EVALUATION ETE-NAF-20130072, REVISION 0

KEWAUNEE SPENT FUEL POOL ZIRCONIUM FIRE PARAMETER COMPARISON

ETE-NAF-20130072-0-0

21. *Distribution*			
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Table of Contents (Recommended for Complex ETE)

NONE

Purpose (Mandatory)

Provide Kewaunee Emergency Planning (EP) with a comparison of industry to Kewaunee zirconium fire related information to assist Kewaunee EP in relaxation of their EP program commensurate with the progressive reduction in the Kewaunee source term. *(CM-AA-ETE-101, Level 1 ETE, 2.3.i)*

Source Document (Mandatory)

A verbal request from WF Zipp, KPS Engineering Programs, to support *Reference 23* which is still a draft at this time.

Record of Revision (Mandatory for Revisions)

N/A (Original)

Cumulative Effects Review (Mandatory for existing Technical Report Addenda)

N/A (Original)

Design Inputs and Assumptions (Optional)

See Discussion

Methodology (Optional)

See Discussion

Discussion (Mandatory)

When a nuclear power plant has been permanently shutdown and the reactor core fuel has been moved to the spent fuel pool, the reactor core source term design basis accidents no longer exist. The remaining accidents are limited to the fuel in the spent fuel pool and its movement/removal. It is this remaining source term that will be addressed in this ETE. Any releases from remaining reactor coolant are bound by spent fuel pool accidents. Fixed contamination on equipment should not be of concern with respect to the public offsite.

Several nuclear power plants have been decommissioned or are in the processing of being decommissioned. In order to better regulate the decommissioning of those in the process or yet to be decommissioning, the NRC, other government facilities and industry organizations have been and are continuing to study these plants and decommissioning.

There has been much documentation on this subject, but two documents will be primarily considered:

NUREG/CR-4982 (*Ref 1*)

NUREG/CR-6451 (*Ref 6*)

Both of these NUREGs assumed that:

(1) the spent fuel pool was completely drained of water and only diabatic air cooling was available.

(2) the likelihood of clad fire initiation is most sensitive to assembly decay heat rate and assembly storage rack configuration which controls the extent of natural convection cooling.

Fuel assembly decay heat rate is dependent on assembly power during its final cycle of operation, total assembly burnup, and decay time since shutdown.

In *Table 1* below:

(1) *NUREG/CR-4982* provides information for the PWR high-density rack case with a rack bottom inlet orifice that bounds Kewaunee's rack configuration, which also happens to be the longest time to prevent clad fire initiation of all the cases analyzed.

(2) *NUREG/CR-6451* provides information for Configuration 1 "Hot Fuel in Spent Fuel Pool" which covers the period from permanent shutdown and reactor vessel defueling until the hottest assemblies are cool enough such that no substantial zircaloy oxidation occurs and cladding remains intact. At the end of Configuration 1

the decay time (that is necessary to ensure that the fuel cladding remains intact given the loss of all spent fuel pool water) is about 17 months for the representative PWR that was analyzed.

TABLE 1
Spent Fuel Pool Zirconium Fire Comparison

Parameter	*NUREG/CR-4982 1987*	*NUREG/CR-6451 1997*	*Kewaunee*
Plant Data			
Power	Typical PWR	1130 MWe (~3330 MWt*)	590 MWe (1772 MWt)
Assemblies	Typical PWR	193	121
MWt per Assembly	-	17.3	14.6
SPF Rack Design			
Design	High Density	High Density	High Density
Material	Stainless Steel	Stainless Steel	Stainless Steel
Pitch	N/A	10.4"	10"
Bottom Orifice Opening per Cell	5" diameter 10" diameter	5" diameter	8.14" equivalent diameter***
Fuel			
Design	Typical PWR	17 x 17	14 x 14
Max Assembly Burnup	High Burnup	60 GWD/MTU *Last Cycle*	55.302 GWD/MTU *Cycle 30*** 55.255 GWD/MTU *Cycle 31*** 46.219 GWD/MTU *Cycle 32***
Source Term			
Decay	700 days *(23 months)* 5" dia 360 days *(12 months)* 10" dia	17 months	< 17 months****
Zirconium Oxidation			
Ignition Temperature	650 °C	565 °C	565 °C

** Based on a 34% thermal efficiency*

*** As of end of cycle: Cycle 30 02/26/2011, Cycle 31 04/05/2012, Cycle 32 05/07/2013*

**** See Attachment A for derivation of equivalent diameter*

***** Based on above KPS rack opening & burnup parameters being bounded by associated NUREG PWR parameters.*

The key *Table 1* Kewaunee parameter is the Source Term Decay time which is the minimum decay time to prevent a zirconium/zircaloy fire given the spent fuel pool is completely drained. The NUREG table information is based upon plants undergoing decommissioning in the 1987-1997 time frame, some of which had already received NRC approval to relax their Emergency Planning (EP) programs.

Table1 shows the NUREG parameters bound the Kewaunee parameters in these areas:

- The *NUREG/CR-6451* 17.3 MWt per Assembly (3330 MWt / 193 Assemblies) is slightly larger than the Kewaunee 14.6 MWt per Assembly (1772 MWt / 121 Assemblies). Larger values mean more source term decay heat.
- Kewaunee's 8.14" equivalent rack bottom orifice opening is bracketed by the *NUREG/CR-4982* 5" and 10" and is larger than the *NUREG/CR-6451* 5". The larger the opening the more air flow cooling.
- The *NUREG/CR-6451* 60 GWD/MTU last cycle burnup is larger than the Kewaunee 46 GWD/MTU last cycle burnup.

The *NUREG/CR-4982* Source Term Decay times are 12 and 23 months (based upon rack bottom orifice openings 10" and 5", respectively) and the *NUREG/CR-6451* Source Term Decay time is 17 months (based upon 5" rack bottom orifice opening). Since the Kewaunee bounding metrics above imply lower heat rate(s) than those cited for *NUREG/CR-6451*, the Kewaunee Source Term Decay time should be less than the *NUREG/CR-6451* 17 months but it is uncertain by how much based upon this qualitative comparison.

NUREG-1738 (*Ref 8*, 2001) provides the following concerning relaxation of the EP program at decommissioning nuclear power plants:

Relaxation of offsite EP a few months after shutdown resulted in only a "small change" in risk, consistent with the guidance of RG 1.174. The change in risk due to relaxation of offsite EP is small because the overall risk is low, and because even under current EP requirements, EP was judged to have marginal impact on evacuation effectiveness in

the severe earthquakes that dominate SFP risk. All other sequences including cask drops (for which emergency planning is expected to be more effective) are too low in likelihood to have a significant impact on risk. For comparison, at operating reactors additional risk-significant accidents for which EP is expected to provide dose savings are on the order of 1e-5 per year, while for decommissioning facilities, the largest contributor for which EP would provide dose savings is about two orders of magnitude lower (cask drop sequence at 2e-7 per year).

Conclusions (Mandatory)

Table 1 compares industry and Kewaunee parameters pertinent to a zirconium/zircaloy fire in the spent fuel pool (SFP) when completely drained. Based upon an analysis of this table, a minimum decay time to prevent a zirconium/zircaloy fire with the SFP completely drained is less than 17 months. The industry data was based upon plants undergoing decommissioning, some of which have already received NRC approval to relax their Emergency Planning (EP) programs.

Precautions and Limitations (Optional)

NONE

Required Actions (Mandatory for Level 2)

NONE

Recommendations (Optional)

NONE

References (Mandatory)*(References are numbered in chronological order)*

1. **NUREG/CR-4982** “Severe Accidents in Spent Fuel Pools in Support of Generic Safety Issue 82”, 06/**1987**.
2. **KW-DWG-000-XK-03599-5** “Spent Fuel Storage Rack Bottom Grid Assembly”, Rev **5**, 02/11/**1988**.
3. **KW-DWG-000-XK-03599-8** “Spent Fuel Storage Rack Bottom Grid Details and Groups”, Rev **6**, 02/11/**1988**.
4. **KW-DWG-000-XK-03599-9** “Spent Fuel Storage Rack Bottom Grid Details”, Rev **2**, 02/11/**1988**.
5. **SECY-93-127** “Financial Protection Required of Licensees of Large Nuclear Power Plants during Decommissioning”, 05/10/**1993**.
6. **NUREG/CR-6451** “A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants”, 04/**1997**.
7. **SECY-00-145** “Integrated Rulemaking Plan for Nuclear Power Plant Decommissioning”, 06/28/**2000**.
8. **NUREG-1738** “Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants”, published 02/**2001**.
9. **SECY-01-0100** “Policy Issues Related to Safeguards, Insurance, and Emergency Preparedness Regulations at Decommissioning Nuclear Power Plants Storing Fuel in Spent Fuel Pools,” 06/04/**2001**.
10. **NRC Internal Memo** From WD Travers to Commissioners Subject: “Status of Regulatory Exemptions for Decommissioning Plants (WITS 200100085, WITS 199900133, WITS 199900072)”, 08/16/**2002**.
11. **KW-DWG-000-S-709-1** “High Density Spent Fuel Racks – Rack Assembly and Details”, Rev **C**, 08/02/**2007**.
12. **SECY-08-0036** “Denial of Two Petitions for Rulemaking Concerning the Environmental Impacts of High-Density Storage of Spent Nuclear Fuel in Spent Fuel Pools (PRM-51-10 and PRM-51-12)”, 03/07/**2008**.
13. **LC713326** “Kewaunee Power Station Applicant's Environmental Report Operating License Renewal Stage”, 08/12/**2008**. *[NRC Accession # ML082341039] (Enclosure to LC713328) (KPS 590 Gross MWe, 556 Net MWe)*
14. **LC713328** DEK Letter to NRC “Dominion Energy Kewaunee, Inc. (DEK) Kewaunee Power Station Application for Renewed Operating License”, SN 08-0462, 08/12/**2008**.
15. **KW-DWG-000-M-235** “General Arrangement Spent Fuel Pool & New Fuel Storage, Rev **N**, 06/10/**2009**.
16. **Calculation C11925** “Kewaunee Unit 1 Cycle 30 TOTE and Isotopics Calculation”, Rev **0**, Add **B**, 03/08/**2011**.
17. **Calculation C12004** “Kewaunee Cycle 32 Design Report Data”, Rev **0**, Add **N/A**, 04/09/**2012**.
18. **Calculation C11989** “Kewaunee Cycle 31 TOTE Calculations and Detailed Isotopics”, Rev **0**, Add **A**, 04/13/**2012**.

19. **GAO-12-797** "Spent Nuclear Fuel Accumulating Quantities at Commercial Reactors Present Storage and Other Challenges", 08/**2012**.
20. **KPS USAR**, Rev 24.02, updated online 04/15/**2013**.
21. **Calculation C12013** "Kewaunee Cycle 32 TOTE Calculations and Detailed Isotopics", Rev **0**, Add **B**, 05/29/**2013**.
22. **USNRC NRR Draft Report** "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor", 06/**2013**.
23. **Letter from DEK to NRC Serial No 13-xxx** "Dominion Energy Kewaunee, Inc. Kewaunee Power Station Request for Exemptions from 10 CFR 50.47 and 10 CFR 50, Appendix E", date TBD. *(Draft to date)*

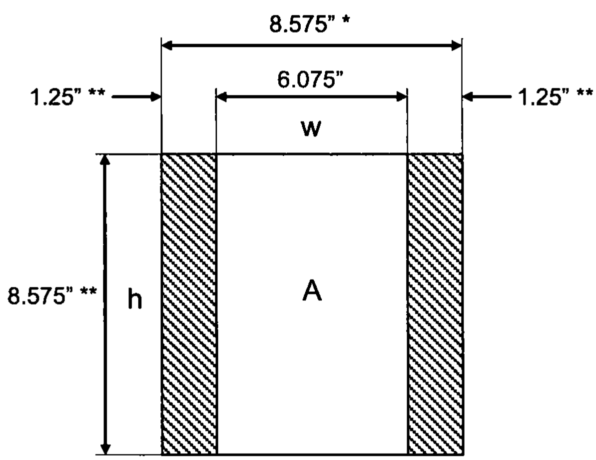
Attachment A

Kewaunee Rack Bottom Orifice Opening Equivalent Diameter

The following drawings provided information to derive the Kewaunee rack bottom orifice opening equivalent diameter:

- XK-03599-5 (*Ref 2*)
- XK-03599-8 (*Ref 3*)

Below is a simplified line drawing of a single assembly rack bottom with dimensions:



** Dwg XK-03599-5*
*** Dwg XK-03599-8*

Use the following formulas to derive the equivalent diameter for Area A above:

$A = hw = \pi\,[d/2]^2$

Solving for diameter d:

$d = 2\,[hw/\pi]^{0.5}$

Substituting for h and w from the line drawing above:

$d = 2\,[\,8.757" \times 6.075" / \pi\,]^{0.5} = 8.14"$