GE Hitachi Nuclear Energy

BWR LOCA

Long-Term Core Cooling

NRC Public Meeting on 'LTC Methodology Guidance'

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Outline

- U.S. BWR fleet LTCC compliance status
- Technical Points of BWR LTCC
  - Summary of 5 LOCA Criteria
  - Long-Term Cooling per 10CFR50.46
    Jet-Pump Plants
    External Pump Plants
  - Debris Blockage Considerations
    Current Status
- Methodology considerations
  - Approach to compliance – near term
  - Addressing debris blockage – intermediate term
- Conclusions / Discussion

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U.S. BWR fleet LTCC compliance status

- A framework survey of the U.S. fleet indicated that:
  - All BWRs rely on the original GE methodology for LTCC. No other fuel supplier's methodology is cited as the basis.
  - In the case of plant-specific evaluations, the original basis is still the GE methodology from FSAR.
- In this aspect, the BWR fleet LTCC bases are fairly uniform.
- The original basis was reaffirmed as part of the LOCA methodology development:

  NEDO-20566A, "General Electric Company Analytical Model for Loss-of-Coolant Analysis in Accordance with 10CFR50 Appendix K," November 1975 (reissued as "approved" NEDE-20566-P-A, September 1986).

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Technical Points

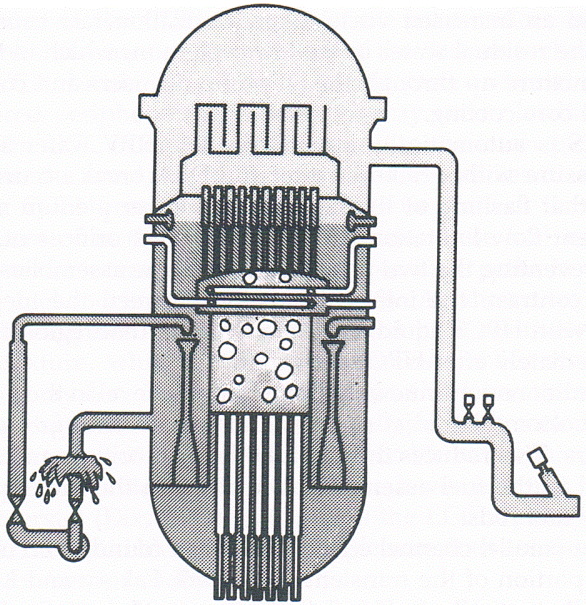

Fig. 8-2 Hypothetical BWR LOCA event—time of initiation.

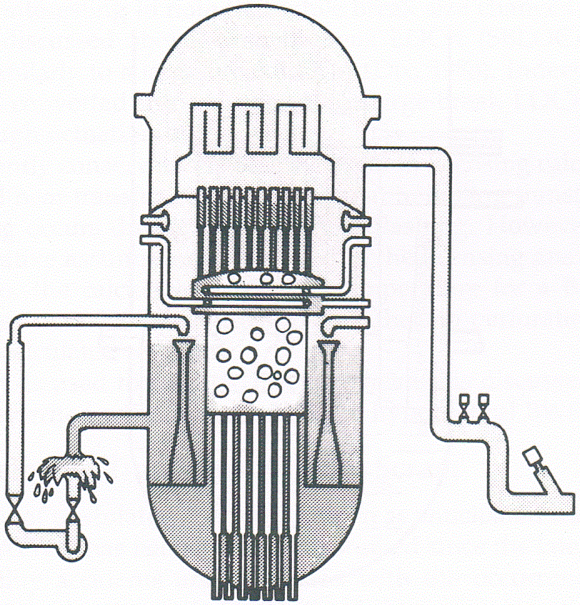

Fig. 8-3 Hypothetical BWR LOCA event—time of jet pump suction uncovery.

The Thermal-Hydraulics of a Boiling Water Nuclear Reactor, 2nd Edition
Richard T. Lahey, F. J. Moody
American Nuclear Society, 1996.

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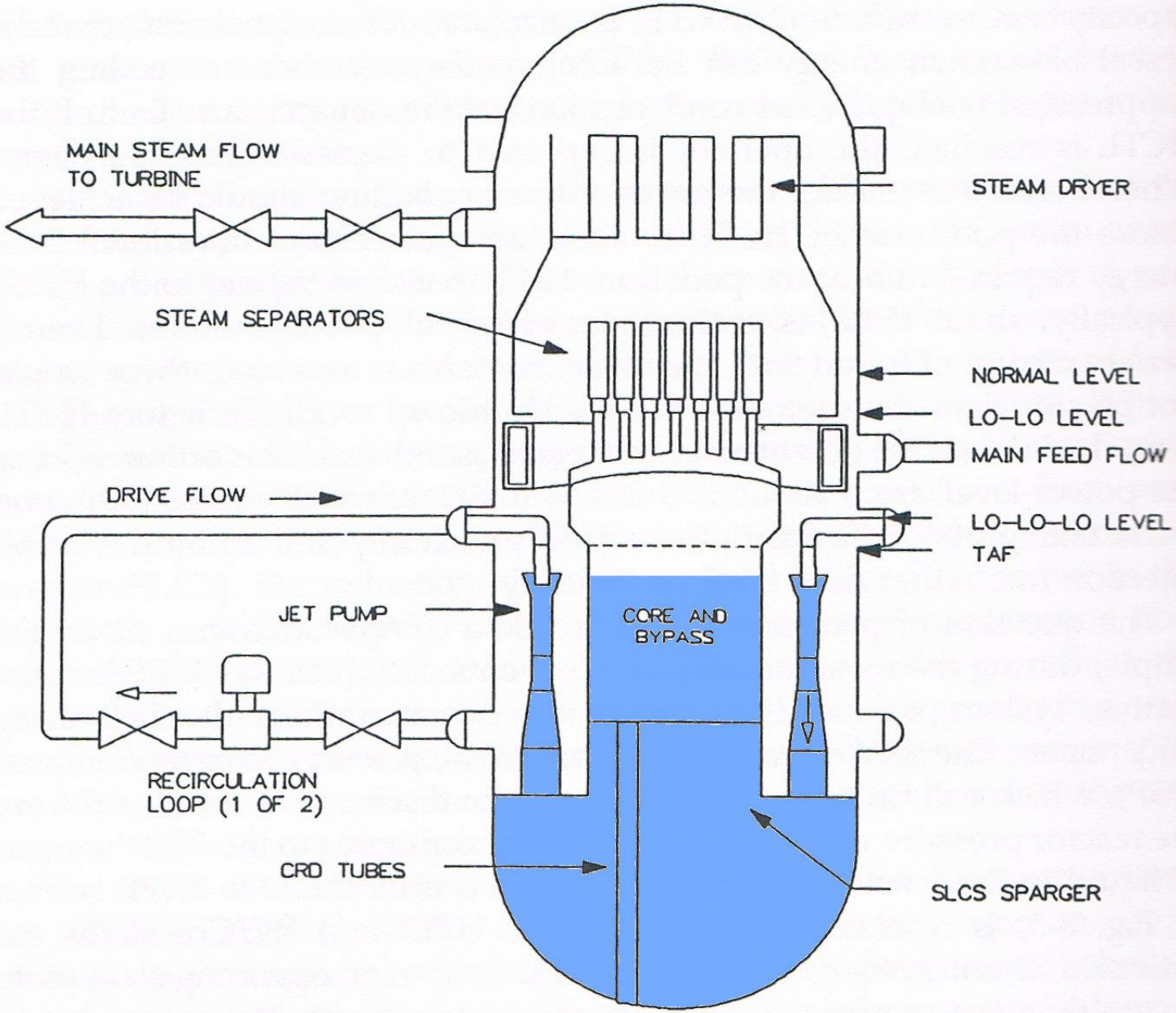
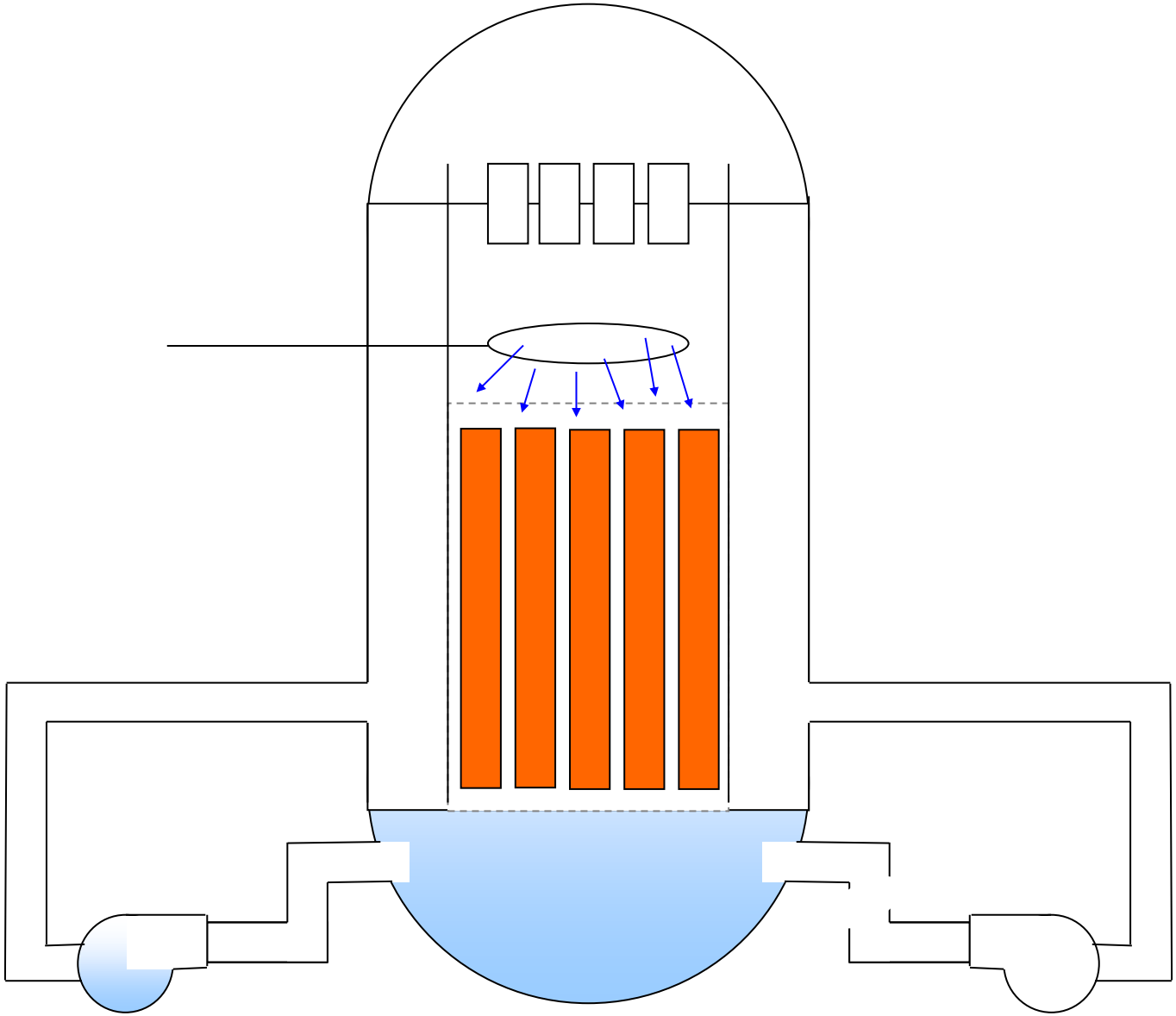

MAIN STEAM FLOW
TO TURBINE
STEAM DRYER
STEAM SEPARATORS
NORMAL LEVEL
LO-LO LEVEL
MAIN FEED FLOW
DRIVE FLOW
LO-LO-LO LEVEL
TAF
JET PUMP
CORE AND
BYPASS
RECIRCULATION
LOOP (1 OF 2)
CRD TUBES
SLCS SPARGER



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The Five Criteria for ECCS Acceptance

10CFR50.46 lists the following as the Emergency Core Cooling System (ECCS) evaluation acceptance criteria:

Peak Cladding Temperature < 2200 °F

Maximum Local Oxidation < 17%

Hydrogen generation, hence core-wide oxidation < 1%

Coolable geometry: core remains amenable to cooling

Long-Term Cooling: After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.

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Compliance with Long-Term Cooling

- Compliance with LTC requirement is documented in NEDE-20566-P-A, for both jet pump and external pump designs.

- Integral and separate effect tests on the core spray sparger designs of the BWRs were verified by means of full-scale mock-ups tested in air at various flow conditions. Steam environment effects are also addressed in NEDO-20566-3.

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Compliance with Long-Term Cooling

- Pipe Breaks Other Than Recirculation System:
  The reactor vessel refloods for all pipe breaks other than in the recirculation system, and the fuel cladding quickly cools to saturation temperature.
  No further perforation nor metal-water reaction will result.

- Recirculation Line Breaks in Non-Jet Pump BWRs:
  As demonstrated in NEDE-20566-P-A, the fuel rods will be wetted by the core spray in a matter of minutes following the accident. The cladding surface area will return quickly to saturation temperature.
  No further perforation nor metal-water reaction will result.

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Compliance with Long-Term Cooling

- Recirculation Line Breaks in Jet Pump BWRs:
  When the core refloods shortly following the postulated LOCA, the fuel rods will return quickly to saturation temperature over their entire length.
  When at least one spray system is available long-term, the upper third of the core will remain wetted by the core spray water as in non-jet pump BWRs, and there will be no further perforation or metal-water reaction.

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Adequacy of Long-Term Cooling

- Adequacy of LTC requirements was further investigated for top peaked axial power shapes and newer core loading patterns. The applicability was confirmed.
- As decay heat falls off, the heat flux in the core will be too small to cause two-phase level above the top of active fuel. This occurs in ~10 minutes for the low-powered peripheral channels and about 30 hours for high-powered bundles.
- There is at least one core spray system available long-term and the upper third of the core will remain wetted and cooled by the spray water as in non-jet pump BWRs.

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Effect of Decay Heat on LTCC

- Decay heat has no direct effect on the magnitude of figures of merit during LTCC phase; it only affects when.
- As the decay heat falls off, the heat flux in the core would be too small to cause two-phase level above the top of active fuel.

  ~ 10 minutes for low-powered peripheral channels
  ~ 30 hours for the high-powered bundles.

- All bundles will undergo similar transient and decay heat level necessary to cause level drop is the same:

  Once the water level has fallen, all bundles require the same amount of cooling regardless of the initial power level because the power has decayed to the same level.

- Therefore, there are no particular concerns on decay standard and/or uncertainties.

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Debris Blockage Considerations

- Current Status:

  BWROG is supporting responses to NRC questions and proposing additional tests to demonstrate that:

  There is no debris blockage impact on initial quench and PCT

  There is sufficient fuel channel inlet flow with potential blockage.

- Additional tests for long-term to assess how long it would take the fuel inlet blockage, if any, is being planned.
- Tools used in LOCA calculation are adequately equipped to handle evaluations for long-term cooling portion.
- Resolution has a framework that contains experimental, analytical, and regulatory aspects.

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Conclusions

- BWR fleet LTCC bases are fairly uniform.
- All BWRs, one way or another, rely on the original GE methodology for LTCC. No other fuel supplier's methodology is cited as the basis.
- No current plans to update the LTCC basis.
- Technical aspects are easier to resolve (e.g. no boron). No significant issues related with meeting LTCC without debris.
- Existing LOCA tools can be utilized in LTCC calculations with application-specific scrutiny – no need for separate methodology.
- The industry guidance document will summarize these points as an embedded portion for BWRs.

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