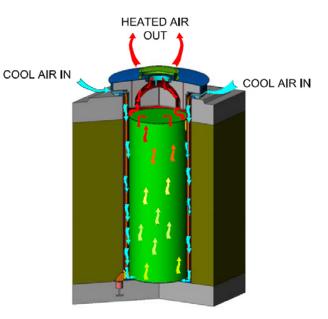


Game changer Indefinite on-site storage

- August 26, 2014 NRC approved
 - 60 years (short term) on-site storage
 - 160 years (long term) on-site storage
 - Indefinite on-site storage
- No other storage sites on horizon
- U.S. thin steel canisters may start failing within 30 years
 - Some may already have stress corrosion cracks
 - Cannot inspect for corrosion or cracks
 - Cannot repair
 - No early warning monitoring
- Diablo Canyon Holtec thin canister has conditions for cracking after only two years!
- Edison plans to spend about \$1.3 billion for another thin canister system for San Onofre spent fuel



Two-year old Diablo Canyon Holtec canister has conditions for cracking

- Temperature low enough to initiate cracks in only 2 years: 85°C (185°F)
 - NRC assumed it would take over 30 years before temperature was low enough NRC proven wrong
 - Temperatures under 85°C allows moist air to dissolve salt on canister
- Highly corrosive MgCl salts on Diablo canister can trigger corrosion and cracks
- No technology to inspect for cracks or corrosion
 - We don't know if canisters are cracking or how deep the cracks are
 - We won't know until they crack through the canister wall and release radiation
 - Only small surface areas of 2 canisters were sampled (January 2014) for temperature, salts, and other surface contaminants, due to limited access via concrete overpack air vents
- No plan in place to replace cracked canisters
- Canisters not repairable and millions of curies of radiation would be released from even a microscopic crack (Holtec President, Dr. Singh, CEP meeting October 14, 2014)





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Thin canisters not what they're cracked up to be

- Condition of all existing canisters unknown
 - No technology exists to inspect these canisters
 - Canisters in use less than 30 years (1986)
 - Won't know until AFTER leaks radiation
- Other welded stainless steel items at nuclear plants failed in 11 to 33 years at ambient temperatures ~20°C (68°F)
- Crack growth about four times faster at 80°C (176°F) in "wicking" tests compared with 50°C (122°F)
- Crack initiation unpredictable
 - Cracks more likely to occur at higher end of temperature range up to 80°C (176°F) instead of ambient temperatures
 - Canister temperatures above 85°C will not crack from marine air chloride salts won't stay and dissolve on canister
- Many corrosion factors not addressed. NRC focus is chloride-induced stress corrosion cracking (CISCC).



Can't repair thin canisters

- No current technology to repair canisters filled with spent nuclear fuel
 - Holtec Dr. Singh: should not attempt repair
 - Creates rough surface which becomes a new creation site for corrosion down the road
 - Microscopic cracks can release millions of curies of radiation
- No plan for replacing cracked canisters or casks
 - Funds not budgeted
 - NRC allows pools to be destroyed, removing only method for replacing canisters and casks
 - Vendor proposal to transport cracked canister in transport cask is unsafe and not NRC approved

No warning before radiation leaks from thin canisters

No early warning monitoring

- Remote temperature monitoring not early warning
- No pressure or helium monitoring
- Thick casks have continuous remote pressure monitoring alerts to early helium leak

No remote or continuous canister radiation monitoring

- Workers walk around canisters with a "radiation monitor on a stick" once every 3 months
- Thick casks have continuous remote radiation monitoring

After pools emptied, NRC allows

- Removal of all radiation monitors
- Elimination of emergency planning to communities no radiation alerts
- Removal of fuel pools (assumes nothing will go wrong with canisters)
 - Humboldt Bay & Rancho Seco pools destroyed
- Saves utilities millions of dollars
 - Eliminates millions in state and local annual emergency planning funds
 - Eliminates millions for funding of positions and related costs

Thin canisters not designed to be replaced

- Welded lid not designed to be removed
- Lid must be unwelded under water
- Fuel transfer from damaged canister to new canister must be done under water
- No spent fuel has ever been reloaded into another thin canister
- Thick casks are designed to remove and reload fuel
- Potential problem unloading fuel from a dry storage canister or cask into a pool with existing fuel

No defense in depth in thin canisters

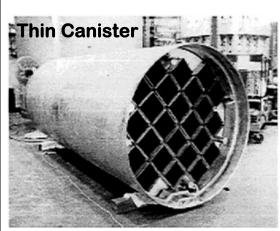
- No protection from gamma or neutron radiation in thin canister
 - Unsealed concrete overpack/cask required for gamma & Neutrons
 - No other type of radiation protection if thin canister leaks
 - Thick steel overpack transfer cask required to transfer from pool
 - Thick steel overpack transport cask required for transport
- High burnup fuel (HBF) (>45 GWd/MTU)
 - Burns longer in the reactor, making utilities more money
 - Over twice as radioactive and over twice as hot
 - Damages protective Zirconium fuel cladding even after dry storage
 - Unstable and unpredictable in storage and transport
- Limited technology to examine fuel assemblies for damage
- Damaged fuel cans vented so no radiation protection
 - Allows retrievability of fuel assembly into another container
- We are only 1/2" to 5/8" away from a radiation disaster

Thin canisters not ASME certified

- Canisters do not have independent quality certification from American Society of Mechanical Engineers (ASME)
- NRC allows exemptions to some ASME standards
- No independent quality inspections
- ASME has not developed standards for spent fuel stainless steel canisters

Thin Canisters vs. Thick Casks

Safety Features	Thin canisters	Thick casks
Thick walls	1/2" to 5/8"	Up to 20"
Won't crack		√
Ability to repair		✓
Ability to inspect		√
Early warning monitor		√
ASME container certification		√
Defense in depth (redundancy)		\checkmark
Stored in concrete building		√
Gamma & neutron protection	With concrete overpack	✓
Transportable w/o add'l cask		√
Market leader	U.S.	World





Thick casks designed for longer storage

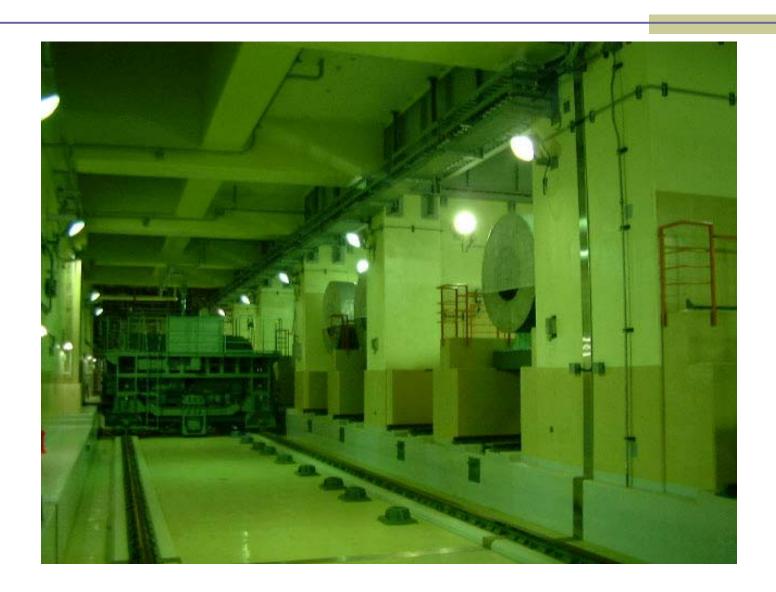
- Market leader internationally
- No stress corrosion cracking
- Maintainable
 - Can inspect
 - Replaceable parts (metal seals, lids, bolts)
 - Double bolted thick steel lids allow reloading without destroying cask
 - 40 years in service with insignificant material aging
- Thick cask body forged steel or thicker ductile cast iron up to 20"
- **Early warning before radiation leak** (remote lid pressure monitoring)
- Cask protects from all radiation, unlike thin steel canisters.
 - No concrete overpack required.
 - No transfer or transport overpack required
 - Stored in concrete building for additional protection
 - Used as both storage and transport cask
- ASME & international cask certifications for storage and transport
- Damage fuel sealed (in ductile cast iron casks)
- Not currently licensed in U.S. (18 to 30 month process)
- Vendors won't request NRC license unless they have customer



Germany interim storage



Fukushima thick casks in building



Fukushima thick casks

Specification of Dry Casks

	Large type	Medium type	
Weight (t)	115	96	
Length (m)	5.6	5.6	
Diameter (m)	2.4	2.2	
Assemblies in a cask	52	37	
Number of casks	5	2	2
Fuel type	8 x 8	8 x 8	New 8 x 8
Cooling-off period (years)	> 7	> 7	> 5
Average burn-up (MWD/T)	<24,000	<24,000	<29,000

Additional 11casks are being prepared for installation.

Sandia Labs: Ductile cast iron performs in an exemplary manner

Safe from brittle fracture in transport

 ...studies cited show DI [ductile iron] has sufficient fracture toughness to produce a containment boundary for radioactive material transport packagings that will be safe from brittle fracture.

Exceeds drop test standards

 ...studies indicate that even with drop tests exceeding the severity of those specified in 1 OCFR7 1 the DI packagings perform in an exemplary manner.

Exceeds low temperature requirements

Low temperature brittle fracture not an issue. The DCI casks were tested at -29°C and -49°C exceeding NRC requirements.

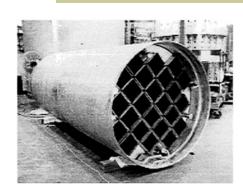
Conclusions shared by ASTM, ASME, and IAEA

Fracture Mechanics Based Design for Radioactive Material Transport Packagings Historical Review, Sandia Labs, SAND98-0764 UC-804, April 1998 http://www.osti.gov/scitech/servlets/purl/654001

Problems with thin stainless steel canisters

Not maintainable

- Cannot inspect exterior or interior for cracks
- Cannot repair cracks
- Not reusable (welded lid)
- No warning BEFORE radiation leaks
- Canisters not ASME certified
 - NRC even allows exemptions from ASME standards
- No defense in depth
 - Concrete overpack vented
 - Unsealed damaged fuel cans
 - No adequate plan for failed canisters
- Early stress corrosion cracking risk
- Inadequate aging management plan



NRC solution Lower aging management standards

- NRC refuses to evaluate thick casks even though thin canister issues would be resolved
 - Mark Lombard, Director of Spent Fuel Management Division
- NRC requires first inspection after 25 years
 - Allows 5 years to develop inspection technology
 - Requires inspection of only one canister per plant
 - That same canister to be inspected once every 5 years
- Allows up to a 75% through-wall crack
 - No seismic rating for cracked canisters
- No replacement plan for cracked canisters
 - Approves destroying fuel pools after emptied
 - No fuel pools at Humboldt Bay and Rancho Seco
 - No money allocated for replacement canisters
- NRC standards revision (NUREG-1927) scheduled for sometime in 2015 to address canister aging issues

Recommendations

- We cannot kick this can down the road
- **Stop procurement of thin canisters**
- Raise U.S. dry storage standards
 - Require best thick cask technology used internationally
 - Base standards on longer term storage needs
 - Not on limitations of thin canister technology
 - Not on vendor promises of future solutions
- Require bids from thick cask vendors
- Replace existing thin canisters with thick casks
- Store in hardened concrete buildings
- Don't destroy defueled pools until waste stored off-site
- Install continuous radiation monitors with on-line public access
- Continue emergency plans until waste is off-site





Additional Slides

References

 Diablo Canyon: conditions for stress corrosion cracking in two years, D. Gilmore, October 23, 2014

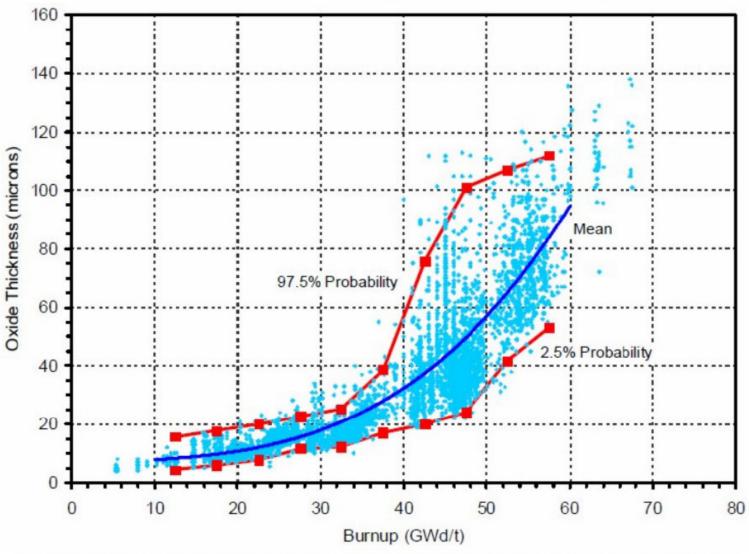
https://sanonofresafety.files.wordpress.com/2011/11/diablocanyonscc-2014-10-23.pdf

Top Ten Reasons to Buy Thick Casks, D. Gilmore, October 14, 2014

https://sanonofresafety.files.wordpress.com/2014/10/thincanistersvsthickcasks2014-10-14.pdf

- Dry Cask Storage Issues, D. Gilmore, September 23, 2014
 https://sanonofresafety.files.wordpress.com/2011/11/drycaskstorageissues2014-09-23.pdf
- Additional references: <u>SanOnofreSafety.org</u>

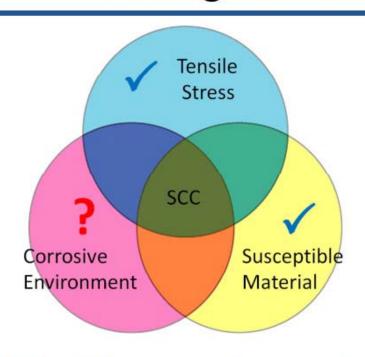
Higher Burnup = Higher Cladding Failure



Higher oxide thickness results in higher cladding failure. Argonne scientists reported high burn-up fuels may result in fuel rods becoming more brittle over time. "... insufficient information is available on high burnup fuels to allow reliable predictions of degradation processes during extended dry storage." U.S. Nuclear Waste Technical Review Board Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel, December 2010, Burnup Chart Page 56

Stress Corrosion Cracking Background Information





2/3 of the requirements for SCC are present in welded stainless steel canisters

- 304 and 316 Stainless steels are susceptible to chloride stress corrosion cracking (SCC)
 - Sensitization from welding increases susceptibility
 - Crevice and pitting corrosion can be precursors to SCC
 - SCC possible with low surface chloride concentrations
- Welded stainless steel canisters have sufficient through wall tensile residual stresses for SCC
- Atmospheric SCC of welded stainless steels has been observed
 - Component failures in 11-33 years
 - Estimated crack growth rates of 0.11 to 0.91 mm/yr

Power Plant Operating Experience with SCC of Stainless Steels



Plant	Distance to water, m	Body of water	Material/ Component	Thickness, or crack depth, mm	Time in Service, years	Est. Crack growth rate, m/s	Est. Crack growth rate, mm/yr
Koeberg	100	South Atlantic	304L/RWST	5.0 to 15.5	17	9.3 × 10 ⁻¹² to 2.9 × 10 ⁻¹¹	0.29 to 0.91
Ohi	200	Wakasa Bay, Sea of Japan	304L/RWST	1.5 to 7.5	30	5.5 × 10 ⁻¹² to 7.9 × 10 ⁻¹²	0.17 to 0.25
St Lucie	800	Atlantic	304/RWST pipe	6.2	16	1.2 × 10 ⁻¹¹	0.39
Turkey Point	400	Biscayne Bay, Atlantic	304/pipe	3.7	33	3.6 × 10 ⁻¹²	0.11
San Onofre	150	Pacific Ocean	304/pipe	3.4 to 6.2	25	4.3 × 10 ⁻¹² to 7.8 × 10 ⁻¹²	0.14 to 0.25

- CISCC growth rates of 0.11 to 0.91 mm/yr for components in service
 - Median rate of 9.6 x 10⁻¹² m/s (0.30 mm/yr) reported by Kosaki (2008)
- Activation energy for CISCC propagation needs to be considered
 - -5.6 to 9.4 kcal/mol (23 to 39 kJ/mol) reported by Hayashibara et al. (2008)

Used Fuel Disposition

Data Gap Summarization

Gap	Priority	Gap	Priority
Thermal Profiles	1	Neutron poisons – Thermal aging	7
Stress Profiles	1	Moderator Exclusion	8
Monitoring – External	2	Cladding – Delayed Hydride Cracking	9
Welded canister – Atmospheric corrosion	2	Examination of the fuel at the INL	10
Fuel Transfer Options	3	Cladding - Creep	11
Monitoring – Internal	4	Fuel Assembly Hardware – SCC	11
Welded canister – Aqueous corrosion	5	Neutron poisons – Embrittlement	11
Bolted casks – Fatigue of seals & bolts	5	Cladding – Annealing of radiation damage	12
Bolted casks – Atmospheric corrosion	5	Cladding – Oxidation	13
Bolted casks – Aqueous corrosion	5	Neutron poisons – Creep	13
Drying Issues	6	Neutron poisons - Corrosion	13
Burnup Credit	7	Overpack – Freeze-thaw	14
Cladding – Hydride reorientation	7	Overpack – Corrosion of embedded steel	14

Imminent need

Immediate to facilitate demonstration early start

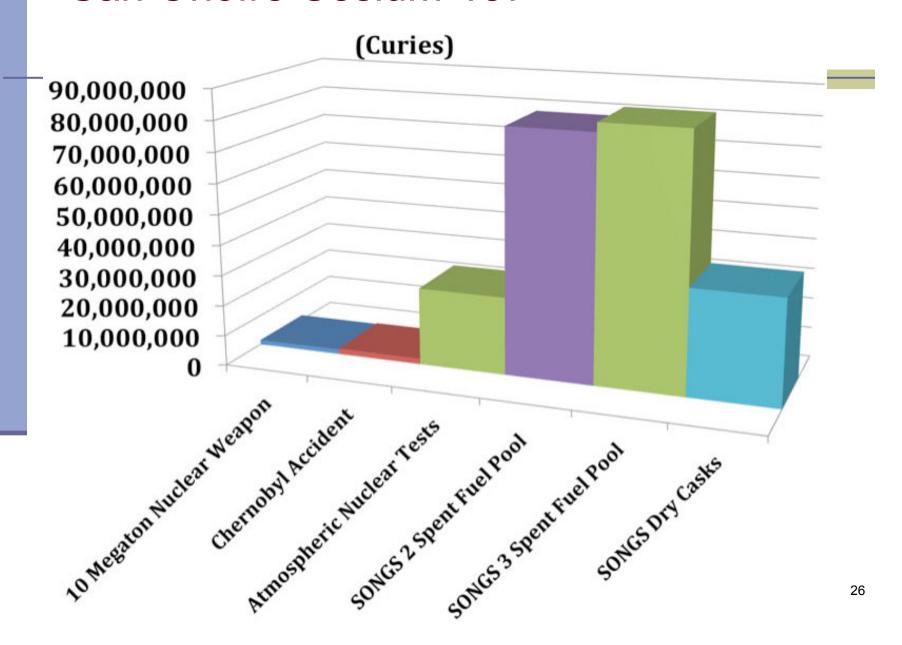
Near-term High or Very High

Long-term High

Near-term Medium or Medium High

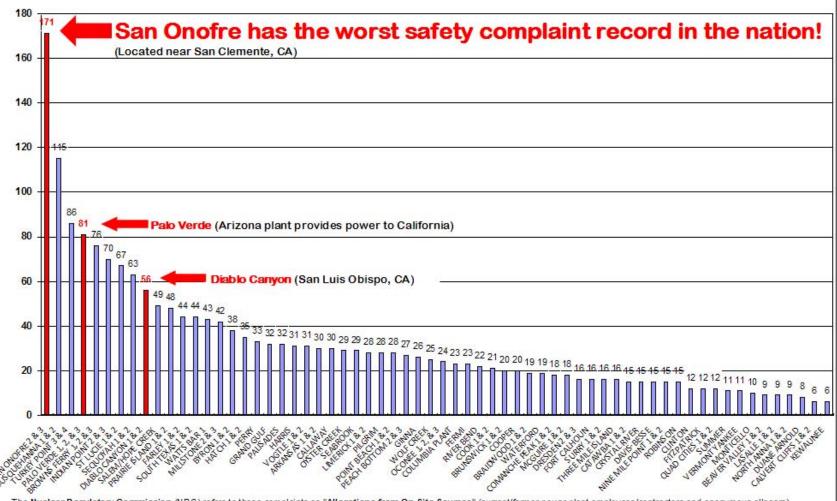
Long-term Medium

San Onofre Cesium-137



Safety Complaints from On-Site Employees & Contractors

U.S. Nuclear Power Plants 2007 to 2012 (6 years)

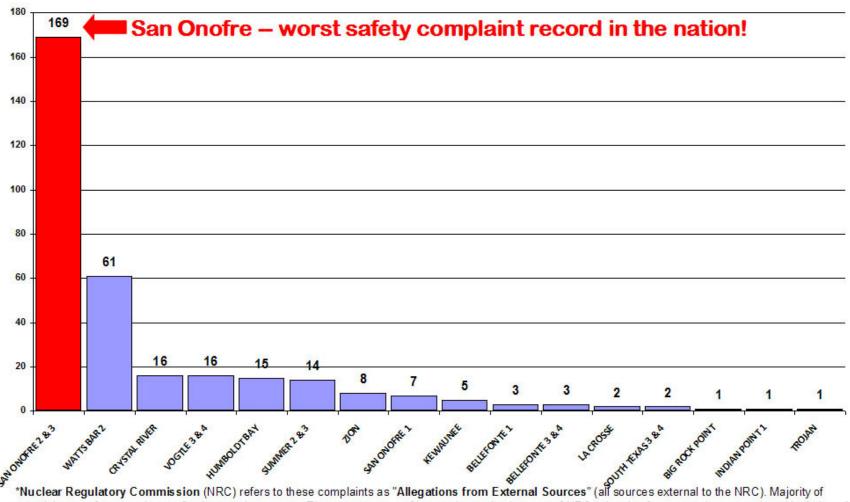


The Nuclear Regulatory Commission (NRC) refers to these complaints as "Allegations from On-Site Sources" (current/former power plant employees/contractors and anonymous allegars). These are reports of impropriety or inadequacy of NRC-related safety or regulatory concerns. One allegation report may contain multiple allegations; however, the NRC counts it as one allegation in these statistics (Note: A concern about a safety-conscious work environment (SCWE) problem at a facility is an important allegation. However, a Notice of Violation cannot be issued, because there is no applicable NRC regulation.) There are 64 U.S. nuclear power plants & 104 reactors. Plants with multiple reactors are noted.

Source: www.nrc.gov/about-nrc/regulatory/all egations/statistics.htm

Safety Complaints to NRC from all External Sources*

Non-Operating U.S. Nuclear Power Reactors January 2009 to August 2013



*Nuclear Regulatory Commission (NRC) refers to these complaints as "Allegations from External Sources" (all sources external to the NRC). Majority of complaints are from employees & other on-site sources. These are reports of impropriety or inadequacy of NRC-related safety or regulatory concerns. Includes all non-operating U.S. operating nuclear power plants & reactors. One allegation report may contain multiple allegations. However, the NRC counts it as one allegation in these statistics. A complaint about a safety-conscious work environment (SCWE) problem is important. However, a Notice of Violation cannot be issued, because there is no applicable NRC regulation. Source: www.nrc.gov/about-nrc/regulatory/allegations/statistics.html

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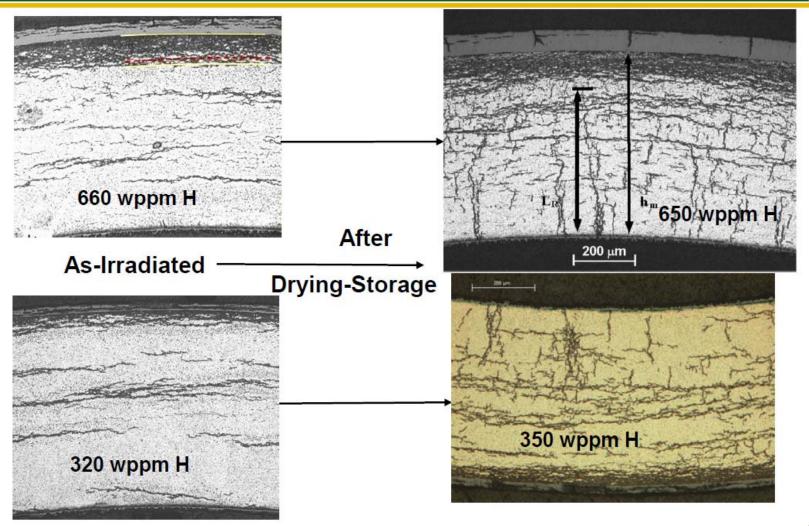
Waste is not going anywhere

- Yucca Mountain geological repository issues unresolved
 - DOE plan: Solve water intrusion issue 100 years AFTER loading nuclear waste
 - Inadequate capacity for all waste
 - Not designed for high burnup fuel
- Congress limited DOE to consider only Yucca Mountain
 - Funding of storage sites unresolved
 - Communities do not want the waste
- Poor track record for finding safe waste solutions
 - New Mexico WIPP repository leaked within 15 years
 - Washington Hanford repository leaking containers
 - Other storage sites leaked
- Inadequate transport infrastructure & potential for accidents
- High burnup fuel over twice as radioactive, hotter, and unstable
 - Zirconium cladding more likely to become brittle and crack -- eliminates key defense in depth. Radiation protection limited to the thin stainless steel canister. Concrete overpack/cask only protects from gamma and neutrons.
- Fuel assemblies damaged after storage may not be retrievable
- Inspection of damaged fuel assemblies is imperfect



Introduction: Circumferential and Radial Hydrides in HBU Cladding

Nuclear Energy





Summary of Results

Nuclear Energy

Susceptibility to Radial-Hydride Precipitation

- Low for HBU Zry-4 cladding
- Moderate for HBU ZIRLO™
- High for HBU M5®

Susceptibility to Radial-Hydride-Induced Embrittlement

- Low for HBU Zry-4
- Moderate for HBU M5®
- High for HBU ZIRLO™

■ DBTT Values for HBU Cladding Alloys

- Peak drying-storage hoop stress at 400°C: 140 MPa→110 MPa→90 MPa→0 MPa
- DBTT for HBU M5[®] after slow cooling:
 80°C → 70°C → <20°C → <20°C
- DBTT for HBU ZIRLO™ after slow cooling: 185°C → 125°C → 20°C → <20°C
- DBTT for HBU Zry-4 after slow cooling:
 55°C → <20°C → → >90°C
 - Embrittled by circumferential hydrides: 615±82 wppm 520±90 wppm 640±140 wppm
 - HBU Zry-4 with 300±15 wppm was highly ductile at 20°C

Container Degradation Mechanisms Base Metal, Welds, Bolts, and Seals

Stressor	Degradation Mechanism	Influenced by VLTS or Higher Burnup	Additional Data Needed	Priority of R&D
Thormal and	Embrittlement of elastomer seals	Yes	Yes	Low
Thermal and Mechanical	Thermomechanical fatigue of seals and bolts	Yes	Yes	Medium
Radiation	Embrittlement of elastomer seals	Yes	Yes	Low
	Atmospheric Corrosion (Including Marine Environment)	Yes	Yes	High
Chemical	Aqueous Corrosion: general, localized (pitting, crevice), SCC, galvanic	Yes	Yes	High







Background information

- CoCs/licenses for high burn-up fuel storage to be renewed over next few years
 - 2012 Prairie Island-TN-40HT, Calvert Cliffs-NUHOMS¹
 - 2015 Transnuclear-NUHOMS 1004
 - 2020 NAC-UMS; Holtec-Hi-STORM
- Storage of high burn-up fuel is relatively recent
 - 9 years Maine Yankee² (since 2003) up to 49.5 GWd/MTU
 - 7 years Robinson (since 2005) up to 56.9 GWd/MTU
 - 6 years Oconee (since 2006) up to 55 GWd/MTU
 - <4 years for most up to 53.8 GWd/MTU</p>
- ~ 200 loaded-casks contain high burn-up fuel
- Most fuel in pools for future loading is high burn-up



High Burnup Fuel Approval

June 1992 Up to 60 GWd/MTU (60 MWD/kg)



UNITED STATES NUCLEAR REGULATORY COMMISSION WASHINGTON, D.C. 20555

June 22, 1992

Mr. A. E. Scherer, Director Nuclear Licensing Combustion Engineering, Inc. P. O. Box 500 Windsor, Connecticut 06095

Dear Mr. Scherer:

SUBJECT: GENERIC APPROVAL OF C-E TOPICAL REPORT CEN-386-P, "VERIFICATION OF THE ACCEPTABILITY OF A 1-PIN BURNUP LIMIT OF 60 MWD/kg FOR COMBUSTION ENGINEERING 16X16 PWR FUEL (TAC NO. M82192)

On November 14, 1991, you requested NRC review and generic approval of the C-E topical report CEN-386-P, entitled "Verification of The Acceptability of A 1-Pin Burnup Limit of 60 MWD/kg for Combustion Engineering 16X16 PWR Fuel." The methodology described in the topical report CEN-386-P was approved for licensing applications for ANO-2 and St. Lucie 2 in NRC safety evaluations dated November 27, 1990, and October 18, 1991, respectively. Based on your submittal and review of the previously approved SERs, we conclude that CEN-386-P is not necessarily plant-specific for ANO-2 or St. Lucie 2, and therefore CEN-386-P can be applied generically to other C-E 16X16 plants. The NRC staff was supported in this review by our consultant, the Pacific Northwest Laboratory, who previously provided input to the approval for applications to ANO-2 and St. Lucie 2. In summary, the NRC staff approves the generic applicability of CEN-386-P for licensing applications. Our evaluation applies only to matters described in the topical report.

In accordance with procedures established in NUREG-0390, "Topical Report Review Status," we request that C-E publish accepted versions of this topical report, proprietary and non-proprietary, within 3 months of receiving this letter. The accepted versions shall include an "A" (designating accepted) following the report identification symbol, and shall include this letter and the ANO-2 SER dated November 27, 1990.

If our criteria or regulations change such that we can no longer accept this report, applicants referencing this topical report will be expected to revise and resubmit their respective documentation, or submit justification that the topical report continues to apply without revision of their respective documentation.

SinceHely

Ashqk C. Thadani, Director Division of Systems Technology Office of Nuclear Reactor Regulation

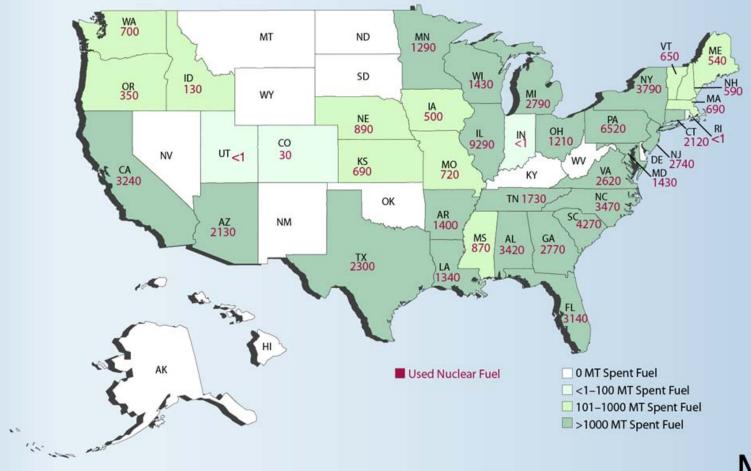
Enclosure: ANO-2 Safety Evaluation

Thin canisters cannot be inspected

- No technology to detect surface cracks, crevice and pitting corrosion in thin canisters filled with nuclear waste
 - Canister must stay inside concrete overpack/cask due to radiation risk, so future inspection technology may be limited
 - Thin canisters do not protect from gamma and neutrons
 - Microscopic crevices can result in cracks
- Thick casks can be inspected
 - Provide full radiation barrier without concrete
 - Surfaces can be inspected
 - Not subject to stress corrosion cracking



Used Nuclear Fuel in Storage (Metric Tons, End of 2013)





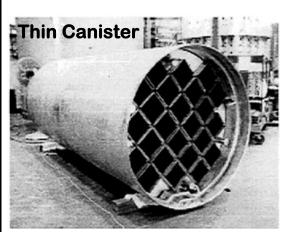
Recommendations

- We cannot kick this can down the road
- **Stop procurement of thin canisters**
- Raise U.S. dry storage standards
 - Require best thick cask technology used internationally
 - Base standards on longer term storage needs
 - Not on limitations of thin canister technology
 - Not on vendor promises of future solutions
- Require bids from thick cask vendors
- Replace existing thin canisters with thick casks
- Store in hardened concrete buildings
- Don't destroy defueled pools until waste stored off-site
- Install continuous radiation monitors with on-line public access
- Continue emergency plans until waste is off-site



Thin Canisters vs. Thick Casks

Safety Features	Thin canisters	Thick casks
Thick walls	1/2" to 5/8"	Up to 20"
Won't crack		✓
Ability to repair		✓
Ability to inspect		✓
Early warning monitor		✓
ASME container certification		✓
Defense in depth (redundancy)		√
Stored in concrete building		√
Gamma & neutron protection	With concrete overpack	✓
Transportable w/o add'l cask		√
Market leader	U.S.	World





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