Chapter 4 Changes From Revision 3 to Revision 4

Item	Location	Description of Change
1.	Chapter 4	Made editorial changes in numerous locations to remove excessive spacing, correct punctuation, delete repeated words, correct misspelling, and correct grammar. Spelled out acronyms where appropriate. Changed GE to GEH where appropriate.
2.	S4.1.2.1, 2nd bullet	Corrected equipment description. Changed from: "Fixed in-core gamma thermometer detectors" to "Fixed in-core gamma detectors"
3.	S4.1.2.1.2, 2nd para.	Corrected equipment description. Changed from: "The control rods occupy alternate spaces between fuel assemblies." to "The control rods occupy the cruciform space created by four fuel cells."
4.	S4.1.4.1.1, last sent.	[Editorial] Changed from "General Electric Nuclear Energy (GENE)" to "General Electric – Hitachi Nuclear Energy (GEH)"
5.	S4.1.4.1.2, last sent.	[Editorial] Changed from "GENE" to "GEH"
6.	S4.1.4.1.3, 1st sent.	[Editorial] Changed from "GENE" to "GEH"
7.	S4.1.4.5, 2nd para.	[Editorial] Changed from "This DORT code" to "The DORT code"
8.	S4.2, 1st sent.	[Editorial Clarification] The fuel system is defined as consisting of the fuel assembly and the reactivity control assembly (control rod).
9.	S4.2, 3rd sent.	[Editorial Clarification] Design criteria for ESBWR fuel are shown in Appendix 4B.
10.	S4.2, 1st sent-2nd para.	[Editorial Clarification] This section also addresses the reactivity control elements (control rods) that extend from the coupling interface of the control rod drive mechanism (per Regulatory Guide 1.70).
11.	S4.2, last sent. 2nd para.	[Editorial Clarification] Design criteria for ESBWR control rods are shown in Appendix 4C.
12.	S4.2.1.1, 1st sent, 1st para.	[Editorial Clarification] …to ensure that ~~possible~~ fuel damage ~~will~~ does not result in the release of radioactive materials…

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13.	S4.2.1.1.1	[Editorial Clarification] The fuel rod centerline temperature is limited to ensure with high probability that fuel melting ~~will~~ does not occur during normal operation, including AOOs.
14.	S4.4.2.1.1.2, 2nd para.	[Editorial Clarification] When the internal pressure exceeds the reactor coolant pressure, the cladding ~~will~~ begins to deform outward (cladding creep out). If the rate of this cladding outward deformation exceeds the rate at which the fuel pellet expands due to irradiation (fission product) swelling (fuel swelling rate), the pellet-cladding gap will begins to open (or increase if the gap is already open). An increase in the pellet-cladding gap ~~will~~ reduces the pellet-cladding thermal conductance thereby increasing fuel temperatures. The increased fuel temperatures ~~will~~ results in further fuel pellet fission gas release, greater fuel rod internal pressure, and correspondingly a faster rate of cladding outward deformation and gap opening.
15.	S4.2.1.1.3, 1st sent.	[Editorial Clarification] The fuel rod cladding strain is limited to ensure that fuel rod failure due to pellet-clad mechanical interaction ~~will~~ does not occur.
16.	S4.2.1.1.5, last sent.	[Editorial Clarification] Negligibly affected ~~for~~ by hydrogen
17.	S4.2.1.1.6, 1st sent.	[Editorial Clarification] ….cladding collapse into a fuel column axial gap ~~will~~ does not occur.
18.	S4.2.1.1.7, 1st sent.	[Editorial Clarification] …to ensure that the fuel ~~will~~ does not fail.
19.	S4.2.1.1.8, 1st para., 1st and 2nd sent.	[Editorial Clarification] "…cyclic loadings will not exceed…" to "…cyclic loadings do not exceed…" "…cladding fatigue will not occur" to "…cladding fatigue does not occur"
20.	S4.2.2.2, 1st sent., 1st para.	[Editorial Clarification] …for safe~~ty~~ shutdown response.

Item	Location	Description of Change
21.	S4.2.3.3, last sent.	[Editorial Clarification] …the fuel rod cladding ~~will~~ does not creep…
22.	S4.2.4	[Editorial Clarification] Change to: The Marathon control rod for the ESBWR is based on the Marathon control rod design for the BWR/2 through BWR/6, which has been ~~licensed~~ approved (Reference 4.2-7) and ~~applied to actual~~ employed at operating plants ~~(Reference 4.2-7)~~. Where the BWR/2 through BWR/6 design and evaluations are ~~was~~ not adequate to apply to the ESBWR, the Advanced Boiling Water Reactor (ABWR) design and evaluations are used.
23.	S4.2.4.2 , 3rd para..	[Editorial Clarification] Change to: ~~The SSE analysis could be performed through testing to show full insertion during fuel channel deflections. For example, testing~~ Testing was performed on the ABWR Marathon to confirm seismic scram capability. The ABWR Marathon was tested at amplitudes of 10, 20, 30, and 40mm. The scram times were found to be acceptable and the control rod was not damaged. The ESBWR channels are ~~will be~~ shorter, making the fuel assemblies stiffer and the fuel channel lateral deflections less. The increase in system stiffness and the decrease in lateral deflection makes the ABWR Marathon seismic scram capability test bounding for the ESBWR conditions.
24.	S4.2.4.3	[Editorial Clarification] Change to: Assuming the FMCRD ~~will~~ exerts….
25.	S4.2.4.9	[Editorial Clarification] Change to: The nuclear lifetime of the initial ESBWR Marathon control rod type is ~~will be~~ established as a 10 percent reduction in reactivity worth ($\Delta k/k$) in any quarter axial; segment, Reference 4.2-9.
26.	S4.2.4.10, 1st para., 1st sent.	[Editorial Clarification] Change to: Similar to the control rods supplied ~~to~~ for the ABWR and BWR/2 through BWR/6.

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27.	S4.2.4.10, 3rd para., 3rd sent.	[Editorial Clarification] Change to: …any orientation of the cruciform control rod between the fuel assemblies ~~shall be~~ is a coupled position, and rotation to an uncoupled position ~~shall~~ is not ~~be~~ possible during reactor operation.
28.	S4.2.4.10, 5th para., 1st sent.	Change to: The control rod is positively coupled to the FMCRD and ~~shall be~~ is designed to remain coupled.
29.	S4.2.5	[Editorial Clarification] GEH has an active program for the surveillance of both production and developmental fuel. The NRC has reviewed the GEH program and approved it in Reference 4.2-6.
30.	S4.3.1.1, 6th sent., 1st para.	Verb tense change.
31.	S4.3.1.2, 1st sent., 1st para.	Verb tense change.
32.	S4.3.1.3, 1st para.	Verb tense change.
33.	S4.3.1.3, 2nd para.	Verb tense change to present tense of monitoring MLHGR limit. Clarification of MLHGR conditions if an overpower condition occurs.
34.	S4.3.1.4, 1st para.	Inserted abbreviation “SDM” following initial use of the term Shutdown Margin.
35.	S4.3.1.5, 3rd para.	Verb tense change.
36.	S4.3.2.1, 3rd para, 1st sent..	Made a generalization of source of 2-D lattice code, change “the” to “a”.
37.	S4.3.3.1, 1st and 2nd paras.	Clarification of information for equilibrium core and initial core references.
38.	S4.3.3.2.1, 2nd para., 1st sent.	Added reference 4.3-10.

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39.	S4.3.3.2.2, 2nd para.	a.) Clarification of information for equilibrium core and initial core references. b.) Remove specific results of equilibrium moderator void coefficient from text.
40.	S4.3.3.2.3, 2nd para.	Sentence structure changed to add clarity.
41.	S4.3.3.2.3, 3rd para.	Clarification of information for equilibrium core and initial core references.
42.	S4.3.3.3.1, 2nd para., 1st sent.	Verb change.
43.	S4.3.3.3.1, 5th para.	Clarification of information for equilibrium core and initial core references.
44.	S4.3.3.3.2, 2nd para.	Clarification of information for equilibrium core and initial core references.
45.	S4.3.3.3.3, 2nd para.	Clarification of information for equilibrium core and initial core references.
46.	S4.3.3.5, 1st para.	Clarification of information for equilibrium core and initial core references.
47.	S4.3.3.6.2, 1st para.	Change in verb.
48.	S4.3.3.6.2, 3rd para.	Stability response changed per RAI 4.3-7, MFN 07-292.
49.	S4.3.4	Title of section changed from “changes” to “Deleted”
50.	S4.3.5	Title of section changed, added applicant action description.
51.	S4.3.6, and S4.3-8	Updated reference release version and added NEDO document information.
52.	S4.3.6	Added Reference 4.3-10
53.	T4.3-1	Title clarified as results for Equilibrium cycle analysis.
54.	F4.3-1	Title clarified as results for Equilibrium cycle analysis.
55.	F4.3-2	Title clarified as results for Equilibrium cycle analysis.
56.	F4.3-3	Title clarified as results for Equilibrium cycle analysis.
57.	F4.3-4	Title clarified as results for Equilibrium cycle analysis.

Item	Location	Description of Change
58.	S4.4.1	Some editorial change and pointing to section 15.2 for most severe AOOs.
59.	S4.4.2.1.1	Context for GEXL correlation added.
60.	S4.4.2.1.3	Clarification and minor editorial change.
61.	S4.4.2.3.2	One long sentence broken up into two sentences for clarity.
62.	S4.4.2.3.4	A new paragraph for clarity.
63.	S4.4.2.4	Minor editorial change.
64.	S4.4.3	Two Table numbers for clarity.
65.	S4.4.3.2, 1st para.	Table numbers expanded for clarity.
66.	S4.4.3.2, 2nd para.	Added Reference 4.4-17 for initial core results.
67.	S4.4.3.6	Reference corrected.
68.	S4.4.4.3	Additional information and reference 4.4-18 added for clarification.
69.	S4.4.4.4	Additional information added for clarification.
70.	S4.4.4.6	Table numbers expanded for clarity.
71.	S4.4.4.7	Minor editorial change.
72.	S4.4.5	Information added as per response to RAI 4.4-7 Supp 2, 4.4-8 Supp 2 and 4.4-9 Supp 2 with some editorial changes.
73.	S4.4.7	No COL information required since initial core analysis information is given in References 4.4-17 and 4.4-18.
74.	S4.4.8	Added References 4.4-17 to 4.4-19. Updated Reference 4.4-12 revision number and date. Reference 4.4-19 added as per response to RAI 4.4-7 Supp 2, 4.4-8 Supp 2 and 4.4-9 Supp 2.
75.	T4.4-1a	Temperature units changed for consistency.
76.	S4.5.1.2.1	[Editorial] Changed from: “Colmonoy and Stellite (or its equivalent) hard surface” To: “Colmonoy and Stellite (or their equivalent) hard surfaced”

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77.	S4.5.1.3, 1st sent.	Equipment part description clarified. Changed from: "Stellite 3/Haynes 25 are used fro rollers/pins at latch (outside, and Haynes 25 for the latch joint pin." To: "Stellite 3/Haynes 25 are used for the rollers/pins on the outside of the hollow piston latches, and Haynes 25 for the latch joint pin."
78.	S4.5.2.1, last sent.	[Editorial] Changed from: "reactor internals are non-coded" To: "reactor internals are non-code"
79.	S4.5.2.3, 1st sent.	[Editorial] Changed from: "core support structures will fully conform and be certified to ASME Section III" To: "core support structures are in conformance with and certified to ASME Section III"
80.	S4.5.2.3, two places	[Editorial] Changed from: "will be examined" To" "are examined"
81.	S4.5.2.4, 1st para.	[Editorial] Changed from: ESBWR will comply fully with Regulatory guide 1.31" To "ESBWR fully complies with Regulatory guide 1.31"
82.	S4.5.2.4, 1st para.	[Editorial] Changed from: "Ferrite content will be determined" To: "Ferrite content is determined"

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83.	S4.5.2.4, 3rd para.	[Editorial] Changed from" "welded assemblies are dispensed from this requirement" To" "welded assemblies are exempt from this requirement."
84.	S4.5.2.5, 6th para.	[Editorial] Changed from; "reactor internals shall be selected" To: "reactor internals are selected"
85.	S4.6.1.1.1	[Editorial] Changed from "shall provide" to provides" (1st and 5th bullet) changed from "shall include" to "includes" (2nd bullet) Changed from "shall be" to "is" (3rd and 4th bullet)
86.	S4.6.1.1.2, 3 places	[Editorial] changed from "shall provide" to "provides
87.	S4.6.1.2.2, **Bayonet Couplings** section	[Editorial] Changed from "bayonet" to "bayonet coupling"
88.	S4.6.1.2.2, **FMCRD Brake and Ball Check Valve** section, 2nd para.	Correction of equipment description Changed from: Changed from: "The electromechanical brake is located between the motor and the position signal detectors. The stationary spring-loaded disk and coil assembly is contained within the brake mounting bolted to the bottom of the motor. The rotating disk is keyed to the motor shaft and synchro shaft." To: "The electromechanical brake is located in the motor unit. The stationary spring-loaded disk and coil assembly is contained within the brake mounting bolted to the bottom of the motor unit top flange. The rotating disk is keyed to the motor unit output shaft."

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89.	S4.6.1.2.2, **Magnetic Coupling** section, 1st para.	Correction of equipment description. Changed from: "The magnetic coupling is located in the spool piece." To: "The magnetic coupling is located at the bottom of the spool piece."
90.	S4.6.1.2.4, 2nd bullet	[Editorial] Changed from: "RWCU/SDC a pump" To: "RWCU/SDC pump"
91.	S4.6.1.2.4, 3rd bullet	[Editorial] Changed "are" to "is"
92.	S4.6.1.2.5, **Alternate Rod Insertion** section, 1st para.	Reference to DCD figure added. Changed from: "low reactor vessel water Level 2" To: "low reactor vessel water Level 2 (Figure 7.7-1)"
93.	S4.6.2.1.1, 2nd sent.	[Editorial change for clarification.] Changed from: "The scram time shown in the description is reflected in Chapter 15 safety analyses." To: "The required scram time is reflected in the Chapter 15 safety analyses."

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94.	S4.6.2.1.4, 5th para.	COL item deleted. Items related to procedures and operations are in the scope of Chapter 13, Conduct of Operations. Changed from: "The COL applicant shall develop maintenance procedures with provisions to prohibit coincident removal of the control rod and CRD of the same assembly. In addition, the COL application shall develop contingency procedures to provide core and spent fuel cooling capability and mitigative actions during CRD replacement with fuel in the vessel." To: "Maintenance procedures prohibit coincident removal of the control rod and CRD of the same assembly. In addition, contingency procedures address core and spent fuel cooling capability and mitigative actions during CRD replacement with fuel in the vessel.
95.	S4.6.3.5, 1st bullet	[Editorial.] Changed from: "Sufficient control rods shall be withdrawn" To: "Sufficient control rods are withdrawn"
96.	S4.6.3.5, 3rd bullet	[Editorial.] Changed from: "The coupling integrity shall be verified" To: "The coupling integrity is verified"
97.	S4.6.3.5, 5th bullet	[Editorial.] Changed from: "At the time of each major refueling outage" To: "At each refueling outage"

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98.	S4.6.6, and S4.6.6.1	COL item deleted. Items related to procedures and operations are in the scope of Chapter 13, Conduct of Operations. See associated change to 4.6.2.1.4 above. Added "None" below 4.6.6 heading Added "(Deleted)" at the end of the 4.6.6.1 heading Deleted the text of subsection 4.6.6.1
99.	F4.6.2	[Editorial.] Changed picture to larger format for better clarity and detail.
100.	F4.6-10	Corrected figure title. Changed from: "Control Rod Drive System Separation Mechanism" To: "FMCRD Anti-Rotation Devices"
101.	S4A.1	Incorporate reference to initial core design reference.
102.	S4A.2	Define minimum critical power ratio abbreviation (MCPR)
103.	S4A.3	Clarify COL applicant's responsibilities. Labeled 4A-1-A applicant action.
104.	S4A.4	Add reference section.
105.	S4B.2	Changed citation and text to point to SRP 4.2 instead of NUREG 0800.
106.	T4B-1, 1st row	Change the subscripting of equation elements in table such that Criterion and governing Equation formats are consistent.
107.	T4B-1, 3rd row	Removed .00 from the statement of the stain criteria. In other words, changed 1.00% to 1%.
108.	S4B.2	Editorial clarification to "Cladding Lift-Off", "High Strain Rate" and "Fuel Rod Stresses" discussions.
109.	S4B.2, **High Strain Rate** section	Changed 1.00% to 1%. Made editorial modifications to more correctly express the effect of barrier cladding on fuel performance.

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110.	S4B.6	Modified Section 4.B.6 per NRC Audit July 31-August 3. Simplified Tier 2* statement regarding Critical Power criteria.
111.	S4C, 2nd & 3rd sent.	[Editorial Clarification] Added "design" after "control rod"
112.	S4C.1, 1st sent.	[Editorial Clarification] Changed from "The control rod will meet…" to "The control rod design meets…"
113.	S4C.1, 1st bullet	[Editorial Clarification] Changed to "Control rod stresses…are evaluated…",and added "structure, or welded connection"
114.	S4C.1, 2nd bullet	[Editorial Clarification] Changed to "The control rod design is evaluated…"
115.	S4C.1, 3rd bullet	[Editorial Clarification] Changed to "Control rod materials are shown…"
116.	S4C.1, 4th bullet	[Editorial Clarification] Changed to "Control rod reactivity worth is included…"
117.	S4C.2, 1st sent. after **Stress, Strain and Fatigue**	[Editorial Clarification] Added "design" after "control rod"
118.	S4C.2 2nd sent. after **Stress, Strain and Fatigue**	[Editorial Clarification] Changed to"…the control rods do not fail"
119.	S4C.2, 1st sent. after **Control Rod Insertion**	[Editorial Clarification] Added, "design" after "control rod"
120.	S4C.2, 2nd sent. after **Control Rod Material**	[Editorial Clarification] Added "design" after "control rod"
121.	S4C.2, 1st sent. after **Reactivity**	[Editorial Clarification] Added "design" after "control rod"
122.	List of Figures	Added a new figure captioned "Two Dimensional Stability Map for ESBWR" and labeled it 4D-1. Relabeled rest of the figures accordingly.
123.	List of Figures	Dropped the word "Proposed" from caption of figure 4D-2-----that figure is already NRC approved.

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124.	S4D	Added quantities in British units, where missing. Replaced quantities in non-SI units, like bar, with SI units. Replaced ºK temperatures with ºC (a project preferred temperature unit).
125.	S4D	Made reference notation consistent with rest of the chapter 4 by deleting square bracket ([]) and adding the word 'Reference' where needed.
126.	S4D	Minor grammatic changes/corrections.
127.	S4D	Removed a reference to the 'future' COL phase. Work on this phase is in progress, particularly on the 'Detect and Suppress' solution.
128.	S4D.1.1, 1st para.	Added to reference to Figure 4D-1
129.	S4D.1.1, 1st para.	Contraction 'GE' changed to 'GEH'
130.	S4D.1.1, 3rd para.	Amended to reflect wider investigations in this domain.
131.	S4D.1.4.4	Removed reference to COL Applicant. Inserted a sentence to clarify need for the verification of a core containing non-GE14 fuel.
132.	S4D.2, 2nd para.	Rephrased part of the paragraph to correct grammar and improve clarity.
133.	S4D.2.2.1, 1st para.	Added a sentence to improve context of reactor startup process.
134.	S4D.2.2.1, 2nd para.	Added a sentence to update the document per progress on the project.
135.	S4D.2.2.1, last para.	Deleted this paragraph as a study with MSIV's open has appeared in LTR #NEDO-33337.
136.	S4D.2.2.3, 1st para.	Removed a reference to COL Applicant. Startup with MSIV's open has appeared in LTR #NEDO-33337.
137.	S4D.3	Removed all 4 COL items because they have been resolved, see next 4 entries.
138.	S4D.3, item 4D.3-1-A	Deleted. Section 4D.2.2.1 now points to the LTR (#NEDO-33337), wherein, the stability of the "final core design" is reported.
139.	S4D.3, Item 4D.3-2-A	Deleted. Section 4.3.3.6.2 states that an NRC approved Confirmation Density Algorithm is utilized for the Detect and Suppress Solution.

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140.	S4D.3, Item 4D.3-3-A	Deleted. Section 4D.2.2.1 points to the LTR (#NEDO-33337) which documents the required study.
141.	S4D.3, Item 4D.3-1-A	Deleted. Section 4D.2.2.1 now indicates the locations (section 4.2.2 and LTR #NEDO-33337) of the relevant values. It also points to the guiding role of Human Factor Engineering in laying out reactor startup procedures.
142.	T4D-1	Added quantities in British units, where missing. Replaced ºK temperatures with ºC (a project preferred temperature unit).