



# MAPS Report: Managing Aging Processes in Storage

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Office of Nuclear Material Safety and Safeguards

ASTM C26.13 Subcommittee Meeting  
June 16-17, 2016



# Disclaimer

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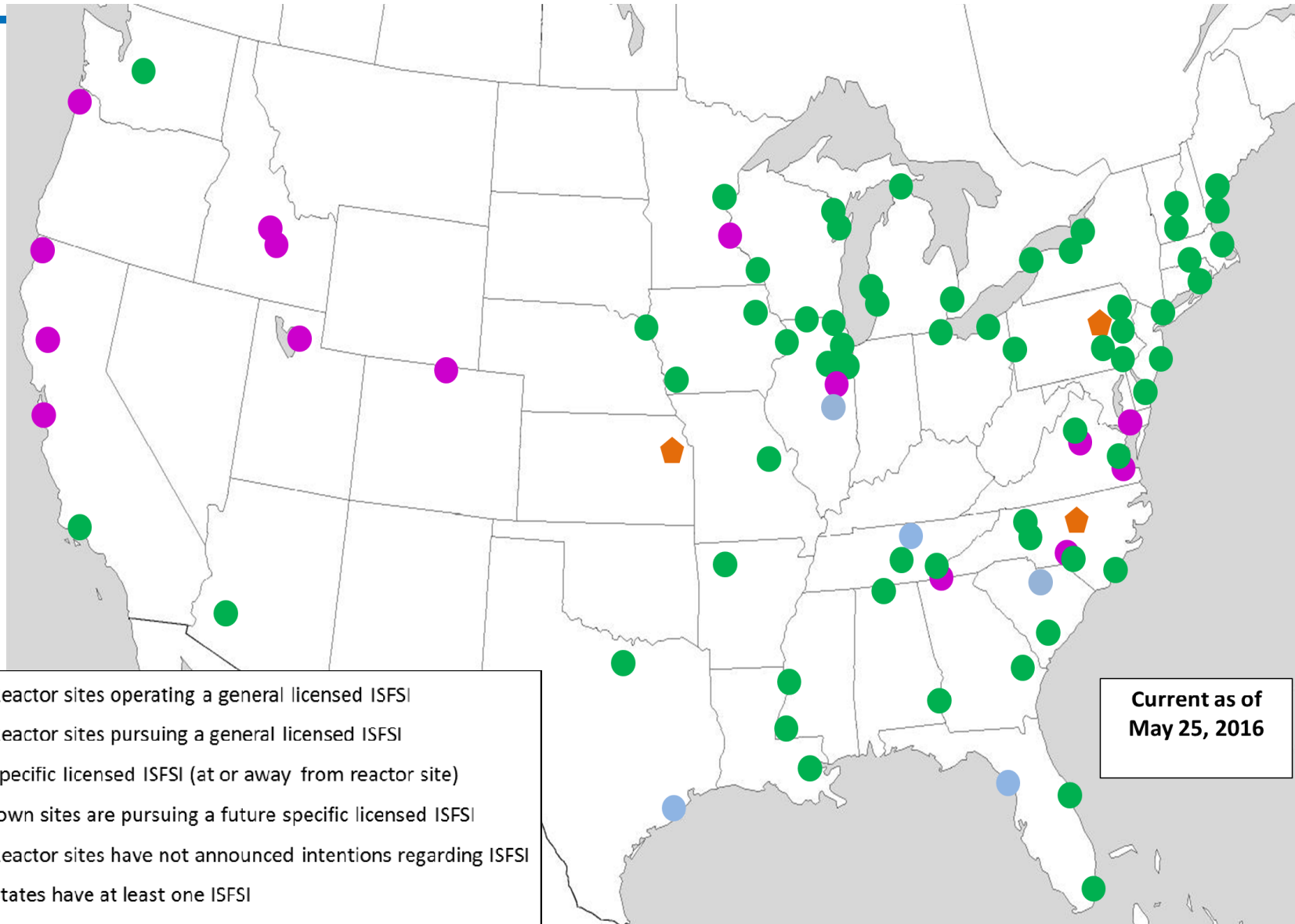
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# Outline

- 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.



- 60 Reactor sites operating a general licensed ISFSI
- 5 Reactor sites pursuing a general licensed ISFSI
- 15 Specific licensed ISFSI (at or away from reactor site)
- No known sites are pursuing a future specific licensed ISFSI
- 3 Reactor sites have not announced intentions regarding ISFSI
- 34 States have at least one ISFSI

**Current as of  
May 25, 2016**

# Regulatory Framework

## 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

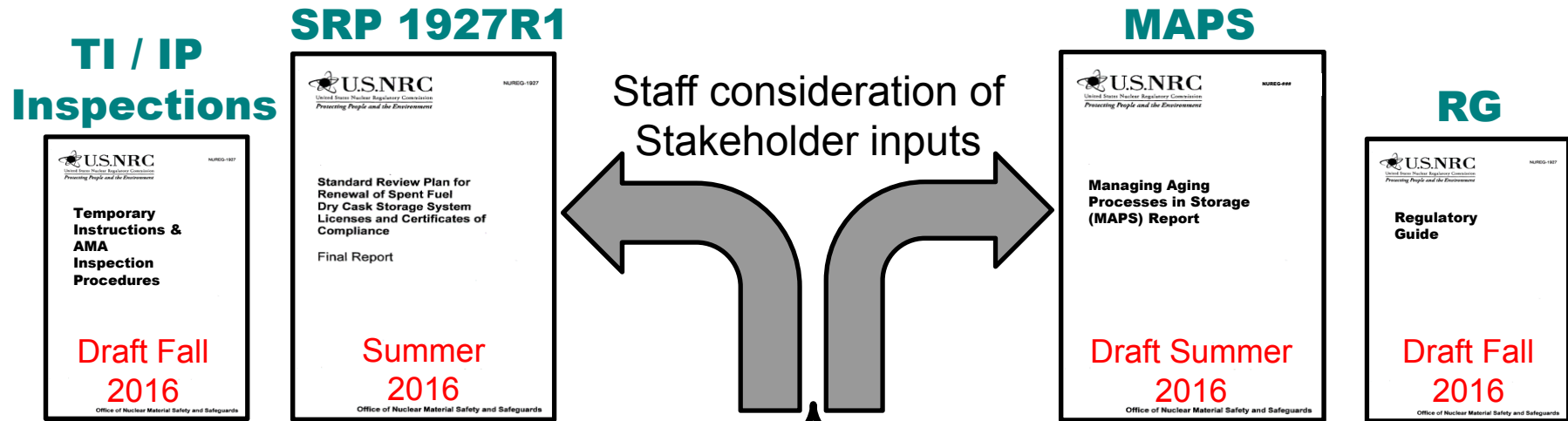
## Specific License

- 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

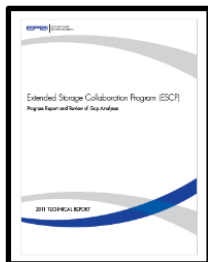
# ISFSI and DSS Renewal

- 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

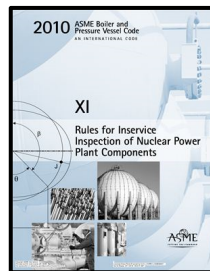
# Storage Renewal Framework



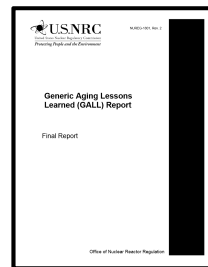
## Technical Issue Resolution



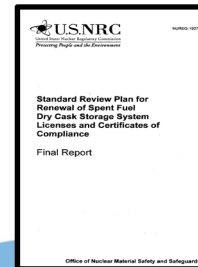
## Consensus Codes



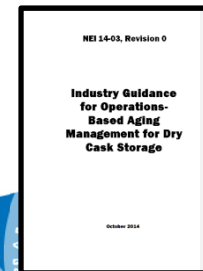
## Storage/Reactor OpE



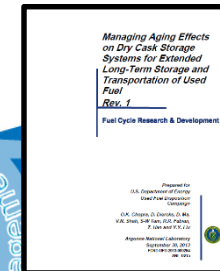
## SRP NUREG-1927R0



## 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

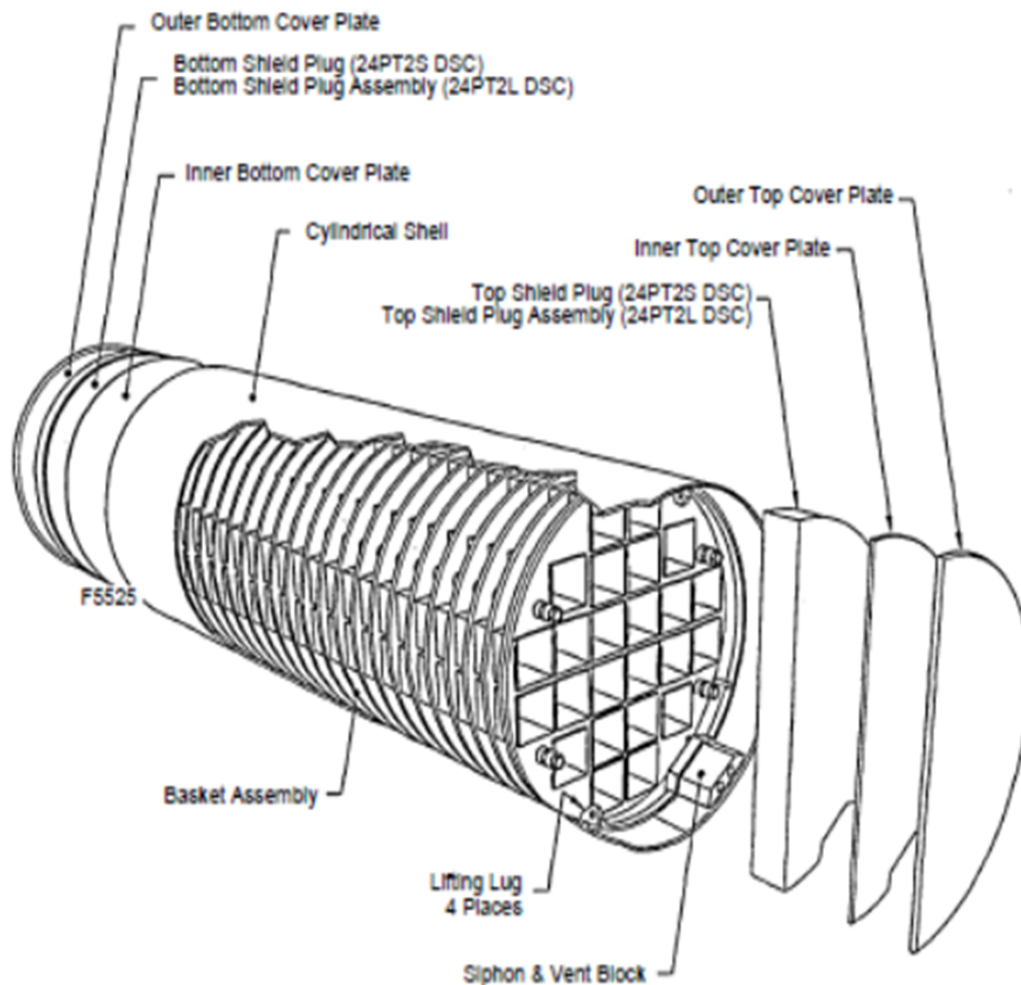


# Environments Considered

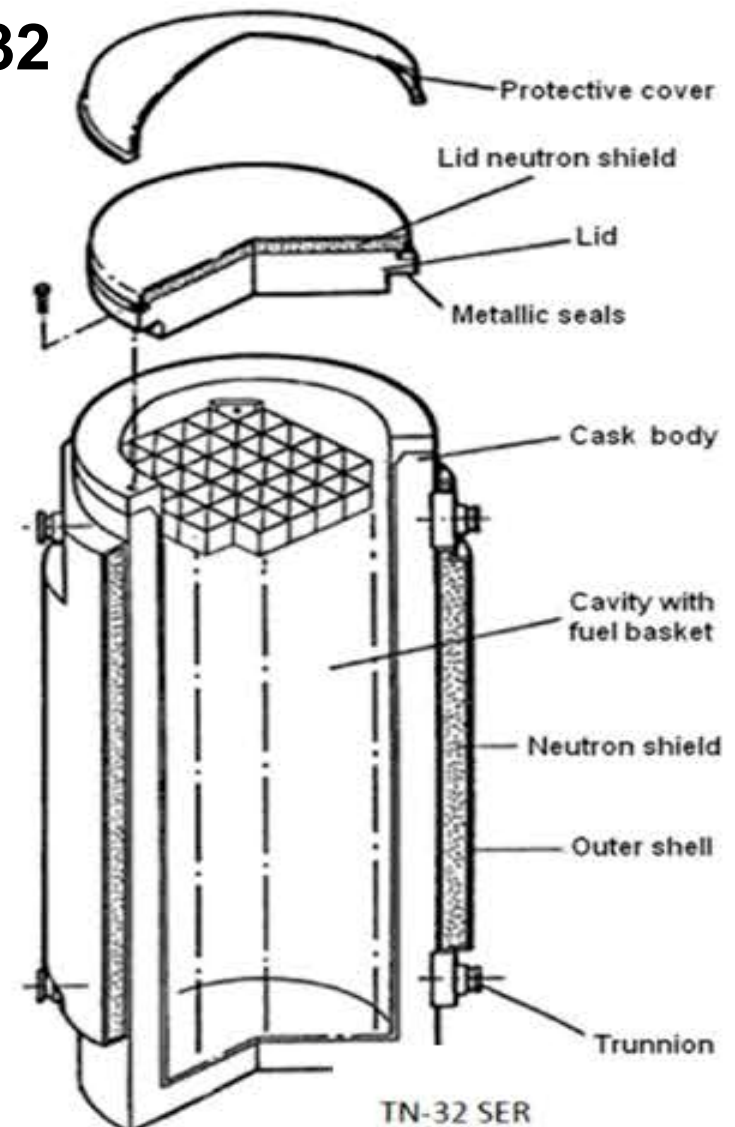
- Sheltered (SH)
- Air-Outdoor (OD)
- Groundwater/ Soil (GW)
  - Includes below-grade
- Helium and other gas (IG)
- Fully-Encased or Lined (FE)
- Embedded (E)
  - Concrete (E-C)
  - Neutron Shield (E-NS)
- Demineralized Water (DW)
- Air Indoor/Outdoor (IO)

# Casks, Canisters and Internals

## DSC



## TN-32



# Casks, Canisters and Internals

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

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

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

# Neutron Absorbers

<b>Borated Aluminum Alloys                      Aluminum MMCs                      Al-B-C Laminate Composites</b>	<b>Credible</b>	<b>Non-Credible/                      Insignificant</b>
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

## INL TMI-2 ISFSI



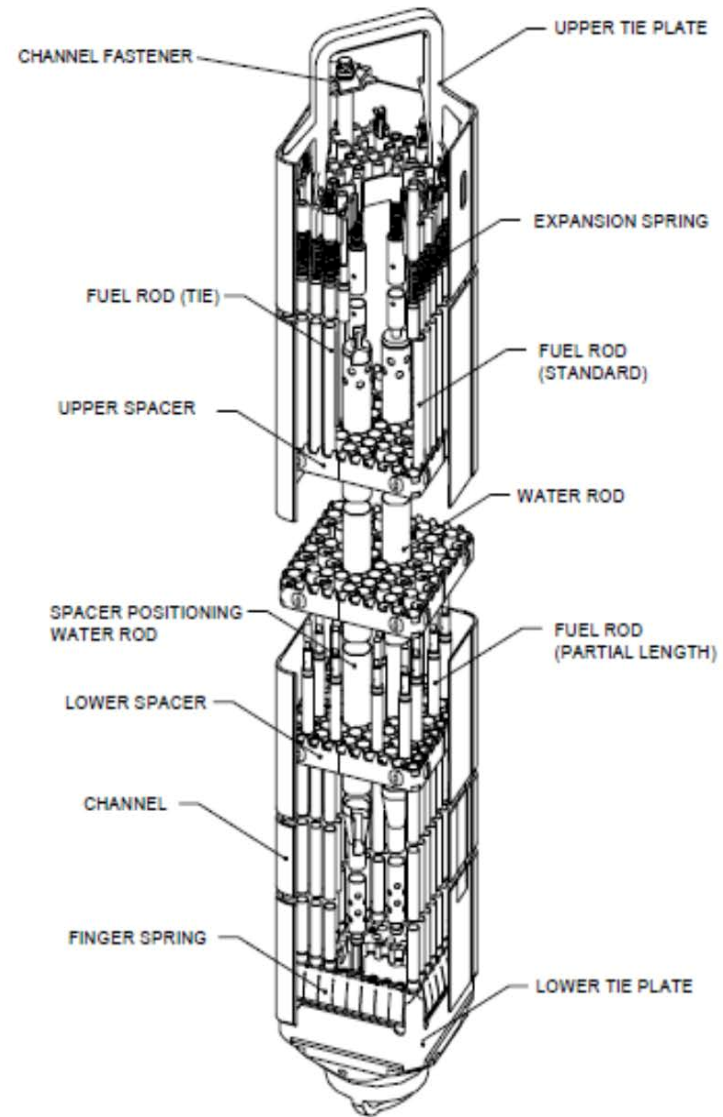
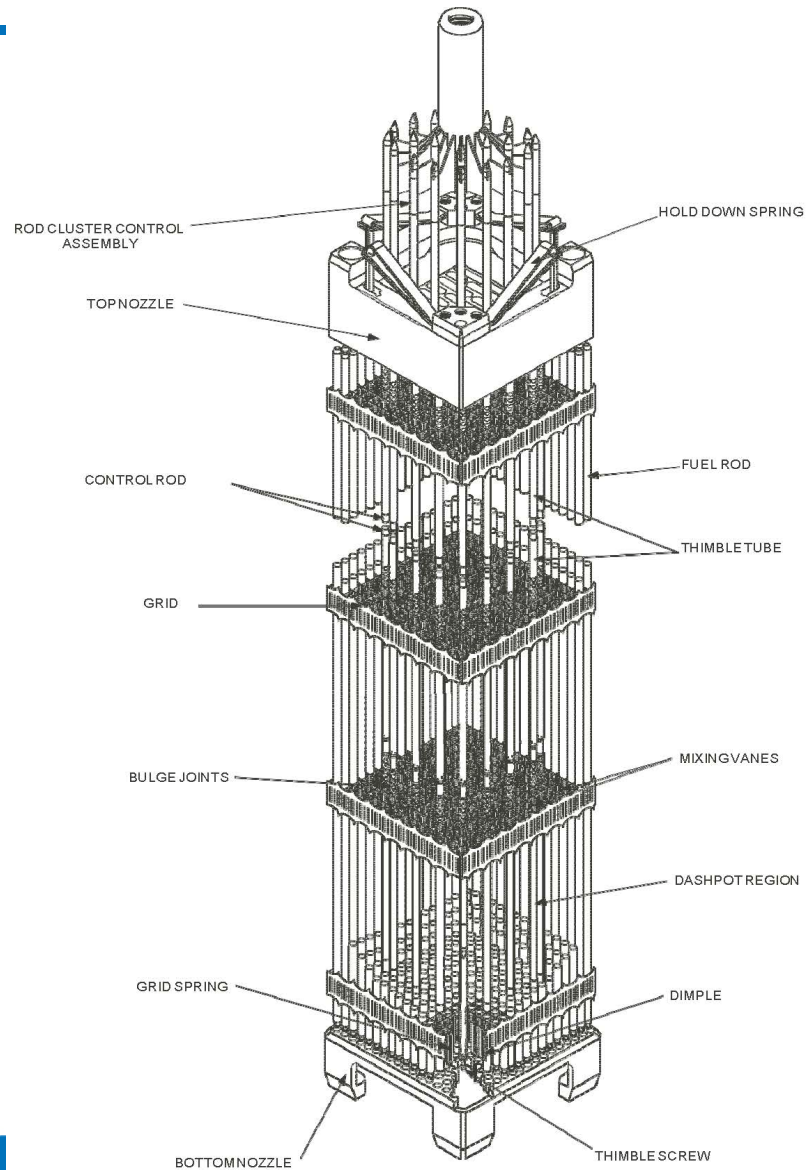
ADAMS Accession Nos.:  
ML12320A697  
ML11097A028



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 <sub>2</sub>	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



# Spent Fuel Assemblies

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

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

# Example DSS Review

**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

# Aging Management Programs



- 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

- 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

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		

# Casks, Canisters and Internals

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

# Casks, Canisters and Internals

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

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

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

# Spent Fuel Assemblies

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

# Acronyms

- 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, “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.