2. Fuel Mechanical Design

This section contains a description of the fuel thermal–mechanical analyses bases currently in use in the U.S. These bases were used to analyze the fuel bundles described in Reference 2–2. A description of the previous analyses bases and a detailed description of the 8x8 and 8x8R fuel designs are given in Reference 2–3. The analyses bases described in Reference 2–3 are also used in those countries whose regulatory bodies have not yet accepted the fuel design bases presented in this section.

The format of this section corresponds to Standard Review Plan 4.2 in NUREG–0800. The design bases for each of the fuel system damage, failure, and coolability criteria identified in SRP Section II.A are provided in Subsection 2.2. A description of the fuel assembly (SRP Section II.B) appears in Reference 2.1a. The design evaluations for each of the fuel system damage, failure, and coolability criteria identified in SRP Section II.C are also provided in Subsection 2.2. Fuel assembly testing, inspection, and surveillance plans (SRP Section II.D) are documented in Subsection 2.3.

2.1 Fuel Assembly Description

Descriptions of the fuel assemblies (including fuel rods, water rods, other fuel assembly components and channels) to which the fuel thermal–mechanical design bases described in this section apply are given in Reference 2–2. These fuel designs meet the criteria in Subsection 1.1.2 or are separately approved by the NRC.

2.2 Design Bases, Limits, and Evaluations

Operating limits are established to ensure that actual fuel operation is maintained within the fuel rod thermal–mechanical design and safety analysis bases. These operating limits define the maximum allowable fuel pellet operating power level as a function of fuel pellet exposure. Lattice local power and exposure peaking factors may be applied to transform the maximum allowable fuel pellet power level into Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) limits for individual fuel bundle designs. Otherwise, the LHGR limit is monitored directly.

[[

]]

2.2.1 Fuel System Damage

This subsection applies to normal operation and anticipated operational occurrences except for Subsections 2.2.1.3, 2.2.1.6 and 2.2.1.7, which apply to normal operation only.

2.2.1.1 Stress/Strain

2.2.1.1.1 Bases

The fuel assembly components are evaluated to ensure that the fuel will not fail due to stresses or strains exceeding the fuel assembly component mechanical capability.

2.2.1.1.2 Limits

[[

]]

2.2.1.1.3 Evaluations

[[

]]

2.2.1.2 Fatigue

2.2.1.2.1 Bases

The fuel assembly and the fuel rod cladding are evaluated to ensure that strains due to cyclic loadings will not exceed the fatigue capability.

2.2.1.2.2 Limits

[[

]]

2.2.1.2.3 Evaluations

[[

]]

2.2.1.3 Fretting Wear

2.2.1.3.1 Bases

The fuel assembly is evaluated to ensure that fuel will not fail due to fretting wear of the assembly components.

2.2.1.3.2 Limits

[[

]]

2.2.1.3.3 Evaluations

[[

]]

2.2.1.4 Oxidation, Hydriding and Corrosion Products

2.2.1.4.1 Oxidation and Corrosion Products

2.2.1.4.1.1 Bases

[[

]]

2.2.1.4.1.2 Limits

[[

]]

2.2.1.4.1.3 Evaluations

[[

]]

2.2.1.4.2 Hydriding

2.2.1.4.2.1 Bases

The fuel rod is evaluated to ensure that failure will not occur due to internal cladding hydriding.

2.2.1.4.2.2 Limits

[[

]]

2.2.1.4.2.3 Evaluations

[[

]]

2.2.1.5 Dimensional Changes

2.2.1.5.1 Bases

The fuel rod is evaluated to ensure that fuel rod bowing does not result in fuel failure due to boiling transition.

2.2.1.5.2 Limits

[[

]]

2.2.1.5.3 Evaluations

[[

]]

2.2.1.6 Internal Gas Pressure

2.2.1.6.1 Bases

The fuel rod is evaluated to ensure that the effects of fuel rod internal pressure during normal steady–state operation will not result in fuel failure due to excessive cladding pressure loading.

2.2.1.6.2 Limits

[[

]]

2.2.1.6.3 Evaluations

[[

]]

2.2.1.7 Hydraulic Loads

2.2.1.7.1 Bases

The fuel assembly is evaluated to ensure that interference sufficient to prevent control blade insertion will not occur.

2.2.1.7.2 Limits

[[

]]

2.2.1.7.3 Evaluations

[[

]]

Two separate aspects of channel box deflection are considered: channel bulge and channel bow. Channel bulge is addressed in Reference 2–4. In response to an NRC question on initial cores, Reference 2–12 provides supplementary information to Reference 2–4, and also contains a discussion of the program GE recommends to utilities obtaining an operating license after May 1982. Channel bow effects on thermal margins are included in Reference 2–16. References 2–4, 2–12 and 2–16 apply only to channels supplied by General Electric.

2.2.1.8 Control Rod Reactivity

Control rod reactivity limits are discussed in Subsections 3.1 and 3.2.4.

2.2.2 Fuel Rod Failure

Subsections 2.2.2.1 through 2.2.2.3 apply to normal operation; Subsections 2.2.2.4, 2.2.2.5 and 2.2.2.7 apply to anticipated operational occurrences; and Subsections 2.2.2.6, 2.2.2.8 and 2.2.2.9 apply to postulated accidents.

2.2.2.1 Hydriding

Hydriding is discussed in Subsection 2.2.1.4.2 of this document.

2.2.2.2 Cladding Collapse

2.2.2.2.1 Bases

The fuel rod is evaluated to ensure that fuel rod failure due to cladding collapse into a fuel column axial gap will not occur.

2.2.2.2.2 Limits

[[

]]

2.2.2.2.3 Evaluations

[[

]]

2.2.2.3 Fretting Wear

Fretting wear is discussed in Subsection 2.2.1.3 of this document.

2.2.2.4 Overheating of Cladding

Overheating of the cladding is addressed in Subsection 4.3.1 of this document.

2.2.2.5 Overheating of Pellets

2.2.2.5.1 Bases

The fuel rod is evaluated to ensure that fuel rod failure due to fuel melting will not occur.

2.2.2.5.2 Limits

[[

]]

2.2.2.5.3 Evaluations

[[

]]

2.2.2.6 Excessive Fuel Enthalpy

Excessive fuel enthalpy is discussed in the country–specific supplement to this document.

2.2.2.7 Pellet–Cladding Interaction

2.2.2.7.1 Bases

The fuel rods are evaluated to ensure that fuel rod failure due to pellet–clad mechanical interaction will not occur.

2.2.2.7.2 Limits

[[

]]

2.2.2.7.3 Evaluations

[[

]]

2.2.2.8 Bursting

Bursting is addressed in the country–specific supplement to this document.

2.2.2.9 Mechanical Fracturing

2.2.2.9.1 Bases

The fuel assembly is evaluated under Safe Shutdown Earthquake and Loss–of–Coolant Accident loading conditions to ensure that loss of fuel assembly coolability, and interference to the degree that control blade insertion is prevented, will not occur.

2.2.2.9.2 Limits

The limits used for this evaluation are described in Reference 2–7 and Subsections 2.2.1.1.2 and 2.2.1.2.2.

2.2.2.9.3 Evaluations

[[

]]

2.2.2.9.3.1 Dynamic Analysis and Component Seismic Loads

[[

]]

2.2.2.9.3.2 LOCA Loads

The pressure differentials on the BWR/4–6 lower tieplates, upper tieplates, and spacers resulting from a recirculation line break or from a steam line break are greater than or equal to the corresponding pressure differentials for BWR/2, 3 fuel assembly components. Water rod pressure differentials are insignificantly small. The methodology for evaluating LOCA pressure differentials for BWR/2, 3 fuel is similar to that used for BWR/4–6 fuel assemblies.

2.2.2.9.3.3 Component Evaluations

[[

]]

2.2.3 Fuel Coolability

This subsection applies to postulated accidents.

2.2.3.1 Cladding Embrittlement

Cladding embrittlement is addressed in the country–specific supplement to this document.

2.2.3.2 Violent Expulsion of Fuel

Violent expulsion of fuel is addressed in the country–specific supplement to this document.

2.2.3.3 Generalized Cladding Melting

Generalized cladding melting is bounded by the cladding embrittlement criteria of Subsection 2.2.3.1.

2.2.3.4 Fuel Rod Ballooning

Fuel rod ballooning is addressed in the country–specific supplement to this document.

2.2.3.5 Structural Deformation

Structural deformation is addressed in Subsection 2.2.2.9 of this document.

2.3 Testing, Inspection and Surveillance Plans

2.3.1 Testing and Inspection of New Fuel

The General Electric quality assurance program is documented in Reference 2–15. The reference covers the quality control areas associated with the manufacture and inspection of new fuel for the areas of:

1. Material and component procurement.
2. Fabrication and assembly of components and systems.
3. Inspection and testing.
4. Cleaning, packaging, and shipping.
5. Installation and erection of systems and components.
6. Pre–operational and startup testing.

The reference further describes that these quality control plans are implemented using the following document types:

1. Acceptance standards.
2. Audit plans and procedures.
3. Calibration procedures.
4. Corrective action procedures.
5. Design control procedures.
6. Engineering drawings and specifications.
7. Handling, storage, packing and shipping procedures.
8. Inspection instructions.
9. Inspection and tester stamp control procedures.
10. Material identification and control procedures.
11. Measuring and test equipment control procedures.
12. Nonconforming material control procedures.
13. Pre–production quality evaluation procedures.
14. Process and personnel qualification procedures.

15. Process control procedures.
16. Product/process quality plans.
17. Purchased material quality control plans.
18. Quality assurance document control procedures.
19. Quality assurance records specifications and instructions.
20. Quality control standards instructions.
21. Receiving inspection plans.
22. Shipment release control procedures.
23. Supplier evaluation and selection procedures.
24. Test instructions.

The quality assurance program described in Reference 2–15 applies explicitly to the Wilmington manufacturing site; however, similar quality assurance programs are implemented in the overseas manufacturing facilities.

2.3.2 On–Line Fuel System Monitoring

Provided by Applicant.

2.3.3 Post–Irradiation Surveillance

General Electric has an active program of interim and post–irradiation surveillance of both lead use assemblies and developmental BWR fuel. The schedule of inspection is contingent on both the availability of the fuel as influenced by plant operation and the expected value of the information to be obtained.

[[

]]

2.4 References

2–1 Letter from J. S. Charnley (GE) to R. Lobel (NRC), *Implementation of GESTR–M*, April 24, 1984.

2–2 *General Electric Fuel Bundle Designs*, NEDE–31152P, Revision 8, April 2001.

2–3 *General Electric Fuel Bundle Designs Evaluated with TEXICO/CLAM Analyses Bases*, April 1986 (NEDE–31151–P).

2–4 *BWR Fuel Channel Mechanical Design and Deflection*, NEDE–21354–2–P (Proprietary) and NEDO–21354–2, July 1977.

2–5 American National Standard for Light Water Reactors Fuel Assembly Mechanical Design and Evaluation, American Nuclear Society Standards Committee Working Group ANS 57.5, ANSI/ANS–57.5–1981.

2–6 W. G. Jameson, Jr., *Fuel Assembly Evaluation of Shipping and Handling Loadings*, NEDE–23542–P (Proprietary), March 1977.

2–7 *Fuel Assembly Evaluation of Combined Safe Shutdown Earthquake (SSE) and Loss–of–Coolant Accident (LOCA) Loadings (Amendment No. 3)*, NEDE–21175–3–P–A (Proprietary) and NEDO–21175–3–A, October 1984.

2–8 Letter from J. S. Charnley (GE) to M. S. Dunenfeld (NRC), *1984 Fuel Experience Report*, October 14, 1985.

2–9 K. W. Hill, et al., *Effect of a Rod Bowed to Contact on Critical Heat Flux in Pressurized Water Reactor Rod Bundles*, American Society of Mechanical Engineers Publication 75–WA/ HT–77.

2–10 E. S. Markowski, et al., *Effect of Rod Bowing on CHF in PWR Fuel Assemblies*, American Society of Mechanical Engineers Publication 77–HT–91.

2–11 Letter from R. L. Gridley (GE) to D. G. Eisenhut (NRC), *Evaluation of Potential Fuel Bundle Lift at Operating Reactors*, July 11, 1977.

2–12 Letter from G. G. Sherwood (GE) to D. G. Eisenhut (NRC), *In the Matter of 238 Nuclear Island General Electric Standard Safety Analysis Report (GESSAR II) Docket No. 50–447*, February 2, 1983.

2–13 *Creep Collapse Analysis of BWR Fuel Using SAFE–COLAPS Model*, NEDO–20606A and NEDE–20606–PA (Proprietary), August 1976.

2–14 Memo from L. S. Rubenstein (NRC) to R.L. Tedesco (NRC), *SER Input for WNP–2*, February 24, 1982.

2–15 *Nuclear Energy Business Group BWR Quality Assurance Program Description*, NEDO–11209–04A, March 1978.

2–16 Letter, J. S. Charnley (GE) to R. C. Jones, Jr. (NRC), *Fuel Channel Bow Assessment*, MFN086–89, November 15, 1989.

2–17 *GE11 Critical Power Test with Rod Bow to Contact*, NEDE–31829P, April 1990.

2-18 Robert A. Rand, *Cladding Creep Collapse Licensing Topical Report*, NEDC-33139P-A, July 2005.