ENCLOSURE 6

Major Accident Methodology Report

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Technical Report

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Approval

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ACRONYMS

Acronym	Definition
ACRS	Advisory Committee on Reactor Safeguards
AOO	Anticipated Operational Occurrences
BDBE	Beyond Design Basis Event
CFR	Code of Federal Regulations
CP	Construction Permit
DBA	Design Basis Accident
DBE	Design Basis Event
DG	Draft Regulatory Guide
EAB	Exclusion Area Boundary
EM	Evaluation Model
ESF	Engineered Safety Feature
HAA	Head Access Area
IVS	In-Vessel Storage
LBE	Licensing Basis Event
LMP	Licensing Modernization Project
LOCA	Loss-of-Coolant Accident
LOOP	Loss of Offsite Power
LPZ	Low Population Zone
LWR	Light Water Reactor
MCA	Maximum Credible Accident
MHA	Maximum Hypothetical Accident
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission

NSRST	Non-Safety-Related with Special Treatment
OL	Operating License
OQE	Other Quantified Event
PLOF	Protected Loss of Flow
PRA	Probabilistic Risk Assessment
PSAR	Preliminary Safety Analysis Report
RC	Release Category
RES	Reactor Enclosure System
RG	Regulatory Guide
RIPB	Risk-Informed, Performance-Based
RXB	Reactor Building
[[	]][(a)(4)]
SR	Safety-Related
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SSC	Structures, Systems, and Components
TEDE	Total Effective Dose Equivalent
ULOF	Unprotected Loss of Flow
ULOHS	Unprotected Loss of Heat Sink

1 INTRODUCTION

This technical report addresses the Major Accident Evaluation Model (EM) development process, the resulting EM, and identifies EM items which require further development. This EM is developed for the Natrium™ reactor, a TerraPower & GE-Hitachi Technology. The methodology development guidance provided by the internal Natrium methodology development and assessment guide was used in the development of this EM. The results of this EM are based on preliminary design information, and any updates as a result of design maturation will be captured prior to submittal of an operating license application.

The Natrium power plant being developed by TerraPower follows the methodology provided in NEI 18-04, Rev. 1 [1], Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development, to identify and evaluate Licensing Basis Events (LBEs), including frequency-based Anticipated Operational Occurrences (AOO), Design Basis Events (DBE), Beyond Design Basis Events (BDBE), and conservative-assumption-oriented Design Basis Accidents (DBAs) [1]. Additionally, the identification and classification of Safety-Related (SR) and Non-Safety-Related with Special Treatment (NSRST) Structures, Systems, and Components (SSCs) are determined consistent with the methodology presented in NEI 18-04 [1]. Figure 1-1: Frequency-Oriented Relationship between AOOs, DBEs, BDBEs, and DBAs.provides a graphical representation showing the AOO, DBE, BDBE, and DBA relationships as well as how they fit within the complete event structure from a frequency perspective.

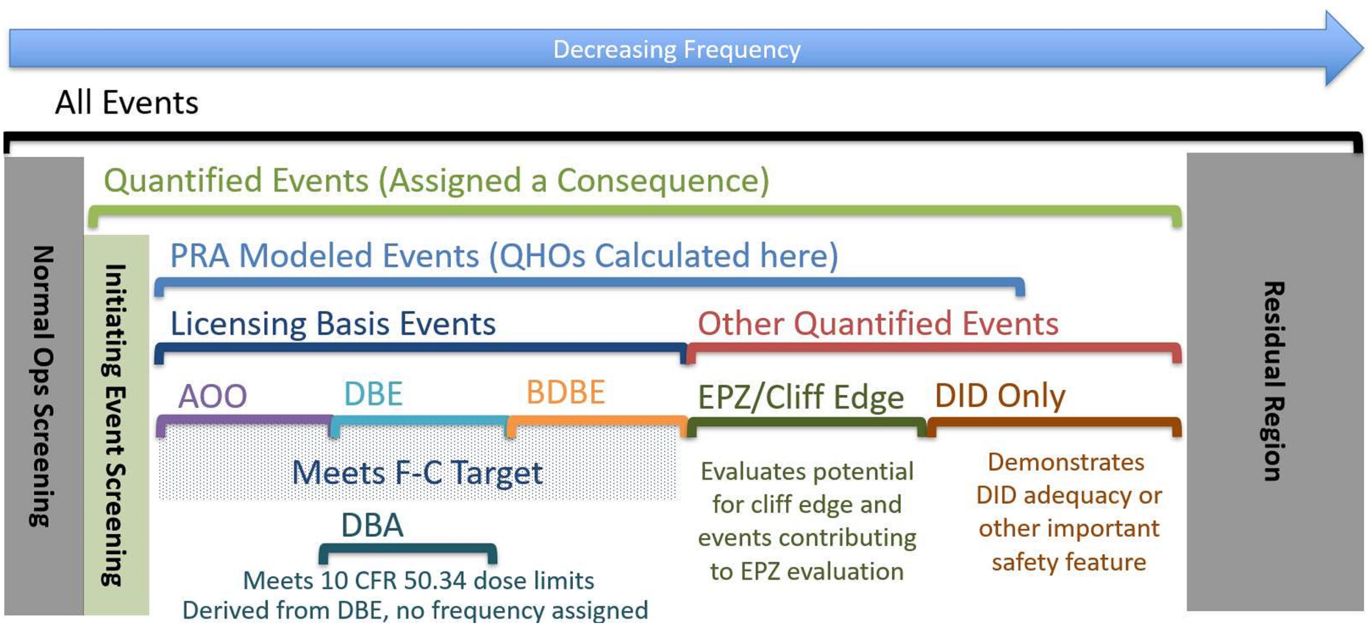

Figure 1-1: Frequency-Oriented Relationship between AOOs, DBEs, BDBEs, and DBAs.

The guidance provided in NEI 21-07 [2] is followed in the development of the Kemmerer Power Station Unit 1 Preliminary Safety Analysis Report (PSAR) [3]. The PSAR is being developed in accordance with the two-part licensing approach established in Title 10 of the Code of Federal Regulations (CFR) Part 50, which involves first obtaining a Construction Permit (CP), followed by an Operating License (OL). The PSAR has been submitted to the Nuclear Regulatory

Commission (NRC) as part of the CP application process. It is important to note that the PSAR contains preliminary design information which will be updated as the process reaches conclusion, and an OL application will be submitted containing finalized design information in the Final Safety Analysis Report (FSAR).

2 SUMMARY

A set of candidate events is generated from which the most risk-significant event is selected to be identified as the major accident for the Natrium plant. The major accident event source term is identified as [[ ]](a)(4), which is an Unprotected Loss of Heat Sink (ULOHS) event. The evaluation methodology for this event is described.

3 BACKGROUND

The licensing framework for Kemmerer Unit 1 is primarily based on the two-step licensing process involving a CP and an OL under 10 CFR 50. Since 10 CFR 50 is focused on conventional large Light Water Reactor (LWR) designs, many sections, subsections, and paragraphs are not directly applicable to advanced non-LWR applications. Under the Risk-Informed, Performance-Based (RIPB) licensing framework, endorsed by Regulatory Guide 1.233 [4], the radiological accident source terms depart from the original non-seismic siting criteria under 10 CFR 100.11 and 10 CFR 50.34, as well as the accident source term under 10 CFR 50.67. The source term should be more mechanistic and use best-estimate phenomenological models including related uncertainties.

The NRC is in the process of developing a position on and guidance for representative source term events for reactors licensed under 10 CFR Part 53. While Kemmerer Unit 1 is not being licensed under 10 CFR Part 53, the RIPB licensing framework influenced the LBE selection. Given the lack of concrete guidance, a discussion of the ongoing activities related to the definition of a Major Accident (also called a Maximum Hypothetical Accident (MHA) or Maximum Credible Accident (MCA)) is included below.

3.1 Relevant Regulations

Historically, the source terms are based on a conservative event that is of hypothetical nature rather than credible nature. Although footnote 1 of 10 CFR 100.11 discusses both 'hypothetical' and 'credible' at the same time, there is a nuanced difference, as shown in the excerpts below from footnotes 6 & 11 to 10 CFR 50.34 and footnote 1 to 10 CFR 50.67. Note that these do not describe the 'credible' language explicitly.

Footnote 1 of 10 CFR 100.11 (emphasis added):

The fission product release assumed for these calculations should be based upon a major accident, <u>hypothesized</u> for purposes of site analysis or postulated from considerations of possible accidental events, that would result in potential hazards not exceeded by those from any accident considered <u>credible</u>. Such accidents have generally been assumed to result in substantial meltdown of the core with subsequent release of appreciable quantities of fission products.

Footnote 6 of 10 CFR 50.34 (emphasis added):

The fission product release assumed for this evaluation should be based upon a major accident, <u>hypothesized</u> for purposes of site analysis or postulated from considerations of possible accidental events. Such accidents have generally been assumed to result in substantial *meltdown of the core with subsequent release into the containment of appreciable quantities of fission products.*

Footnote 11 of 10 CFR 50.34 (emphasis added):

The fission product release assumed for these calculations should be based upon a major accident, <u>hypothesized</u> for purposes of site analysis or postulated from considerations of possible accidental events, that would result in potential hazards not exceeded by those from any accident considered <u>credible</u>. Such accidents have generally been assumed to result in substantial meltdown of the core with subsequent release of appreciable quantities of fission products.

3.2 Regulatory Guidance

The guidance for the LWR accident source term in RG 1.183, Rev. 1 [5] provides a definition for the MHA and MCA. While the first footnote below seems to indicate that MHA and MCA refer to the same thing, there appears to be a nuanced difference, highlighted in the excerpt from NUREG-1537, Part. 1 [6] below. Relevant history was described during the February 17, 2022 Advisory Committee on Reactor Safeguards (ACRS) meeting (as shown on beginning on line 10 of page 146 of the meeting transcript [7]). The MCA would be the highest consequence event among the credible accidents, which may not bound hypothetical events.

Footnote 1 of RG 1.183, Rev. 1 [5] (emphasis added):

The MHA (also referred to as the maximum credible accident) is that accident whose consequences, as measured by the radiation exposure of the surrounding public, would not be exceeded by any other accident whose occurrence during the lifetime of the facility would appear to be <u>credible</u>. The MHA LOCA, as used in this guide, refers to a loss of core cooling resulting in substantial meltdown of the core with subsequent release into containment of appreciable quantities of fission products. These evaluations assume containment integrity with offsite hazards evaluated based on design basis containment leakage.

Footnote 2 of RG 1.183, Rev. 1 [5]:

The MHA should be modeled with the deterministic substantial fuel melt source term being injected or overlaid into the radiological consequence analysis notwithstanding the operation of safety-related equipment designed to preclude significant fuel failure. The purpose of this approach would be to test the adequacy of the containment and other safety-related systems. Safety-related systems may be credited as described in Regulatory Position 5.1.2, as this designation ensures reliability in performing their safety function.

NUREG-1537, Part. 1 [6] Introduction page xix (emphasis added):

Chapter 6 lists the design bases and describes the functions of engineered safety features (ESFs) that may be required to mitigate consequences of postulated accidents at the facility. This includes design-basis accidents and a maximum hypothetical accident (MHA). The MHA, which assumes an <u>incredible</u> failure that can lead to fuel cladding or to a fueled experiment containment breach, is used to bound <u>credible</u> accidents in the accident analysis.

NUREG-1537, Part 1 [6] Chapter 13, page 13-2 (emphasis added):

The accidents analyzed should range from such anticipated events as a loss of normal electrical power to a postulated fission product release with radiological consequences that exceed those *of any accident considered to be credible. This limiting accident is named the maximum hypothetical accident (MHA) for nonpower reactors; the details are reactor specific. Because the MHA is not expected to occur, the scenario need not be entirely credible.*

3.3 Non-LWR Precedents

It should be noted that the language used in footnote 6 of 10 CFR 50.34 does not specify that the core melt event is a requirement, but rather is a precedent. This position was communicated to the NRC by both Oklo and Kairos Power, as excerpted below.

Section 5.1.1 of the Aurora FSAR [8]:

It is clear that the intent is to provide reasonable assurance that the greatest potential radiological consequences of any credible event have been identified. The regulation does not require consideration of a core meltdown, stating only that meltdowns have "generally been assumed."

…

Thus, it is reasonable to infer that the NRC would acknowledge that advanced reactors may be designed such that the probability of accidents yielding significant release of radioactivity is so remote that such accidents are not credible.

Section 1.3.1 of the Kairos Power Mechanistic Source Term Methodology report [9]:

The regulations cited above require an applicant to consider a fission product release from the core to evaluate dose. However, the regulations do not require a specific type of accident or source term to be evaluated. Footnote 6 states that core meltdown accidents have generally been assumed but stops short of requiring that an applicant postulate such an accident.

3.4 Latest Regulatory Guidance and Conclusions

TerraPower has been in communication with the NRC about its approach for the major accident/MHA methodology [10], which is informed by the proposed guidance in DG-1404 [11]. The two options in [10] and [11] are summarized briefly as:

Option 1: Use the DBA dose consequence results from an LMP-based approach to establish the acceptability of the EAB and LPZ

…

Under this option, depending on the nature of the DBA, the application may need to include an exemption from the regulations in 10 CFR 50.34 or 10 CFR 52.79 that require an assumed "major accident" to demonstrate containment performance and to confirm that the EAB and LPZ doses are below the reference values in the regulations.

…

Option 2: Use the greater of the dose consequence results from the bounding DBA and from a bounding BDBE, as identified in the LMP-based approach, to establish the acceptability of the EAB and LPZ.

It should be noted that the term "major accident" is used in the discussion above, and as such, the term major accident will be used herein, as opposed to MHA or MCA. In addition, it is judged that "major accident" is a more appropriate term, as it avoids explicitly describing what "hypothetical" and "credible" mean in event frequency space and facilitates the selection of an event based on characteristics other than strictly highest dose.

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4 DISCUSSION

4.1 Identification of Major Accident Candidates

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Table 4-1: DBA Major Accident Candidates

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Table 4-2: BDBE and OQE Major Accident Candidates

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Table 4-3: Additional OQE Major Accident Candidates

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4.2 Selection of Major Accident Event

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Table 4-4: DBA Major Accident Screening

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Table 4-5: BDBE and OQE Major Accident Screening

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Table 4-6: Additional OQE Major Accident Screening

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Table 4-7: Major Accident Candidates Final Screening

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4.3 Description of Major Accident Methodology

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Figure 4-1: Major Accident EM Structure

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[[

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5 RESULTS

The candidate events for the major accident are compiled in Section 4.1. The event considered for a major accident has been identified as a ULOHS. The specific source term case selected is the

[[ ]]$^{(a)(4)}$ as described in Section 4.2, and summarized in the Kemmer Unit 1 PSAR [3] Table 3.2-19. The evaluation methodology for this major accident event is described in Section 4.3.

6 CONCLUSIONS

The major accident methodology developed and described in this report is used to support the selection of the major accident described in the PSAR for Kemmerer Unit 1 and to support the CP application.

7 REFERENCES

[1] NEI 18-04, Revision 1, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development," Nuclear Energy Institute, 2019.

[2] NEI 21-07, "Technology Inclusive Guidance for Non-Light Water Reactor Safety Analysis Report: For Applicants Utilizing NEI 18-04 Methodology," Nuclear Energy Institute, 2022.

[3] TerraPower, LLC, "Kemmerer Power Station 1 Preliminary Safety Analysis Report," 2024.

[4] RG-1.233, Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors, US Nuclear Regulatory Commission, 2020.

[5] RG-1.183, Rev. 1, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," US Nuclear Regulatory Commission.

[6] NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," US Nuclear Regulatory Commission.

[7] ACRS Transcript (Adams Accession Number ML22060A171), "Advisory Committee on Reactor Safeguards Future Plant Designs Subcommittee," US Nuclear Regulatory Commission, 2022.

[8] Oklo FSAR (ADAMS Accession Number ML21278B097), "Part II: Final Safety Analysis Report," Oklo, 2020.

[9] KP-TR-012-NP, Rev. 3 (ADAMS Accession Number ML22088A231), "KP-FHR Mechanistic Source Term Methodology," Kairos Power, 2022.

[10] TP-LIC-LET-0085, Rev. 0 (ADAMS Accession Number ML23180A301), "SARRDL Functional Containment Major Accident Presentation Materials," TerraPower, 2023.

[11] DG-1404, Rev. 1, "Guidance for a Technology-Inclusive Content-of-Application Metholody to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," US Nuclear Regulatory Commission, 2023.

[12] TP-LIC-RPT-0003, Rev. 1, "Radiological Source Term Methodology Report," TerraPower, 2024.

[13] TP-LIC-RPT-0005, Rev. 0, "Radiological Release Consequences Methodology Topical Report," TerraPower, GE Hitachi, 2023.

[14] [[ ]]$^{(a)(4)}$

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