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MAPS Report:
Managing Aging Processes in Storage

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ASTM C26.13 Subcommittee Meeting
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Disclaimer

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NRC staff views expressed herein are preliminary and do not constitute a final judgment or determination of the matters addressed or of the acceptability of any licensing action that may be under consideration at the NRC.

Outline

- Background
  - NRC licensing and certification process/requirements
  - Regulatory framework for storage renewals
- MAPS Report
  - Outline
  - Credible / non-credible aging mechanisms
  - DSSs reviewed in Rev. 0
  - Aging Management Programs
- Path Forward

ISFSIs in the U.S.

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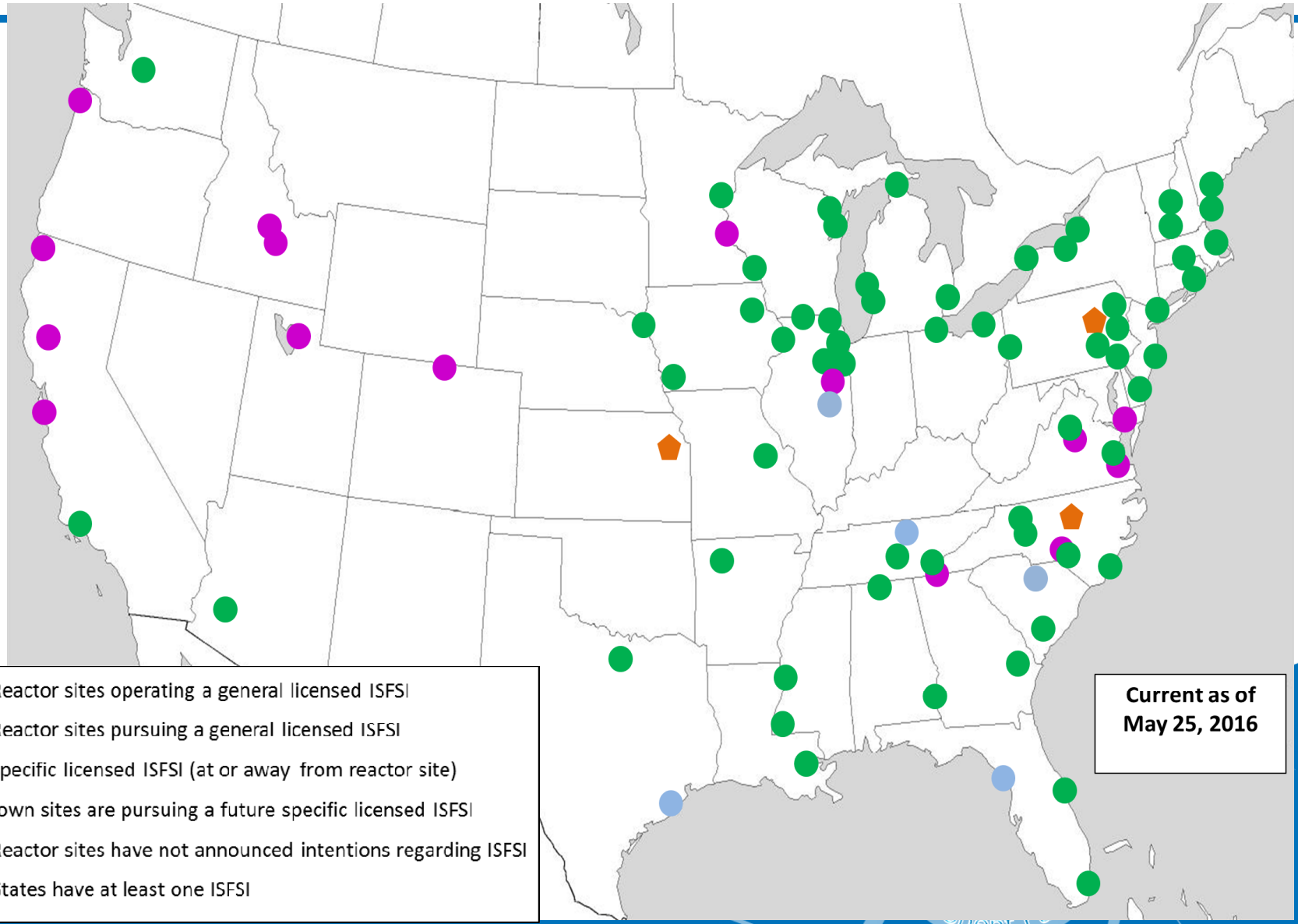

Regulatory Framework

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General License

- Authority provided to Part 50 and 52 license holders (power reactors)
- Storage of spent fuel in NRC-approved DSS designs (CoC)
- Requires site evaluation to verify compatibility with DSS design
- Term is tied to the CoC in use (i.e. GLs are not renewed)
- DSS initial CoC term up to 40 years
- DSS design requirements in 10 CFR Part 72, Subpart L

Specific License

- Available to 10 CFR Part 50 licensees and others
- Required for away-from-reactor sites (unless decommissioned)
- Initial license term up to 40 years
- Overall requirements in 10 CFR Part 72, Subpart F

ISFSI and DSS Renewal

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- First ISFSI licensed in 1986 / First CoC issued in 1986
- Licenses/CoCs to date issued for 20 years
- Licenses/CoCs renewed for up to 40 additional years, at a time
- Must demonstrate that storage can safely continue in light of potential age-related degradation
  - Aging Management Programs (AMPs) provide measures for prevention, mitigation, monitoring and/or inspection
  - Time Limited Aging Analyses (TLAAs): calculations that demonstrate that a component can maintain its function throughout the renewed term

Storage Renewal Framework

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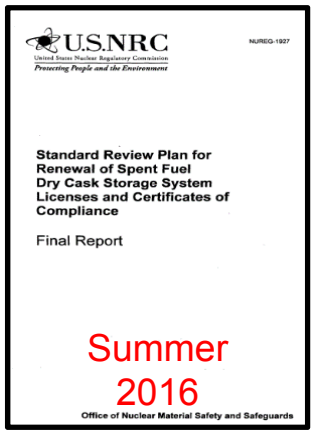
TI / IP Inspections

Draft Fall 2016

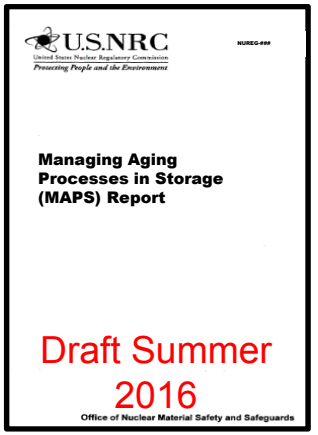
SRP 1927R1



Summer 2016

Staff consideration of Stakeholder inputs

MAPS



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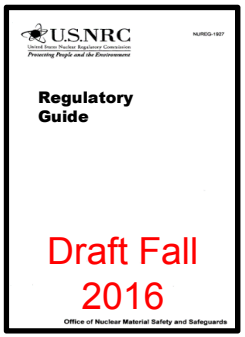
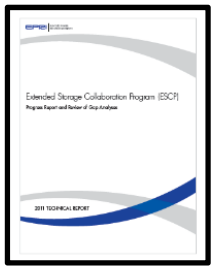
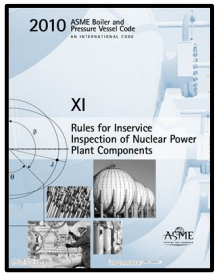


Draft Fall 2016

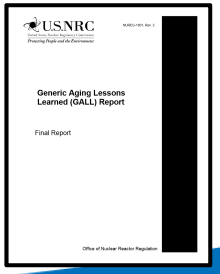
Technical Issue Resolution



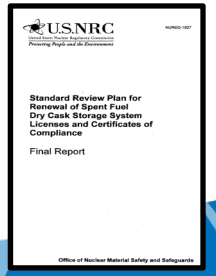
Consensus Codes



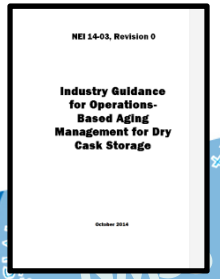
Storage/ Reactor OpE



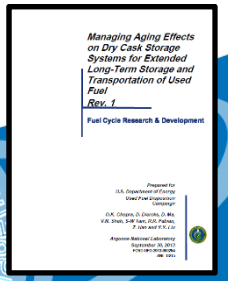
SRP NUREG-1927R0



NEI 14-03



DOE/ANL Report



MAPS Report Outline

- Introductory Material, Definitions
- Evaluation of Aging Mechanisms (Technical Bases)
  - Casks, Canisters and Internals
  - Neutron Shielding
  - Neutron Absorbers
  - Concrete Overpacks, Support Pads, Ceramic Fiber Insulation
  - Spent Fuel Assemblies
- Analyses of DSSs and SFAs
- Example Aging Management Programs

Environments Considered

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- Sheltered (SH)
- Air-Outdoor (OD)
- Groundwater/ Soil (GW)
  - Includes below-grade
- Helium and other gas (IG)
- Fully-Encased or Lined (FE)
- Embedded (E)
  - Concrete (E-C)
  - Neutron Shield (E-NS)
- Demineralized Water (DW)
- Air Indoor/Outdoor (IO)

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Casks, Canisters and Internals

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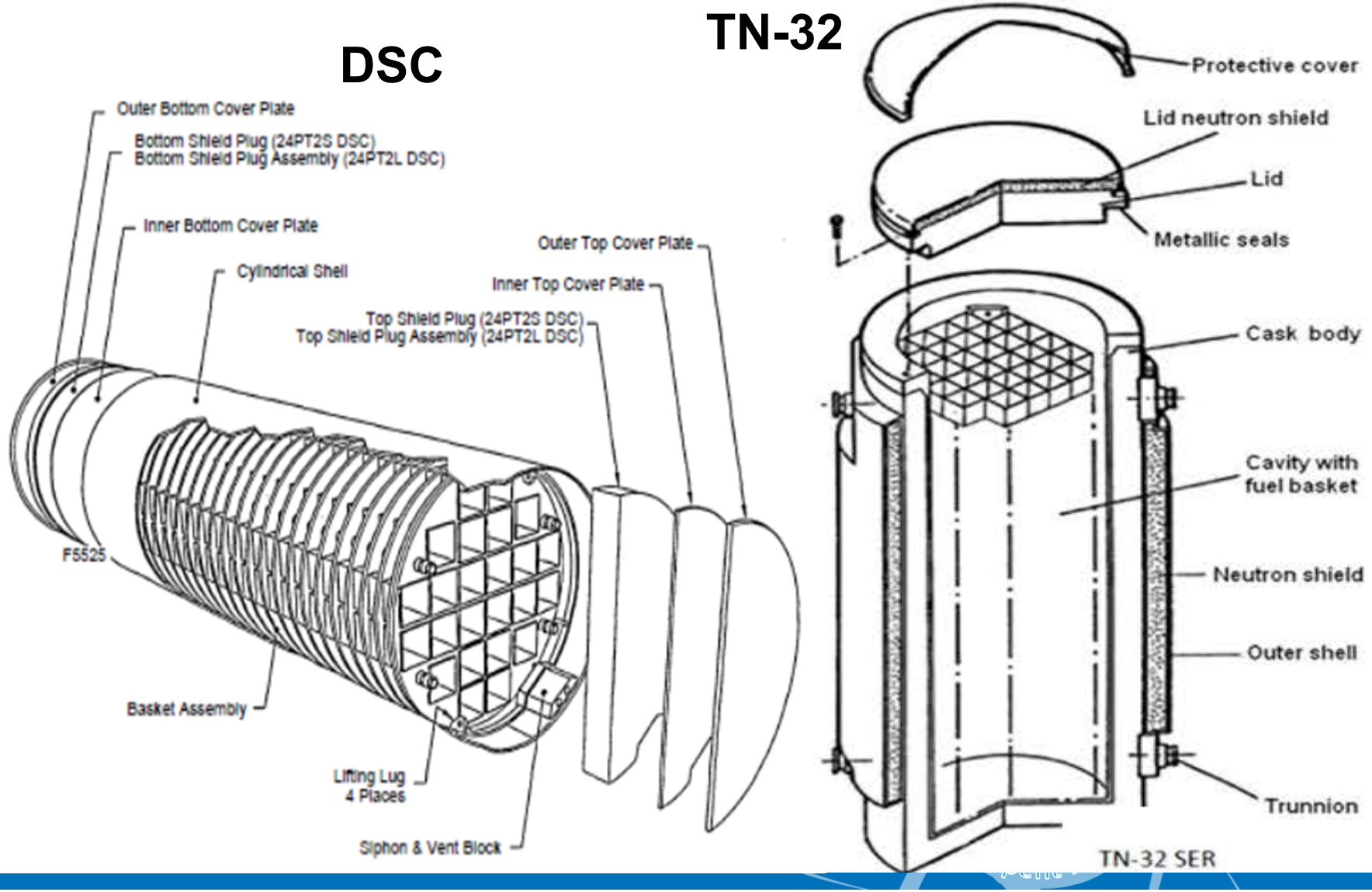

Casks, Canisters and Internals

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Stainless Steel	Credible	Non-Credible/ Insignificant
General Corrosion		All environments
Pitting and Crevice Corrosion	OD, SH	IG, E, DW
Galvanic Corrosion	OD, SH	
MIC		SH, OD, DW, IG, E
SCC	OD, SH	IO, DW, IG
Creep		SH, OD, DW, GW, E, IG
Thermal Aging		
Fatigue	Review per DSS-specific design bases (e.g. TLAA)	
Radiation Embrittlement		
Stress Relaxation		SH, OD
Wear	IO	

Casks, Canisters and Internals

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Steel	Credible	Non-Credible/ Insignificant
General Corrosion	OD, SH, DW, GW, E-C, E-NS	IG
Pitting and Crevice Corrosion	OD, SH, DW, GW, E-C	E-NS, IG
Galvanic Corrosion	OD, SH	DW
MIC	GW, E-C	SH, OD, DW, IG, E-NS
SCC		SH, OD
Creep		SH, OD, DW, GW, E, IG
Thermal Aging		
Fatigue	Review per DSS-specific design bases (e.g. TLAAs)	
Radiation Embrittlement		
Stress Relaxation		SH, OD
Wear	IO	

Neutron Shielding

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Borated polyester resin Borated polypropylene Holtite-A™	**Credible**	**Non-Credible/ Insignificant**
Absorber Depletion	Review per DSS-specific design bases (e.g. TLAA)	
Thermal Aging		FE
Radiation Embrittlement		FE

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Neutron Absorbers

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Borated Aluminum Alloys Aluminum MMCs Al-B-C Laminate Composites	**Credible**	**Non-Credible/ Insignificant**
General Corrosion		IG
Galvanic Corrosion		IG
Wet Corrosion / Blistering		IG
Absorber Depletion	Review per DSS-specific design bases (e.g. TLAA)	
Creep		IG
Thermal Aging		IG
Radiation Embrittlement		IG

Concrete Overpacks/ Support Pads

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INL TMI-2 ISFSI

ADAMS Accession Nos.:
ML12320A697
ML11097A028

Reinforced Concrete Plain Concrete	Credible	Non-Credible/ Insignificant
Freeze/Thaw	OD, GW (above freeze line)	FE, SH, GW (below freeze line)
Salt Scaling		
Creep		All environments
Reaction with Aggregates	All environments	
Differential Settlement	All environments	
Aggressive Chemical Attack	OD, GW	SH, FE
Corrosion of Reinforcement	OD, GW	SH, FE
Shrinkage		All environments
Leaching of $CaOH_2$	OD, SH, GW	FE
Radiation Damage	Review per DSS-specific design bases (e.g. TLAA)	
Fatigue		
Dehydration at High Temp.		All environments
Microbiological Degradation	GW	OD, SH, FE
Delayed Ettringite Formation		All environments

Spent Fuel Assemblies

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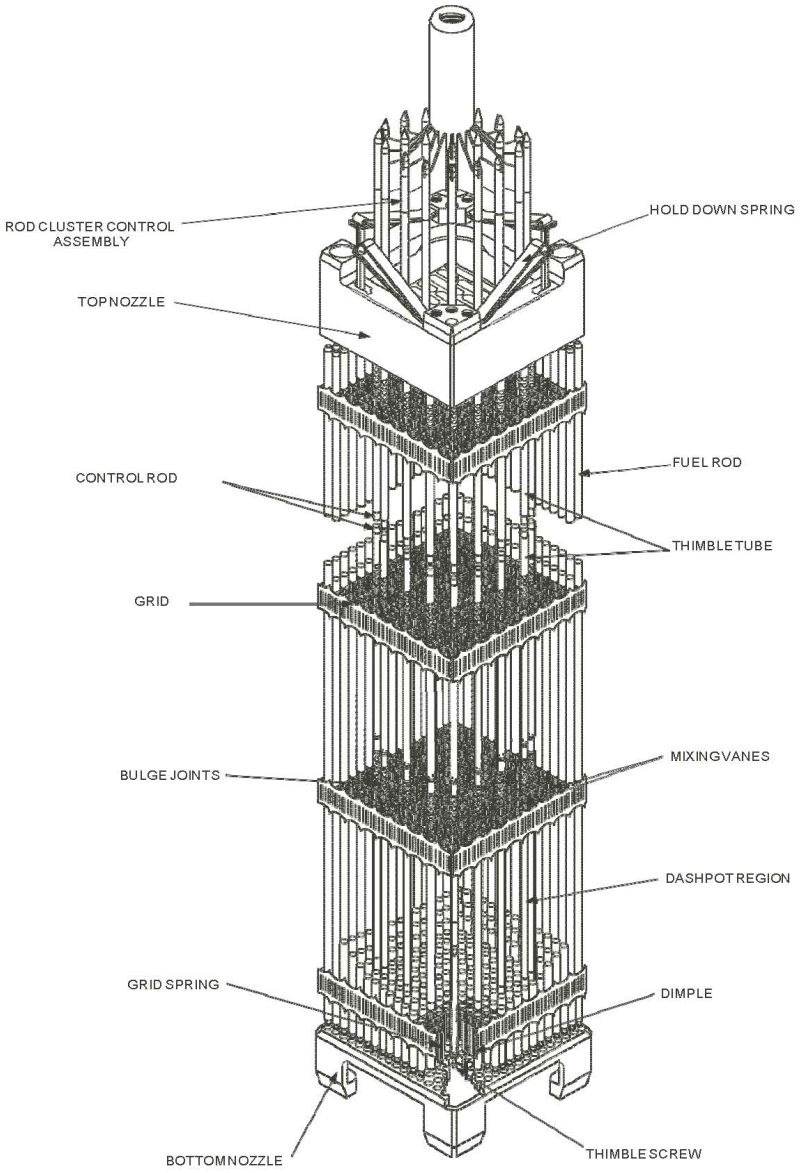

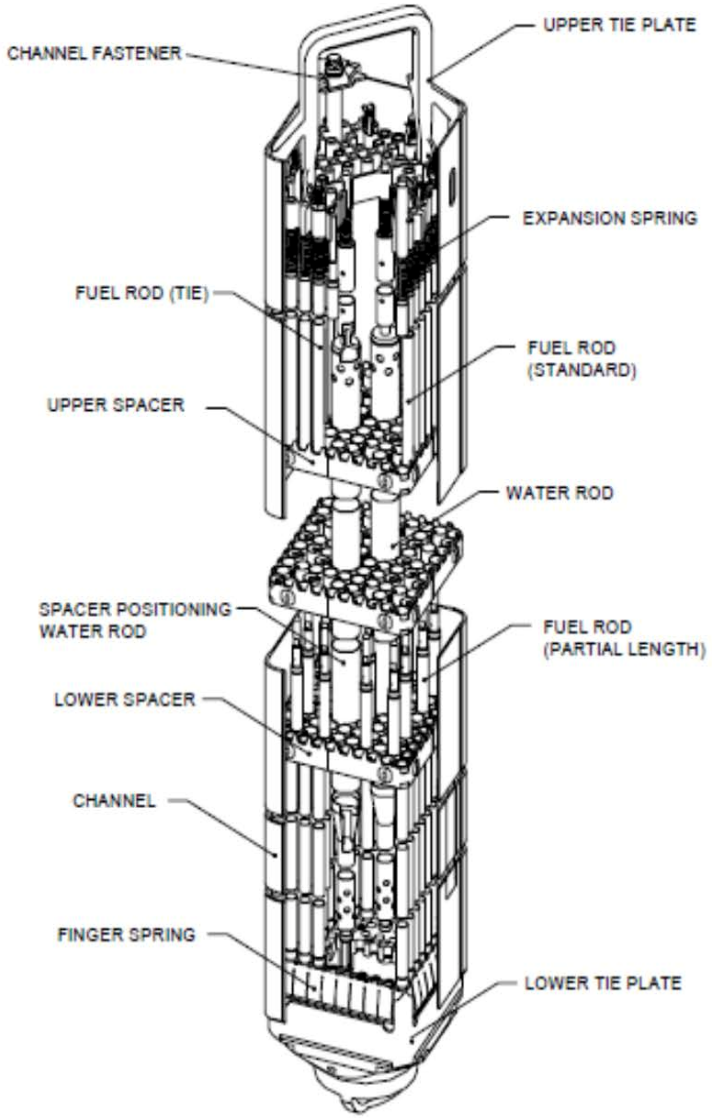

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Fuel Cladding	Credible	Non-Credible/ Insignificant
Hydride Reorientation and Hydride-Induced Embrittlement		IG
Delayed Hydride Cracking		IG
Thermal Creep	IG	
Low Temperature Creep		IG
Mechanical Overload		IG
Oxidation		IG
Pitting Corrosion		IG
Galvanic Corrosion		IG
SCC		IG
Radiation Embrittlement		IG
Fatigue		IG

DSSs reviewed in Rev. 0

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Name	NRC Docket No.	Amendments evaluated
Standardized NUHOMS®	72-1004	1-11 and 13
HI-STORM 100	72-1014	1-9
HI-STAR 100	72-1008	1 and 2
TN-32	72-1021	1
TN-68	72-1027	1

- NAC, EnergySolutions, and variations of other Holtec and AREVA-TN systems in review

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Example DSS Review

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Table 4.3-1. HI-STORM / HI-STAR Multipurpose Canister							
Structure, System, or Component	**Intended Safety Function**	**Material**	**Environment**	**Aging Mechanism**	**Aging Effect**	**Aging Management**	**Technical Basis (Section)**
Shell	CO, SH, SR, TH	Stainless steel (welded)	Sheltered	Atmospheric stress corrosion cracking	Cracking	Localized Corrosion and Stress Corrosion Cracking of Welded Stainless Steel Dry Storage Canisters AMP	3.2.2.5
		Stainless steel	Sheltered	Pitting and crevice corrosion	Loss of material (Precursor to stress corrosion cracking)	Localized Corrosion and Stress Corrosion Cracking of Welded Stainless Steel Dry Storage Canisters AMP	3.2.2.2
				Microbiologically influenced corrosion	Loss of material	No	3.2.2.4
				Fatigue	Cracking	TLAA/AMP or a supporting analysis is required	3.2.2.7
				Radiation embrittlement	Cracking	TLAA/AMP or a supporting analysis is required	3.2.2.9
			Helium and other gas	Fatigue	Cracking	TLAA/AMP or a supporting analysis is required	3.2.2.7

Aging Management Programs

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- Localized Corrosion and SCC of Welded Stainless Steel Canisters
- Reinforced Concrete Structures
- External Surfaces Monitoring of Metallic Components
- Ventilation Systems
- Bolted Cask Seal Leakage Monitoring
- Transfer Casks
- High Burnup Fuel Monitoring and Assessment

Path Forward

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- Review/ Publishing Plan
  - Draft for public comment – Summer 2016
  - Staff addresses public comments
  - Advisory Committee on Reactor Safeguards
  - Final report published

MAPS Technical Contributors

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Additional Reviewed SSCs

Casks, Canisters and Internals

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Aluminum	Credible	Non-Credible/ Insignificant
General Corrosion		SH, E, IG
Pitting and Crevice Corrosion	SH	IG, E
Galvanic Corrosion	SH	IG
MIC		SH, E, IG
Creep	Review per DSS-specific design bases (e.g. TLAA)	
Thermal Aging		
Fatigue		
Radiation Embrittlement		

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Casks, Canisters and Internals

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Nickel Alloys	Credible	Non-Credible/ Insignificant
General Corrosion		All environments
Pitting and Crevice Corrosion		OD
Galvanic Corrosion		OD
MIC		OD
SCC		IO, SH, OD
Fatigue	Review per DSS-specific design bases (e.g. TLAA)	
Radiation Embrittlement		
Stress Relaxation		OD

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Copper-Alloys	Credible	Non-Credible/ Insignificant
General Corrosion	OD	
Pitting and Crevice Corrosion		OD
MIC		OD
Radiation Embrittlement		OD

Lead	Non-Credible/ Insignificant
No credible aging mechanisms for fully-lined (encased) lead components	

Neutron Absorbers

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Borated Stainless Steel	Credible	Non-Credible/ Insignificant
General Corrosion		IG
Galvanic Corrosion		IG
Wet Corrosion / Blistering		IG
Absorber Depletion	Review per DSS-specific design bases (e.g. TLAA)	
Creep		IG
Thermal Aging		IG
Radiation Embrittlement		IG

Ceramic Fiber Insulation

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Ceramic Fiber Insulation	Credible	Non-Credible/ Insignificant
Radiation Damage	Review per DSS-specific design bases (e.g. TLAA)	
Moisture Absorption		FE

Spent Fuel Assemblies

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Assembly Hardware	Credible	Non-Credible/ Insignificant
Creep		IG
Hydriding		IG
General Corrosion		IG
SCC		IG
Radiation Embrittlement		IG
Fatigue		IG

Acronyms

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- ACRS: Advisory Committee on Reactor Safeguards
- ADAMS: Agencywide Documents Access and Management System
- AMP: Aging Management Program
- ANL: Argonne National Laboratory
- ASTM: American Society for Testing and Materials
- CFR: Code of Federal Regulations
- CoC: Certificate of Compliance
- DOE: Department of Energy
- DSC: Dry Shielded Canister
- DSS: Dry Storage System
- GL: General License
- INL: Idaho National Laboratory
- IP: Inspection Report
- ISFSI: Independent Spent Fuel Storage Installation
- MAPS: Managing Aging Processes in Storage
- MIC: Microbiologically Influenced Corrosion
- NAC: NAC International
- NEI: Nuclear Energy Institute
- NRC: Nuclear Regulatory Commission
- OpE: Operating Experience
- RG: Regulatory Guide
- SFA: Spent Fuel Assembly
- SRP: Standard Review Plan
- SSC: Stress Corrosion Cracking
- TI: Temporary Instruction
- TLAA: Time-Limited Aging Analyses
- TMI-2: Three Mile Island Unit 2
- TN: Transnuclear

References

- 10 CFR Part 72, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste,” Washington, DC.
- Chopra, O.K., D. Diercks, D. Ma, V.N. Shah, S-W Tam, R.R. Fabian, Z. Han and Y.Y. Liu, “Managing Aging Effects on Dry Cask Storage Systems for Extended Long-Term Storage and Transportation of Used Fuel”, Rev. 1, Argonne National Laboratory, 2013.
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- NRC, “Generic Aging Lessons Learned (GALL) Report,” NUREG-1801, Rev. 2, Washington, DC, 2010, ADAMS Accession No. ML103490041.
- NRC, “Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance,” NUREG-1927, Rev. 0, Washington, DC, 2011, ADAMS Accession No. ML111020115.
- NRC, “Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel,” NUREG-1927, Rev. 1, Draft Report for Comment, Washington, DC, 2015, ADAMS Accession No. ML15180A011.