U.S.NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

Regulatory Framework Applicability Assessment

and Licensing Pathway Diagram

for the Licensing of ATF-Concept, Higher Burnup,

and Increased Enrichment Fuels

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Regulatory Framework Applicability Assessment and Licensing Pathway Diagram for the Licensing of ATF-Concept, Higher Burnup, and Increased Enrichment Fuels

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1. Background

In preparation for forthcoming submittals of topical reports (TRs) and license amendment requests (LARs) from vendors and licensees requesting the approval of near-term ATF concept, higher burnup, and increased enrichment fuels, the staff performed an assessment of the applicability of existing regulations and guidance for the licensing of these fuel types. Near-term ATF concepts are those for which the agency can largely rely on existing data, models, and methods for its safety evaluations. Coated cladding and doped UO_2 pellets are the current near-term ATF concepts. This document contains the results of this assessment, referred to as the Regulatory Framework Applicability Assessment (RFAA), as shown in Table 2-1, below. The U.S. Nuclear Regulatory Commission (NRC) staff does not consider the RFAA table to be exhaustive and will update it, as necessary, as more information is developed.

In conjunction with the RFAA table, the NRC staff has developed a licensing pathway diagram that provides a potential approach to licensing these fuel types.

2. Regulatory Framework Applicability Assessment

As stated in Section 1, the NRC staff determined the applicability of existing regulations and guidance for near-term ATF concept, higher burnup, and increased enrichment fuels. The NRC staff assessed each regulation and guidance document listed in the table for whether it was fully applicable to ATF, higher burnup, and increased enrichment fuels. If the NRC staff determined that a regulation or guidance did not account for a particular phenomenon, the RFAA table identifies this fact and provides an explanation for the determination. In the RFAA table, a regulation or guidance document that is listed as not being not fully applicable means that the staff foresees potential hurdles if the regulation or guidance is applied to a particular concept in the table. For example, some guidance may not address phenomena unique to high burnup, increased enrichment, or near-term ATF concept fuels and some regulations or guidance have stated limits of applicability that would be challenged if the regulation or guidance were used for these concepts. In some instances, the applicability of the regulation or guidance document is irrelevant because other regulations or guidance replace or supersede it. In other instances, other regulations and guidance documents do not supersede the relevant regulation or guidance document but the efficiency of the NRC's review does not depend on the evaluated regulation or guidance document being fully applicable. For some cases where the regulation or guidance document is not fully applicable, but full applicability will increase NRC review efficiency, the NRC staff has already discussed the matter in public meetings and has determined a path towards achieving full applicability. In those cases, the RFAA table will state the relevant closure path. In other cases, a closure path has not yet been determined upon and the table will indicate as such. The RFAA table also makes note of some information an applicant could consider to ensure they correctly apply the regulation or guidance while developing a submittal. Finally, the NRC staff notes that the RFAA table is provided for informational purposes only. The RFAA table is intended to inform discussions at meetings between the NRC, industry, and the public. The results of the staff's assessment do not supersede any regulations or guidance and the information presented in the table should not be interpreted as new regulatory requirements or guidance.

<u>Table 2-1 Key</u>
Green: actions for NRC
Fully applicable: the document can be applied to the concept
Not fully applicable: the staff foresees potential hurdles if the document or parts of the document in its current form are applied to the concept, reasons for which are detailed. Staff may recommend changes to the document or supplemental information to justify the use of the document with a particular concept the concept.
Priority: items listed as "high priority; near-term" are items the NRC staff is currently working on and are estimated to be completed within a 1.5-2-year timeframe. The NRC staff estimates that actions listed as "medium priority; medium-term" will be completed within a 5-year timeframe and that actions listed as "low priority; long-term" will take longer than 5 years to complete.
AST: alternate source term
B&W: Babcock and Wilcox
BU: burnup
CATEX: categorical exclusion
CE: Combustion Engineering
GE: General Electric
EA: environmental assessment
FFRD: fuel fragmentation, relocation, and dispersal
FGR: fission gas release
GWd/MTU: gigawatt day per metric ton of uranium
HBU: higher burnup (i.e., burnup that exceeds current licensing limits of 62 GWd/MTU. In this document two proposed burnup limits above 62 GWd/MTU are examined, 68 and 75 GWd/MTU)
LAR: license amendment request
LOCA: loss of coolant accident
MHA: maximum hypothetical accident
RES: the NRC's Office of Research
RG: regulatory guide
RIA: reactivity-initiated accident
RIL: research information letter
RXA: recrystallized annealed
SRP: NRC standard review plan
STS: standard technical specifications
TS: technical specifications
Wt%: weight-percent

Table 2-1: Regulatory Framework Applicability Assessment

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
1	RG 1.183ASTs for Evaluating Design Basis Accidents at Nuclear Power Reactors Draft Revision 1 (ML21204A065) Analytical guidance for predicting dose	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
2	RG 1.183ASTs for Evaluating Design Basis Accidents at Nuclear Power Reactors Draft Revision 1 (ML21204A065) MHA/LOCA source terms	• Not fully applicable • Reason: Fragmentation-induced FGR of high burnup fuel pellets may change MHA/LOCA source term and timing of releases Closure: Informal assistance request to RES addresses this (available in ADAMS at accession number ML21197A062); insights from this informal assistance request to be	• Not fully applicable • Reason: SAND-2011-0128 is not validated to 75 GWd/MTU Closure: Re-analysis of SAND-2011-0128 to higher BU is being conducted by RES and Sandia National Laboratory through 75 GWd/MTU Priority: High; near-term • Reason: Fragmentation-induced FGR of high burnup fuel pellets may change MHA/LOCA source	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		incorporated in RG 1.183 Rev. 1 Priority: High; near-term	term and timing of releases Closure: Informal assistance request to RES addresses this (available in ADAMS at accession number ML21197A062); insights from this informal assistance request to be incorporated in RG 1.183 Rev. 1 Priority: High; near-term			
3	RG 1.183 ASTs for Evaluating Design Basis Accidents at Nuclear Power Reactors Draft Revision 1 (ML21204A065) Non-LOCA steady-state and transient releases	• Not fully applicable • Reason: Fragmentation-induced FGR of high burnup fuel pellets may change non-LOCA steady state and transient source term Closure: Revision 1 of RG 1.183 will address this. Priority: High; near-term	• Not fully applicable • Analytical procedure remains applicable • Tables 3 and 4 not applicable • Note: The FAST (Fuel Analysis under Steady-state and Transients) code is not validated up to 75 GWd/MTU. RES is working on the validation of FAST models to higher burnup. A data needs report has been issued from RES to examine what specifically is needed to expand	• Analytical procedure remains applicable • Table 3 remains applicable • Note: With respect to Table 4, extent of ^{235}U enrichment in RIA empirical database unknown. Analytical procedure can be used in lieu of Table 4.	• Fully applicable • No data gaps	• Not fully applicable • Analytical procedure remains applicable • Tables 3 and 4 not applicable • Note: FAST is not validated for doped fuel. RES is working on validation of FAST models to doped fuel. A data needs report has been issued from RES to examine what specifically is needed to expand

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
			the FAST capabilities to 75 GWd/MTU • Reason: Fragmentation-induced FGR of high burnup fuel pellets may change source term Closure: Revision 1 of RG 1.183 will address this. Priority: High; near-term • Reason: RIA transient FGR is not currently well quantified up to 75 GWd/MTU • Closure: RIA transient FGR data may be helpful for quantifying HBU FGR			the FAST capabilities to doped pellets • Reason: RIA transient FGR for doped fuel has not been well quantified Closure: RIA transient FGR data for doped fuel are likely necessary

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
4	RG 1.195 Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Power Reactors (ML03490640) Release fractions from TID-14844	• Not fully applicable • Reason: Validated only up to 62 GWd/MTU for non-LOCA accidents Closure: No closure necessary. HBU release fractions and source term to be addressed by RG 1.183 Rev. 1.	• Not fully applicable • Reason: Validated only up to 62 GWd/MTU for non-LOCA accidents Closure: No closure necessary. HBU release fractions and source term to be addressed by RG 1.183 Rev. 1.	• Fully applicable • No data gaps	• Not fully applicable • Reason: Non-LOCA accident release fractions are not validated for rods with coated cladding Closure: No closure necessary. Analytical procedure outlined in RG 1.183 Rev. 1 can be applied to coated cladding.	• Not fully applicable • Reason: Non-LOCA accident release fractions are not validated for doped fuel pellets Closure: No closure necessary. Analytical procedure outlined in RG 1.183 Rev. 1 can be applied to doped fuel.
5	RG 1.236 PWR Control Rod Ejection and BWR Control Rod Drop Accidents (ADAMS Accession No. ML20055F490)	• Fully applicable • No data gaps	• Not fully applicable • Note: Empirical database limited beyond 68 GWd/MTU. • Reason: FFRD as a result of HBU and possible loss of coolable geometry during RIA has not been well quantified or understood Closure: RIA data on HBU fuel rod segments with deposited energy beyond predicted cladding damage	• Not fully applicable • Reason: Stated applicability limited to 5.0 wt%. Increased enrichment could potentially lead to higher rod worth and peaking factors Closure: RIA experimental data for fuel with increased enrichment may be helpful to demonstrate the	• Not fully applicable • Reason: Stated applicability is limited to current LWR fuel rod designs Closure: Thin coating not expected to significantly alter fuel rod response. Cladding failure thresholds and damaged core coolability limits remain applicable. • No data gaps	• Not fully applicable • Reason: Stated applicability is limited to current LWR fuel rod designs and doped fuel RIA performance has not been well quantified. Closure: Data for irradiated, doped UO_2 fuel pellets and integral fuel burnable absorber fuel pellets may be helpful to better

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			may be helpful to investigate FFRD and loss of coolable geometry. Ideally, these data would also include transient FGR. • Reason: HBU effects on RIA not well quantified. HBU cladding failure thresholds should be defined. Closure: RIA data on HBU fuel rod segments, especially RXA cladding, with low corrosion may be helpful to better understand burnup-effects and define cladding failure thresholds.	RG 1.236 limits remain applicable • Note: Extent of ^{235}U enrichment in RIA empirical database unknown.	• Note: Guidance states that coated claddings will be addressed on a case-by-case basis	understand impact of additive agents (e.g., larger grain size, retained fission gas, grain boundary hold-up, thermal conductivity) on cladding failure thresholds, FFRD, transient FGR, and coolable geometry. • Note: Guidance states that doped pellets will be addressed on a case-by-case basis.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
6	10 CFR 50.46 LOCA Prescriptive Analytical Requirements	• Fully applicable • Note: 50.46 does not address recent HBU LOCA findings documented in NUREG/CR-7219. 50.46c rulemaking is being conducted to address HBU phenomena in the regulations. Ideally, industry submittals should discuss the recent LOCA findings in NUREG/CR-7219.	• Fully applicable • Note: 50.46 does not address recent HBU LOCA findings documented in NUREG/CR-7219. 50.46c rulemaking is being conducted to address HBU phenomena in the regulations. Ideally, industry submittals should discuss the recent LOCA findings per NUREG/CR-7219.	• Fully applicable • No data gaps	• Not fully applicable • Reason: 50.46(a)(1)(i) only speaks to zircaloy and ZIRLO cladded fuel. Closure: An applicant will need to meet the analytical requirements. Exemption requests may have to be submitted. Refer to coated cladding interim staff guidance (ML19343A121).	• Fully applicable • No data gaps

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
7	LOCA Embrittlement Research Findings - Draft RG 1.222 Measuring Breakaway Oxidation Behavior (ML15281A170) - Draft RG 1.223 Determining Post Quench Ductility (ML15281A188) - Draft RG 1.224 Establishing Analytical Limits for Zirconium-Alloy Cladding Material (ML15281A192)	• Fully applicable • Large population of fuel rods beyond threshold for cladding inner diameter oxygen embrittlement.	• Fully applicable • Large population of fuel rods beyond threshold for cladding inner diameter oxygen embrittlement.	• Fully applicable • No data gaps	• Fully applicable • Rate for oxidation and embrittlement different from bare zirconium • <u>Note</u>: Single sided steam oxidation data and subsequent mechanical data as well as double sided integral steam oxidation data and subsequent mechanical data are necessary to establish post quench ductility limits.	• Fully applicable • Large population of fuel rods beyond threshold for cladding inner diameter oxygen embrittlement • <u>Note</u>: Hot cell post irradiation examination data may be helpful to define threshold for fuel-clad bond layer.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
8	Standard Technical Specifications (STS) NUREG-1430, Rev. 5 STS – B&W Plants (ML21272A363): Figure 3.7.16-1 4.2.1 4.3.1 NUREG-1431, Rev. 4 STS – Westinghouse Plants (ML12100A222): Figure 3.7.17-1 4.2.1 4.3.1 NUREG-1432, Rev. 4 STS CE Plants (ML12102A165): Figure 3.7.18-1 4.2.1 4.3.1 NUREG-1433 and -NUREG-1434, Rev. 4 STS GE Plants (ML12104A192 and ML12104A195, respectively): 4.2.1 4.3.1	• TS 4.2.1 and 4.3.1 are fully applicable • No data gaps • Figure 3.7.16-1, 3.7.17-1, and 3.7.18-1 are fully applicable • <u>Note</u>: Licensees should provide plant-specific figure for TS with LAR.	• TS 4.2.1 and 4.3.1 are fully applicable • No data gaps • Figure 3.7.16-1, 3.7.17-1, and 3.7.18-1 are fully applicable • <u>Note</u>: Licensees should provide plant-specific figure for TS with LAR.	• TS 4.2.1 is fully applicable • NRC and TSTF to discuss whether or not the term “slightly” in TS 4.2.1 includes fuels enriched beyond 5%	• TS 4.2.1 is fully applicable • <u>Note</u>: Licensees should specify chromium coated cladding in TS 4.2.1 with LAR.	• TS 4.2.1 is fully applicable • <u>Note</u>: Licensees should specify doped pellets in TS 4.2.1 with LAR.
9	10 CFR 50.67 Accident Source Term	Potential impacts to accident source term described above for RG 1.183 Revision 1.				

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
10	10 CFR 50.68 Criticality Accident Requirements	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • Note: 5 wt% enrichment limit (without criticality monitoring system) explicitly stated, thus, licensees can submit exemption requests or, as stated in 50.68, adopt 70.24. See below for a discussion of 70.24's applicability. In December 2021, NRC staff issued SECY-21-0109, "Rulemaking plan on Use of Increased Enrichment of Conventional and Accident Tolerant Fuel Designs for Light Water Reactors" (ML21232A237). As a part of this rulemaking plan, the NRC stated plans to amend the 5 wt% enrichment limit in 50.68. • Note: Criticality analyses may need to be updated.	• Fully applicable • No data gaps	• Fully applicable • No data gaps

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
11	10 CFR Part 50 Appendix K: ECCS Evaluation Models	• Fully applicable • Note: Appendix K does not address recent updates to physical phenomena. For example, thermal conductivity degradation (TCD) is not addressed. TCD occurs under HBU conditions. More information on TCD is available in Information Notice 2009-23 (ML091550527 and ML121730336). • Note: FFRD is not addressed. FFRD should be addressed in LOCA evaluation methodologies. If burst and, thus, FFRD is expected to occur, technical justification for the threshold (e.g., BU) for which FFRD is to be considered may be helpful, as well as a technical justification for when the effect of fragmentation-induced FGR is to be considered. The limiting condition for rupture with	• Fully applicable • Note: Appendix K does not address recent updates to physical phenomena. For example, thermal conductivity degradation (TCD) is not addressed. TCD occurs under HBU conditions. More information on TCD is available in Information Notice 2009-23 (ML091550527 and ML121730336). • Note: FFRD is not addressed. FFRD should be addressed in LOCA evaluation methodologies. If burst and, thus, FFRD is expected to occur, technical justification for the threshold (e.g., BU) for which FFRD is to be considered may be helpful, as well as a technical justification for when the effect of fragmentation-induced FGR is to be considered. The limiting condition for rupture with	• Fully applicable • No data gaps	• Not fully applicable • Reason: The Baker-Just metal-water reaction rate correlation is not applicable to coated cladding, as it was developed for bare zircaloy cladding Closure: An oxidation kinetics model based on chromium-coated cladding should be developed. If the benefits of the coating are not to be realized and the Baker-Just correlation is used, it should be demonstrated that it bounds the coated cladding oxidation kinetics. • Note: Coated cladding may have an impact on thermal-hydraulics, e.g., changes in wettability and hydraulic diameter can affect the critical heat flux/critical power correlation. Emissivity also has the potential to be significantly	• Fully applicable • No data gaps

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		fragmentation should be analyzed as well. Additionally, examining the impact of fuel fragment/particle transport and deposition on coolability and criticality, including addressing potential sump blockage caused by fuel fragments/particles in the coolant may be helpful to better understand the effects of FFRD. • Note: The NRC's understanding of recent FFRD research is documented in RIL 2021-13 (ML21313A145). Applicants may potentially find this document useful when addressing FFRD in LOCA evaluation methodologies.	fragmentation should be analyzed as well. Additionally, examining the impact of fuel fragment/particle transport and deposition on coolability and criticality, including addressing potential sump blockage caused by fuel fragments/particles in the coolant may be helpful to better understand the effects of FFRD. • Note: The NRC's understanding of recent FFRD research is documented in RIL 2021-13 (ML21313A145). Applicants may potentially find this document useful when addressing FFRD in LOCA evaluation methodologies.		different, so consideration to this and other surface conditions is important when modeling coated cladding. Although thermal-hydraulic impact of coated cladding is expected to be minimal, this should be justified to confirm the continued applicability of thermal-hydraulic models.	

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
12	10 CFR 51.21 Environmental Assessment (EA) and 51.22 Categorical Exclusion (CATEX) - NMSS	• 10 CFR 51.21 is fully applicable • 10 CFR 51.22 lists the NRC's CATEXs. CATEXs are for categories of actions that the Commission has found do not individually or cumulatively have a significant effect on the human environment. • It is premature to decide now to apply a CATEX for nuclear power plant LARs due to the range of different ATF technologies and our uncertainty about what the licensees will submit. For example, the staff is expecting changes to the source term to be applied in various safety analyzes (e.g., RG 1.183 calculations) with results that cannot yet be determined. Given this situation, the NRC staff is currently considering a path forward on the environmental reviews of ATF licensing actions. • Note: Due to plant changes and unanalyzed environmental impacts (i.e., effluent releases, accidents, and transportation of fuel and waste) as a result of adopting fuels with increased enrichment and higher burnup levels, it is expected that the NRC staff will perform an EA in the first LAR application for this ATF type.				
13	10 CFR 51.51, Uranium fuel cycle environmental data – Table S-3 - NMSS	• Fully applicable • Several aspects of the uranium fuel cycle are expected to remain unchanged from current processes (e.g., uranium recovery and conversion). • Note: Fuel cycle facility changes necessary for use of ATF may require NRC approval. For example, fuel fabricators will have to determine whether they can manufacture the fuel assemblies under their existing licenses or whether they will require NRC authorization in the form of LARs. At the time of an ATF LAR from a nuclear power plant licensee, these associated fuel cycle impacts will be evaluated and, where appropriate, analysis from prior environmental reviews may be incorporated by reference into the LAR NEPA review. NEPA analyses may also "tier off" previous analyses. • Priority: High; near-term •				

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
14	10 CFR 51.52, Environmental effects of transportation of fuel and waste - Table S-4 - NMSS	• Not fully applicable • Note: The proposed enrichment and burnup levels are beyond the conditions specified in 10 CFR 51.52(a) and analyzed in the License Renewal GEIS (NUREG-1437 Revision 1). Further, chromium-coated cladding falls outside of the conditions described in 10 CFR 51.52(a)(2) because 10 CFR 51.52(a)(2) only speaks to zircaloy-clad fuel. The staff would need to assess the impacts with regard to enrichment, burnup, and cladding by conducting a full description and detailed analysis of the environmental effects of transportation of fuel and waste to and from the reactor, including values for the conditions of transport and for the environmental risks from accidents in transport (see 10 CFR 51.52(b)). • Priority: High; near-term • Note: NUREG/CR-6703 (ML010310298) did attempt to analyze BU levels greater than 62 GWd/MTU but found there was too much uncertainty in changes in the gap-release fraction associated with increasing fuel BU. NUREG/CR-6703recommends that the staff re-evaluate this as the methods for assessing fission gas releases are validated with data for higher BUs (see page 52 of NUREG/CR-6703). The NRC staff are performing an analysis of transportation impacts based on the aspects of NUREG/CR-6703 and other transportation assessments for higher BU levels.				
15	10 CFR 70.24 Criticality Accident Requirements	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
16	NUREG-0630 Cladding Swelling and Rupture Models for LOCA Analysis (ML053490337)	• Not fully applicable • Reason: NUREG-0630 models are hot-rod models and thus do not consider interactions between rods. Interactions between rods affect swelling and rupture behavior, which may impact the amount of fragmented fuel that may disperse, and should, thus, not be neglected.	• Not fully applicable • Reason: NUREG-0630 models are hot-rod models and thus do not consider interactions between rods. Interactions between rods affect swelling and rupture behavior, which may impact the amount of fragmented fuel that may disperse, and should, thus, not be neglected.	• Fully applicable • No data gaps	• Not fully applicable • Reason: Cladding swelling and burst data presented is from bare zircaloy cladding, so should not be used if the benefits of coated cladding are to be credited. Closure: As stated in coated cladding interim staff guidance (ML19343A121), if NUREG-0630 is used, it would be	• Fully applicable • No data gaps

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		Closure: Interactions between rods should be considered for swelling and rupture modelling. • Reason: HBU rod internal pressures may exceed the rod internal pressures of the data provided in NUREG-0630. Closure: If the NUREG-0630 data is desired to be used, licensees should show that HBU rod internal pressures are bounded by the data provided in NUREG-0630.	Closure: Interactions between rods should be considered for swelling and rupture modelling. • Reason: HBU rod internal pressures may exceed the rod internal pressures of the data provided in NUREG-0630. Closure: If the NUREG-0630 data is desired to be used, licensees should show that HBU rod internal pressures are bounded by the data provided in NUREG-0630.		useful for licensees to show that data bounds the performance of the coated cladding, or if new burst stress and ballooning strain limits are proposed, a significant body of data would be useful to demonstrate that the degree of swelling will not be underestimated. • Framework/approach described for modeling swelling and rupture remains fully applicable.	

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
17	NUREG-0800 SRP Chapter 4.2 Fuel System Design (ML070740002)	• Not fully applicable • Reason: Interim RIA guidance provided in Appendix B does not match the most recent guidance given in RG 1.236. Closure: Appendix B should be updated, and readers should be directed to RG 1.236. Priority: Low (this is administrative in nature as RG 1.236 has been published to address RIA guidance up to 68 GWd/MTU); long-term • Reason: FFRD not thoroughly addressed. Closure: Potential addition of vendor requirements for submittals where rod burst is assumed to occur. Priority: TBD	• Not fully applicable • Reason: Interim RIA guidance provided in Appendix B does not match the most recent guidance given in RG 1.236. Closure: Appendix B should be updated, and readers should be directed to RG 1.236. Note that RG 1.236 is not fully applicable to 75 GWd/MTU. Priority: Low; long-term • Reason: FFRD not thoroughly addressed. Closure: Potential addition of vendor requirements for submittals if rod burst is assumed to occur. Priority: TBD	• Not fully applicable • Reason: Interim RIA guidance in Appendix B does not match the current RIA guidance in RG 1.236. RG 1.236 is also not applicable to fuel enriched to greater than 5.0 wt%. Closure: See discussion on RG 1.236 • Note: Increased enrichment could potentially lead to higher rod worth and peaking factors. Sections 2.1.4 and 2.2.1.3 of RG 1.236 state that the effect of rod worth and power peaking limits should be considered in RIA analyses.	• Not fully applicable • Note: Coated cladding interim staff guidance (ML19343A121) created to supplement SRP Section 4.2 in coated cladding reviews. • Reason: Interim RIA guidance in Appendix B does not match the current RIA guidance in RG 1.236. Note that RG 1.236 is also not applicable to coated cladding. Closure: See discussion on RG 1.236 and coated cladding interim staff guidance (ML19343A121).	• Not fully applicable • Reason: Interim RIA guidance in Appendix B does not match the current RIA guidance in RG 1.236. RG 1.236 is also not applicable to doped fuel. Closure: See discussion on RG 1.236 • Reason: Impact of additives on fuel performance has not been extensively quantified. Closure: Data on irradiated, doped UO_2 fuel pellets and integral fuel burnable absorber fuel pellets may be helpful to better understand impact of additive agents (e.g., larger grain size, retained fission gas, grain boundary hold-up, thermal conductivity) on cladding failure thresholds, FFRD, transient FGR, and coolable geometry.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
18	NUREG-1465 Accident Source Terms for Light Water Reactor Nuclear Power Plants (ML041040063)	Potential impacts to accident source term described above for RG 1.183 Revision 1.				
19	NUREG-2121 FFRD During the LOCA (ML12090A018)	• Not fully applicable • Reason: Published in 2012, so does not include recent FFRD research findings Closure: Recent FFRD research findings are covered in RIL 2021-13 (ML21313A145) • Note: Halden tests described in the NUREG include several tests at > 75 GWd/MTU • Note: Studsvik tests described in the NUREG include several tests at > 70 GWd/MTU • Note: More data may be helpful to properly address FFRD if the burst is predicted to occur. If burst and, thus, FFRD is expected to occur, technical justification for the threshold (e.g., BU) for which	• Not fully applicable • Reason: Published in 2012, so does not include recent FFRD research findings Closure: Recent FFRD research findings are covered in RIL 2021-13 (ML21313A145) • Note: Halden tests described in the NUREG include several tests at > 75 GWd/MTU • Note: Studsvik tests described in the NUREG include several tests at > 70 GWd/MTU Note: More data may be helpful to properly address FFRD if burst is predicted to occur. If burst and, thus, FFRD is expected to occur, technical justification for the threshold (e.g., BU) for which	• Not fully applicable • Note: The effect of enrichment on FFRD phenomena was not a part of NUREG-2121 • Note: INL Power Burst Facility tests included fuel enriched to 9.6 wt%.	• Not fully applicable • Reason: Only uncoated cladding considered in tests described in the NUREG. Closure: Justification for the application of the NUREG-2121 data to coated cladding may be necessary	• Not fully applicable • Reason: Only traditional UO_2 fuel considered in the tests described in the NUREG. Impact of additives on fuel performance has not been extensively quantified. Closure: Data for irradiated, doped UO_2 fuel pellets and integral fuel burnable absorber fuel pellets may be helpful to better understand impact of additive agents (e.g., larger grain size, retained fission gas, grain boundary hold-up, thermal conductivity) on cladding failure thresholds, FFRD,

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		FFRD is to be considered may be helpful, as well as a technical justification for when the effect of fragmentation-induced FGR is to be considered. Additionally, examining the impact of fuel fragment/particle transport and deposition on coolability and criticality, including addressing potential sump blockage caused by fuel fragments/particles in the coolant may be helpful to better understand the effects of FFRD. • The NRC's understanding of recent FFRD research is documented in RIL 2021-13 (ML21313A145). Applicants may potentially find this document useful when addressing FFRD in LOCA evaluation methodologies.	FFRD is to be considered may be helpful, as well as a technical justification for when the effect of fragmentation-induced FGR is to be considered. Additionally, examining the impact of fuel fragment/particle transport and deposition on coolability and criticality, including addressing potential sump blockage caused by fuel fragments/particles in the coolant may be helpful to better understand the effects of FFRD. • The NRC's understanding of recent FFRD research is documented in RIL 2021-13 (ML21313A145). Applicants may potentially find this document useful when addressing FFRD in LOCA evaluation methodologies.			transient FGR, and coolable geometry.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
20	NUREG/CR-7219 Cladding Behavior During Postulated LOCA (ML16211A004)	• Fully applicable • No data gaps	• Fully applicable • Note: Section 3.3.2 details "current" post quench ductility results for only up to 70 GWd/MTU	• Fully applicable • No data gaps	• Not fully applicable • Reason: Data only included bare zirconium. Rate of oxidation and embrittlement expected to be different Closure: TBD • Note: Zircaloy embrittlement mechanisms presented in NUREG/CR-7219 may remain applicable due to presence of base zircaloy cladding. • Note: Single sided steam oxidation data and subsequent mechanical data as well as double sided integral steam oxidation data and subsequent mechanical data may be helpful to establish post quench ductility limits	• Not fully Applicable • Reason: BU threshold for the formation of fuel-clad bond layer has not been well quantified in most doped fuel. Closure: Hot cell post irradiation examination may be helpful to define threshold for fuel-clad bond layer

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
21	RG 1.157 Best-Estimate Calculations of ECCS Performance (ML003739584)	• Not fully applicable • Reason: RG 1.157 is not fully applicable to the current BU limit of 62 GWd/MTU because it does not address recent updates to physical phenomena. For example, thermal conductivity degradation (TCD) is not addressed. TCD occurs under HBU conditions. More information on TCD is available in Information Notice (IN) 2009-23 (ML091550527 and ML121730336). Closure: The staff has been aware of issues such as TCD for some time and plans to update RG 1.157 in the medium term. Priority: Medium; medium term • Reason: FFRD is not addressed Closure: FFRD should be addressed in LOCA	• Not fully applicable • Reason: RG 1.157 is not fully applicable to the current BU limit of 62 GWd/MTU because it does not address recent updates to physical phenomena. For example, thermal conductivity degradation (TCD) is not addressed. TCD occurs under HBU conditions. More information on TCD is available in Information Notice (IN) 2009-23 (ML091550527 and ML121730336). Closure: The staff has been aware of issues such as TCD for some time and plans to update RG 1.157 in the medium term. Priority: Medium; medium term • Reason: FFRD is not addressed Closure: FFRD should be addressed in LOCA	• Fully applicable • No data gaps	• Not fully applicable • Reason: Cathcart-Pawel correlation and associated data is referenced as acceptable for calculating the rates of energy release, hydrogen generation, and cladding oxidation, but was developed for bare zircaloy cladding. Use of the Cathcart-Pawel correlation would not realistically model oxidation kinetics. Chromium-coated cladding is expected to have better oxidation performance than bare zirconium cladding. Closure: An oxidation kinetics model based on chromium-coated cladding should be developed. If the licensee is not crediting the benefits of the coating and the	• Not fully applicable • Reason: Section 3.2.1 on initial stored energy in the fuel is out of date. It also references an acceptable initial stored energy model. This model was developed for UO_2 and is not acceptable currently for doped fuel. Closure: Licensees should show that the stored energy does not change much from a vendor's current UO_2 models, or new models should be proposed.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		evaluation methodologies. If burst and thus FFRD is expected to occur, technical justification for the threshold (e.g., BU) for which FFRD is to be considered may be helpful, as well as a technical justification for when the effect of fragmentation-induced FGR is to be considered. The limiting condition for rupture with fragmentation should be analyzed as well. Additionally, examining the impact of fuel fragment/particle transport and deposition on coolability and criticality, including addressing potential sump blockage caused by fuel fragments/particles in the coolant may be helpful to better	evaluation methodologies. If burst and thus FFRD is expected to occur, technical justification for the threshold (e.g., BU) for which FFRD is to be considered may be helpful, as well as a technical justification for when the effect of fragmentation-induced FGR is to be considered. The limiting condition for rupture with fragmentation should be analyzed as well. Additionally, examining the impact of fuel fragment/particle transport and deposition on coolability and criticality, including addressing potential sump blockage caused by fuel fragments/particles in the coolant may be helpful to better		Cathcart-Pawel correlation is used, it should be demonstrated that it bounds the coated cladding oxidation kinetics. • <u>Note</u>: this RG provides a means of meeting the 50.46 prescriptive analytical requirements; those requirements are not applicable for fuel rods with coated cladding due to the wording of 50.46(a)(1)(i), so this RG is *fully* applicable pending an approved exemption to 50.46.	

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		understand the effects of FFRD. • Note: The NRC's understanding of recent FFRD research is documented in RIL 2021-13 (ML21313A145). Applicants may potentially find this document useful when addressing FFRD in LOCA evaluation methodologies. • Reason: The limiting rod may not be the hot rod when considering swelling and rupture (see NUREG-0630 discussion) Closure: Rod-to-rod interactions should be considered for swelling and rupture in LOCA analyses.	understand the effects of FFRD. • Note: The NRC's understanding of recent FFRD research is documented in RIL 2021-13 (ML21313A145). Applicants may potentially find this document useful when addressing FFRD in LOCA evaluation methodologies. • Reason: The limiting rod may not be the hot rod when considering swelling and rupture (see NUREG-0630 discussion) Closure: Rod-to-rod interactions should be considered for swelling and rupture in LOCA analyses.			

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
22	RG 1.203 Transient and Accident Analysis Methods (ML053500170)	• Fully applicable • <u>Note</u>: Vendors may need to validate their evaluation models to higher BU.	• Fully applicable • <u>Note</u>: Vendors may need to validate their evaluation models to higher BU.	• Fully applicable • <u>Note</u>: Vendors may need to validate their evaluation models to higher enrichments	• Fully applicable • <u>Note</u>: RG 1.203 discusses 50.46 requirements, so this RG is only *fully* applicable pending an accepted exemption to 50.46. See discussion on 50.46 for more details. • <u>Note</u>: Vendors will likely need to update and validate their evaluation models to consider coated cladding	• Fully applicable • <u>Note</u>: Vendors may need to update and validate their evaluation models to consider doped fuel

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
23	RG 1.240 Fresh and Spent Fuel Pool Criticality Analysis (ML20182A788) NEI 12-16, Rev. 4 (ML18269E069)	• Not fully Applicable • Reason: Cites use of gap release fractions from RG 1.183 and PNNL-18212 Rev 1. RG 1.183 Rev 0 is only applicable up to 62 GWd/MTU and PNNL-18212 Rev 1 is only applicable up to 65 GWd/MTU. Closure: Will be fully applicable upon the publication of RG 1.183 Rev 1, which will provide tables for gap release fractions	• Not fully applicable • Reason: Cites use of gap release fractions from RG 1.183 and PNNL-18212 Rev 1. RG 1.183 Rev 0 is only applicable up to 62 GWd/MTU and PNNL-18212 Rev 1 is only applicable up to 65 GWd/MTU. Closure: Will be fully applicable upon the publication of RG 1.183 Rev 1, which will provide an analytical procedure for calculating gap release fractions that is applicable.	• Not fully applicable • Reason: Mentions gap release fractions from RG 1.183 Rev. 0, which is not fully applicable. RG 1.183, Rev. 1 will not be fully applicable, but the analytical procedure remains applicable. Closure RG 1.183 Rev 1 will provide an analytical procedure for calculating gap release fractions that is applicable. Note: Criticality code validation will ideally demonstrate that validation is applicable to the increased enrichment range (Section 7.1.4.1 of Version 1.2 of the ATF Project Plan (ML21243A298 discusses various ways of benchmarking criticality analyses that could be used to validate criticality codes))	• Fully applicable • No data gaps	• Not fully applicable • Reason: Mentions gap release fractions from RG 1.183 Rev. 0, which is not fully applicable. RG 1.183, Rev. 1 will not be fully applicable, but the analytical procedure remains applicable. • Closure: RG 1.183 Rev 1, will provide an analytical procedure for calculating gap release fractions that is applicable. • Note: Section 9.3 of NEI 12-16, Rev. 4 describes how to approach new fuel designs. • Note: If dopant increases density, higher density fuel may lead to more ^{235}U in the spent fuel pool • Note: Criticality codes may need to be validated for doped fuel. Per Section 7.1.4.1 of version 1.2 of the ATF Project Plan

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
				• Note: Criticality analyses may need to be updated to show adherence to the k-effective regulatory limits.		(ML21243A298), discusses various ways of benchmarking criticality analyses. These methods may be used for validating codes. • Note: RG 1.240 Section C paragraph o states that for new fuel designs, justification for continued use of the assumptions presented in NEI 12-16 Rev. 4 may be necessary.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
24	NUREG-0800 SRP Chapter 9.1.1 Criticality Safety of Fresh and Spent Fuel Storage and Handling (ML070570006)	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • Note: Compliance with 10 CFR 50.68 is a part of the stated review procedures. • Note: Criticality code validation will ideally demonstrate that validation is applicable to the increased enrichment range (Section 7.1.4.1 of version 1.2 of the ATF Project Plan (ML21243A298) discusses various ways of benchmarking criticality analyses that could be used to validate criticality codes) • Note: Criticality analyses may need to be updated to show adherence to the k-effective regulatory limits.	• Fully applicable • No data gaps	• Fully applicable Note: Criticality codes may need to be validated for doped fuel. Section 7.1.4.1 of version 1.2 of the ATF Project Plan (ML21243A298), discusses various ways of benchmarking criticality analyses. These methods may be used for validating codes.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
25	NUREG-0800 SRP Chapter 9.1.2 New and Spent Fuel Storage (ML070550057)	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • Note: Compliance with 10 CFR 50.68 is a part of the stated review procedures.	• Fully applicable • No data gaps	• Fully applicable • No data gaps
26	NUREG-1520 SRP for Fuel Cycle Facilities License Applications (ML15176A258) – NMSS	• Not applicable • Reason: HBU is not relevant to uranium conversion, enrichment, fuel fabrication, or greater-than-critical mass facilities. Closure: No closure necessary	• Not applicable • Reason: HBU is not relevant to uranium conversion, enrichment, fuel fabrication or greater-than-critical mass facilities. Closure: No closure necessary	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
27	NUREG-1065 Acceptable Standard Format and Content for the Fundamental Nuclear Material Control (FNMC) Plan Required for Low-Enriched Uranium Facilities (ML031340288) - NMSS	• Not applicable • Reason: HBU is not relevant to fuel fabrication. Closure: No closure necessary	• Not applicable • Reason: HBU is not relevant to fuel fabrication. Closure: No closure necessary.	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
28	NUREG/CR-5734 Recommendations to the NRC on Acceptable Standard Format and Content for the Fundamental Nuclear Material Control (FNMC) Plan Required for Low-Enriched Uranium Enrichment Facilities (ML15120A354) - NMSS	• Not applicable • Reason: HBU is not relevant to fuel enrichment. Closure: No closure necessary.	• Not applicable • Reason: HBU is not relevant to fuel fabrication. Closure: No closure necessary.	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
29	NUREG-2214, Managing Aging Processes in Storage (MAPS) Report (ML19214A111) - NMSS	• Not fully applicable • Reason: The evaluations of aging mechanisms for spent fuel cladding need to be extended to burnups greater than 62 GWd/MTU. This higher BU may influence which aging mechanisms are credible during extended storage and may warrant unique recommended preventive actions (e.g., fuel drying criteria) and other aging management approaches. Closure: Fuel performance modeling and characterization of irradiated cladding with higher BU (e.g., mechanical testing, microstructure characterization) may be needed to assess credible aging mechanisms.		• Not fully applicable • Reason: Increased use of burnable absorbers may affect cladding hoop stresses and the associated aging mechanisms. Closure: Fuel performance modeling and characterization of irradiated cladding with increased enrichment (e.g., mechanical testing) may be needed to assess credible aging mechanisms.	• Not fully applicable • Reason: The evaluations of aging mechanisms for spent fuel cladding do not consider the potential effects of Cr coating. Closure: Characterization of irradiated Cr-coated cladding (e.g., mechanical testing, microstructure analysis) may be needed to assess credible aging mechanisms, such as hydrogen effects, thermal creep, and corrosion.	• Not fully applicable • Reason: Doped fuel pellets may affect cladding hoop stresses (via pellet-clad interactions or fission gas release) and the associated aging mechanisms. Closure: Fuel performance modeling and characterization of irradiated cladding with doped pellets (e.g., mechanical testing) may be needed to assess credible aging mechanisms.
30	NUREG-2215, SRP for Spent Fuel Dry Storage Systems and Facilities (ML20321A086) - NMSS	• Not fully applicable • Reason: Guidance provided is limited to BU up to 60 GWd/MTU. Closure: TBD • Note: Shielding discussions in submissions may need to consider HBUs and fuel composition to account for increase source term. Literature reviews and research will provide information on this technical issue. • Note: Criticality discussion in submissions may need to consider higher BUs for BU credit analyses, as well as benchmark the		• Not fully applicable • Reason: Guidance is limited to enrichments up to 5wt%. Closure: TBD • Note: Shielding discussion in submissions may need to consider higher enrichments to account for	• Under review • Note: Guidance provides information on Zr alloy cladding. No discussion of unique considerations for Cr coating on cladding performance. Staff will assess this	• Under review • Note: Staff is evaluating the need to address potential validation variations and fuel dopant effect on fuel density. • Note: Guidance does not address potential unique considerations of

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
		criticality analysis and address bounding profiles for HBU fuels. Literature reviews and research will provide information on this technical issue. • Note: Materials evaluation in submissions may need to consider higher BUs' effect on cladding performance. Staff will assess this impact when lead test assembly data becomes available. Applicants could also provide this information.		increase burnable absorber use and impact on source term. Literature reviews and research will provide information on this technical issue. • Note: Criticality discussion in submissions may need to consider higher enrichment as well as benchmark the criticality analysis and address bounding profiles for higher enrichment fuels. Literature reviews and research will provide information on this technical issue. • Note: Materials discussion in submissions may need to consider if an increase in burnable absorber use which may affect cladding hoop stress and, consequently, the	impact when lead test assembly data becomes available. Applicants could also provide this information.	fuel dopants on cladding hoop stresses. Staff will assess this impact when lead test assembly data becomes available. Applicants could also provide this information.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
				recommended fuel drying criteria to support adequate cladding performance. Literature reviews and research will provide information on this technical issue.		
31	NUREG-2216, SRP for Transportation Packages for Spent Fuel and Radioactive Material (ML20234A651) - NMSS	• Not fully applicable • Reason: Guidance provided is limited to burnups up 60 GWd/MTU. Closure: TBD • Note: Shielding discussion in submissions may need to consider HBUs and fuel composition to account for increase source term. Literature reviews and research will provide information on this technical issue. • Note: Criticality discussion in submissions may need to consider HBUs for BU credit analyses, as well as benchmark the criticality analysis and address bounding profiles for HBU fuels. Literature reviews and research will provide information on this technical issue. • Note: Materials evaluation in submissions may need to consider HBUs' effect on cladding performance. Staff will assess this impact when lead test assembly data becomes available. Applicants could also provide this information.		• Not fully applicable • Reason: Guidance is limited to enrichments up to 5 wt%. Closure: TBD • Note: Shielding discussion in submissions may need to consider higher enrichments to account for increase burnable absorber use and impact on source term. Literature reviews and research will provide information on this technical issue. • Note: Criticality discussion in submissions may need to consider	• Under review • Note: Guidance provides information on Zr-alloy cladding. No discussion of unique considerations for Cr coated on cladding performance. Staff will assess this impact when lead test assembly data becomes available. Applicants could also provide this information.	• Under review • Note: Staff is evaluating the need to address potential validation variations and fuel dopant effect on fuel density. • Note: Guidance does not address potential unique considerations of fuel dopants on cladding hoop stresses. Staff will assess this impact when lead test assembly data becomes available. Applicants could also provide this information.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
				higher enrichments as well as benchmark criticality analysis, address additional isotopic depletion, and address bounding profiles. Literature reviews and research will provide information on this technical issue. • Note: Materials discussion in submissions may need to consider if an increase in burnable absorber use which may affect cladding hoop stress and, consequently, the recommended fuel drying criteria. Literature reviews and research will provide information on this technical issue.		

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
32	NUREG-2224, Dry Storage and Transportation of High Burnup Spent Nuclear Fuel (ML20191A321) - NMSS	• Not fully applicable • Reason: The evaluations of fuel cladding performance and recommended licensing approaches need to be extended to higher BU (greater than 62 GWd/MTU). BU above 62 GWd/MTU may influence cladding internal pressure, mechanical properties, and the credible aging mechanisms during extended storage. The increased BU may also warrant revised recommended fuel drying practices to maximize cladding performance. Closure: Fuel performance modeling and characterization of irradiated cladding with HBU (e.g., mechanical testing, microstructure characterization) may be needed to demonstrate adequate cladding performance.		• Not fully applicable • Reason: Increased use of burnable absorbers may affect cladding hoop stresses and the associated cladding behavior. Closure: Fuel performance modeling and characterization of irradiated cladding with increased enrichment (e.g., mechanical testing) may be needed to demonstrate adequate cladding performance.	• Not fully applicable • Reason: The evaluations of fuel cladding performance do not consider the potential effects of Cr coating (e.g., cladding oxidation, hydrogen pickup). Revised fuel drying criteria to consider effects of reduced hydrogen pickup in the reactor may be warranted. Closure: Characterization of irradiated Cr-coated cladding (e.g., mechanical testing, microstructure analysis) may be needed to demonstrate adequate cladding performance.	• Not fully applicable • Reason: Doped fuel pellets may affect cladding hoop stresses (via pellet-clad interactions or fission gas release) and the associated cladding performance Closure: Fuel performance modeling and characterization of irradiated cladding with doped pellets (e.g., mechanical testing) may be needed to demonstrate adequate cladding performance.

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
33	RG 3.48 Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage) (ML19141A092) - NMSS	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
34	RG 7.9 Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material (ML050530321) - NMSS	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
35	RG 3.71 Nuclear Criticality Safety Standards for Nuclear Materials Outside Reactor Cores (ML18169A258) - NMSS	• Not applicable • Reason: HBU is not relevant to fuel enrichment or fabrication. RG 3.71 endorses ANS Standard 8.27 for use of burnup credit in storage and transportation criticality. The ANS standard does not limit enrichment or burnup. NRC action would be to review, and if appropriate, endorse a new standard. Closure: No closure necessary	• Not applicable • Reason: HBU is not relevant to fuel enrichment or fabrication. Closure: No closure necessary	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps
36	RG 3.67 Standard Format and Content for Emergency Plans for Fuel Cycle and Materials Facilities (ML103360487)	• Not applicable • Reason: This RG is specific to format and content of emergency plans for fuel cycle and material facilities and does not reference specific burnup criteria. Closure: No closure necessary	• Not applicable • Reason: This RG is specific to format and content of emergency plans for fuel cycle and material facilities and does not reference specific burnup criteria. Closure: No closure necessary	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps

#	Guidance Document Regulation	Burnup to 68 GWd/MTU	Burnup to 75 GWd/MTU	^{235}U Enrichment beyond 5.0 wt%	Chromium-coated Zirconium Cladding	Doped UO_2 Fuel Pellets
37	NUREG-0800 SRP Chapter 4.3 Nuclear Design (ML070740003)	• Fully Applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps	• Fully applicable • No data gaps

3. Licensing Pathway Diagram

As discussed in Section 1, the NRC staff has developed the below licensing pathway diagram to serve as a companion to the information presented in the RFAA table in Section 2. Based on its current understanding of vendor and licensee plans, the NRC staff has chosen to limit the scope of the diagram to the licensing of HBU and increased enrichment fuels. Should circumstances change such that additional diagrams may be beneficial, the NRC staff will evaluate the potential benefit and develop additional diagrams, as necessary.

The licensing pathway diagram is intended to show a potential plan or path forward, given the current state of technical and regulatory progress for the given fuel concept. This diagram does not identify all of the issues or requirements that may need to be addressed as a part of the review of a given TR or LAR for in-reactor use. The NRC staff encourages vendors and licensees to engage with the staff early in the process of developing a TR or LAR to help support the early identification and resolution of any technical and policy issues associated with a given approach.

Following the same color scheme from the RFAA table, green colored boxes in the diagrams are items to be addressed by NRC staff and blue colored boxes are items that may need to be addressed by a fuel vendor or a licensee. This is also illustrated by items above the horizontal line (NRC actions) and below the horizontal line (potential fuel vendor or licensee information needs).

The dashed border around the Advisory Committee on Reactor Safeguards (ACRS) Review box on the plant-specific LAR review pathway indicates the possibility of an ACRS review. Should the Commission refer a plant-specific LAR to the ACRS for review, the NRC staff will endeavor to minimize the impact on the LAR review schedule by engaging with the ACRS early in the review.

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3.1: Higher Burnup and Increased Enrichment Licensing Pathways

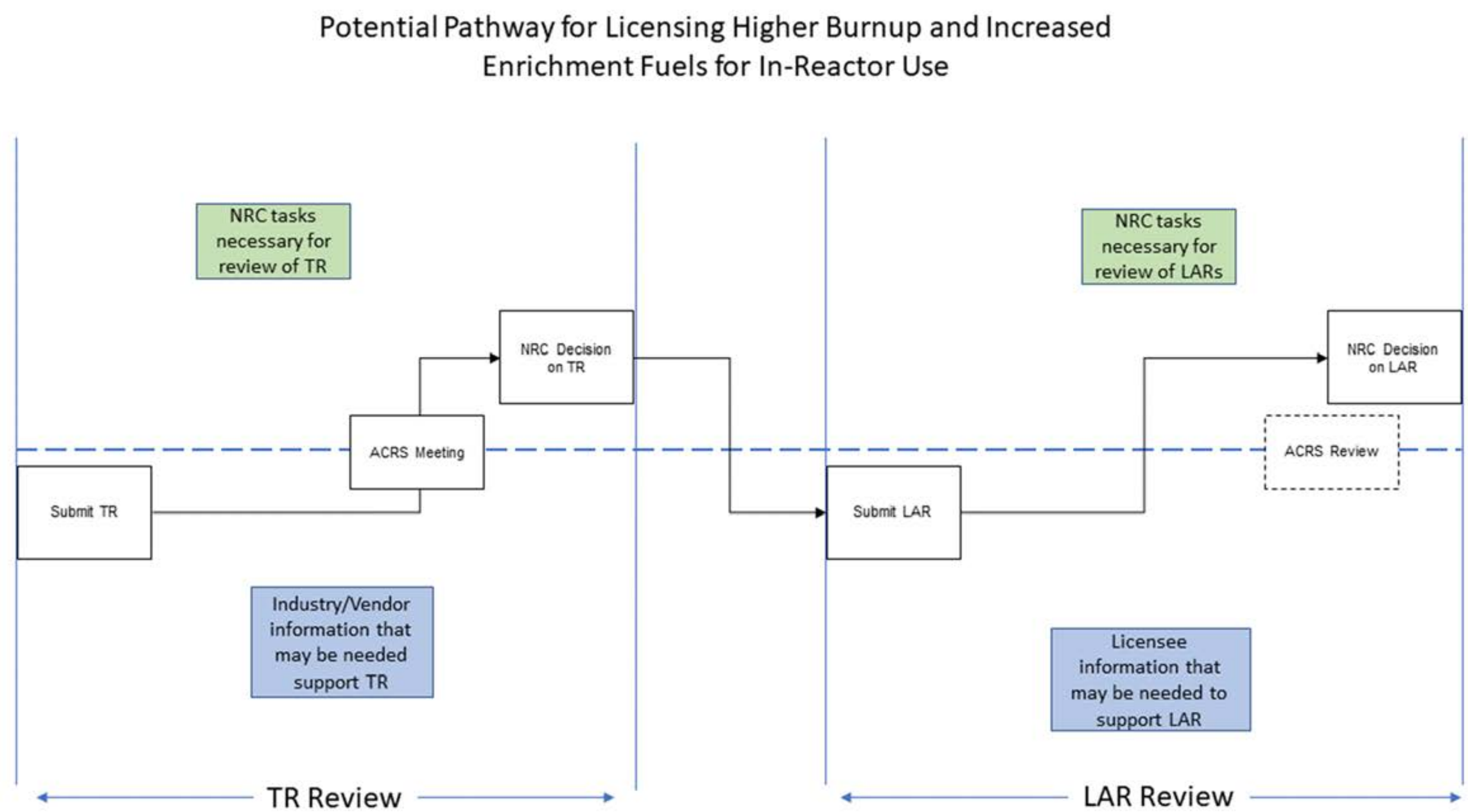

Figure 3.1-1 Potential Pathway for Licensing Higher Burnup and Increased Enrichment Fuels for In-Reactor Use