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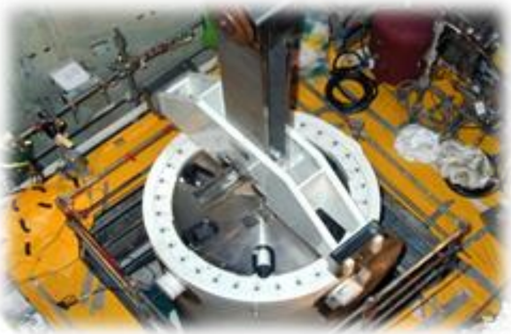
Spent Fuel Dry Storage: Challenges and Lessons Learned From Recent Project Experience at Shutdown Nuclear Plants in the U.S.



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Outline

1. Decommissioning status and trends
2. Decommissioning dry storage status & drivers
3. Decommissioning dry storage challenges
4. Recent decommissioning dry storage projects
5. Summary and Conclusion

U.S Decommissioning Market Status

- Current nuclear plant status
  - 99 Commercial reactors in operation (Compared to 104 in 2014)
  - 5 Commercial reactors under construction (Vogtle [2 units], VC Summer [2 units], Watts Bar Unit 2)
- Recent Shutdown Reactor Status:

Plant	Rating	Shutdown Date	Owner	Reason
Crystal River	860 MWe	February 2013	Duke	Economics/Repairs
Kewaunee	566 MWe	May 2013	Dominion	Economics/Market
San Onofre 2&3	2,160 MWe	June 2013	SCE	Economics/Repairs
Vermont Yankee	635 MWe	December 2014	Entergy	Economics

- All five recently shutdown reactors plan to proceed with prompt defueling into dry storage followed by a period of safe preservation prior to dismantlement and decontamination (D&D).

U.S. Decommissioning Alternatives

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- SAFSTOR (deferred dismantlement) – Facility is placed and maintained in a condition that allows the facility to be safely stored until subsequent decontamination and dismantling (up to 60 years)
- DECON – Facility is considered undergoing decontaminating and dismantling to levels that permit release for unrestricted use
- ENTOMB - Radioactive structures are encased onsite with grout or concrete (provides structural protection and shielding). The facility is then maintained and monitored until the radioactivity decays to a level permitting restricted release of the property.

FACT: Of the 20 shutdown reactors with fuel onsite in the U.S., 9 are in SAFSTOR, 4 are in DECON, and 7 have completed DECON

U.S Decommissioning Dry Storage Status

Reactor Name	Type	MWth	State	License Issued	Shutdown Date	Status
Big Rock Point	BWR	240	MI	5/1/1964	8/29/1997	DECON completed ISFSI on site
Fort St. Vrain	HTG	842	CO	12/21/1973	8/18/1989	
Haddam Neck	PWR	1,825	CT	12/27/1974	12/5/1996	
Maine Yankee	PWR	2,700	ME	6/29/1973	12/6/1996	
Trojan	PWR	3,411	OR	11/21/1975	11/9/1992	
Rancho Seco	PWR	2,772	CA	8/16/1974	6/7/1989	
Yankee Rowe	PWR	600	MA	12/24/1963	10/1/1991	
Humboldt Bay 3	BWR	200	CA	8/28/1962	7/2/1976	DECON in progress ISFSI on site
San Onofre 1[(a)]	PWR	1,347	CA	3/27/1967	11/30/1992	
Zion 1	PWR	3,250	IL	10/19/1973	2/21/1997	
Zion 2	PWR	3,250	IL	11/14/1973	9/19/1996	
LaCrosse	BWR	165	WI	7/3/1967	4/30/1987	SAFSTOR with ISFSI on site
Crystal River 3	PWR	2,609	FL	12/3/1976	2/20/2013	SAFSTOR - ISFSI pending
Kewaunee	PWR	1,772	WI	12/21/1973	5/7/2013	
San Onofre 2	PWR	3,438	CA	2/16/1982	6/7/2013	
San Onofre 3	PWR	3,438	CA	11/15/1982	6/7/2013	
Vermont Yankee	BWR	1,912	VT	3/21/1972	12/29/2014	
Dresden 1	BWR	700	IL	9/28/1959	10/31/1978	SAFSTOR (other operating reactors)
Indian Point 1	PWR	615	NY	3/26/1962	10/31/1974	
Millstone 1	BWR	2,011	CT	10/31/1986	7/21/1998	

U.S Decommissioning Dry Storage Status

There are fourteen (14) shutdown sites (sites with no other operating reactors)

- Ten (10) sites have relocated all spent fuel into dry storage
  - Seven (7) completed DECON
  - Two (2) with DECON in process
  - One (1) in SAFSTOR
- Four (4) sites (recent shutdowns) planning to defuel within 5 years.

Note: Five (5) out of the ten (10) shutdown sites that have relocated all spent fuel into dry storage systems use NAC cask technology

U.S. Decommissioning Recent Trends

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- SAFSTOR with prompt transfer of SF into dry storage
  - Safety and robustness of dry storage (National Academy of Science study)
  - Heightened stakeholder interest in getting pool out of shutdown pools post 9/11 and post-Fukushima
  - Strong economic driver for removing fuel from pool
  - $10M-$30M annually in reduced operations and security staff

FACT: SAFSTOR with dry storage is viewed as having safety, security and economical advantages over SAFSTOR with wet storage

U.S. Decommissioning Recent Trends

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- Dismantle & decommission when safe and economically viable
  - Adequate decommissioning funds for project, including risks
  - Decommissioning fund growth (time value of money vs. cost)
  - Adequate time for decay of radioactivity for worker safety and lower decommissioning costs
- Some communities/stakeholders pushing for prompt decommissioning
- Most stakeholders agree on accelerated movement of the fuel to dry storage regardless of the decommissioning approach.

U.S Decommissioning Dry Storage Drivers

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- Safety – regulatory certification is a prerequisite
- Security (physical) – including some assurance of capability beyond design basis
- Schedule - prompt loading and completion of ALL fuel loading – even damaged fuel, reconstituted assemblies, lead test assemblies, high burnup fuel, “underburned” fuel, etc.
- Reasonable assurance of transportability
- Low financial risk (for plant owner)

Decommissioning Dry Storage: Zion Achievements/Lessons Learned

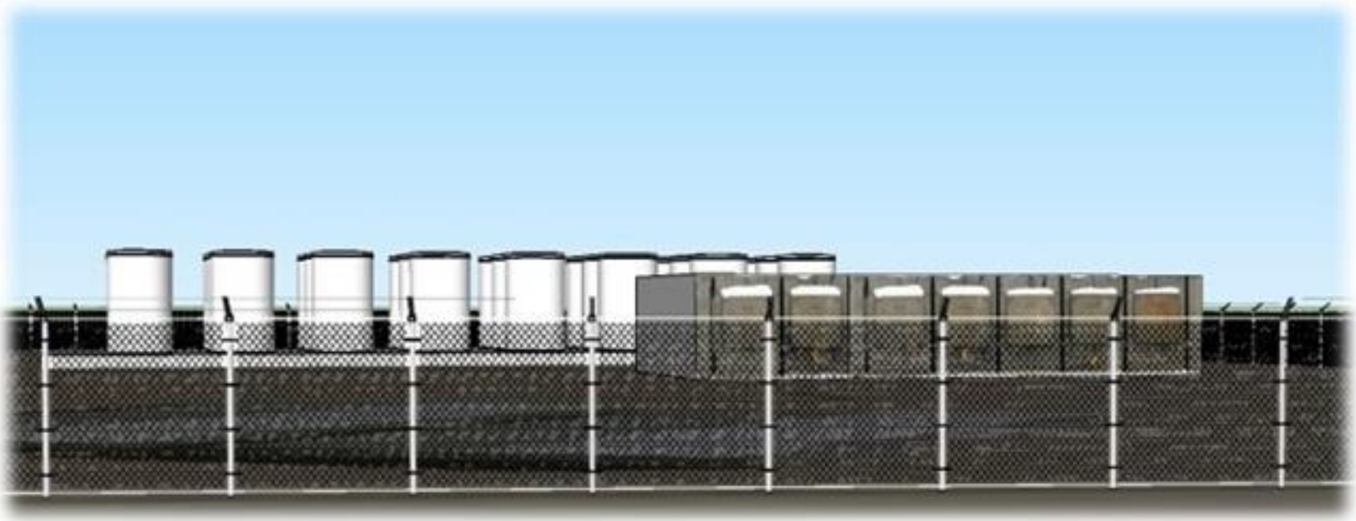
- Designed and licensed revisions to address site specific contents and operational requirements
  - Damaged fuel was canned
  - HBU fuel was canned (transport licensing expediency in consideration of specific contract requirements)
  - Underburned (1 cycle) fuel reactivity mitigated by loading with full length Rod Control Cluster Assemblies
  - Optimized loading plan for adhering to offsite boundary dose rate limits with new tighter site boundary (550 ft from ISFSI)
- Used three different fabricators (Hitachi Zosen, GEH, Peterson) to managed risk of delivery
- Largest U.S. single dry storage campaign of 61 spent fuel casks in less than 55 weeks

Kewaunee Dry Storage Project: Site Specific Requirements and Achievements

- Development of a 4-Zone cask loading pattern that permits the MAGNASTOR system to accept Kewaunee assemblies up to 1.8 kW from the last cycle (3- year cool time) with colder fuel (up to 0.8 kW) on the periphery to limit radiological dose
- Design and deployment of and integrated yoke/chain hoist system to address seismic requirements and optimize canister transfer operations
- Design and construction of an ISFSI facility that will accommodate MAGNASTOR casks to co-exist with horizontal systems already onsite
- Develop a cask loading sequences that address site boundary dose rate requirements upon complete defueling of the Kewaunee spent fuel pool

Dominion Kewaunee Power Station Project Status

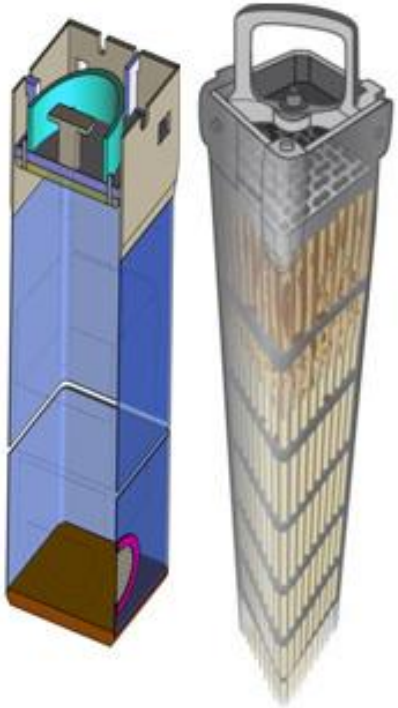
- MAGNASTOR CoC Amendment 5 published in the U.S. Federal Register
- TSCs and VCC liners in fabrication; progress on track
- ISFSI expansion design and site A/E essentially complete
- Kewaunee county permits approved
- VCC construction campaign started in May
- Operating procedures under development



Summary and Conclusion

- U.S. Decommissioning Trend on the Rise – 5 reactors shutdown since 2013
  - A few other reactors are at risk of shutdown due to economic reasons (low power costs in deregulated markets)
- Safety, Security and Economics drive a sound decommissioning strategy
- In fact, all of the shut down sites (those with no operating reactors) have implemented or are planning to promptly implement dry storage
  - The inherent safety of dry cask storage and the potential for a smaller plant security footprint and associated benefits is a key driver for prompt defueling of shutdown reactors.
- Two recent NAC projects demonstrate that dry storage technology selection plays a key role in the safety and economics of a decommissioning defueling operation.
  - The Zion spent fuel transfer was the largest dry storage campaign ever implemented in the U.S. and it was completed in about a year.
  - Lessons learned and further innovations are being leveraged at the Kewaunee project to achieve plant defueling a just 3.5 years after plant shutdown. This is about two years earlier than originally planned

Decommissioning Dry Cask Storage: Addressing Damaged Spent Fuel Contents



To meet U.S. regulations, a Damage Fuel Can (DFC) must confine gross fuel particles, debris, or damaged assemblies to a known volume within the cask, demonstrate that compliance with the criticality, shielding, thermal, and structural requirements are met; and permit normal handling and retrieval from the cask.