SanOnofreSafety.org

September 20, 2016

To: Dr. Ronald Ballinger and other members of the Advisory Committee on Reactor Safeguards (ACRS)

Re: Short-Term Failure Risks of U.S. Thin-Wall Spent Fuel Storage Canisters

Thank you for your request for more information regarding the early failure of the Koeberg nuclear power plant container, considered by the NRC as comparable to U.S. thin-wall stainless steel spent fuel canisters. NRC (Darrell Dunn) reported the refueling water storage tank (RWST) at the Koeberg nuclear plant in South Africa failed after only 17 years from chloride induced stress corrosion cracking (CISCC), triggered by corrosive salt in the marine environment. Koeberg is located in a similar corrosive marine environment as San Onofre and Diablo Canyon: on-shore winds, surf and frequent fog. I've included information on Koeberg and other information regarding critical urgent problems with U.S. thin-wall stainless steel spent nuclear fuel canisters.

The Koeberg tank had cracks as deep as 0.61″. The San Onofre thin-wall stainless steel canisters are 0.625″ thick. The thin-wall stainless steel canisters at other California locations are even thinner (0.50″). Most of the over 2000 loaded canisters in the U.S. are only 0.50″ thick. Dunn and other sources state 304/316L have similar crack growth rates and all are susceptible to CISSC.

San Onofre began loading canisters in 2003. If San Onofre canisters have experience similar to Koeberg, that means a canister at San Onofre may start releasing radiation into the environment as early as 2020. Southern California Edison has no approved plan to replace failed canisters, especially if the spent fuel pools are allowed to be destroyed after emptied.

The NRC 8/5/2014 Darrell Dunn presentation stated power plant operating experience with stress corrosion cracking of stainless steel shows estimated crack growth rate of up to 0.91 mm (0.036 inch) per year for cold metal Hotter metal, such as spent fuel dry storage canisters, will have increased crack growth rate, although initiation of the crack may take longer**.** However, EPRI found a **two-year old** Diablo Canyon canister had temperatures low enough for moisture to dissolve any salts on the canister. They also found corrosive magnesium chloride salts on the canister.
https://sanonofresafety.files.wordpress.com/2011/11/diablocanyonscc-2014-10-23.pdf

See Table on Slide 9 of Darrell Dunn's 8/5/2014 slide presentation. I've included it on page 2 of this document. C*hloride-Induced Stress Corrosion Cracking Tests and Example Aging Management Program*, Darrell S. Dunn Darrell S. Dunn, NRC/NMSS/SFST Public Meeting with Nuclear Energy Institute on Chloride Induced Stress Corrosion Cracking Regulatory Issue Resolution Protocol, August 5, 2014
http://pbadupws.nrc.gov/docs/ML1425/ML14258A082.pdf

This NRC August 5, 2014 meeting summary states once a cracks starts it can grow through the wall of the canister in as little as 16 years. At this NRC meeting, the Diablo Canyon data was not available. At the time the NRC stated they thought it would take over 30 years for a crack to start, due to too high of temperatures for salts to dissolve on the canister. Now that the NRC has the Diablo Canyon data, they may want to correct this to "2 years" instead of 30.

The Koeberg tank required dye penetrant testing (PT) to reveal cracks. This cannot be done with canisters filled with spent fuel. Note: South Africa uses thick (about 14″ thick) ductile cast iron (DCI) cask storage for Koeberg spent nuclear fuel. DCI casks do not have cracking issues.

The Koeberg South Africa plant 304L stainless steel refueling water storage tank **(**RWST**)** had multiple cracks up to 15.5 mm (0.61 inch) deep within 17 years, which is deeper than the thickness of most U.S. canisters (0.61 inch vs. 0.50 to 0.625 inch thick)**.**

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)

August 5, 2014 NRC Public meeting with NEI on CISCC RIRP 9

http://pbadupws.nrc.gov/docs/ML1425/ML14258A081.pdf

A Sandia Lab Chart shows higher temperatures can cause canisters to penetrate the wall in less than 5 years. The Chart on page 46 (and included on next page of this document) assumes canister wall is 0.625″ (5/8″) thick.

The majority of the U.S. canisters are only 0.50″ (1/2″) thick. It is unknown when a crack will start, but these canisters are subject to corrosion and cracking from numerous environment conditions such as ocean salts (chlorides), air pollution (e.g., vehicle exhaust sulfides), pitting, and microscopic scratches.

> Draft *Geologic Disposal Requirements Basis for STAD Specification*, A. Ilgen, C. Bryan, and E. Hardin, Sandia National Laboratories, March 25, 2015, FCRD-NFST-2013-000723 SAND2015-2175R http://prod.sandia.gov/techlib/access-control.cgi/2015/152175r.pdf

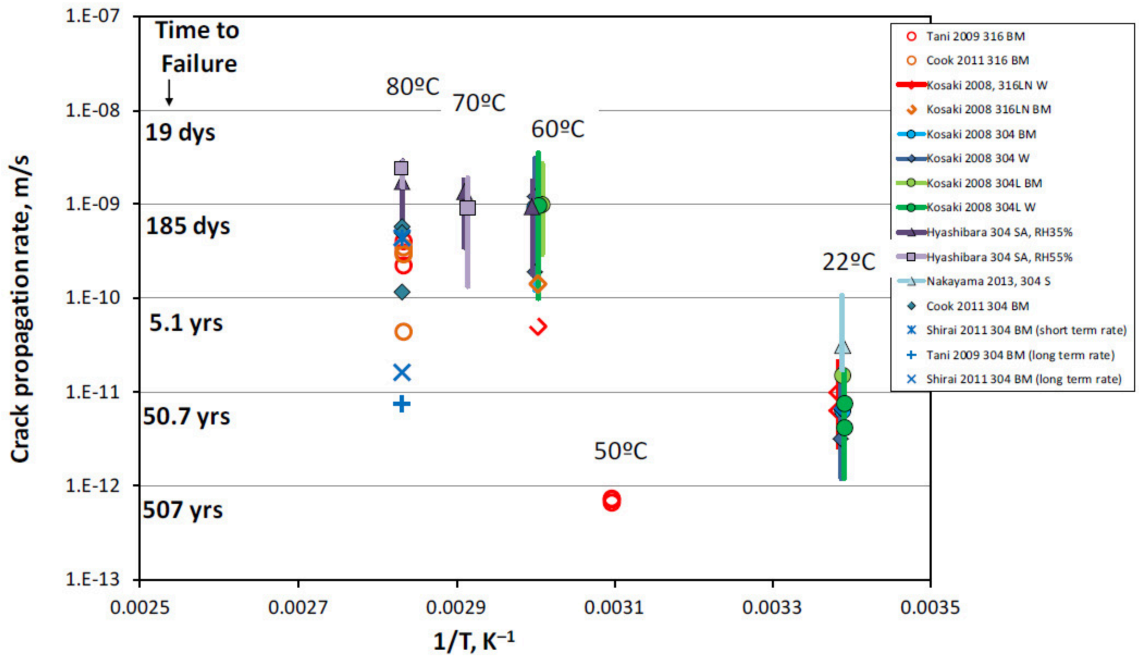

Figure E-5. SCC propagation rates for atmospheric corrosion of 304SS and 316SS. BM –base metal; W–weld sample; SA–solution annealed; S–sensitized. Bars represent reported ranges (if more than one), while symbols represent average values. Time to failure corresponds to the time required to penetrate a 0.625" thick canister wall.

Other references and related information

Regulatory Issue Resolution Protocol (RIRP) Pilot: Marine Atmosphere Stress Corrosion Cracking (SCC), Sara DePaula, Materials Engineer, NMSS/SFST, Greg Oberson, Materials Engineer, RES/DE, April 12, 2012 http://pbadupws.nrc.gov/docs/ML1212/ML12128A200.pdf

Provides multiple examples and details of Koeberg and others

Slide 20 Koeberg Units 1 and 2 (South Africa)

- Cracking in 304L piping connected to tank exposed to outdoor environment FN4
- Extensive crack networks initiating from surface pits
- Cracks in 304L PTR tanks FN5
- Primarily in areas adjacent to welds
- Fabricated to ASME Code, Section III, Subsection NC
- Water maintained between 7 and 40°C

FN4. M. van Dalen, C. Wicker, G. Wilson, "*Non Destructive Testing of Materials Subject to Atmospheric Stress Corrosion Cracking*," 17th World Conference on Nondestructive Testing, Shanghai, China, 2008.
FN5. RFI No. NUC110801/WB, Appendix 6.1, Ref. DSG-310-301, "*Technical Specification for Replacement PTR Tanks for Koeberg Nuclear Power Station*," 2001.
http://mp2mas17.eskom.co.za/tenderbulletin/details.asp?id=936 [link doesn't work]

November 14, 2012 NRC INFORMATION NOTICE 2012-20: *POTENTIAL CHLORIDE-INDUCED STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEEL AND MAINTENANCE OF DRY CASK STORAGE SYSTEM CANISTERS*
http://pbadupws.nrc.gov/docs/ML1231/ML12319A440.pdf

Pressurized Water Reactor (PWR) Systems, NRC Reactor Concepts Manual, *Pressurized Water Reactor Systems* (describes refueling water storage tanks)
http://www.nrc.gov/reading-rm/basic-ref/students/for-educators/04.pdf

Environmentally induced transgranular stress-corrosion cracking of 304Lstainless steel components at Koeberg, Basson, J.P.; Wicker, C.
https://inis.iaea.org/search/searchsinglerecord.aspx?recordsFor=SingleRecord&RN=35038747#

> Contribution of materials investigation to the resolution of problems encountered in pressurized water reactors:
> *Koeberg is a seawater-cooled, 2 x 920 MW Pressurised Water Reactor plant, with a three-loop Framatome nuclear steam supply system. Koeberg is situated 30 km North of Cape Town, South Africa, on the Atlantic coast. Koeberg have detected numerous externally initiated cracks, some through-wall, on seamed piping of safety related systems, the refuelling storage water tanks and cast valves of both units. The tanks, piping and valves are manufactured out of austenitic stainless steel grade 304L and the systems typically operate at temperatures below 50 C. Metallurgical assessment of the cracks concluded it to be transgranular stress-corrosion cracking (SCC) associated with the marine environment (chlorides), susceptible material (304L) and stresses associated with cold forming, welding and casting shrinkage. The cracking was almost exclusively initiated through surface pitting of the components. The problem presented a challenge in that a vast number of components were affected by SCC and due to the largely subsurface nature of the cracking the inspection method had to include grinding of all the pipe surfaces to allow use of dye penetrant testing (PT) to reveal cracks. This paper describes the background to the problem, the inspection method, the morphology and the recovery strategy.*

The NRC (Mark Lombard) and Southern California Edison (Tom Palmisano) referenced EPRI Report 3002002785 as justification as to why there would be no problems at San Onofre for at least 80 years. However, this report excluded the data regarding Diablo Canyon and Koeberg and excluded the San Onofre and Koeberg environment variables of on-shore winds, surf and frequent fog. See critique of the EPRI report:

> *Critique of EPRI Flaw Growth and Flaw Tolerance Assessment for Dry Cask Storage Canisters*, D. Gilmore, May 17, 2015 (EPRI ignored Koeberg and Diablo Canyon data)
> https://sanonofresafety.files.wordpress.com/2013/06/epri-critiqueandkoebergplant2015-05-17.pdf
>
> *Flaw Growth and Flaw Tolerance Assessment for Dry Cask Storage Canisters*. EPRI, Palo Alto, CA: October 14, 2014. 3002002785. *EPRI has since removed this report from their website, but I can send you a copy.*

Koeberg Tank Replacement
http://www.nnr.co.za/wp-content/uploads/2015/02/6th-CNS-National-Report-2013.pdf

> *Reactor cavity and spent fuel pit cooling system (PTR) tank replacement. These tanks, which are susceptible to through wall cracks due to stress corrosion cracking, will be replaced. In view of premature ageing of the refuelling water storage (PTR) tanks (due to atmospheric stress corrosion cracking), the NNR issued a requirement to Eskom in February 2011 to replace the tanks by no later than outages 121 and 221 (2015). In order to meet these deadlines, Eskom have indicated their intention to initiate the PTR tank replacement project. The tanks in their present state do not pose an unacceptable risk, as Eskom to date have been able to maintain their integrity with the approval of the NNR.*

*Koeberg generators, tank replacement projects still on trac*k, 5/15/2015 Engineering News, Mia Breytenbach, Creamer Media Writer
http://www.engineeringnews.co.za/article/koeberg-generators-tank-replacement-projects-still-on-track-resources-provider-2015-05-15

> [good photo]
> *PTR Tank Project Lesedi and Group Five were jointly appointed the principal contractor (PTR Tank consortium), with Areva a main subcontractor for the PTR Tank project, which entails the replacement of two large stainless steel tanks used in the cooling of the plant. The project scope includes tank design, manufacture and installation, and the decontamination and disposal of the old tanks. Lesedi and Group Five remain on track to install the first of two tanks for the project in outage KB 221, in December. The installation date of the second tank would be performed in a subsequent outage*.

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

> *The rate of crack propagation is strongly dependent on temperature but is relatively unaffected by stress intensity. Rates of CLSCC propagation can vary from 0.6mm per year at near ambient temperatures to >30mm per year at temperatures ~100° C.*
>
> The following applies to inspections in vessels and pipes, but indicates the limitations of various inspection options, even in containers without spent nuclear fuel.
>
> *…Leak detection is not a reliable indicator of CLSCC [chloride stress corrosion cracking] because cracks are highly branched and may be filled with corrosion products. Nevertheless, it is recommended that where pipework or vessels develop leaks in service, they should always be investigated for possible CLSCC by NDE non-destructive examinations] or by in-situ metallography.*
>
> *CLSCC can generate very large cracks in structures where, as in the case of reactors, the residual stress from welding dominates and operational stresses are low by comparison. If undetected by NDE, the large cracks might introduce failure modes with consequences that were not anticipated by the original design, e.g. complete*

separation of attachments, toppling of tall columns under wind loading or collapse of long pipe runs due to self-weight.
The simplest and most effective NDE technique for detecting CLSCC is dye penetrant testing. 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.

Crack sizing by eddy current testing may be limited and is not possible by penetrant testing.

Ultrasonic flaw detection can be applied as a manual or an automated NDE technique for detecting CLSCC. For structures with complex design features and welds as on the reactors, the trials indicated that ultrasonic testing would require a range of probes, several complimentary scans and be very time consuming. Ultrasonic flaw detection did not cover all design details and possible crack position orientations found on the reactor, and crack sizing was difficult.

An April 13, 2000 ACRS letter to the NRC stated spent fuel in the pool could potentially explode if exposed to air at any temperature. I would like to know if the same applies to fuel in dry storage canisters, particularly with high burnup fuel or damaged fuel. I have not been able to find any reports that address this issue. I asked at the NRC 2015 Spent Fuel Management Conference if there was information on this. I was told by the NRC that there was no one at the Conference that could answer this question. Mark Lombard was there.

Draft Final Technical Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants, Dana A. Powers, ACRS, April 13, 2000
http://pbadupws.nrc.gov/docs/ML0037/ML003704532.pdf

Since each of these canisters hold a "Chernobyl's worth or more of Cesium-137", our local communities are very concerned. Especially since we could have failed canisters and radiation leaks in as little as four years and the NRC, canister vendors and Southern California Edison have no approved plan or system in place to remediate the situation. Even the inspection plan is vaporware at this point.

The Nuclear Waste Policy Act (NWPA) requires monitored retrievable storage. The NRC has ignored these requirements with their approval of these thin-walled canisters that cannot be inspected (even on the outside), cannot be repaired or maintained, have no early warning system to prevent radiation leaks, and no plan to replace canisters or remediate fuel failures in canisters.

The thick-walled bolted-lid casks originally use in the U.S. and used extensively throughout the rest of the world do not have these limitations and do not have the cracking issues of the thin canisters.

In Japan, the Fukushima thick metal casks were inspected on the inside. TEPCO determined the aluminum alloy baskets were not likely to last 60 years, so they banned their use a few years ago. The NRC has not addressed or resolved this issue, even though U.S. canisters use aluminum alloy baskets. Given NRC's continued approval of welded lid canisters, they have in essence eliminated the ability to inspect the internals of the canisters.

In today's ACRS meeting, Mark Lombard said he was limited with what he can do by existing regulations. I am not aware of any regulation that would require him to ignore the Nuclear Waste Policy Act or that would prevent the NRC from raising NRC minimum standards based on the new requirement that spent nuclear fuel may need to remain in dry storage indefinitely. In fact, NRC Commissioners directed staff to "*encourage the adoption of state of the art technology for storage and transportation*" (*Staff Requirements – COMDEK-09-0001 – Revisiting the Paradigm for Spent Fuel Storage and Transportation Regulatory Programs*, February 18, 2010 http://pbadupws.nrc.gov/docs/ML1004/ML100491511.pdf). It states:

> *The staff should undertake a thorough review of the regulatory programs for spent fuel storage and transportation to evaluate their adequacy for ensuring safe and secure storage and transportation of spent nuclear fuel for extended periods beyond the 120 year timeframe considered up to this point. This review should include the standards, regulations, guidance, review processes, and inspection and enforcement procedures. The staff should also undertake research to bolster the technical basis of the NRC's regulatory framework to support extended periods. The review should identify risk-informed, performance-based enhancements that will bring increased predictability and efficiency to the regulatory processes, and should investigate ways to incentivize these processes to encourage the adoption of state of the art technology for storage and transportation in a risk-informed, performance-based manner. The review should be conducted in a transparent, participatory, and collaborative manner with our stakeholders.*
>
> *The review should also benefit from experience gained through the Multi-National Design Evaluation Process (MDEP) for reactors and consider opportunities for comparing and, where appropriate, harmonizing, international standards for transport packages and storage casks.*
>
> *The staff should develop a project plan for Commission approval, including objectives, plans, potential policy issues, projected schedules, performance measures, and projected resource requirements. Such a plan should leverage, as appropriate, improvement initiatives that the staff already has underway.*

Instead, the NRC has continued to reduce standards, approving storage containers that cannot be inspected, repaired, maintained or adequately monitored to prevent radiation leaks. The NRC is approving license renewals even though there is no adequate aging management technology available for these thin-walled canisters and they know they are subject to potentially short-term cracks and leaks. They also allow decommissioning plants to destroy spent fuel pools even though there is no other plan or system in place to replace failing canisters or to retrieve fuel assemblies from canisters. As long as the U.S. continue use and mismanage these inferior thin-walled canisters, the health and financial well-being of our communities and nation are at risk. Additional information is available at SanOnofreSafety.org.

Thank you for your interest in these issues.

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