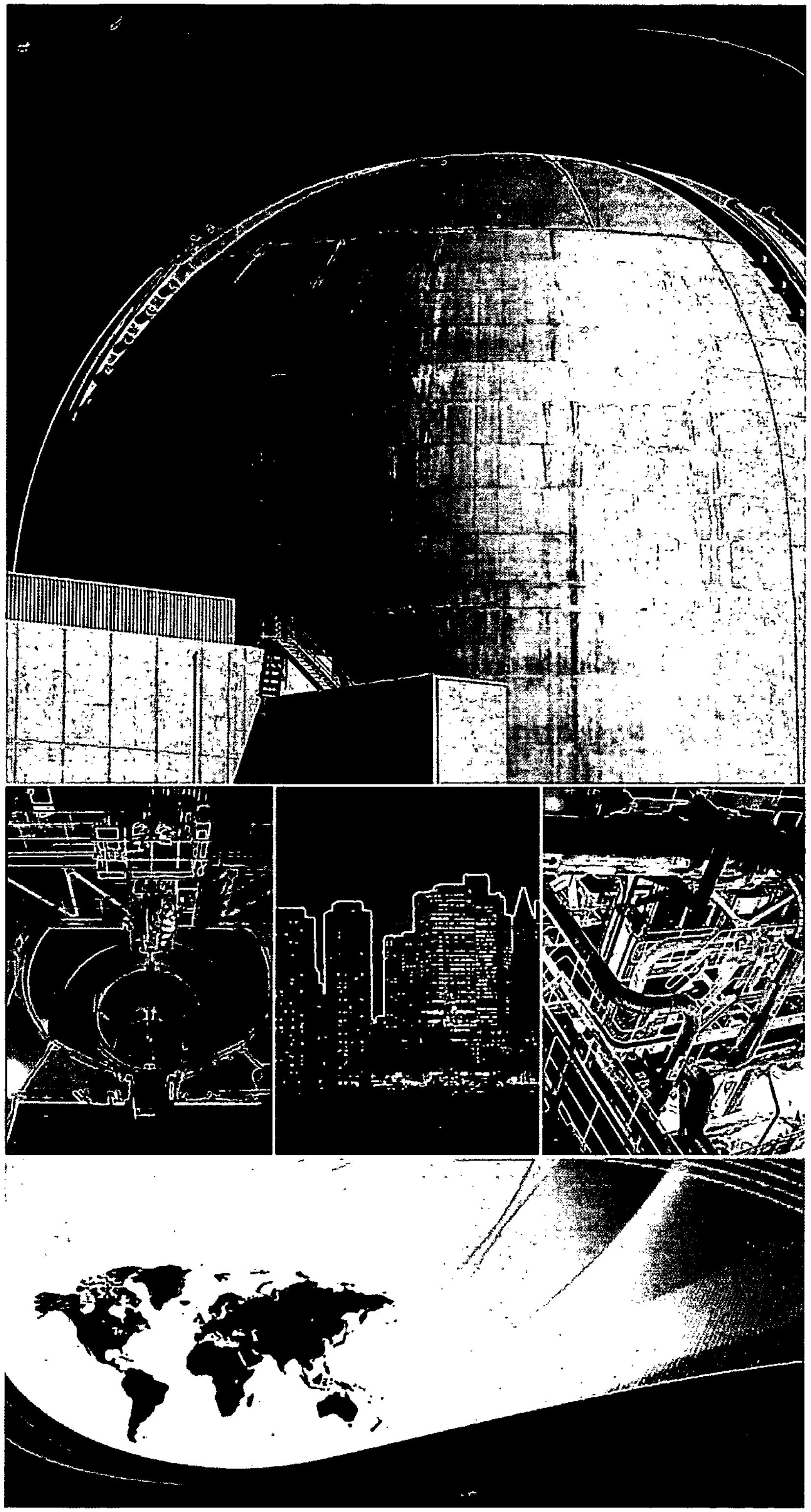

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Issues Related to Long-term Dry Storage of Used Nuclear Fuel

Nuclear Waste Technical Review Board Meeting

Las Vegas NV, 11 June 2009

John Kessler
Manager, Used Fuel and HLW Management Program

Outline

- Dry cask storage system functions
- Dry Cask Storage Characterization Project (DCSC) review
- Potential long-term degradation mechanisms
- EPRI plans for future work

Functions of a Dry Cask Storage System that Must be Maintained

- NUREG-1536 (NRC, 1997) identifies the functions important to safety that the dry cask systems must maintain:
  - thermal performance
  - radiological protection
  - confinement
  - sub-criticality
  - retrievability

Dry Cask Storage Characterization (DCSC) Project Review

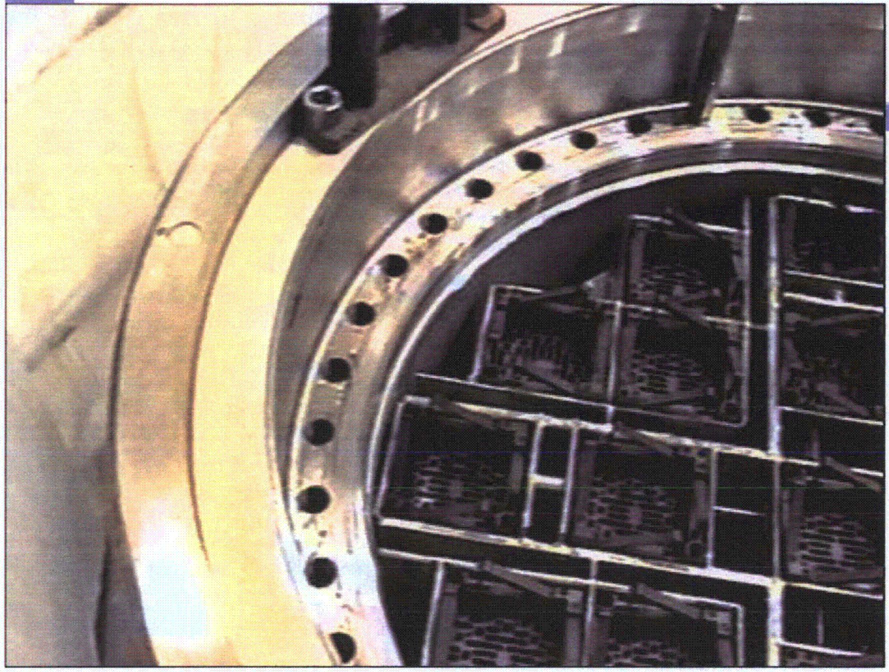
- Four-year effort (1999-2002)
- Impetus: end of the initial 20-year licenses (2006)
- Investigation of Castor V/21 cask at INL
  - In dry storage for 15 years
  - Represented the lead (spent) fuel in dry storage in the U.S.
- Co-funded by NRC-Research, EPRI, DOE-RW, DOE-EM
- Documented in EPRI reports:
  - Interim report 1000157 (2000)
  - Interim report 1003010 (2001)
  - Final report 1002882 (2002)

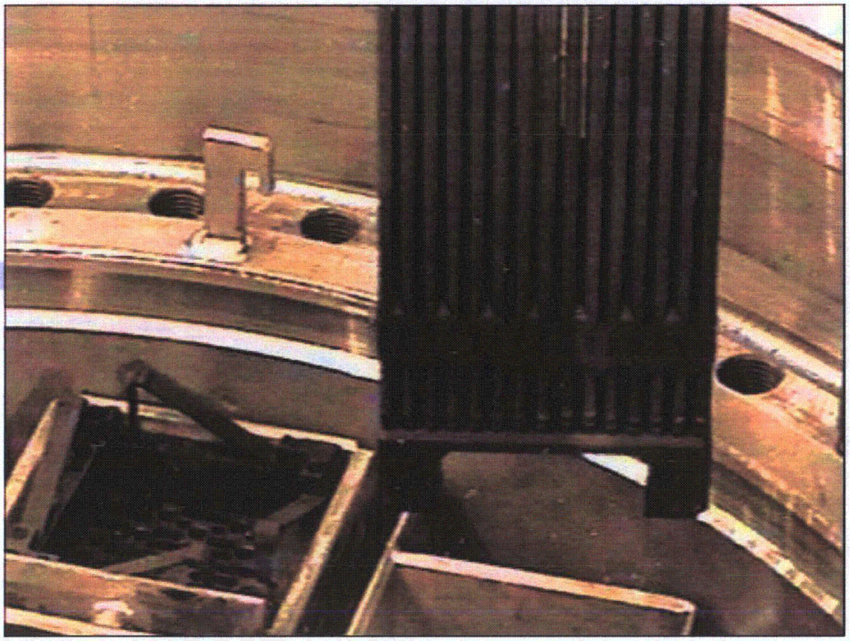
DCSC Project Tasks

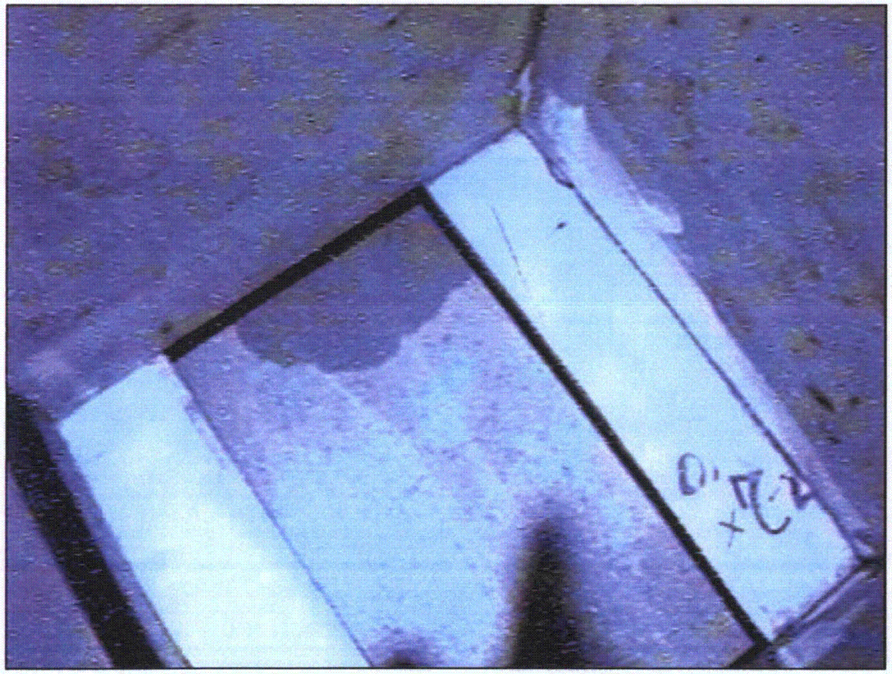
- Reopen Castor V/21 at INL
  - Cask cavity gas analysis
  - External dose rate measurements
  - Visual inspection of assemblies and cask internals
  - Remove rods from assembly in Castor at INL
- Rod testing at ANL
  - Profilometry at ANL-West
  - Rod puncturing for fission gas release at ANL-West
  - Destructive exams of Zircaloy at ANL-East

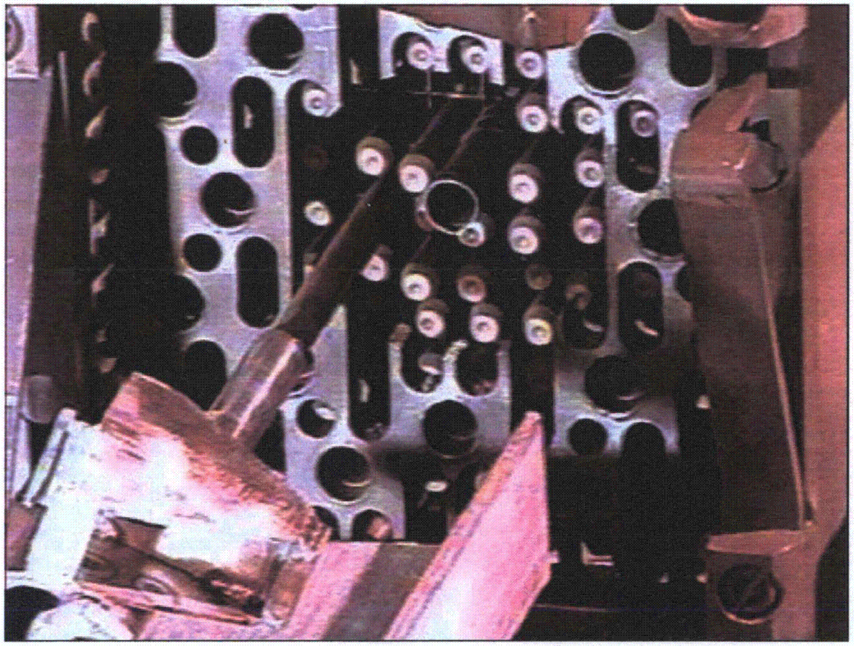
Castor V/21 on Transporter Headed to Hot Shop

DCSC Photos



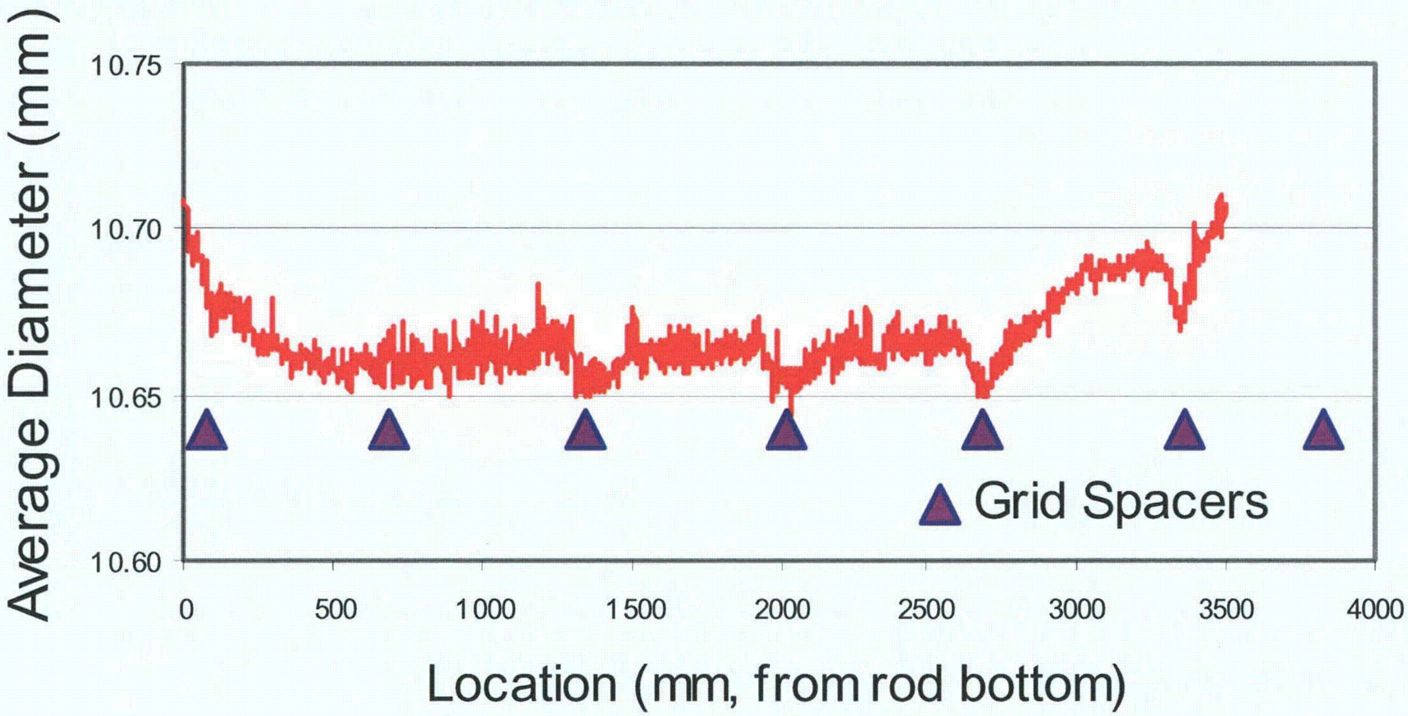




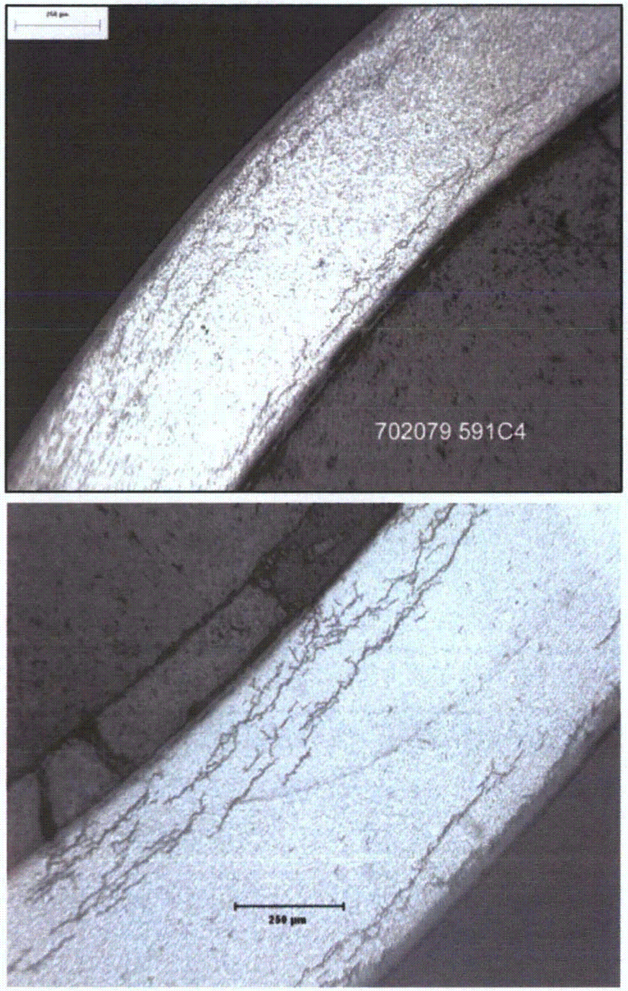


DCSC Profilometry: No Evidence of Creep During Storage

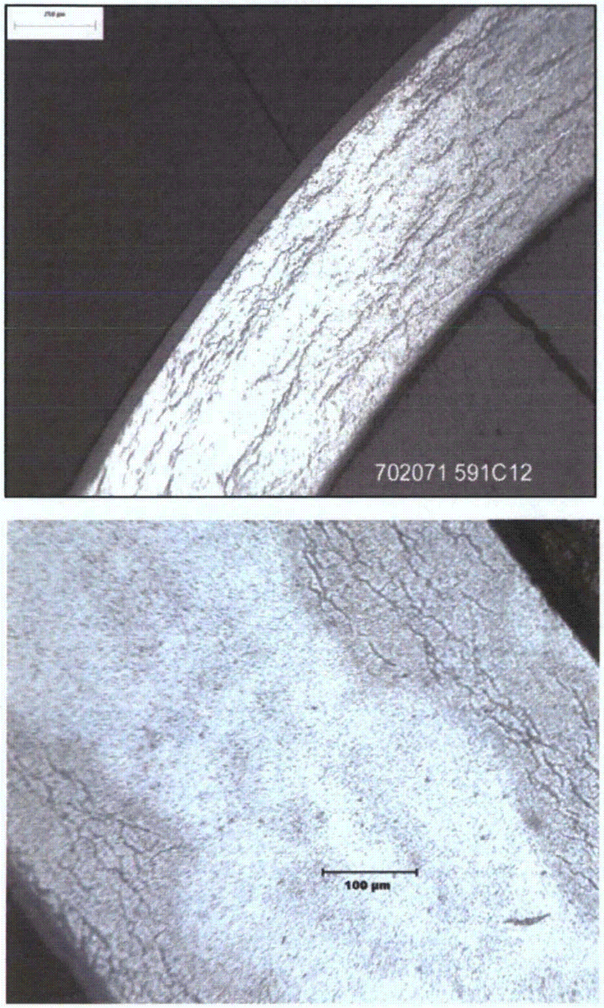
The nominal as-fabricated cladding outer diameter is 10.72 mm.



DCSC: Morphology of Hydrides Mostly Circumferential



Mid plane



0.5m above mid plane

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Main Conclusions from the Four-Year DCSC Effort

- No cask functional degradation observed
- Assemblies still look the same
  - No sticking; no significant bowing upon removal
  - No visual signs of degradation (color, oxide, damage)
- No leaks during storage
- No significant additional fission gas release to rod internals
- No significant hydride reorientation
- Zero to minuscule creep during storage
- "Creep life" remains
- Result: basis for license extensions out to ~60 years
- Most severe conditions are during first 20 years

Examples of Issues the DSCS Program did not Address

- High burnup used fuel
- Long-term concrete degradation
- Effect of marine environments (examined in EPRI report 1011820, September 2005)

Review of Potential Degradation Mechanisms – Outline (from EPRI report 1003416, December 2002)

Mechanism	Fuel		Cladding	
	Initial	Extended	Initial	Extended
Normal				
Oxidation	N	N		
fgr	Y	N		
Creep,			Y	N
DCCG			N	N
H_2 reorientation			Y	N
DHC			N	N
SCC			maybe	N
→ H_2 embrittlement			N	Y
H_2 migration			Y	N
Annealing			Y	N
Crud Spallation			maybe	N
Off-Normal				
→ Oxidation due to air ingress	Y	Y	Y	Y
Creep			Y	DE
Annealing			Y	DE
Accident-impact				
Fracture	DE	DE		
Oxidation	DE	DE		
Impact Breach			DE	DE
Crud spallation			DE	DE
→ **Accident-fire**				
Stress rupture			Y	Y
Annealing			Y	Y
H_2 reorientation			Y	Y

DHC = Delayed Hydrogen Cracking
DCCG = Diffusion Controlled Cavitation Growth
Fgr = fission gas release
SCC = Stress Corrosion Cracking
DE = Depends on the event

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Temperature-related Dry Storage System Degradation Mechanisms

- Fuel cladding creep caused by increased cladding ductility and increased stress
  - Due to higher temperatures causing higher pressures inside the cladding
- Hydride reorientation in the spent fuel cladding
- Corrosion
- Degradation of neutron shielding
- Concrete dry-out and cracking

Changes as the System gets Cooler

- Mostly good things
  - Reduced metal creep rates
  - Reduced corrosion rates
  - Reduced gamma and neutron radiation
- Potential negatives (mostly related to cladding)
  - Additional hydride precipitation
  - Decreased ductility
    - *Potentially* more susceptible to breakage during storage and transportation

Reduced Degradation with Time does not Mean Degradation Stops

- Corrosion (in oxidizing environments)
- Helium buildup inside fuel rods

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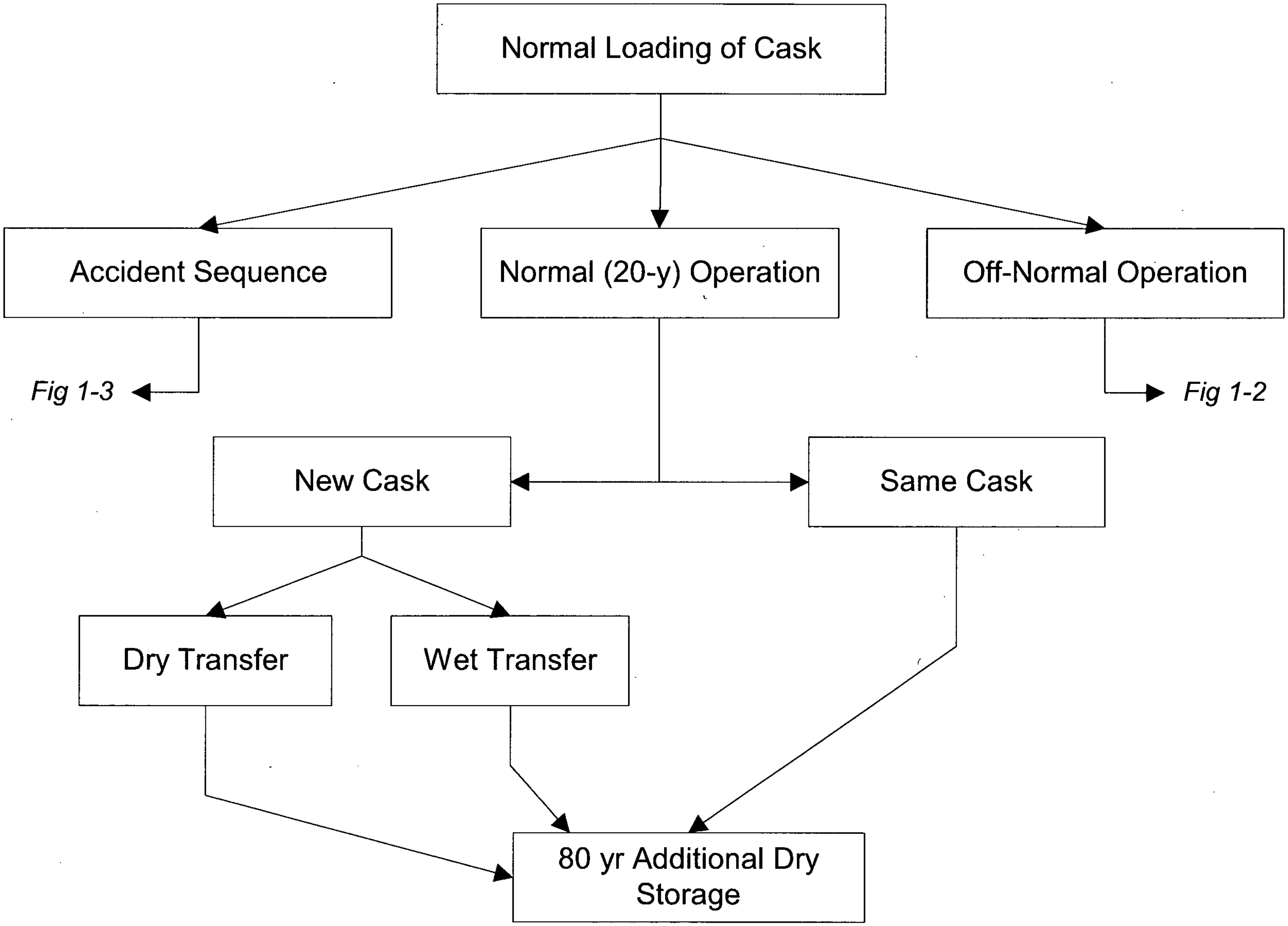
Aging Management Options

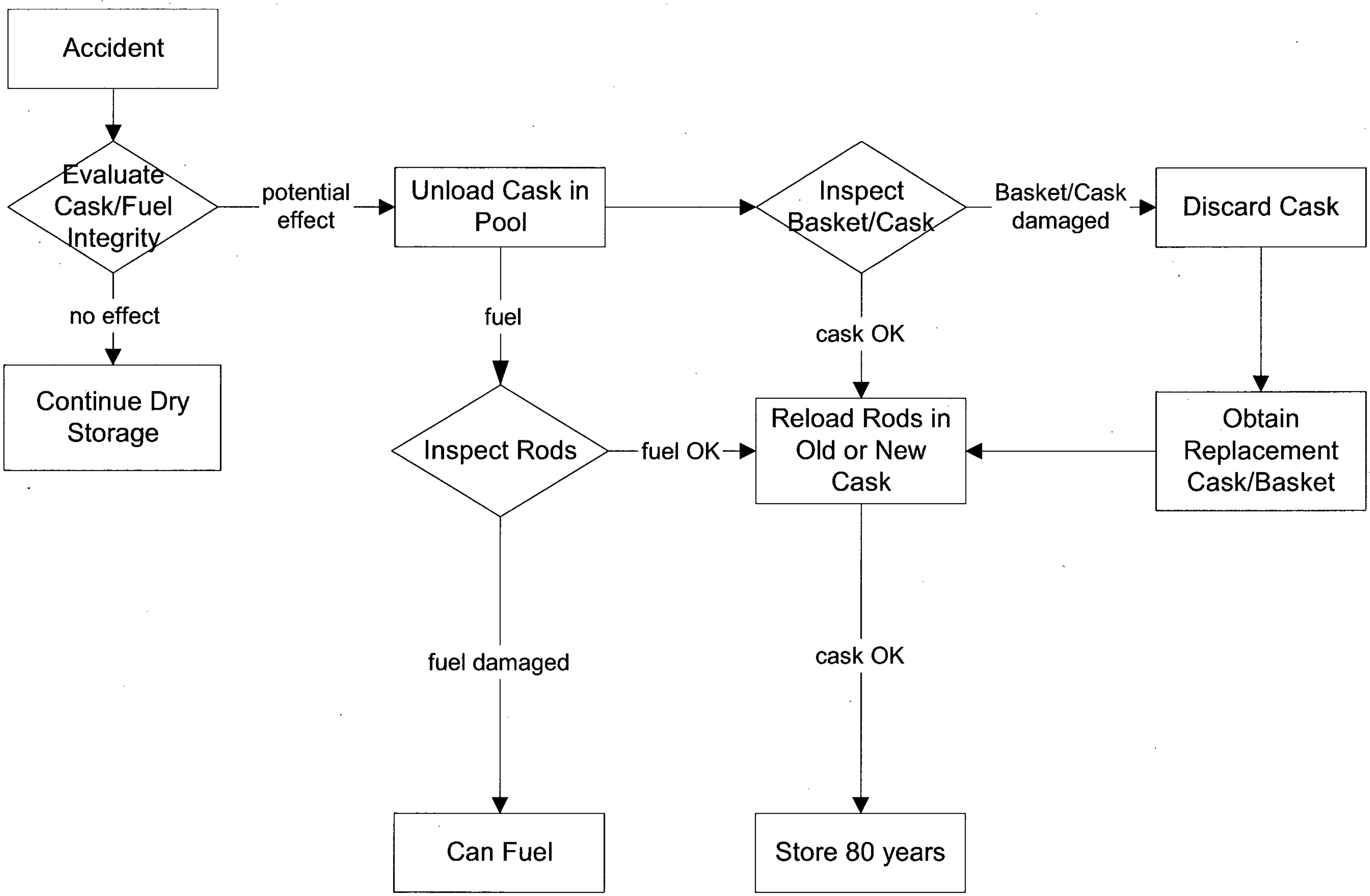
- "Initial" activities
  - Additional analyses to extend progress of degradation mechanisms
  - Enhanced monitoring and inspection
- "Eventually"
  - Canning
  - Repackaging
  - Over-packaging

- When is "eventually"?

Potential Sequence of Events for Extended Dry Storage (from EPRI report TR-108757, 1998, assumes 100-yr storage)



Potential Sequence of Events for Extended Dry Storage After an Accident Event



Potential EPRI Work on Very Long-term Used Fuel Storage and Transportation Issues

- Workshop (Fall 2009)
- "Paper" analyses
- Experimental (with others?)
- Licensing issues
- Operational issues

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