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NUREG-2224, Dry Storage and Transportation of High Burnup Spent Nuclear Fuel, Draft Report for Comment.

Comment On: NRC-2018-0066-0001
Dry Storage and Transportation of High Burnup Spent Nuclear Fuel

Document: NRC-2018-0066-DRAFT-0010
Comment on FR Doc # 2018-16994

Submitter Information

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General Comment

See attached for detailed comments. Sufficient evidence exists that moderate and high burnup fuels are unstable in storage and transport. NUREG-2224 ignores significant operating data and other data that shows significant problems with both moderate and high burnup fuels in storage and transport. Instead of trying to justifying high burnup fuel as safe, the NRC needs to require more robust storage containers so spent nuclear fuel and its containment can be inspected, maintained and managed to avoid major leaks, explosions and criticalities, cause by this unstable fuel and other factors.

In the Nuclear Waste Technical Review Board (NWTRB) 2010 report regarding the Technical Basis for Extended Storage of Used Fuel for Storage and Transport, it references over 4,400 measurements from commercial fuel-rods taken from reactors around the world (Figure 20). The data shows zirconium oxides and zirconium hydrides are created in moderate and high burnup fuel, with significant increases starting at ~35 GWd/MTU. There is a direct correlation with oxides and hydrides. See NWTRB report for the Chart showing the hydrides. Zirconium metal hydrides cause damage to the cladding, making it more brittle, thinner, and increases hydrogen gas explosion risks if fuel rods are exposed to air (whether in pool or dry storage). Zirconium hydrides ignite at only 270 degrees Celsius.

The NRC continues to ignore this operating data. I have asked in numerous NRC technical meetings over the years why the NRC ignores this data, including at the one public meeting held on NUREG-2224 (September 6, 2018). Normally the NRC will respond with some type of answer to my questions. When I ask about this operating data, they dont even do that. They change the subject. I would like a response as to why the NRC ignores this data. See this and more comments on attachment.

Attachments

NUREG-2224DonnaGilmoreComments2018-09-24

September 24, 2018

TO: Michael Layton, Director
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RE: NUREG-2224 High Burnup Storage and Transport Draft Comments from Donna Gilmore, Docket NRC-2018-0066

Sufficient evidence exists that moderate and high burnup fuels are unstable in storage and transport. NUREG-2224 ignores significant operating data and other data that shows significant problems with both moderate and high burnup fuels in storage and transport. Instead of trying to justifying high burnup fuel as safe, the NRC needs to require more robust storage containers so spent nuclear fuel and its containment can be inspected, maintained and managed to avoid major leaks, explosions and criticalities, cause by this unstable fuel and other factors.

Operating data ignored

In the Nuclear Waste Technical Review Board (NWTRB) 2010 report regarding the *Technical Basis for Extended Storage of Used Fuel for Storage and Transport*,[1] it references over 4,400 measurements from commercial fuel-rods taken from reactors around the world (Figure 20). The data shows zirconium oxides and zirconium hydrides are created in moderate and high burnup fuel, with significant increases starting at ~35 GWd/MTU. There is a direct correlation with oxides and hydrides. See NWTRB report for the Chart showing the hydrides. Zirconium metal hydrides cause damage to the cladding, making it more brittle, thinner, and increases

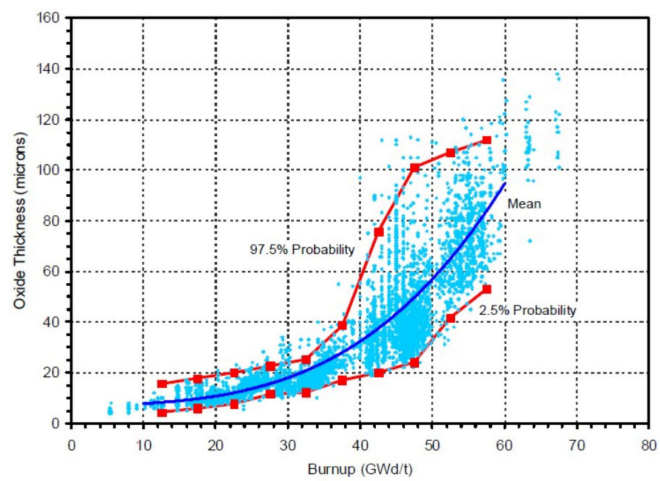

Figure 20 Cladding Outer Surface Oxide Layer Thickness versus Rod Average Burnup (Gigawatt days/ton of uranium). NWTRB 2010

[1] Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel, Nuclear Waste Technical Review Board (NWTRB), Douglas Rigby, December 2010, Page 55 and 56
https://www.nwtrb.gov/docs/default-source/reports/eds-final.pdf?sfvrsn=8&sfvrsn=8
Plotting more than 4,400 measurements from commercial fuel-rods taken from reactors around the world, Figure 20 shows the maximum outer-surface oxide-layer thickness data in low-Sn Zircaloy-4 cladding plotted as a function of burnup. Taking these oxide thickness measurements, the maximum wall thickness average (MWTA) hydrogen content can be calculated using a hydrogen evolution model. Figure 21 plots the wall-average hydrogen content in low-Sn Zircaloy-4 cladding as a function of burnup from both measured and model-calculated data. For a discharge burnup in the range of 60-65 GWd/MTU, the maximum oxide thickness is 100 µm and the average hydrogen concentration is 800 ppm, which corresponds to a metal loss of 70 µm using conservative assumptions.
Spent Fuel Transportation Applications – Assessment of Cladding Performance: A Synthesis Report, EPRI-TR-1015048, December 2007, page 2-2 and 2-3
http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001015048

hydrogen gas explosion risks if fuel rods are exposed to air (whether in pool or dry storage). Zirconium hydrides ignite at only 270 degrees Celsius.

The NRC continues to ignore this operating data. I have asked in numerous NRC technical meetings over the years why the NRC ignores this data, including at the one public meeting held on NUREG-2224 (September 6, 2018). Normally the NRC will respond with some type of answer to my questions. When I ask about this operating data, they don't even do that. They change the subject. I would like a response as to why the NRC ignores this data.

Insufficient operating data

Instead, NUREG-2224 relies on insufficient operating data, and data that does not reflect normal operating conditions of fuel burnup. A high burnup fuel rod from H.B. Robinson that does not reflect normal operating conditions of fuel burnup isn't even valid operating data. H.B. Robinson rods were handled in an abnormal way. They were moved to new fuel assemblies after each cycle, rather than continuing to burn in fuel assemblies with other higher burnup rods.[2] Cherry picking operating data to reach a conclusion that high burnup fuel is safe in storage and transport is not acceptable science. This should be reason enough to reject NUREG-2224.

Explosion risks increased with moderate and high burnup fuel

As fuel degrades during dry storage, canisters can over pressurize, resulting explosions from hydrogen gas not being monitored or released to avoid over pressurization. The majority of U.S. highly radioactive nuclear waste storage canisters are thin-wall (mostly ½" inch welded stainless steel) that have no pressure monitoring or pressure release valves for use during dry storage or transport. The NRC gives exemptions to ASME pressure vessel standards that require this. That may have been acceptable for 20-year storage, but not for the longer time periods that the NRC admits may likely occur. This is a major concern of the NWTRB in their December 2017 report to Congress on Spent Nuclear Fuel.[3]

In this same NWTRB December 2017 report, they are also concerned no one knows how much water remains in these canisters, since all water cannot be removed from canisters during drying. Once welded shut, these canisters cannot be opened without destroying the canister. The NRC is guessing a litre or two, but they admit they really don't know.

In this Department of Energy (DOE) 2000 report regarding *Transitioning Metallic Uranium Spent Nuclear Fuel from Wet to Dry Storage*,[4] the reason given by the DOE to exclude hydrogen gas pressure relief valves to maintain and monitor the gas was based on cost, assuming canisters would only be needed for 40 years of storage and assuming no problems would occur before then. What other reason does the NRC have for the exemption to ASME standards for pressure relieve valves? This report, along with

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[2] Design, Operation, and Performance Data for High Burnup PWR Fuel from the H. B. Robinson Plant for Use in the NRC Experimental Program at Argonne National Laboratory, EPRI, May 4, 2001
https://www.epri.com/#/pages/product/1001558/?lang=en
[3] Report to the United States Congress and the Secretary of Energy, Management and Disposal of US Department of Energy Spent Nuclear Fuel, NWTRB, December 2017
http://www.nwtrb.gov/docs/default-source/reports/nwtrb-mngmntanddisposal-dec2017-508a.pdf?sfvrsn=12
[4] Transitioning Metallic Uranium Spent Nuclear Fuel from Wet to Dry Storage, P.G. Loscoe, U.S. Department of Energy (DOE), Hanford, WM'00 Conference, February 27 – March 2, 2000, Tucson, AZ
http://www.wmsym.org/archives/2000/pdf/54/54-9.pdf

other reports discuss the uranium fuel explosion risks and other risks of spent fuel storage and transfer. The NRC needs to address these issues.

- *Both uranium metal and uranium hydride are pyrophoric materials; that is, they are capable of spontaneous ignition in the presence of air. This is a consequence of the significant heat produced in their reactions with air… and is especially a concern when the materials are in a form that has a high specific area (ratio of surface area to mass).*
- *Uranium hydride is always formed with high specific area [26] and therefore has a deserved reputation for pyrophoric behavior.*
- *"Uranium metal is chemically unstable with respect to its oxides and will therefore tend to react with air, water or water vapor. These reactions are sufficiently exothermic (see the Appendix) so that if heat is not rejected at a sufficient rate during the drying process, when water or water vapor is present in the absence of air, the temperature of the fuel will increase. This temperature increase will, in turn, cause the reaction to proceed more rapidly, resulting in an autocatalytic reaction."*

This Idaho National Laboratory (INL) 2005 report regarding *Damaged Spent Nuclear Fuel at U.S. DOE Facilities, Experience and Lessons Learned,*[5] addresses similar issues. What, if any of this operating data informed the NRC analysis in NUREG-2224? If not, why not?

- *Each cycle of fuel-water reaction results in fission product releases and contamination of water in the canister or the storage pool.*
- *The generation of high surface area uranium metal SNF [spent nuclear fuel] fragments and uranium hydride necessitates additional measures during SNF drying, dry storage, and transportation because of the pyrophoric nature of these materials when exposed to air. As a result, degraded uranium metal fuels are stored and transported in inerted canisters after removal from the basin and drying.*
- *Radiolysis of water within the SNF-water corrosion products must also be addressed for long-term storage because of the ability of the resultant gases to overpressurize containers, embrittle welds on containers, and reach flammable concentrations.*

This 2011 IAEA Nuclear Energy Series document regarding *Impact of High Burnup Uranium Oxide and Mixed Uranium– Plutonium Oxide Water Reactor Fuel on Spent Fuel Management*,[6] discusses damages to uranium oxide high burnup fuel. Was any of this considered?

> *The grain size changes within high burnup fuel as you proceed from the central portion to the outer rim of the fuel. The major portion of high burnup fuel will have a grain size similar to (unchanged from) the as-fabricated grain size of approximately 10 µm typical of commercial fuel. The central portion of the fuel may have some grain growth (up to a factor of 2)9. The rim portion of high burnup fuel will have much higher burnups than the pellet average and forms restructured fine sub-grains at pellet average burnups > 40 GWd/t U. The sub-grain sizes are generally between 0.1 µm to 0.3 µm [39.49–51]. As the burnup of the [fuel pellet] rim increases*

[5] Damaged Spent Nuclear Fuel at U.S. DOE Facilities, Experience and Lessons Learned, INL, Nov 2005 INL/EXT-05-00760, Pages 4 & 5 https://inldigitallibrary.inl.gov/sites/sti/sti/3396549.pdf

[6] Impact of High Burnup Uranium Oxide and Mixed Uranium– Plutonium Oxide Water Reactor Fuel on Spent Fuel Management, IAEA Nuclear Energy Series, No. NF-T-3.8, VIENNA, 2011, page 36 http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1490_web.pdf

> *the original as-fabricated grain boundaries begins to disappear as the sub-grain structure becomes dominant.* ***This restructured rim is not present in the older fuel where rod or bundle burnups did not exceed 33 GWd/t U****.*

NRC's 1997 NUREG-1536 Standard Review Plan for Dry Cask Storage Systems[7] defines high burnup as >40 GWd/MTU, but in the July 2010 NUREG-1536[8] revision it redefines it as >45 GWd/MTU. The 1997 NUREG-1356 page 96 states:

> *High-burnup of fuel (greater than 40,000 MWD/MTU) causes effects, such as wall thinning from increased oxidation and increased internal rod pressure from fission gas buildup, and changes in fuel dimensions that must be evaluated. The SAR [Safety Analysis Report] should use conservative values for surface oxidation thickness. Oxidation may not be of a uniform thickness along the axial length of the fuel rods and average values may under predict wall thinning. Temperature limits will be more restrictive with increased fuel cooling time (and/or increased burnup), largely as a result of creep cavitation.*

What evidence was used to redefine high burnup fuel from > 40 GWd/MTU to >45 GWd/MTU when there is evidence showing damage starting above 33 GWd/MTU? The scope of the high burnup NUREG-2224 should evaluate moderate burnup fuel, also.

In this 2013 DOE A Project Concept for Nuclear Fuels Storage and Transportation report[9] it states: "

> *Experimental data over the last twenty years suggest that fuel utilizations as low as 30,000 MWd/t [30 GWd/MTU] can present performance issues including cladding embrittlement under accident conditions as well as normal operations. The NRC is actively seeking rulemaking to address cladding performance for loss of coolant accidents and reactivity insertion accidents. These cladding performance issues need to be addressed before extended fuel utilization fuel can be loaded into dry casks and transportation systems. Section 9.1 discusses needed R&D.*

Why is the above referenced experimental data being discounted?

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[7] NRC 1997 NUREG-1536 Standard Review Plan for Dry Cask Storage Systems, page 96
http://www.orau.org/ptp/PTP%20Library/library/NRC/NUREG/1536.pdf

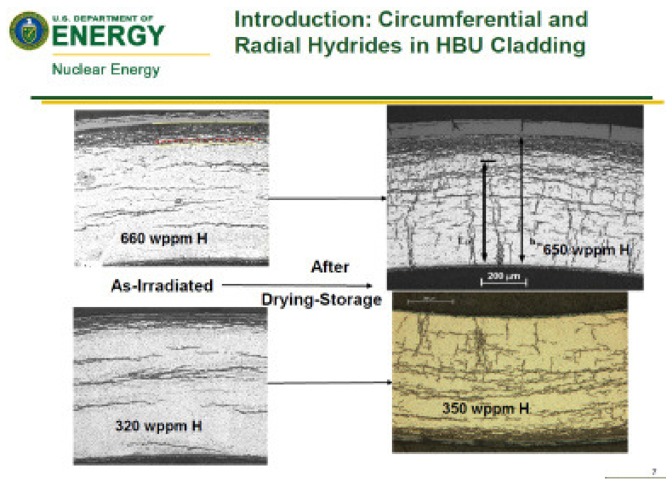
[8] July 2010 NRC NUREG-1536 Revision 1,
http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1536/r1/sr1536r1.pdf

[9] U.S. Department of Energy, Nuclear Fuels Storage and Transportation Planning Project, Joe Carter (SRNL) Scott Dam, et. al. (TechSource, Inc.), June 15, 2013, FCRD-NFST-2013-000132, Rev. 1, Page 29
https://www.hsdl.org/?view&did=739345

High burnup fuel not treated as damaged

There is experimental evidence to show embrittlement will occur **during** dry storage, such as this 2012 M.C. Billone report.[10]

"…the trend of the data generated in the current work clearly indicates that failure criteria for high-burnup cladding need to include the embrittling effects of radial-hydrides for drying-storage conditions that are likely to result in significant radial-hydride precipitation...A strong correlation was found between the extent of radial hydride formation across the cladding wall and the extent of wall cracking during RCT [ring-compression test] loading."



The NRC does not require damaged fuel to be put in individual damaged fuel cans, even though studies by Billone show high burnup fuel can become damaged during dry storage.

How will high burnup fuel in dry storage be monitored to ensure it has not become damaged?

How will high burnup fuel that has become damaged in dry storage be canned in damaged fuel cans? The NRC allows spent fuel pools to be destroyed once all fuel at a site is in dry storage. What possible options are there other than building a hot cell or a pool to do this? Before allowing any more spent fuel pools to be destroyed, the NRC should address these issues.

With damaged fuel cans, there are vents on both ends of the damaged fuel cans, so the fuel can be dried at the same time as the rest of the fuel assemblies in the canister. However, it means the sealed fuel rods have not been adequately replaced, which will allow gases to escape from damaged fuel rods. As fuel degrades over time, especially high burnup fuel, this can be a major problem. In other countries that are not reprocessing, the individual damaged fuel rods are put in helium filled sealed tubes, sometimes called quivers. This fully replaces the damaged rods and can contain the gases. Has the NRC considered this option? If not, why not?

The NRC allows drying temperatures up to 400 degrees C. for high burnup fuel. Japan limits this to 250 C. in order to reduce damage to the fuel. What operating evidence do you have that states the fuel rods will not become damaged at 400 degrees C. or even 300 degrees C.?

[10] Ductile-to-Brittle Transition Temperature for High-Burnup Zircaloy-4 and ZIRLO™ Cladding Alloys Exposed to Simulated Drying-Storage Conditions M.C. Billone, T.A. Burtseva, and Y. Yan Argonne National Laboratory September 28, 2012. http://pbadupws.nrc.gov/docs/ML1218/ML12181A238.pdf

Explosion and criticality risks from cracking canisters

Zirconium hydrides ignite at 270 degrees Celsius. The NRC assumptions no air or water will enter the canisters is based on no through wall cracks in the canisters. However, there are numerous conditions that can cause the canisters to crack. The NRC states once cracks start, they can grow through the wall in 16 years.[11]

At Diablo Canyon a low enough temperature was found for corrosive salts to dissolve on a 2-year old canister. No one knows if it has started to crack, since canisters have not been inspected for cracks or depth of cracks.[12]

Chlorides are only one trigger for crack initiation. At San Onofre, new Holtec MPC-37 canisters are being loaded in Holtec UMAX holes. Two canisters almost dropped 18 feet. The workers cannot see in the holes and the canister (MPC) Guide ring protrudes into the hole with only ½" clearance between the canister and the guide ring. It requires multiple tries to get the canister in the hole. In the process the sides of the canisters become scratched. This is a trigger for pit corrosion cracking, so these new canisters may already be cracking. A similar system is at Callaway. However, they apparently didn't have a Holtec whistleblower come forward to talk about this.[13]

NUREG-1927 Rev. 1[14] states if canisters have a 75% through-wall crack (ASME pressure vessel code), they must be taken out of service. Canisters are being loaded so hot (~30Kw and higher), they can no longer meet their license requirement to be able to return fuel back to the pools in order to take the canisters out of service. With no adequate inspection or repair technology in place, and an inability to return fuel to the pools, the likelihood of through-wall cracks is real. Some canisters are already 25 years old, so we are on borrowed time. The older canisters with stainless steel cladding may not explode. But the canisters with zirconium hydrides are at higher risk of explosions. And either one will go critical if water enters the canisters while in dry storage or transport.[15]

Technology gaps admitted to in NUREG-2224

There are critical unknowns about high burnup fuel in storage and transport to have confidence it is safe. For example, NUREG-2224 Page 1-6 is concerned about structural performance of the fuel rods. It states: *However, the staff recognizes that there is no reliable predictive tool available to calculate this rim thickness, which varies along the fuel-rod length, around the circumference at any particular axial location, from fuel rod to fuel rod within an assembly, and from assembly to assembly.*

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[11] Summary of August 5, 2014 Public Meeting with the Nuclear Energy Institute on Chloride Induced Stress Corrosion Cracking Regulatory Issue Resolution Protocol, September 9, 2014 http://pbadupws.nrc.gov/docs/ML1425/ML14258A081.pdf

[12] Diablo Canyon: conditions for stress corrosion cracking in 2 years, October 23, 2014, D. Gilmore https://sanonofresafety.files.wordpress.com/2011/11/diablocanyonscc-2014-10-23.pdf

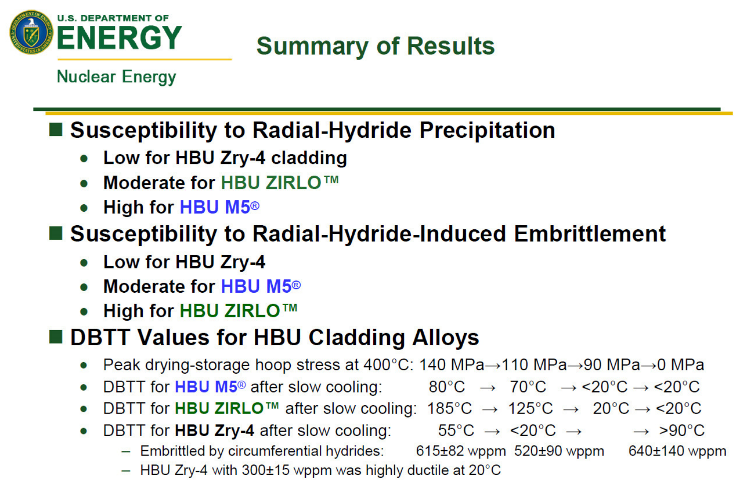
[13] David Fritch video https://youtu.be/fnM9rfhWmic David Fritch transcript https://sanonofresafety.files.wordpress.com/2018/08/davidfritchcep08-09-2018transcriptdg.pdf

[14] NUREG-1927 Rev. 1 Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel Final Report, June 2016 https://www.nrc.gov/docs/ML1617/ML16179A148.pdf

[15] Risk of criticality in dry storage if unborated water enters canister, comments for Docket ID NRC-2016-0238, NUREG/CR 2214 Managing Aging Processes in Storage (MAPS), December 26, 2017 (ML17363A209) https://www.nrc.gov/docs/ML1736/ML17363A209.pdf

The H.B. Robinson operating data used by NUREG-2224 is Zircoloy 4. New zirconium alloy fuels (M5 and Zirlo) are more susceptible to failure, yet were not evaluated. Zirlo and M5 degrade faster with high burnup fuel than earlier claddings, such as Zircaloy-4. And there are many critical unknowns.[16]

These new fuels have been approved for use by the NRC[17] without evaluating how they perform in dry storage. Data from Mike Billone[18] was available, but seems to be ignored by the NRC, as the NRC continues to approve these new fuels. The DOE Mike Billone slide presentation has a summary of the issues. Instead of addressing the existing high burnup fuel problems, the nuclear industry and Department of Energy are pushing for even higher burnup fuels, with the misnomer name of "Accident Tolerant Fuels". Instead, the NRC should push back and state existing problems need to be solved before increasing burnups.



Billone Slide 6 Cladding Mechanical Properties and Failure Limits

- Available for HBU Zircaloy-4 (Zry-4) with circumferential hydrides
- Available for Zry-2 but data needed at high fast fluence (i.e., HBU)
- **Data needs**
    - Tensile properties of **HBU M5® and ZIRLO™** cladding alloys
    - Failure limits for **all cladding alloys following drying and storage**
    - Radial hydrides can embrittle cladding in elastic deformation regime

Billone Slide 12 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™**

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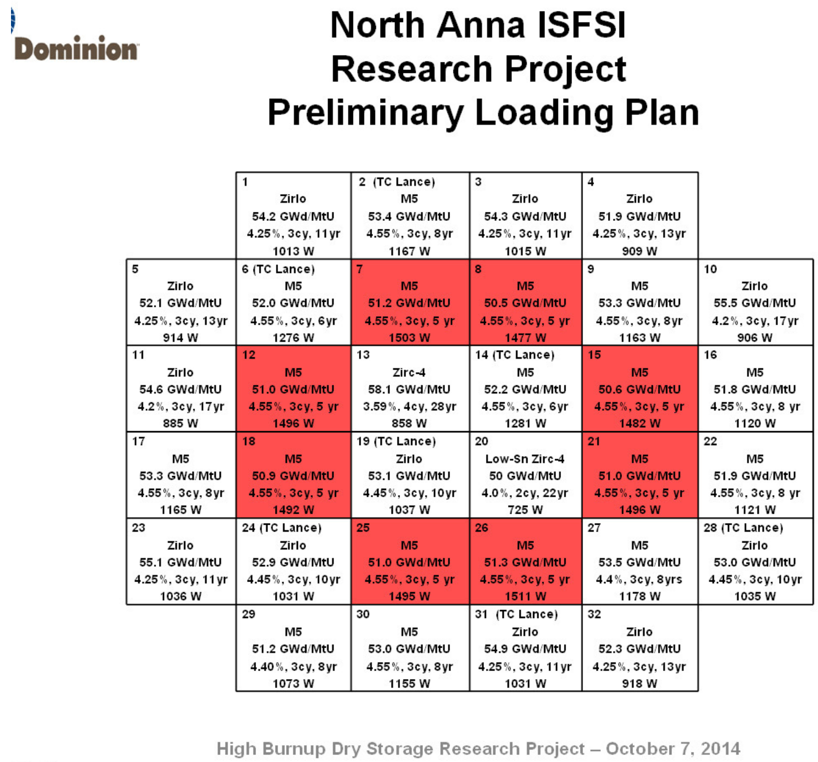
[16] Ductile-to-Brittle Transition Temperatures for High-Burnup PWR Cladding Alloys Mike Billone, Yung Liu, Argonne National Laboratory, U.S. NWTRB Winter Meeting November 20, 2013, DOE Slide Presentation https://www.nwtrb.gov/docs/default-source/meetings/2013/november/billone.pdf?sfvrsn=7

[17] San Onofre and other plants are approved for use of M5 cladding. http://www.gpo.gov/fdsys/pkg/FR-2009-12-28/html/E9-30674.htm
Diablo Canyon uses Zirlo cladding. http://pbadupws.nrc.gov/docs/ML0037/ML003764792.pdf

[18] Report for Billone slides: Fuel Disposition Campaign: Embrittlement and DBTT of High-Burnup PWR Fuel Cladding Alloys, Prepared for DOE Used Fuel Disposition Campaign, M.C. Billone, T.A. Burtseva, Z. Han and Y.Y. Liu, Argonne National Laboratory September 30, 2013, FCRD-UFD-2013-000401 https://sanonofresafety.files.wordpress.com/2014/02/billone2013-09-30embrittlementdbtthighbrnup-pwrfuelclad-alloys.pdf

DOE Demonstration Program is insufficient to justify safe storage of high burnup fuel

The DOE "Demonstration Program" (High Burnup Dry Storage Project) will only use 32 fuel rods in one thick-wall cask over a 10-year storage period. At the February 2016 NWTRB meeting a member said to the DOE "*you're spending a lot of money and time to get very few data points*".[19] Yet, the NRC states it is considering this "Demonstration Program" sufficient to determine the long-term behavior of high burnup fuel currently stored.



Why isn't the NRC requiring examining the fuel in least one of the oldest existing canisters, such those at Calvert Cliffs?

Why isn't the NRC using the operating data from the over 4,400 commercial fuel rods? Is it because the NRC does not want to acknowledge the hydride and other damage caused by moderate and high burnup fuels -- make the fuel unstable in storage and transport?

Transport regulations being weakened in spite of evidence of safety risks

Regarding transport of high burnup fuel, there is no significant evidence that the likely brittle high burnup fuel can withstand train vibrations. The fuel and canisters need to be inspected before transport, yet the NRC allows transport without inspecting the high burnup fuel or the canister. As long as the canister is not leaking, the NRC is approving them. This is a weakening of the NRC's own safety regulations. Cracked canisters cannot be safely transported according to NRC regulations. The below NRC regulation and Technical Specifications from the Areva NUHOMS high burnup transport cask makes this clear.

> **NRC Regulation 10 CFR § 71.85 Packaging and Transportation of Radioactive Materials**. Preliminary determinations. Before the first use of any packaging for the shipment of licensed material — (a) The certificate holder shall ascertain that there are no cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce the effectiveness of the packaging.[20]

[19] Transcript of Winter 2016 NWTRB meeting, Nuclear Waste Technical Review Board, February 17, 2016, Page 300 https://www.nwtrb.gov/docs/default-source/meetings/2016/february/feb2016.pdf?sfvrsn=4

[20] NRC Regulation 10 CFR § 71.85 Packaging and Transportation of Radioactive Materials http://www.nrc.gov/reading-rm/doc-collections/cfr/part071/full-text.html#part071-0085

NRC Certificate of Compliance [Areva] NUHOMS-MP197HB, Certificate 9302, April 23, 2014 (ML14114A099), Page 17, "For any DSC [Dry Storage thin-wall Canister] that has been used in storage, the condition of the DSC must be evaluated, prior to transportation, to verify that the integrity of the canister is maintained."[21]

In spite of this, the NRC approved the Holtec HI-STAR 190 Transport Cask using the Holtec Safety Analysis Report as their justification.[22]

The NRC used this document to justify the August 2017 approval of the Holtec HI-STAR 190 for high burnup spent fuel. The NRC is ignoring its own safety regulations with this approval. For example:

- Inspection for canister cracks or for canister content (damaged fuel, damaged fuel baskets) is not required before transport.
    - The NRC knows there is no current technology that can inspect for cracks in canisters loaded with spent nuclear fuel, yet it approved this transport cask.
    - The NRC knows Japan abolished use of aluminum alloy fuel baskets, yet does not require inspection of Holtec aluminum alloy (Metamic) fuel baskets. Baskets are needed to prevent a nuclear criticality "accident".
    - The NRC knows high burnup fuel assemblies can degrade after dry storage, yet does not require inspection of the fuel assemblies before transport.
- Unloading the canister at the destination location or elsewhere is not part of this Safety Analysis Report (SAR). Page 1.2-12 (Pdf page 32) states: Any further operations, such as unloading fuel assemblies from the MPC [Multi-Purpose thin-wall canister] if that is required, and consideration of HBF [High Burnup Fuel] condition during unloading need to be performed under the jurisdiction of the location where the cask is unloaded, and is not part of this SAR.
- Holtec's application for the New Mexico UMAX CIS facility states if a transport cask received at the NM UMAX CIS site arrives leaking radiation they will return to sender. They claim they will never need to unload fuel from canisters. Therefore, the issue of unloading a failing canister is not addressed at either the sender or receiving site.

The NRC in this Response to Second Request for Additional Information (ML17031A363)[23] states Holtec's plan for transporting without adequate inspection for canister cracks and fuel assembly integrity is unacceptable, yet the NRC approved this transport system. It is unclear what justification was used to ignore these NRC engineers' valid concerns. Since transport casks are approved without official public comment, I was not able to address these issues in the Holtec transport approval. Hopefully, you will respond and clarify the justification for ignoring these concerns.

- Chapter 2 – Materials Evaluation, NRC RAI 2-1: Justify the adequacy of the proposed sampling process using MIL-STD-105 for reasonably demonstrating that MPCs [thin-wall canisters], with **degraded conditions exceeding surface defects equal to or greater than 2mm depth, will be identified prior to transport**.

  In response to RAI 2-8, dated April 8, 2016, the applicant stated that the MPC enclosure vessel shell shall undergo a surface defect inspection prior to shipment to ensure that existing defects and flaws do not develop into cracks during hypothetical accident conditions of transport. The

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[21] NRC Certificate of Compliance [Areva] NUHOMS-MP197HB, Certificate 9302, April 23, 2014 http://pbadupws.nrc.gov/docs/ML1411/ML14114A099.pdf

[22] Safety Analysis Report Holtec HI-STAR 190 Package (Revision 1), Holtec Report No. HI-2146214, June 8, 2017 https://www.nrc.gov/docs/ML1716/ML17166A448.pdf

[23] Response to 2nd Request for Additional Information, Holtec International, Docket No. 71-9373 HI-STAR 190 Transportation Package 2/26/2017 https://www.nrc.gov/docs/ML1703/ML17031A363.pdf

applicant further stated that this inspection may be conducted on the population of MPCs at an Independent Spent Fuel Storage Installation (ISFSI) using a statistical testing approach suggested in Military Standard MIL-STD-105E (1989) titled "Sampling Procedures and Tables for Inspection by Attributes". The applicant clarified that not every MPC at a given ISFSI requires inspection.

However, the applicant did not provide a basis for the adequacy of the proposed standard guide for reasonably demonstrating that MPCs, with degraded conditions exceeding the proposed acceptance criteria, are adequately identified prior to transport. This information is required to determine compliance with 10 CFR 71.71 and 71.73.

- **Chapter 7 – Package Operations, NRC RAI 7-1:** Revise Chapter 7, "Package Operations", of the application to clarify that the **user must confirm that the analyzed configuration of stored high burnup fuel [HBF] has been maintained throughout the renewed storage period of the MPC prior to transport** in the Model No. HI-STAR 190 package.

  The application assumes that the configuration of HBF stored in an MPC during a renewed storage period (i.e. 20-60 years) has been maintained. Although age-related degradation of the fuel is not expected to compromise the configuration of the fuel during the renewed storage period, an Aging Management Program (AMP) is expected to be in place for providing confirmation to this effect (refer to Appendices B and D in NUREG-1927, Rev. 1).

  Therefore, prior to transport in the Model No. HI-STAR 190 package, the user would be expected to confirm that the general licensee implementing the approved HBF AMP has not concluded that the analyzed configuration has been compromised during the renewed period of dry storage. This information is required to determine compliance with 10 CFR 71.55(e), 71.73 and 71.85(a).

Enclosure 2 to Holtec Letter 5024006, Response to Request for Additional Information, raises more concerns.[24]

- ***Bounding loaded weight 450,000 lbs.*** is higher than all other spent nuclear fuel assembly transport casks.
- ***NRC RAI 2-8: Regarding MPCs previously in dry storage under a 10 CFR Part 72 license:***
  1. *Revise the application to provide acceptance criteria for the MPC enclosure vessel integrity, which clearly defines allowable degraded conditions prior to transport. The acceptance criteria should demonstrate MPC containment integrity during hypothetical accident conditions.*
  2. *Discuss methods (e.g. transport inspections) used to ensure that the MPC meets the proposed acceptance criteria.*

     The application (Section 8.2.1, "Structural and Pressure Tests") states that the MPC maintenance program shall include an Aging Management Program (AMP) (under a 10 CFR Part 72 license) that verifies that the MPC pressure and/or containment boundary is free of cracks, pinholes, uncontrolled voids or other defects that could significantly reduce the effectiveness of the packaging. However, the application does not define acceptance criteria for other credible degraded conditions (e.g. loss of material due to localized corrosion pits, etching, crevice corrosion; presence of corrosion products) that ensures that cracks will not develop during transport, which could compromise the validity of the leak-tightness criterion

[24] Enclosure 2 to Holtec Letter 5024006, Response to Request for Additional Information, Holtec International, Docket No. 71-9373, HI-STAR 190 Transportation Package (ML16238A214), August 30, 2016 https://www.nrc.gov/docs/ML1623/ML16238A214.pdf

during transport. The structural evaluation of the HI-STAR 190 package does not consider potential degraded conditions of the MPC during dry storage under a Part 72 license. Therefore, the application should describe the methods used to ensure that the acceptance criteria for the MPC enclosure vessel integrity are met. This could include pre- and post transport inspections that ensure that the safety analyses remain valid and the MPC is free of cracks, pinholes, uncontrolled voids, or other defects that could compromise the enclosure vessel integrity.

The staff notes that sole reliance on a Part 72 AMP is an overly-simplistic and inadequate approach, as the AMP may identify certain aging effects that the Part 72 licensee deems acceptable for continued storage following review under its corrective action program (CAP), but which could potentially compromise the MPC containment integrity during hypothetical accident conditions (HAC). For example, the acceptance criteria in the AMP for localized corrosion and stress corrosion cracking included in Appendix B of draft NUREG-1927, Rev. 1 (ML15180A011) states that any indications of localized corrosion pits, etching, crevice corrosion, stress corrosion cracking, red-orange colored corrosion products require additional examination and disposition under the Part 72 licensee's CAP.

During the CAP review, the Part 72 licensee may use data from non-destructive examination and other analyses to support the conclusion that a given aging effect (e.g. loss of material due to localized corrosion pits, etching, crevice corrosion; presence of corrosion products) will not compromise the confinement function of the MPC for the expected loads during normal, off-normal and accident conditions of storage. Those loads, however, are not expected to be commensurate with HAC transport loads.

Therefore, reliance on a 10 CFR Part 72 AMP to assure compliance with the HI-STAR 190 structural safety analyses is inadequate.

This information is required to determine compliance with 10 CFR 71.55(e), 71.73 and 71.85(a).

Holtec Response to RAI 2-8:

We agree with staff's position regarding the need for a higher level of confidence with respect to the MPC's containment integrity under the § 71.73 free drop loading scenario than that assured by a Part 72-compliant Aging Management Plan. New Subsection 8.1.8 titled "MPC Enclosure Vessel Shell Surface Defect Inspection" has been incorporated in SAR Revision 0.C (provided with this RAI response) as a remedy to this matter with the following key commitments:

• MPC's containing high burn-up fuel and stored beyond the duration of the initial 20 year license period under the provisions of 10CFR 72 shall undergo an MPC enclosure vessel shell surface defect inspection prior to shipment to ensure that existing defects and flaws do not develop into cracks during hypothetical accident conditions of transport.

• The MPC shall be subject to an Eddy current testing (ECT) regimen that is capable of identifying any surface defect equal or greater than 2 mm deep anywhere on the external cylindrical surface of the enclosure vessel.

• This test may be conducted on the population of MPCs at an ISFSI using a statistical testing approach suggested in Military Standard MIL-STD-105E (1989) titled "Sampling Procedures and Tables for Inspection by Attributes". Not every MPC at a given ISFSI requires inspection.

• Any flaw that exceed 2 mm in depth will disqualify the canister for transport until further investigation is performed and the NRC accepts, under the exemption process or other appropriate licensing action, the owner-provided evidence that the affected canister will survive a HAC. Inasmuch as the ECT is considered the most definitive detector of cracks, pits and other types of surface flaws and is universally relied upon for detecting minute degradation in the tubing of critical nuclear plant heat transfer equipment such as Steam Generators, we propose to use this proven technology to determine the structural integrity status of the MPC's.

> **[NOTE: Eddy Current Testing is inadequate to detect or measure cracks, despite what Holtec said above.** For example, as stated in the following Parrott report:[25]
>
> *The simplest and most effective NDE technique for detecting CLSCC [chloride stress corrosion cracking] is dye penetrant testing [which cannot be done in canisters loaded with nuclear waste]. Eddy Current Testing (ECT) is effective with purpose-designed probes that have been calibrated on known defects.* ***ECT was found to be ineffective on the samples from the reactor due to limited penetration of the current and sensitivity to surface imperfections that could not be distinguished from cracking.]***

We believe the above commitments provide a robust means to ensure that only those MPCs that have a structurally competent containment boundary to meet the transport accident of §71.73 will be transported in HI-STAR 190.

See Holtec response to RAI 2-12 for additional proposed changes to Section 1.0, Subsection 1.A.3.2, Table 8.2.1, Appendix A and Table 8.A.1 regarding this inspection. In addition, Section 7.0, Subsection 7.1.2, Subsection 7.1.3, Appendix 7.B have been revised to incorporate the surface inspection as appropriate.

Recommendations

Moderate and high burnup fuels are unstable in storage and transport. The NRC has not provided sufficient operating or experimental evidence to show otherwise. And sufficient evidence exists to show high burnup fuel is not stable in storage or transport. NUREG-2224 needs to address the above issues, rather than cherry picking data to meet unsafe conclusions.

The NRC has limited resources. Instead of focusing on using them to justify high burnup storage and transport, resources need to be utilized to enforce NRC safety regulations for longer storage periods.

- This requires moving all spent nuclear fuel to thick-wall dry storage casks in a manner that the spent nuclear fuel and its containment can be maintained and monitored in a manner to prevent major leaks and explosions.
- Fuel assemblies need to cool sufficiently in the pools before being moved to dry storage, so they can be returned back to the pools, when needed and so fuel doesn't become damaged.
- The NRC needs to evaluate whether hot cells will be needed at existing sites due to risks of returning high burnup fuel back into pools.
- The NRC needs to stop approving elimination of spent fuel pools until all fuel is removed from the site, unless another mechanism is identified to inspect, repair, maintain or replace containers, fuel assemblies or fuel baskets.

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[25] Chloride stress corrosion cracking in austenitic stainless steel, Assessing susceptibility and structural integrity, UK, prepared by the Health and Safety Laboratory for the Health and Safety Executive, 2011, R. Parrott, et. al., SK17 9JN. http://www.hse.gov.uk/research/rrpdf/rr902.pdf

We're running out of time before these canisters have major leaks, explosions or criticalities. The NRC and nuclear industry have kicked these cans down the road for over 20 years, but we're getting to the end of that road. Since aging canisters have not and cannot be inspected for cracks or depth of cracks, let alone repaired, the fuse may be lit on many of these aging canisters, but we cannot see them.

Many of the Holtec UMAX canisters at San Onofre and Callaway are likely already scratched from being loaded blind in the UMAX CEC holes and being scratched against the MPC Guide ring (with only ½" clearance from the Guide ring to the canister. That means pit corrosion cracking has likely already started.

How much time do we have left before through wall cracks will occur in these canisters?

How much time do we have left before they explode?

How much time before water enters through cracks, causing criticalities?