Germany (first German NPP phase out law 2000, second 2012)
4. 3 Contamination Issue 1998

Fraction of Consignments of Spent Fuel Transport Casks to and from Germany with Surface Contamination above regulatory Limits [F.Lange et al. PATRAM 2001]

After Stop of Transports, intensive Investigation of Causes, Implementation of Strict Decontamination Measures and Control Programs, the Transports proceeded without any further Problems

Loading of Cask with Contamination Prevention Skirt
4.4 Large Components Transport by Sea Ship

Loading of Steam Generators (KKS) onto MS SYGYN
4.5 Large Components Transport by Inland Waterway Vessel

2 Steam Generators (KWO) in Europe’s highest Ship Lifting Device (Niederfinow, 36 m)

Fotos: NCS

Bernhard Droste

PATRAM 2013
4.6 Mechanical Assessment of Large Components

Only computational Methods are applicable

Here: Finite Element Analysis of a 30 cm horizontal Drop
(Normal Conditions of Transport mechanical Test, in Handling Position)

/S. Komann et al., PATRAM 2010/
Decay Storage of 6 dismantled RPVs, various Steam Generators and shielded Core Components at ZLN Lubmin, Hall 8 (EWN)
Transport of reactor compartments in the dock PD-42
4.8.2 Russian/German Project for Dismantling of nuclear Submarine Reactor Compartments

Prepared Reactor Compartments on the Storage site LTSF Saida Bay, Russia

EWN 19.07.2006 / S33_DSC00454
4.9 Testing independently of Size

Smallest and largest specimen tested by BAM

Ir-192-capsule for Brachytherapy after impact test (ADR 2.2.7.4.5); length 3.2 mm, diameter 0.72 mm, wall thickness 0.05 mm.

Spent fuel transport and storage cask CONSTOR V/TC before 9 m drop test (ADR 6.4.17.2a); mass 181 t, length 7445 mm, diameter 3510 mm.
4.10 Reminiscence

PATRAM became really INTERNATIONAL 1980

6th PATRAM Conference in Berlin (West), Germany, hosted by BAM

International Congress Center
…1980 it was brand new (1 year old)
…2013 its decommissioning is discussed
VOYAGER 1&2 Mission

- Started end of 1977
- Developed for 5 Years Mission to explore Jupiter and Saturn
- 35 Years later still operating, and leaving the Limits of our Sun System

Relation to Transport and Packaging of Radioactive Material:

- Powered by Pu Batteries
- Carrying a „Golden Record“ with Human Messages, Pictures and Music (to inform extraterrestrial Cultures) packed into an Aluminium Cover with a Coating containing U-235 (what allows extraterrestrial Observers to estimate the Age of the Capsule by Analysis of the Decay Products)

Conclusions:

A lot of developments occurred during the past 35 years on package designs, safety assessment methods, transport and storage operations. Some problematic cases happened, which had to be managed.

In 1978 the situation was dominated by nuclear energy start-ups. In 2013 the situation is dominated by managing the remainders of the nuclear operations during the past 35 years.

…but there will be always further Development!
„panta rei“
Let me conclude with the first Law of Loss Prevention:

„Those who ignore the past are condemned to repeat it“

Thank you very much for your attention!