UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 21, 2016

Mr. Regis T. Repko
Senior Vice President
Governance, Projects and Engineering
Duke Energy Carolinas, LLC
P.O. Box 1006/EC07H
Charlotte, NC 28201-1006

SUBJECT: CATAWBA NUCLEAR STATION, UNITS 1 AND 2 (CATAWBA 1 AND 2), MCGUIRE NUCLEAR STATION, UNITS 1 AND 2 (MCGUIRE 1 AND 2), AND OCONEE NUCLEAR STATION, UNITS 1, 2, AND 3 (OCONEE 1, 2, AND 3) – PLAN FOR THE REGULATORY AUDIT REGARDING LICENSE AMENDMENT REQUEST FOR ALTERNATE FISSION GAS GAP RELEASE FRACTIONS (CAC NOS. MF6480, MF6481, MF6482, MF6483, MF6484, MF6485, AND MF6486)

Dear Mr. Repko:

By letter dated July 15, 2015 (Agencywide Documents Access and Management System Accession No. ML15196A093), Duke Energy Carolinas, LLC, license amendment requires to use a new set of fission gas gap release fractions for high burnup fuel rods that exceed the linear heat generation rate limit detailed in Regulatory Guide 1.183, Table 3, Footnote 11.

An audit of at Duke's general office was performed October 26 to October 28, 2016. The audit was conducted in accordance with NRR Office Instruction LIC-111, "Regulatory Audits." The audit was an opportunity for the NRC staff to gain understanding, verify information, and to identify information that needs to be docketed to support the basis of the NRC staff's regulatory decision. The NRC staff has completed its report of the audit and said document is enclosed with this letter. Additional information needs, if necessary, will be communicated to you by separate correspondence. If you have any questions, please call me at 301-415-2481.

Sincerely,

G. Edward Miller, Project Manager
Plant Licensing Branch II-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-413, 50-414, 50-369, 50-370, 50-269, 50-270, 50-287

Enclosure: Audit Report

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AUDIT REPORT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RADIOLOGICAL SOURCE TERM GAP FRACTIONS

MCGUIRE NUCLEAR STATION, UNITS 1 AND 2

DOCKET NOS. 50-369 AND 50-370

CATAWBA NUCLEAR STATION, UNITS 1 AND 2

DOCKET NOS. 50-413 AND 50-414

OCONEE NUCLEAR STATION, UNITS 1, 2, AND 3

DOCKET NOS, 50-269, 50-270, AND 50-287

1.0 Purpose

By letter dated July 15, 2015 (Reference 1), Duke Energy Carolinas, LLC, (Duke) submitted a license amendment request (LAR) detailing a revised alternate source term (AST) radiological source term. The revised gap fractions were necessary to address high burnup fuel rods that were projected to exceed the linear heat generation rate limit detailed in Regulatory Guide (RG) 1.183, Table 3, Footnote 11. To assist in its review, the NRC staff conducted an audit at the Duke Energy facilities in Charlotte, North Carolina on October 26 – 28, 2015. The purpose of this audit was to review the Duke engineering calculations which form the bases of the revised gap fractions. More detail is provided in the audit plan (Reference 2). Duke Energy and NRC staff which participated in the audit are listed in Table 1.

2.0 Team Assignments

Area of Review	Assigned Auditor
Audit Team Lead	Paul Clifford (NRC)
Technical Reviewer	Matthew Hardgrove (NRC)
Technical Reviewer	William MacFee (NRC)
Technical Reviewer	Josh Whitman (NRC)

Enclosure

3.0 Discussion

Section 2 of Enclosure 1 to RA-15-0013 (Ref. 1) provides the following description of the revised source terms.

> This License Amendment Request (LAR) proposes gap release fractions for high-burnup fuel rods (i.e., greater than 54 GWD/MTU) that exceed the 6.3 kW/ft LHGR limit in Footnote 11 of Table 3 in Regulatory Guide 1.183 ("Non-LOCA Fraction of Fission Product Inventory in Gap"). Footnote 11 states:
>
> > "As an alternative *[to the non-LOCA gap fractions in Table 3 and the limits of Footnote 11]*, fission gas release calculations performed using NRC-approved methodologies may be considered on a case-by-case basis. To be acceptable, these calculations must use a projected power history that will bound the limiting projected plant-specific power history for the specific fuel load."
>
> Duke Energy proposes to increase non-LOCA gap fractions for a maximum of 25 high-burnup fuel rods (i.e., greater than 54 GWD/MTU) in each fuel assembly that operates in the Catawba, McGuire and Oconee reactors. A detailed technical evaluation is provided in Section 3.1. The increases are as follows:
>
> - The values in Regulatory Guide 1.183, Table 3 will be **tripled** for 85Kr, 133Xe, 34Cs, and 137Cs.
> - The values in Regulatory Guide 1.183, Table 3 will be **doubled** for all other radioisotopes.
>
> These increased gap fractions allow LHGRs up to 7.0 kW/ft for rod burnup between 54 and 60 GWD/MTU, and 6.9 kW/ft for rod burnup between 60 and 62 GWD/MTU. Future fuel cycle designs for Catawba, McGuire and Oconee may include up to 25 fuel rods per fuel assembly operated at LHGRs up to the proposed limits.

During the audit the NRC staff reviewed Duke Energy Calculation DPC-1201.30-00-0014, "Fission Gas Release Calculation to Support Exceeding Reg. Guide 1.183 High Burnup LHR Limit," Revision 0, October 1, 2014. This engineering calculation documents the technical basis for the final gap fractions shown in the LAR. The following assumptions and bases were employed for the gap release analysis:

1. Nominal (i.e., best estimate) fuel rod design/operational input was used for the PAD and COPERNIC models.

2. The McGuire, Catawba and Oconee rod operational power histories selected for this analysis (see Table 2) bound the limiting plant-specific power histories, in accordance with Footnote 11 to Table 3 of Regulatory Guide 1.183.

3. The Regulatory Guide 1.183 Fuel Rod LHGR limit above 54 GWD/MTU burnup (i.e., 6.3 kW/ft) is associated with the heat produced in the fuel (~ 0.973 fraction of total power produced), and does not include energy deposited directly to the coolant.

4. It is sufficient to characterize the inventories of short half-life isotopes (e.g., I-131) as dependent only on instantaneous power level. Any burnup-dependent effects were deemed negligible or otherwise dispositioned.

5. For each of the McGuire, Catawba and Oconee reactors, 102% of nominal original reactor power was used as the "baseline" operating power in PAD and COPERNIC. This bounds the Measurement Uncertainty Recapture power uprates that have been or will be implemented at the sites. The 102% power corresponds to 3479 MWth for McGuire and Catawba, and 2619 MWth for Oconee.

6. For sufficient detail in the gap fraction calculations, all fuel rod evaluations were performed using 24 equally-spaced axial fuel segments and 10 (PAD) or 15 (COPERNIC) equal-volume radial rings in the fuel pellet. The ANS 5.4 [1982] standard requires at least 6 radial nodes of equal volume, while the ANS 5.4 [2011] standard requires at least 7 equal-volume radial nodes. Both standards require 10 or more axial nodes of equal length for the gap fraction computations.

7. Fuel assembly axial burnup and power data from recent core designs were employed to determine appropriate axial power shapes for the fuel performance codes.

8. Steady state reactor power operation was assumed for applicability to fuel handling accidents. No major transients are considered that could release significant quantities of volatile fission products to the fuel rod gap.

9. For each of the isotopes considered, the highest gap fraction was taken from variations on central fuel enrichment, presence or absence of integral poisons and gas release computational method (ANS 5.4 [1982] versus ANS 5.4 [2011]).

10. The TCD model in the PAD code is assumed to be valid, even though the model has not been reviewed by the NRC for the current licensed version of PAD. In Section 3.1.3, gapfrac results from the TCD cases with fuel temperatures generated by PAD were compared with those generated by COPERNIC to verify the adequacy of this assumption.

During the audit, the NRC staff requested that the licensee identify which portion of the calculations (i.e., COPERNIC, PAD4TCD, gapfrac, etc.) employed each of the above assumptions. The licensee responded all except assumptions 2, 4, 8, and 10 are directly applicable to the previously listed computer codes. The remaining assumptions/bases provide information and insight to the case setup or programming of the codes used. The source information for assumption 7 that stated the fuel assembly axial burnup and power data from recent core designs were employed to determine appropriate axial power shapes for the fuel performance codes was also determined during the audit. Lastly, the NRC staff reviewed assumption 2 in regards to a reload checklist for each plant for the power histories. The licensee responded that the power profiles shown in Table 4-1 of the main calculation were developed to bound the "limiting projected plant-specific power history for the specific fuel load" per Footnote 11 of RG 1.183. That limiting plant-specific power history is provided in the REDSAR (reload design safety analysis report) document that is prepared with each cyclical core design for McGuire, Catawba, and Oconee, and included in that calculation.

The NRC staff reviewed the calculational notes for the "gapfrac" macro source code for compliance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." The licensee stated in the calculational notes that an additional check on the validity of the gap releases computed by PAD, COPERNIC, and gapfrac were made. The results of the no-TCD PAD, which modeled the PNL-18212 (Ref. 3) report bounding PWR power profile using its ANS 5.4 [1982] gas release option, were compared with a gapfrac run that employed the no-TCD fuel temperatures. A graphical representation in the calculational notes was reviewed and displayed excellent agreement between the gas release calculations of both PAD and gapfrac for the ANS 5.4 [1982] model.

The results from the COPERNIC case, along with gapfrac, using temperatures from the COPERNIC case for HTP fuel (AREVA), and gapfrac results for RFA fuel (WEC) from the PAD case, with TCD applied, were all graphically represented in the calculational notes. There was good agreement among the different codes and fuel types for the PNNL-18212 bounding PWR power profile. The gap fractions shown in the graphic from the calculational notes also compares favorably with the FRAPCON results for the PNNL-18212 Figure 2.5 PWR power profile.

Duke performed numerous calculations encompassing a wide range of fuel rod configurations and analytical techniques. These calculations are summarized below.

Reactor	Oconee	McGuire and Catawba
Fuel Rod Design	AREVA Mark B-HTP	Westinghouse RFA
Fuel Type	UO2 and Gad	UO2 and IFBA
Power History	Bounding, See Table 2 of Ref. 1	
Fuel Performance Model	COPERNIC	PAD4TCD
ANS-5.4 Release Standard	1982 and 2011	

Results from the COPERNIC and PAD4TCD runs were entered into an EXCEL/VBA macro referred to as 'gapfrac.' This macro calculated the various radionuclide release fractions using both the 1982 and 2011 ANS-5.4 standard. During the audit, the macro was examined line-by-line and compared to the ANS-5.4 standards; no discrepancies were found. Figure 1 provides a cut/paste of the relevant sections of source code along with notes indicating the purpose of the indicated section. During the review of the source code, the NRC staff verified the modifications to diffusion coefficients for isotopes such as Iodine and Cesium. In addition, the NRC staff verified that the 95/95 recommendations of ANS 5.4 (2011) were applied.

Table 2 compiles the results of the gapfrac macro calculations and makes a comparison against the radionuclide inventories in RG 1.183. Examination of Table 2 reveals that, with the exception of Cs-134 and Cs-137, the 1982 ANS standard produces larger inventories than the 2011 ANS standard. These results are consistent with the PNNL report which implemented the latest ANS-5.4 standard. Duke Energy conservatively used the limiting results from both ANS standards. These calculations, summarized in Table 2, confirm the conservatism and adequacy of the multipliers proposed by Duke Energy.

Next, confirmatory FRAPCON 4.0 runs were conducted to provide context to the trends provided in Figures 5 and 6 in the submittal (Reference 1). Input decks were generated using the Oconee (HTP) fuel inputs and power history provided in Table 2 of Reference 1, along with default 15x15 fuel design parameters, axial power distribution (PWR MOC), and PWR coolant conditions from the FRAPCON input generator. The ANS 5.4 (2011) fission gas release model was implemented in FRAPCON 4.0 to compare trends relative to Duke calculations. ANS 5.4 (1982) was not used, as the output of FRAPCON does not list individual isotopes such as I-131 and Kr-85m for comparison. The NRC staff recognized that input differences may introduce biases in this benchmark, but overall trends should be comparable.

The results of the NRC staff's calculations revealed a problem with the ANS 5.4 (2011) model in FRAPCON 4.0. The short-lived isotopes such as Kr-85m were accumulating over the power history when the gap fraction should have moved up and down with the changing power history. After contacting RES and alerting them of the problem, a patch was sent over and the input decks were re-run using the fixed ANS 5.4 (2011) standard.

The long-lived Kr-85 gap fractions were compared between COPERNIC and FRAPCON 4.0. The COPERNIC code has an Upper-Bound model that over predicts approximately 95% of the data points used to calibrate the best-estimate code. To maintain consistency, the FRAPCON code was adjusted to obtain a 95/95 prediction in accordance with Reference 3. Examining the results of the comparison demonstrated that the COPERNIC predictions were conservative relative to FRAPCON.

Figure 2 shows the difference between the short-lived I-131 release-to-birth ratio (R/B) predicted by the 'gapfrac' macro and FRAPCON 4.0. A multiplier of 5.0 was consistently applied to the COPERNIC and FRAPCON Kr-85m R/B predictions in accordance with the ANS-5.4 (2011) standard. Examination of Figure 2 reveals similar trends in predicted R/B for the short-lived I-131 isotope.

The NRC staff's independent FRAPCON 4.0 calculations provide assurance that the Duke Energy proposed multipliers on the RG 1.183 gap fractions are conservative and appropriate.

Several years ago, the NRC staff proposed a revision to RG 1.183 Table 3, "Non-LOCA Fraction of Fission Product Inventory in Gap." The proposed revision was in response to several AST LARs which were unable to satisfy the applicability limit in Footnote 11 and a request by the Boiling Water Reactor Owners Group (BWROG) to expand the allowable rod power operating history. The technical basis of the revised Table 3 gap fractions is documented in Reference 3. This proposed revision is currently identified as Draft Guide 1199 (DG-1199).

Table 3 provides a comparison of the original and revised gap fractions along with the Duke proposal. Figure 3 provides a comparison of the rod power histories used to develop the different gap fractions. Application of the 2011 ANS-5.4 standard provides significant benefit (i.e., lower R/B) for the short-lived isotopes for a given rod power history. For setting the power history envelope of Reference 3, the NRC staff elected to expand the rod power history until the target 8.0% I-131 was achieved. Hence, using the beneficial reduction in short-lived isotope releases afforded by the ANS-5.4 (2011) standard. The result is an expanded operating domain relative to Footnote 11 in RG 1.183 Revision 0.

For each radionuclide, Duke Energy has elected to select the larger value calculated using ANS-5.4 (1982) and ANS-5.4 (2011). This approach is clearly conservative. Examination of Figure 3 reveals that the Duke Energy allowable rod power history is much more benign than the rod power envelope in Reference 3. Yet, the predicted I-131 is twice as large (2x multiplier on 8.0%). This is attributed to the differences between ANS-5.4 (1982) and ANS-5.4 (2011). For the long-lived isotopes (Kr-85 and Cesium), the Duke Energy proposed gap fractions are smaller than those in the bounding case of Reference 3. This is directly related to the more restrictive rod power envelope.

Comparison to prior FRAPCON 3.4 calculations (Reference 3) provides assurance that the Duke Energy proposed multipliers on the RG 1.183 gap fractions are conservative and appropriate.

4.0 Conclusion

During the audit, the NRC staff reviewed the underlying Duke Energy engineering calculations, performed independent FRAPCON 4.0 calculations, and compared results to previous FRAPCON 3.4 calculations (Reference 3). The analytical technique, inputs, and assumptions used in the Duke Energy calculations were found to be conservative, appropriate, and consistent with both ANS-5.4 (1982) and ANS-5.4 (2011). Based upon this audit, the proposed multipliers on the RG 1.183 gap inventories is acceptable.

Table 1: List of Attendees

Name	**Affiliation**	**Contact Number**	**E-mail**
Jordan Vaughan	Duke	704-382-1117	Jordan.Vaughan@duke-energy.com
Joe Coletta	Duke	704-382-7985	Joe.Coletta@duke-energy.com
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William MacFee	NRC	301-415-1326	William.MacFee@nrc.gov
Chris Nolan	Duke	704-382-7426	Chris.Nolan@duke-energy.com
Geoff Pihl	Duke	704-382-6810	Geoff.Pihl@duke-energy.com
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Art Zaremba	Duke	980-373-2062	Arthur.Zaremba@duke-energy.com
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David Culp	Duke	704-382-8833	David.Culp@duke-energy.com
Leo Martin	Duke	980-373-9364	Leo.Martin@duke-energy.com

Table 2: Comparison of Duke Gap Fractions

Isotope / Group	RG 1.183 Rev.0	ANS 5.4 1982 Predictions*	ANS 5.4 2011 Predictions*	Maximum Ratio	Bounding Multiplier
Long-Lived Isotopes (> 1 year half-life)					
Kr-85	0.10	0.224	0.2016	2.24	**3.0**
Cs-134	0.12	0.237	0.285	2.38	**3.0**
Cs-137	0.12	0.249	0.285	2.38	**3.0**
Short-Lived Isotopes (< 1 year half-life)					
I-131	0.08	0.159	0.009	1.99	2.0
Other Halogens					
I-130	0.05	0.055	0.004	1.10	2.0
1-132	0.05	0.025	0.010	0.50	2.0
1-133	0.05	0.070	0.005	1.40	2.0
I-134	0.05	0.016	0.003	0.32	2.0
I-135	0.05	0.041	0.004	0.82	2.0
Br-83	0.05	0.026	0.002	0.52	2.0
Br-85	0.05	0.004	0.001	0.08	2.0
Br-87	0.05	0.002	0.001	0.01	2.0
Other Nobles					
Kr-83m	0.05	0.009	0.002	0.18	2.0
Kr-85m	0.05	0.014	0.004	0.28	2.0
Kr-87	0.05	0.007	0.002	0.14	2.0
Kr-88	0.05	0.011	0.003	0.22	2.0
Kr-89	0.05	0.001	0.001	0.02	2.0
Xe-131m	0.05	0.092	0.010	1.84	2.0
Xe-133m	0.05	0.044	0.006	0.88	2.0
Xe-133	0.05	0.130	0.008	2.60	**3.0**
Xe-135m	0.05	0.003	0.003	0.06	2.0
Xe-135	0.05	0.060	0.005	1.20	2.0
Xe-137	0.05	0.002	0.001	0.04	2.0
Xe-138	0.05	0.003	0.001	0.06	2.0
Alkali Metals					
Rb-86	0.12	0.140	0.011	1.17	2.0
Rb-88	0.12	0.005	0.001	0.04	2.0
Rb-89	0.12	0.005	0.001	0.04	2.0
Rb-90	0.12	0.002	0.001	0.02	2.0
Cs-136	0.12	0.124	0.014	1.03	2.0
Cs-138	0.12	0.007	0.001	0.06	2.0
Cs-139	0.12	0.004	0.001	0.03	2.0

* Maximum calculated long-lived gap fraction or short-lived R/B between COPERNIC (Oconee) and PAD4TCD (Catawba).

Table 3: Comparison of Gap Fractions

Isotope / Group	RG 1.183 Rev.0	RG 1.183 Rev.1	Duke Proposal
I-131	0.08	0.08	0.16
I-132	0.05	0.09	0.10
Kr-85	0.10	0.38	0.30
Other Noble Gases	0.05	0.08	0.10
Other Halogens	0.05	0.05	0.10
Alkali Metals	0.12	0.50	0.36

Figure 1: Duke Energy 'gapfrac' Macro

```
'big loop to calculate all gap releases at each time step
For igstep = 1 To istepmax
rdelt(igstep) = Sheets("input_burn").Cells(igstep + 1, 3)
rbustep(igstep) = Sheets("input_burn").Cells(igstep + 1,
delbu = rbustep(igstep) - rbustep(igstep - 1)
rsppwr = delbu / rdelt(igstep) * 3600 * 24 'specific powe
(MW/MTU)
rkwft = rsppwr * fload / nrods / fstack 'rod tot kw/ft
Cells(igstep + 5, 1) = igstep
Sheets("fgr_1982_lo").Cells(igstep + 5, 1) = igstep
Sheets("fgr_2011").Cells(igstep + 5, 1) = igstep
Cells(igstep + 5, 2) = rkwft
Sheets("fgr_1982_lo").Cells(igstep + 5, 2) = rkwft
Sheets("fgr_2011").Cells(igstep + 5, 2) = rkwft
Cells(igstep + 5, 3) = rbustep(igstep)
Sheets("fgr_1982_lo").Cells(igstep + 5, 3) = rbustep(igstep)
Sheets("fgr_2011").Cells(igstep + 5, 3) = rbustep(igstep)
For ii = 1 To iaxmax
bum(ii) = 0#
For jj = 1 To iradmax
bum(ii) = bum(ii) + rbu(ii, jj, igstep) 'calc avg bu in axial node for ans
5.4(2011) calcs
For kk = 1 To igstep
For mm = 1 To 3
rtau(ii, jj, kk, mm) = 0# 'need to re-zero rtau array e
Next mm
Next kk
Next jj
bum(ii) = bum(ii) / iradmax
Next ii
For mm = 1 To 3
rfrac(mm) = 0#
rprodtot(mm) = 0#
Next mm
For nn = 1 To 28
rfracsh(nn) = 0#
roverbsh(nn) = 0#
Next nn
rpowtot = 0#
For ii = 1 To iaxmax
For jj = 1 To iradmax
If igstep = 1 Then
rbubeg = 0#
Else
rbubeg = rbu(ii, jj, igstep - 1)
End If
rbuend = rbu(ii, jj, igstep)
rbumid = (rbuend + rbubeg) / 2
rprate(ii, jj, igstep) = (rbuend - rbubeg) / rdelt(igstep) 'power in node
during time step
```

This section begins the timestep loop.
Average power during the time step is calculated based on burnup

This simply copies some input parameters into the output of the macro for ease of plotting

This loop calculates the average burnup across radial nodes for each axial node.

This axial section calculates a power for each and radial node. This is used as a weighting factor later, as ANS5.4 1982 prescribes release fractions.

```
rpowtot = rpowtot + vfrac(ii) * rprate(ii, jj, igstep)
rdprime(ii, jj, igstep) = 0.61 * (Exp(-72300 / (1.987 *
((rtemp(ii, jj, igstep) - 32) / 1.8 + 273.15)))) * (100
rdprimesh(ii, jj, igstep) = 0.61 * (Exp(-72300 / (1.987
((rtemp(ii, jj, igstep) - 32) / 1.8 + 273.15)))) * (100
igstep) / 28000))
rfdenom = 0#
bub = rbubeg / 1000000# 'bu values in TWD/MTU (for good
bue = rbuend / 1000000#
bux = rbumid / 1000000#
'do ans 5.4(1982) high-temp long-lived calcs for kr-85, cs-134, and cs-137
For mm = 1 To 3
ploc = (mm - 1) * 4
If igstep = 1 Then 'fprodb,fgrode,fgrodx--> inventory at begin,end,middle of
time step igstep
fprodb = 0# 'no inventory at 0 bu
Else
fprodb = prodx(ploc + 1) + prodx(ploc + 2) * bub + prc
+ prodx(ploc + 4) * bub ^ 3
End If
fprode = prodx(ploc + 1) + prodx(ploc + 2) * bue + prodx(ploc + 3) * bue ^ 2
+ prodx(ploc + 4) * bue ^ 3
fprodx = prodx(ploc + 1) + prodx(ploc + 2) * bux + prodx(ploc + 3) * bux ^ 2
+ prodx(ploc + 4) * bux ^ 3
rfdenom = 0#
fprate(ii, jj, igstep, mm) = (fprode - fprodb) / rdelt(igstep) 'production
rate during timestep
rfnumer(mm) = 0#
For kk = 1 To igstep
For nn = kk To igstep
rtau(ii, jj, kk, mm) = rtau(ii, jj, kk, mm) + rdpri
* diffs(mm)
Next nn
If rtau(ii, jj, kk, mm) < 0.1 Then
rgtau(ii, jj, kk, mm) = 1 - 4 * (rtau(ii, jj, kk, mm) / rpival) ^ 0.5 + _
3 * rtau(ii, jj, kk, mm) / 2
Else
rgtau(ii, jj, kk, mm) = 1 / (15 * rtau(ii, jj, kk, mm)) - (6 / rtau(ii, jj,
kk, mm)) _
* (Exp(-1 * rpival ^ 2 * rtau(ii, jj, kk, mm)) / rpival ^ 4 + _
Exp(-4 * rpival ^ 2 * rtau(ii, jj, kk, mm)) / (16 * rpival ^ 4) + _
Exp(-9 * rpival ^ 2 * rtau(ii, jj, kk, mm)) / (81 * rpival ^ 4))
End If
Next kk
For kk = 1 To igstep
If kk = igstep Then
```

Rdprime is the calculated value of D' from Eq 2. (1982 standard) from the midpoint of the burnup step. Rdprimesh is from the end of the burnup step.

This calculates inventory in each node to allow for weighting the gas release fractions

rtau is the tau_i Eq. 2
rgtau is the $g_i=g(tau_i)$ from Eq. 2

```
rfnumer(mm) = rfnumer(mm) + fprate(ii, jj, kk, mm) * rdelt(kk) * rgtau(ii,
jj, kk, mm)
Else
rfnumer(mm) = rfnumer(mm) + fprate(ii, jj, kk, mm) * (rtau(ii, jj, kk, mm) *
rgtau(ii, jj, kk, mm) _
- rtau(ii, jj, kk + 1, mm) * rgtau(ii, jj, kk + 1, mm))
kk) * diffs(mm))
```

This creates the sums from the F_k = 1-{ ...} portion of Eq. 2.
rfterm is F_k

```
End If
rfdenom = rfdenom + fprate(ii, jj, kk, mm) * rdelt(kk)
Next kk
rfterm(ii, jj, igstep, mm) = 1 - rfnumer(mm) / rfdenom
rfrac(mm) = rfrac(mm) + vfrac(ii) * fprodx * rfterm(ii, jj, igstep, mm)
'weight the nodal gap frac by inventory
rprodtot(mm) = rprodtot(mm) + vfrac(ii) * fprodx
produced in rod
Next mm
'next, calculate all ans 5.4 (1982) short-lived (
releases at each time step
For nn = 1 To 28
rmu = rdecay(nn) / (rdprimesh(ii, jj, igstep) * diffp(nn))
rsqrt = rmu ^ 0.5
If rsqrt > 20 Then 'coth(rsqrt) essentially=1 when rsqrt>20
rfracs = 3 * (1 / rsqrt - 1 / rmu)
Else 'use exponential form of coth function (no explic
rfracs = 3 * ((Exp(rsqrt) + Exp(-1 * rsqrt)) / (Exp(rs
_
/ rsqrt - 1 / rmu)
End If
rfracsh(nn) = rfracsh(nn) + vfrac(ii) * rfracs * rprat
Next nn
'finally, do ans 5.4(2011) short-lived (< 1-yr half life) calculations
...
End Sub
```

Vfrac and fprodx are weighting factors to account for total production in the node and annular pellets in the blanket region.

This section implements Eq. 5 from the 1982 ANS 5.4 standard. The strange math is a workaround for shortcomings in the VBA math functions.

The last section of the code deals with the 2011 standard and is addressed elsewhere in the audit report.

Figure 2: I-131 Gap Fraction Comparison, FRAPCON 4.0 versus "gapfrac" macro

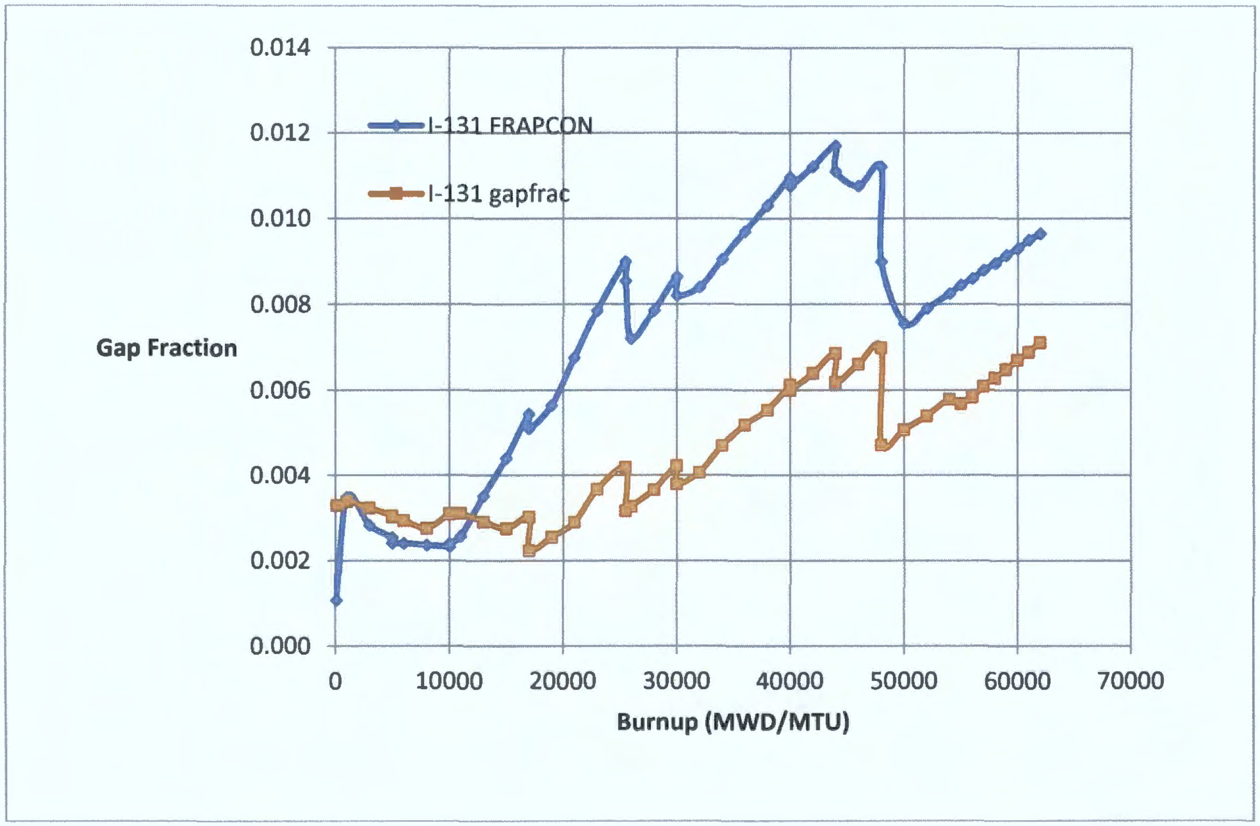
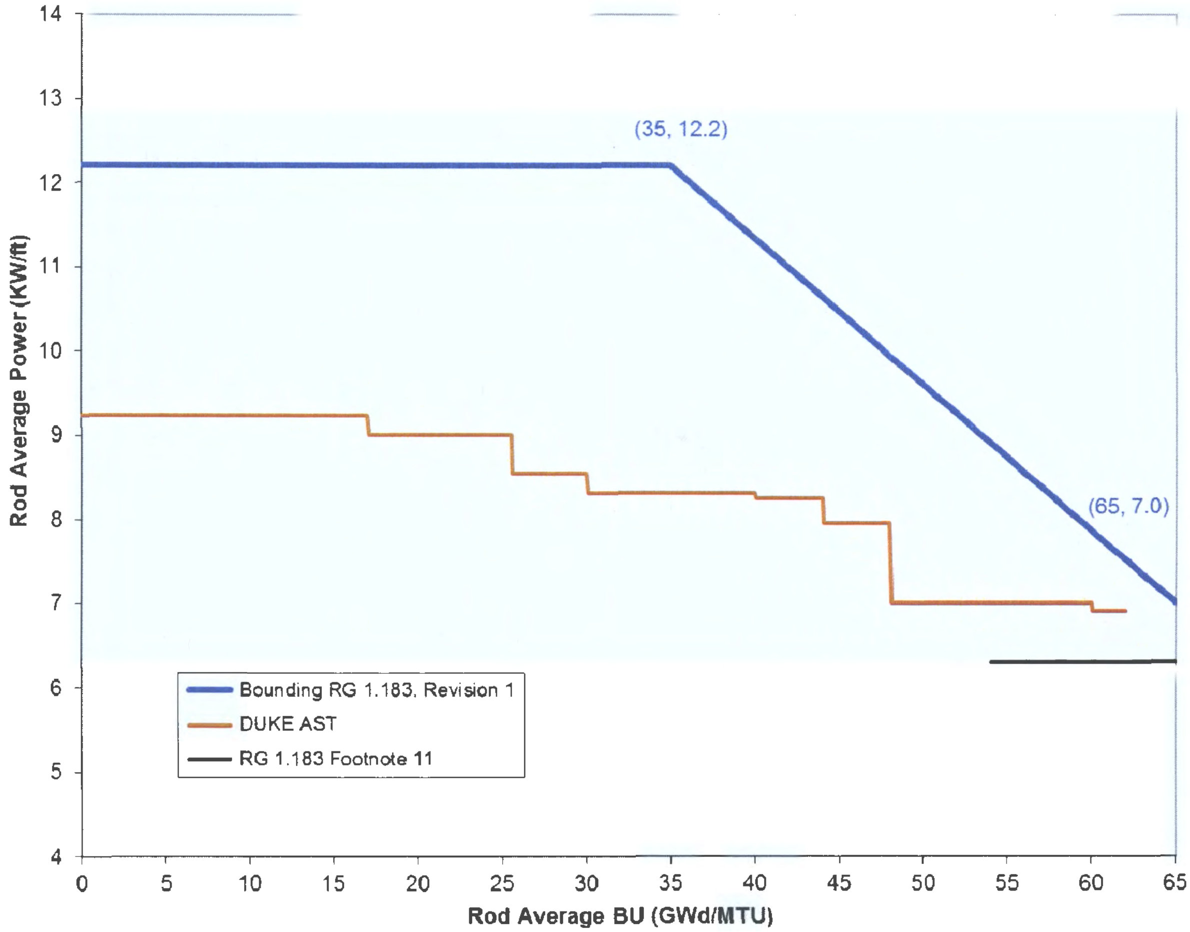


Figure 3: Comparison of Rod Power Histories



References:

1. Duke LAR, "License Amendment Request Proposing a New Set of Fission Gas Gap Release Fractions for High Burnup Fuel Rods that Exceed the Linear Heat Generation Rate Limit Detailed in Regulatory Guide 1.183, Table 3, Footnote 11," RA-15-0013, July 15, 2015 (ADAMS Accession No. ML15196A093).

2. NRC Letter, "Catawba Nuclear Station, Units 1 and 2 (Catawba 1 and 2), McGuire Nuclear Station, Units 1 and 2 (McGuire 1 and 2), and Oconee Nuclear Station, Units 1, 2, and 3 (Oconee 1, 2, and 3) – Plan for the Regulatory Audit Regarding License Amendment Request for Alternate Fission Gas Gap Release Fractions," October 22, 2015 ADAMS Accession No. ML15281A293).

3. PNNL Report PNNL-18212, Revision 1, "Update to Gap Release Fractions for Non-LOCA Events Utilizing the Revised ANS 5.4 Standard," June 2011 (ADAMS Accession No. ML112070118)

March 21, 2016

Mr. Regis T. Repko
Senior Vice President
Governance, Projects and Engineering
Duke Energy Carolinas, LLC
P.O. Box 1006/ECO7H
Charlotte, NC 28201-1006

SUBJECT: CATAWBA NUCLEAR STATION, UNITS 1 AND 2 (CATAWBA 1 AND 2), MCGUIRE NUCLEAR STATION, UNITS 1 AND 2 (MCGUIRE 1 AND 2), AND OCONEE NUCLEAR STATION, UNITS 1, 2, AND 3 (OCONEE 1, 2, AND 3) – PLAN FOR THE REGULATORY AUDIT REGARDING LICENSE AMENDMENT REQUEST FOR ALTERNATE FISSION GAS GAP RELEASE FRACTIONS (CAC NOS. MF6480, MF6481, MF6482, MF6483, MF6484, MF6485, AND MF6486)

Dear Mr. Repko:

By letter dated July 15, 2015 (Agencywide Documents Access and Management System Accession No. ML15196A093), Duke Energy Carolinas, LLC, license amendment request to use a new set of fission gas gap release fractions for high burnup fuel rods that exceed the linear heat generation rate limit detailed in Regulatory Guide 1.183, Table 3, Footnote 11.

An audit at Duke's general office was performed October 26 to October 28, 2016. The audit was conducted in accordance with NRR Office Instruction LIC-111, "Regulatory Audits." The audit was an opportunity for the NRC staff to gain understanding, verify information, and to identify information that needs to be docketed to support the basis of the NRC staff's regulatory decision. The NRC staff has completed its report of the audit and said document is enclosed with this letter. Additional information needs, if necessary, will be communicated to you by separate correspondence. If you have any questions, please call me at 301-415-2481.

Sincerely,
/RA/
G. Edward Miller, Project Manager
Plant Licensing Branch II-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-413, 50-414, 50-369, 50-370, 50-269, 50-270, 50-287

Enclosure: Audit Report

cc w/encl: Distribution via Listserv

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ADAMS Accession No. ML16067A291 ***Via email**

OFFICE	DORL/LPL2-1/PM	DORL/LPL2-1/LA	DSS/SRXB/BC	DSS/SNPB/BC	DORL/LPL2-1/BC
NAME	GEMiller	SFigueroa	EOesterle*	JDean*	MMarkley (SWilliams for)
DATE	03/15/16	03/10/16	03/15/16	03/15/16	03/21/16

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