Dry Storage of Spent Nuclear Fuel Problems and Solutions

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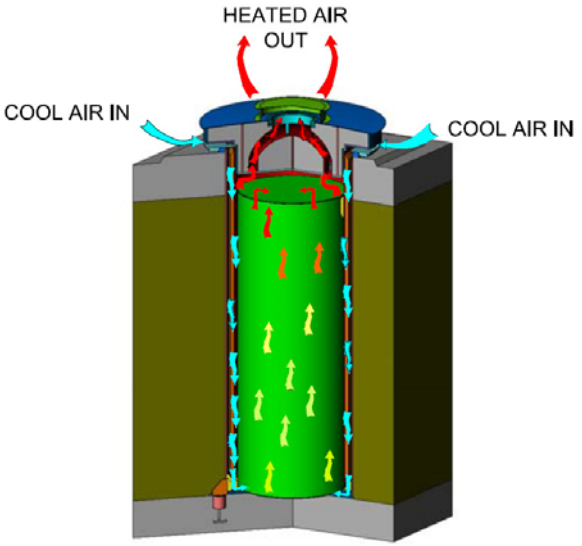
Game Changer: Indefinite on-site storage



- NRC 2014 decision: 100+ years on-site
  - No other sites on horizon
- Canisters may fail after 20-30 yrs storage
  - Some may already have cracks
  - Cannot be inspected or repaired
- No solution in place for cracked canisters
- No warning until AFTER radiation leaks
- Impact
  - One canister contains more radiation than released by Chernobyl
  - Could destabilize state, national and international economy
  - One canister can release millions of curies of radiation from a microscopic through-wall crack
    - Canister vendor Holtec CEO, Dr. Kris Singh, 10/14/2014

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

- Canister temperatures low enough to dissolve salt on canister – major trigger for corrosion and cracking
- Other factors for cracking not investigated

Similar Koeberg tank failed in 17 years

- **Koeberg South Africa site has similar high risk conditions as CA West Coast**
  - Frequent salt & high moisture from on-shore winds, surf, & fog
  - Higher risk for chloride-induced stress corrosion cracking (CISCC)
- **Koeberg steel tank 0.6” crack is deeper than thickness of most U.S. spent fuel storage canisters (0.5”)**
  - Koeberg crack up to 0.6” (15.5 mm) deep[1]
  - Diablo Canyon, Humboldt Bay, Rancho Seco canisters only 0.5” thick
  - San Onofre canisters only 0.625” thick
- **Nuclear industry EPRI[2] report cherry-picked data[3]**
  - Ignored 17-year Koeberg tank failure
  - Ignored 2-year old Diablo Canyon canister conditions for cracking
  - Ignored frequent salt & high moisture from on-shore winds, surf & fog

[1] Power Plant Operating Experience with SCC of Stainless Steel, Slide 9, NRC, D. Dunn, August 5, 2014
https://sanonofresafety.files.wordpress.com/2013/06/8-5-14-scc-rirp-nrc-presentation.pdf

[2] Electric Power and Research Institute (EPRI)

[3] Critique: EPRI Flaw Growth and Flaw Tolerance Assessment for Dry Cask Storage Canisters, D. Gilmore, May 7, 2015
https://sanonofresafety.files.wordpress.com/2013/06/epri-critiqueandkoebergplant2015-05-17.pdf

Action needed now
CA canisters may leak in 6 to 14 years

	1st loaded	May leak in*
Rancho Seco	2001	6 years
San Onofre	2003	8 years
Humboldt Bay	2008	13 years
Diablo Canyon	2009	14 years

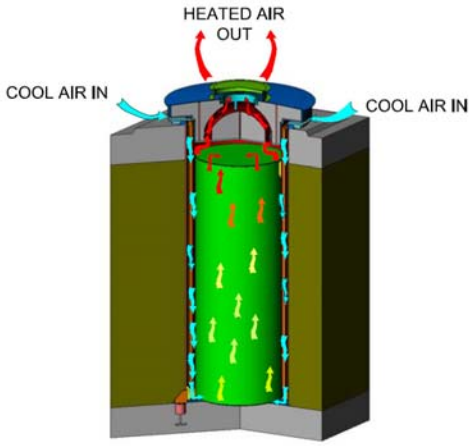
- **Most U.S. thin canisters in use less than 20 years****
  - Earliest: 1989 (Robinson, H.B., SC), 1990 (Oconee, SC), 1993 (Calvert Cliffs, MD)

* Assumes failure no earlier than 20 years

** Failure Modes and Effects Analysis (FMEA) of Welded Stainless Steel Canisters for Dry Cask Storage Systems, EPRI, Final Report, December 2013, Table 2-2

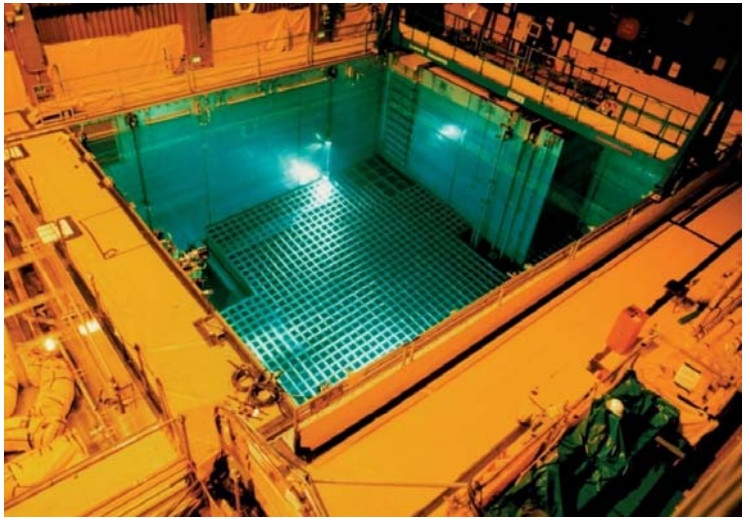
SCE wants over $1 billion for new thin canister system at San Onofre

- **Holtec UMAX underground system is experimental**
- **Never used anywhere in world**
  - 2008 Humboldt Bay underground system **not** similar, yet water intrusion despite no vents
- **Not NRC approved**
  - Needs seismic evaluation
- **NRC license ignores aging over 20 years**
- **Known problems with underground systems (corrosion, moisture, limited inspection)**
  - Higher corrosion from ground chemicals and moisture
  - Higher corrosion in marine environments
  - Inspection & repair technology limited or not possible
  - Flooding and moisture risks
  - More likely to overheat in low or no wind conditions



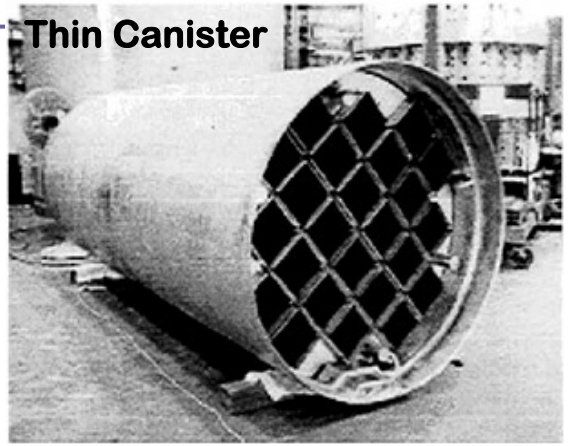
SCE plans to destroy San Onofre spent fuel pools

- **Pools are only method to replace failed canister**
  - Dry transfer systems not available
  - Nesting failed canisters (like Russian dolls) does not fix problem, is expensive & not NRC approved
- **Pools already destroyed at Rancho Seco & Humboldt Bay**
- **No funds to replace pools**



Only option is use thick casks

Safety Features	Thin canisters	Thick casks
Thick walls	1/2” to 5/8”	**Up to 20”**
Won’t crack		√
Repairable (replace seals)		√
Inspectable		√
Early leak detection		√
ASME **container** certification		√
Defense in depth (redundancy)		√
Stored in concrete building		√
Gamma & neutron protection	With concrete overpack	√
Transportable cask		√
Market leader	**U.S.**	**World**



Germany interim storage

Solutions

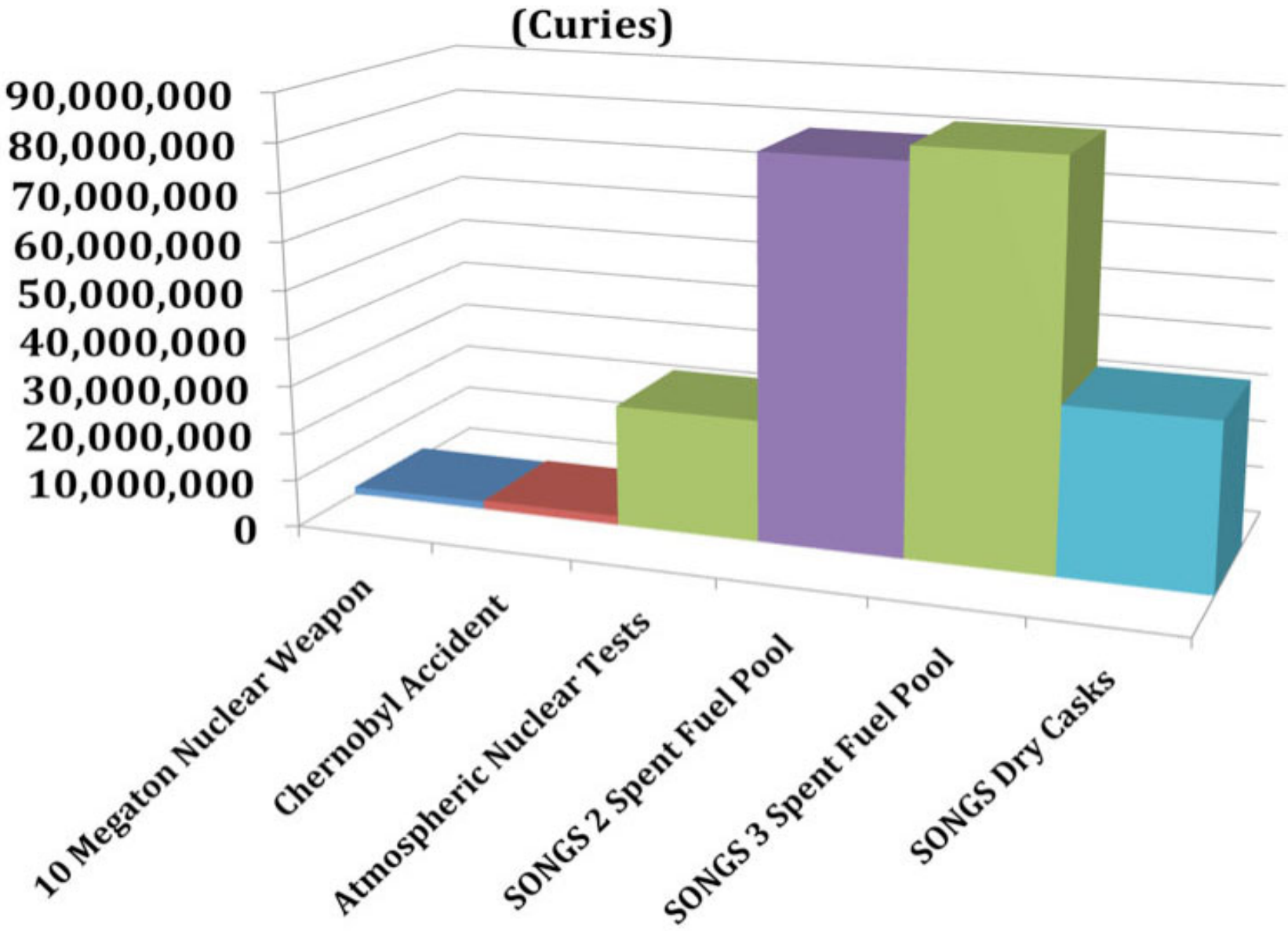

CASTOR® - Type V/19 cask

- **Stop Edison from spending over $1 billion on thin canisters**
  - Don't buy vendor promises of future capabilities (vaperware)
- **Require Edison to accept bids from thick cask vendors**
  - Vendors won't request NRC license unless they have customer
  - NRC license takes 18 to 30 months and costs millions of dollars
- **Mandate safe as possible dry storage**
  - Maintainable, inspectable, repairable, no cracking, replaceable parts (seals)
  - Continuous early warning monitoring prior to radiation leaks
  - Redundant systems (no single point of failure, e.g., double lids)
  - Transportable and cost-effective for longer term (100 year)
  - Store in hardened concrete buildings
- **Keep pools until waste removed from site**
- **Emergency planning until waste is off-site**
  - Add on-line radiation monitoring with public access

Actions needed now

- **Propose city, county & other resolutions**
  - Sample resolutions and letters available
- **Lobby local, state, & federal elected officials & regulators**
- **Host educational events**
  - Speakers, handouts available
- **Media outreach**
  - Letters to the editor, social media, national & local press
- **Network**
  - Influential allies, celebrities, organizations, etc.
- **Details at SanOnofreSafety.org**

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 allegers). 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/allegations/statistics.htm

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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
- Reasons to buy thick nuclear waste dry storage casks and myths about nuclear waste storage, April 16, 2015, D. Gilmore
  https://sanonofresafety.files.wordpress.com/2011/11/reasonstobuythickcasks2015-04-16.pdf
- Donna Gilmore's CPUC Pre-Hearing Conference Statement (A1412007), March 20, 2015
  http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M148/K824/148824935.PDF
- Additional references: **SanOnofreSafety.org**

Roadblocks to transporting waste

- **Major transport problems:** Infrastructure issues, no funding, existing canisters may be cracking, daily accident risks, no adequate emergency plans for accidents, high burnup fuel unstable in transport
- **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 hotter, unstable & more radioactive high burnup fuel
  - Numerous technical, legal and political issues unresolved
  - No other geological sites being considered by Congress
- **Interim storage sites unlikely for decades, if ever**
  - No funding source, technical, legal & political challenges
  - Communities do not want the waste; tried numerous times before and failed
  - U.S. military, California & other states do not want the waste
- **No safe waste solutions & broken promises**
  - WIPP repository leaked in 15 years, currently closed; broken promises to New Mexico
  - Hanford, Savannah River, Nevada Nat. Security & other sites leak – broken promises
  - No state authority over problems; cheaper rather than safer solutions
  - Waste creep – more waste & waste types stored than promised
  - Fuel assemblies damaged after storage may not be retrievable
  - Identification of damaged fuel assemblies imperfect

Proposed rail, highway and barge routes to Yucca Mountain (2002)

NRC rubber stamps & ignored these recommendations

- **Require best technology used internationally**
- **Base standards on longer term storage needs**
  - Not on limitations of thin canister technology
  - Not on vendor promises of future solutions
- **Store in hardened concrete buildings**
- **Don't destroy spent fuel pools until waste off-site**
- **Require continuous radiation monitoring**
- **Continue emergency plans until waste off-site**
  - Require on-line public access to radiation monitoring
- **Certify safety of dry storage systems for 100 years, but require 20-year license renewals**

NRC license excludes aging issues

- **Ignores issues that may occur after initial 20 year license, such as cracking and other aging issues**
- **Refuses to evaluate thick casks unless vendor applies**
- **Requires first canister inspection after 25 years**
  - Allowing **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 2015**

California Jurisdiction

- **State jurisdiction excludes radiation related impacts, but includes other areas of nuclear facilities. Partial list:**
- **Coastal Commission**
  - California Coastal Act
- **California Public Utilities Commission**
  - Cost and reliability
- **State Land Commission**
  - Leases, manage & protect natural & cultural resources on certain public lands within the state & the public's rights to access these lands
- **State Water Resources Control Board**
  - Once-through cooling
- **California Energy Commission**
  - California energy policy
- **Governor**
  - Major decision maker

More details at http://sanonofresafety.org/once-through-cooling/

Coastal Commission

Public Resources Code Reg. §30253

Photo: Cleveland Nash

New development shall do all of the following:

(a) **Minimize risks to life and property in areas of high geologic, flood, and fire hazard**.

(b) **Assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs.**

(c) Be consistent with requirements imposed by an air pollution control district or the State Air Resources Board as to each particular development.

(d) Minimize energy consumption and vehicle miles traveled.

(e) Where appropriate, **protect special communities and neighborhoods** that, because of their unique characteristics, are popular visitor destination points for recreational uses.

Recommendations:
Mandate safe as possible dry storage


CASTOR® - Type V/19 cask

- **Procure thick, maintainable, transportable storage casks**
  - **Inspectable, repairable, replaceable parts** (e.g., metal seals, lids, bolts)
  - **Proven technology** (40 years in service with insignificant material aging)
  - **Option for permanent storage with added welded lid**
  - **Redundancy -- no single point of failure**
    - Two independently bolted double lids, each with double seals
  - **Will not crack and will not significantly corrode for 100 years**
    - Ductile cast iron up to 20” thick
  - **ASME quality manufacturing certification**
    - NRC currently allows exceptions to ASME quality manufacturing standards
  - **Contains all radiation types in one thick storage/transport cask**
  - **Store in hardened concrete buildings for additional protection**
  - **Continuous remote early warning monitoring BEFORE radiation leak**
    - Pressure monitoring
- **Cost-effective for longer term storage (100+ years) and transport**
- **Keep spent fuel pools until waste removed**
- **Continue emergency planning**
- **On-line remote radiation monitoring with public access**
- **Vendors will not request NRC license unless they have customer**
  - **NRC license process requires 18 to 30 months and millions of dollars**

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**

Koeberg steel tank failed in 17 years

- **CA coastal environment similar to Koeberg plant in South Africa**
  - **Salt and high moisture from on shore winds, surf and fog**
  - **EPRI excluded these factors in their crack analysis**
- **Koeberg refueling water storage tank failed with 0.6” deep crack**
  - **EPRI excluded this fact in their crack analysis (cherry picked data)**
- **CA thin canisters only 0.5” to 0.625” thick**
  - **Diablo Canyon 0.5”** steel canister, inside vented concrete cask
  - **Humboldt Bay 0.5”** steel canister inside thick bolted lid steel cask, inside experimental underground concrete system
  - **Rancho Seco 0.5”** steel canister inside vented concrete overpack
    - Also at risk from salt air and fog
  - **San Onofre 0.625”** steel canister inside vented concrete overpack
- **San Onofre proposed Holtec underground UMAX system not used anywhere in the world**
- **Koeberg cracks could only be found with dye penetrant test**
  - **Test cannot be used with canisters filled with spent nuclear fuel**

Condition of existing canisters unknown

- **No technology exists to inspect canisters for cracks**
  - Most thin canisters in use less than 20 years
- **Won't know until AFTER leaks radiation**
- Similar steel components at nuclear plants **failed in 11 to 33 years** at ambient temperatures ~20°C (68°F)
- **Crack growth rate about four times faster** at higher temperatures
  - 80ºC (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).

Thick cask advantages


CASTOR® - Type V/19 cask

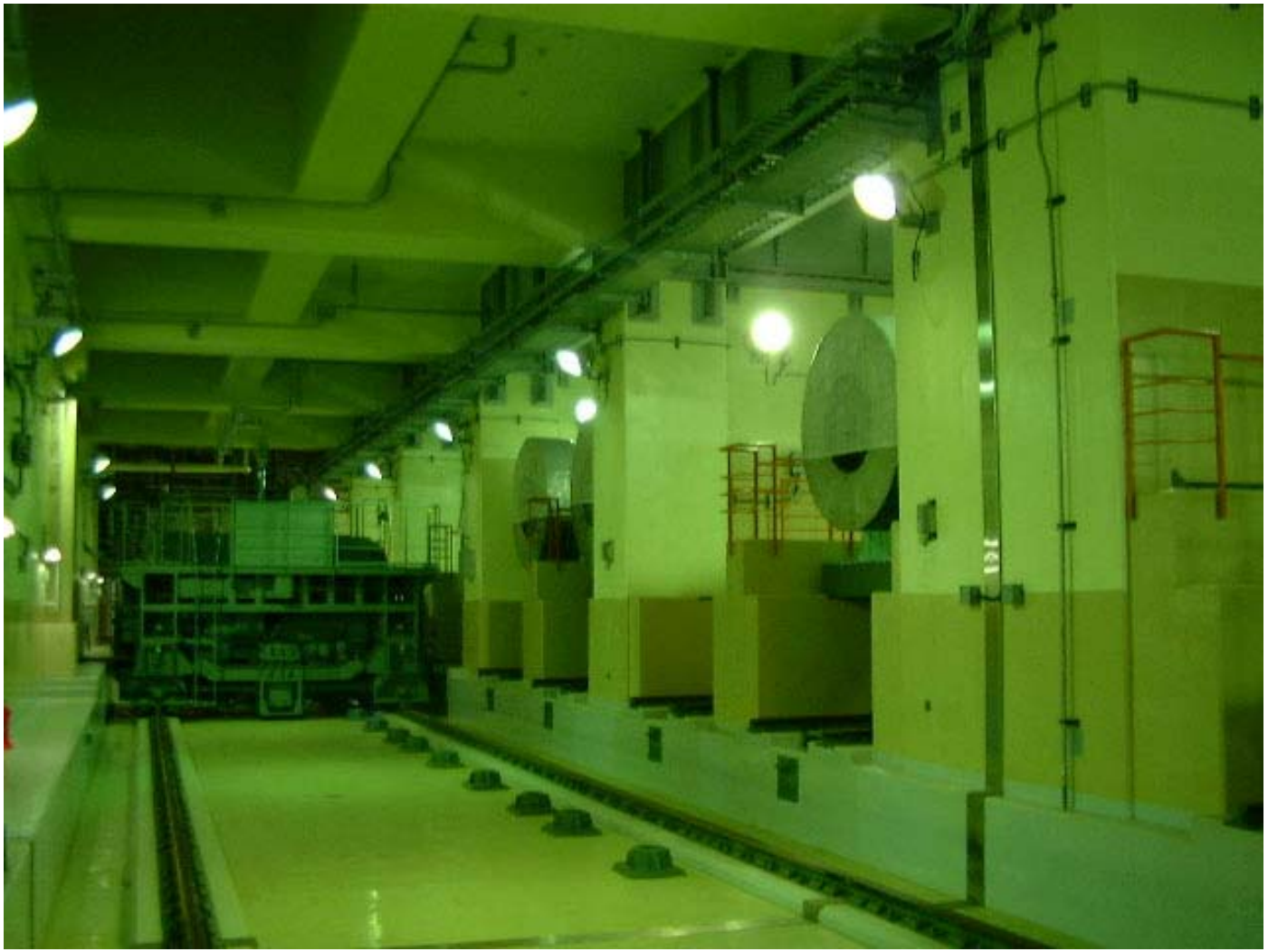
- **Market leader internationally**
- **Maintainable**
  - No cracking or significant corrosion*
  - Inspectable, repairable, replaceable parts (metal seals, lids, bolts)
  - 40 years in service with insignificant material aging*
  - Thick cask body − steel up to 10” or DCI* up to 20”
  - ASME & international quality cask certifications for storage & transport*
- **Redundancy – no single point of failure**
  - Two independently bolted thick steel lids, each with double seals*
  - Can reload fuel without destroying cask
- **Early warning before radiation leak**
  - Continuous remote lid pressure monitoring
- **Permanent storage option with added welded lid***
- **Thick casks protect from all radiation, reducing cost & handling**
  - No concrete overpacks required
  - No steel transfer and transport casks required
  - Used for both storage and transportation (with transport shock absorbers)
- **Store in concrete building for additional protection**
- **Vendors won’t request NRC license unless they have customer**
  - NRC license requires 18 to 30 month and millions of dollars

* Ductile cast iron (DCI)

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

Fukushima thick casks in building



Fukushima thick casks

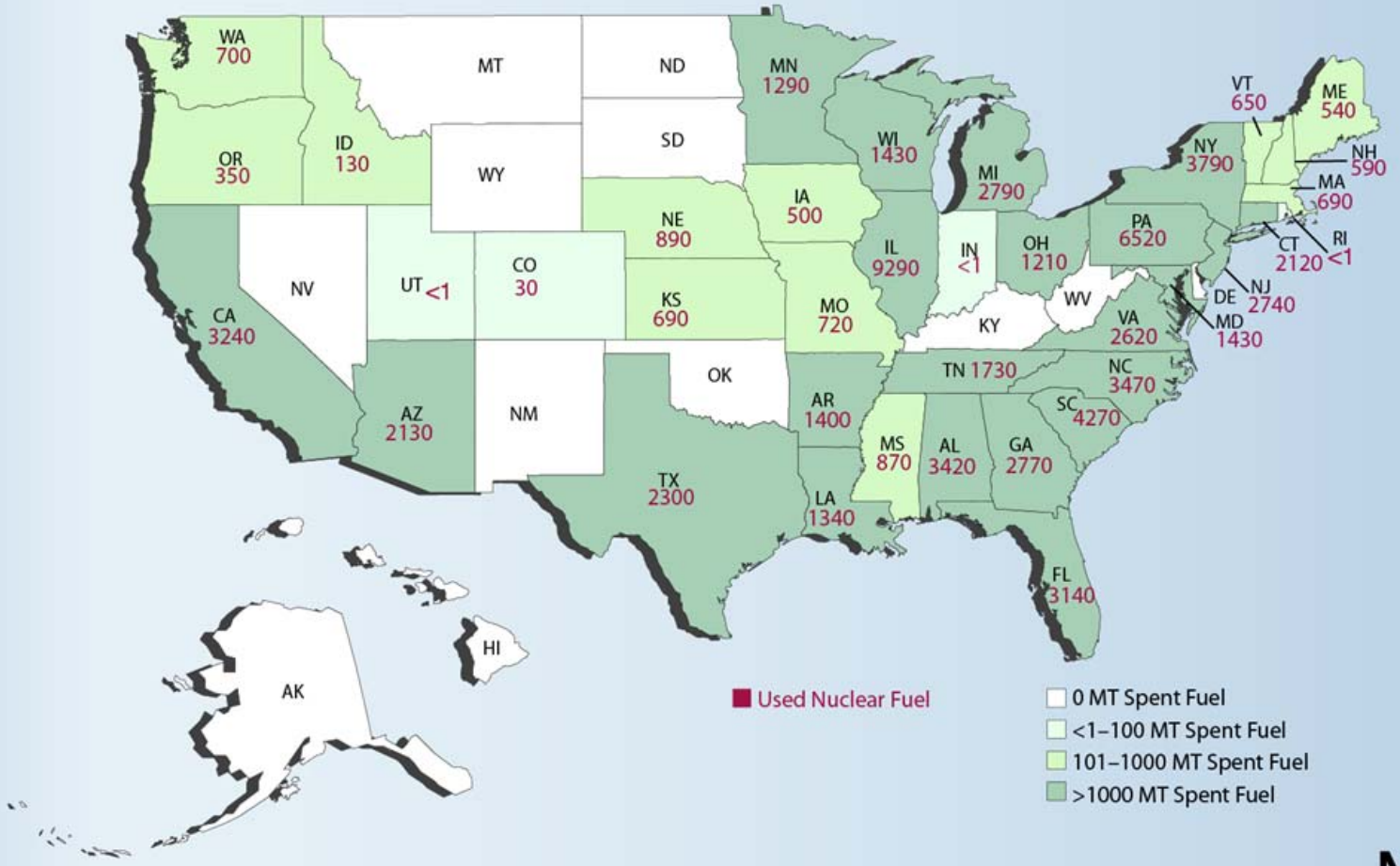
Specification of Dry Casks

	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.

Used Nuclear Fuel in Storage

(Metric Tons, End of 2013)



NEI
NUCLEAR ENERGY INSTITUTE

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

- **Temperature low enough to initiate cracks in 2 years <85°C (185°F)**
- **Moisture dissolves sea salt – trigger for corrosion and cracking**
- **Only small surface area of two canisters sampled Jan 2014**
  - Sampled temperature and part of surface for salt and other surface contaminants, due to limited access via concrete air vents
- **Canisters not repairable & millions of curies of radiation would be released from even a microscopic crack**
  - Holtec CEO Dr. Singh,10/14/2014 http://youtu.be/euaFZt0YPi4
- **No plan in place to replace cracked canisters**

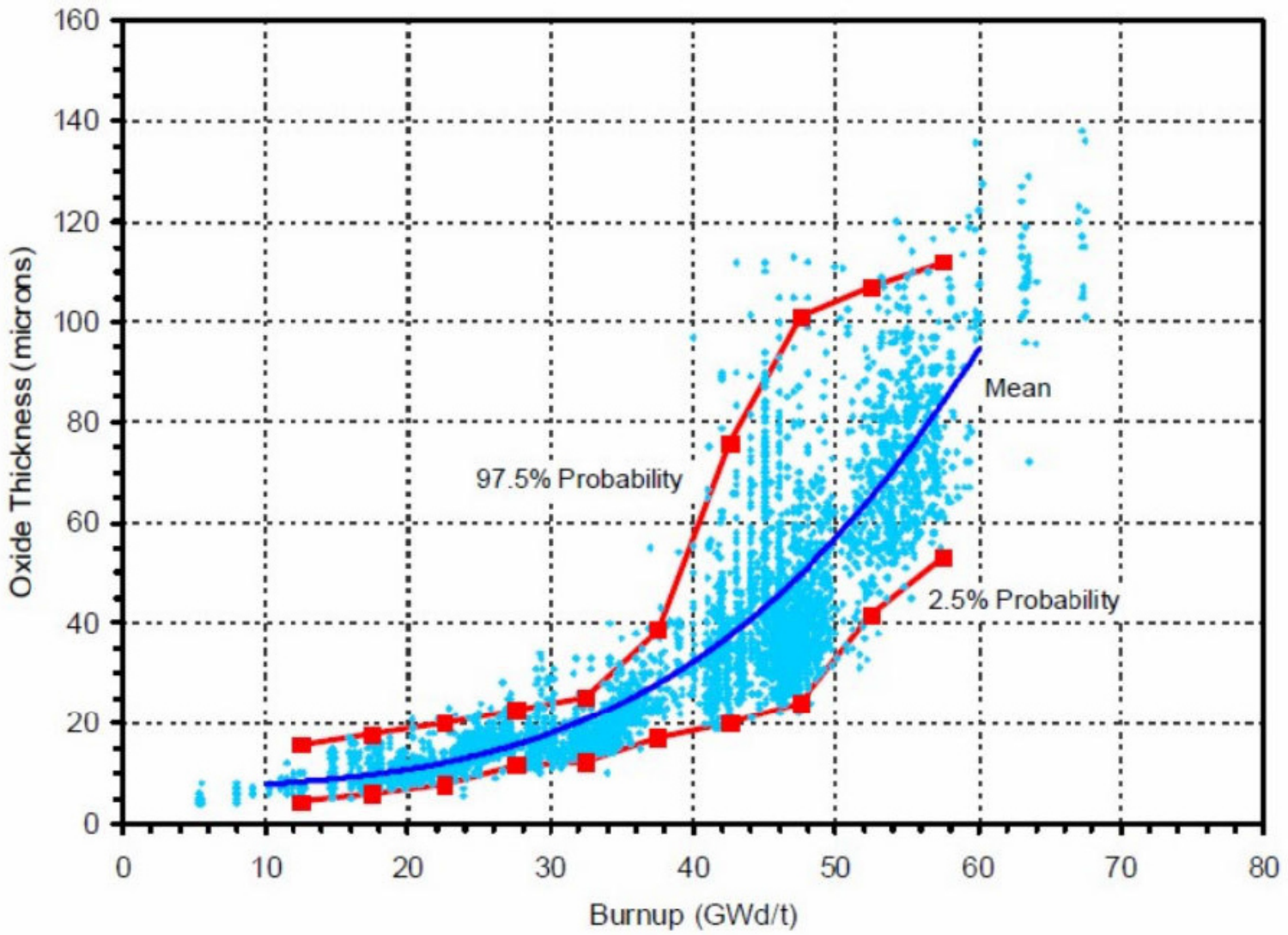
Thin canisters not designed to be replaced

- 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

Higher Burnup = Higher Cladding Failure



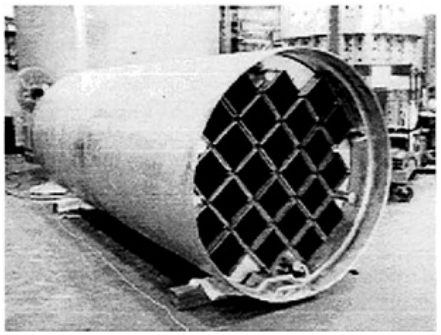
Higher oxide thickness results in higher cladding failure. Argonne scientists reported high burn-up fuels may result in fuel rods becoming more brittle over time. "… insufficient information is available on high burnup fuels to allow reliable predictions of degradation processes during extended dry storage." 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

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
- Quality control has been an issue with thin canisters

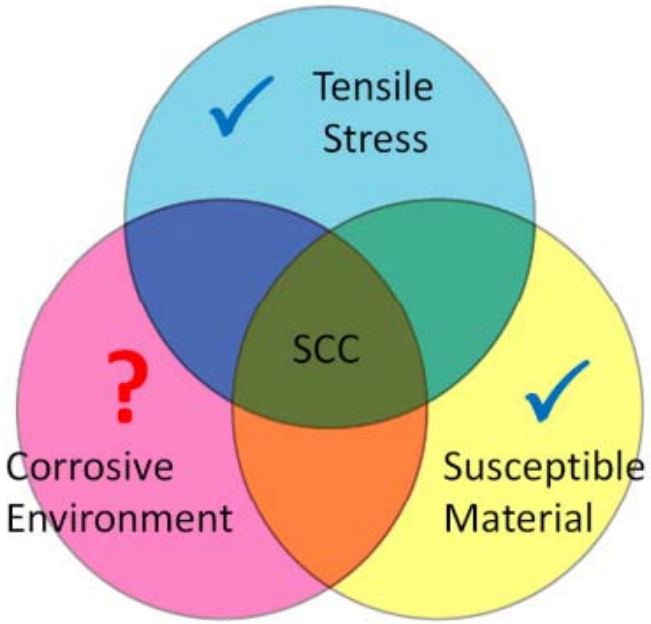
Problems with thin stainless steel canisters

- **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 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**



Stress Corrosion Cracking Background Information

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment



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

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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 9.6×10^{-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

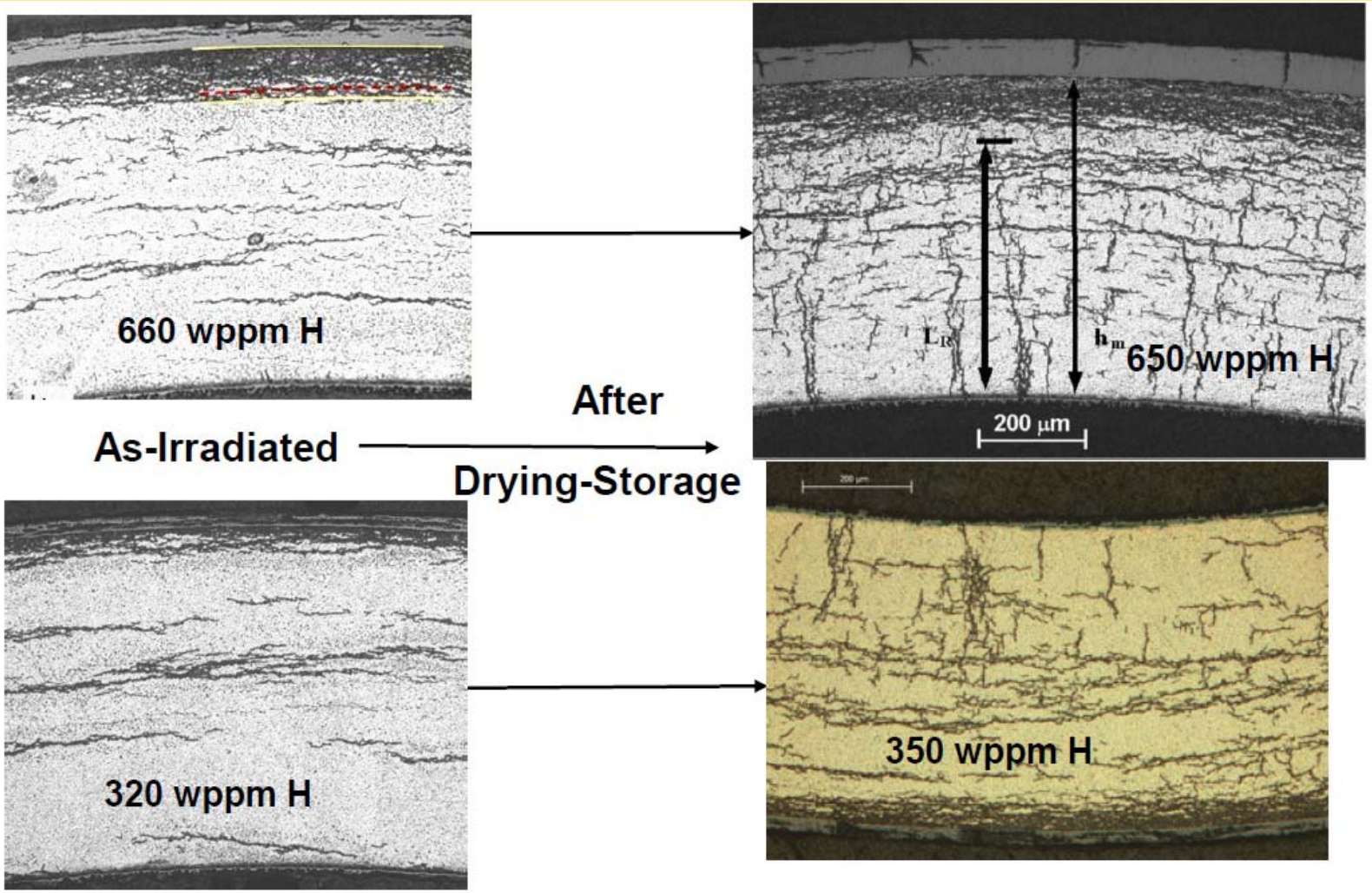
Near-term Medium or Medium High

Long-term Medium

U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Introduction: Circumferential and Radial Hydrides in HBU Cladding



U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Summary of Results

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

Background information

- CoCs/licenses for high burn-up fuel storage to be renewed over next few years
  - 2012 Prairie Island-TN-40HT, Calvert Cliffs-NUHOMS[1]
  - 2015 Transnuclear-NUHOMS 1004
  - 2020 NAC-UMS; Holtec-Hi-STORM
- Storage of high burn-up fuel is relatively recent
  - 9 years – Maine Yankee[2] (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
- ~ 200 loaded-casks contain high burn-up fuel
- Most fuel in pools for future loading is high burn-up

NEI

1) Since 1992, allowable burn-up to 47 GWd/MTU, since 2010, up to 52 GWd/MTU
2) All high burn-up fuel is in damaged fuel cans

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
  - Air pollution can trigger corrosion & cracking
  - Microscopic scratches from insects & rodents
- **Thick casks can be inspected**
  - Provide full radiation barrier without concrete
  - Surfaces can be inspected
  - Not subject to stress corrosion cracking

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