BWR Owners' Group

New Stability Limit

Presentation to USNRC
Mike May, Exelon Corp.

November 5, 2002

Agenda

• Purpose	Mike May
• Background	Mike May
• New Stability Limit	Ron Engel
• Feasibility Study Results	Jerry Potts
• Conclusions	Mike May
• Milestones	Mike May

Purpose

- Discuss a new stability limit that will provide the best basis for final resolution for D&S Plants
- In July, the BWROG proposed a study to assess the feasibility of a new stability limit
- Present results of feasibility study
- Obtain NRC feedback

Background

- Current D&S methodology defines cycle-specific calculation to ensure MCPR safety limit protection
- Current reload method relies on generic DIVOM curves of CPR change vs. oscillation magnitude
- June 2001: GE reported that generic DIVOM curves may be non-conservative, resulted in Part 21 notification
  - Plants implemented corrective actions
- BWROG D&S Committee re-formed to develop new generic DIVOM correlation

Background

- Concluded that generic DIVOM approach not viable for Option III
  - DIVOM curve slope too steep (unacceptably low OPRM setpoints)
  - Unable to develop good generic DIVOM curve correlation
- Looked at several alternatives and selected an approach that:
  - Uses TRACG to calculate best-estimate CPR response to oscillations and initiating events
  - Establishes generic setpoints which provide SLMCPR protection
  - Completed some analyses for Options III and I-D and demonstrated feasibility of approach for existing designs
- Reviewed approach with NRC at 5/1/02 meeting

Background

- Reassessed current program to seek opportunity for:
  - Greater probability of long term viability
  - Wider range of applicability (new operating domains, power uprate, fuel vendors, new fuel types)
  - Less likely to have unnecessary scrams
- Identified need for a new stability limit
  - One related to actual fuel characteristics
  - Applicable to stability as a Special Event
  - No longer based on MCPR

New Stability Limit

Objectives for New Stability Limit

- Meet applicable fuel design limits for stability
- Ensure broad based stability solution
- Select a limit consistent with actual impact on fuel
- Ensure small effect on fuel cladding from power oscillations

BWROG Requirements for New Limit

- Must satisfy regulatory requirements
- Must satisfy applicable fuel design limits for stability
- Must allow a return to operation immediately after a stability event (i.e., no additional evaluations necessary)
- Applicable to all BWR fuel vendors
- Compatible with existing stability based hardware/software
- Maintain stability scram setpoints near current values

Proposed New Stability Limit

Limit on oscillation magnitude and duration such that there is:

- *No predicted fuel rod failure*
- *Negligible change in fuel rod properties from those assumed in design and licensing analyses*

Benefits of New Limit

- Ensure a more robust solution that is not susceptible to methodology issues in the future
- Expand solution applicability for current and future core and fuel designs (including all BWR fuel vendors) and operating domains
- Produce solution applicable to all plants
- Bring permanent closure to BWR D&S stability issues

Regulatory Considerations

- GDC 12 - Suppression of reactor power oscillations
  "The reactor core and associated coolant, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed."
- All design limits are described in SRP Section 4.2
- SRP 4.2 - Fuel System Design
  - SRP 4.2 used to identify applicable fuel design limits for stability
  - Applicable to all fuel vendors
  - Includes requirements for cladding overheating
- All design limits in SRP 4.2 have been evaluated for applicability to stability

SRP 4.2 Fuel Rod Cladding Overheating

- Current Limit:

  "It has been traditional practice to assume that failures will not occur if the thermal margin criteria (DNBR for PWRs and CPR for BWRs) are satisfied."

- Provision for new limit is provided in SRP 4.2:

  "Although a thermal margin criterion is sufficient to demonstrate the avoidance of overheating from a deficient cooling mechanism, it is not a necessary condition (i.e., DNB is not a failure mechanism) and other mechanistic methods may be acceptable. There is at present little experience with other approaches, but new positions recommending different criteria should address cladding temperature, pressure, time duration, oxidation, and embrittlement."

New Stability Limit Approach

- Permit oscillations of limited magnitude and duration
  - Allows fuel rods to go into and out of boiling transition
  - Avoids sustained boiling transition (rewetting each cycle necessary)
  - Limits cladding temperature increase
- Select applicable fuel design limits for stability
- Confirm that applicable fuel design limits are satisfied with new stability limit

Feasibility Study Results

November 5, 2002 New Stability Limit Slide 15

Feasibility Study Results - Applicable Design Limits for Stability

Design Limits selected by BWR Fuel Vendors

- Cladding and channel stress and strain, including:
  - creep deformations
  - annealing of irradiation hardening
  - pellet cladding mechanical interaction
- Cladding fatigue
- Cladding oxidation
- Dimensional changes (fuel rod growth, cladding collapse)
- Increased fission gas release and fuel rod internal pressure
- Fuel centerline melting

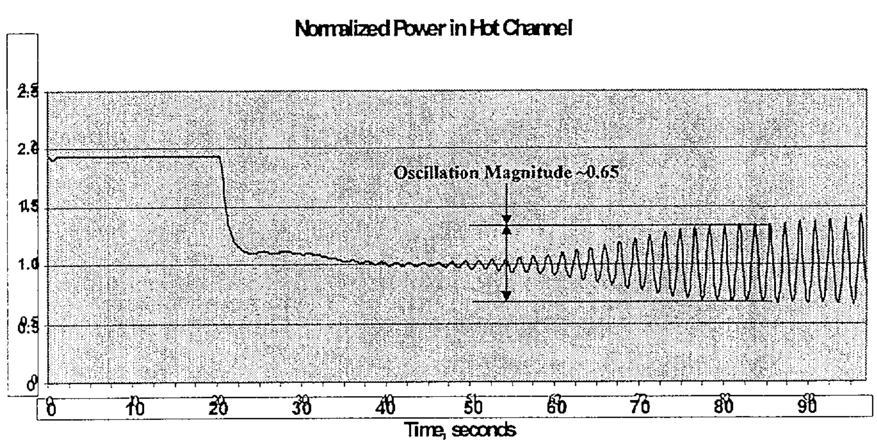
These design limits establish all required detailed fuel evaluations for stability

November 5, 2002 New Stability Limit Slide 16

Feasibility Study Results – Fuel T/H Evaluation

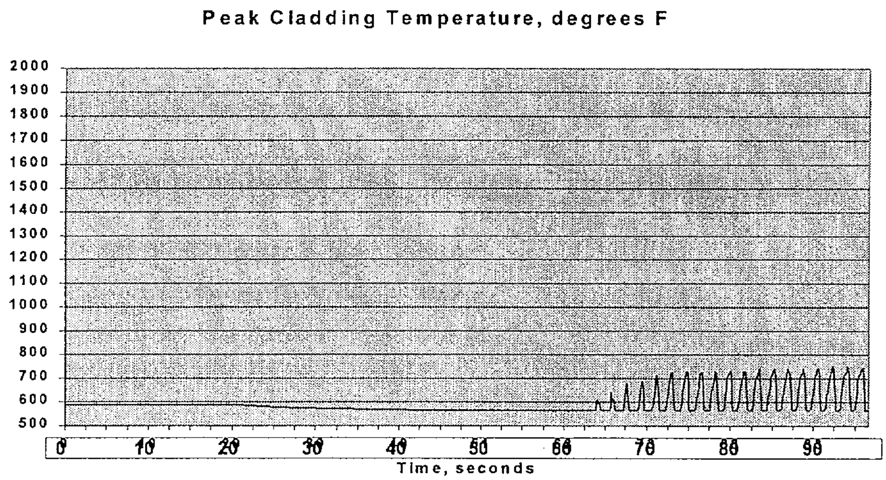
- A representative TRACG case for a BWR/6 loaded with 10x10 fuel and regional oscillations following a two-pump trip resulted in :
  - Near limit cycle oscillations with a hot channel oscillation magnitude of ~0.65, which corresponds to an OPRM scram setpoint of ~1.20
  - The hot channel cycled in and out of boiling transition for this oscillation magnitude (case started with very low MCPR)
  - The PCT in the hot channel oscillated due to dryout and subsequent rewet during each cycle
  - Maximum cladding temperature < 800 degrees F

TRACG Results



Representative results based on current methods and qualification

TRACG Results



Representative results based on current methods and qualification

Feasibility Study Results - Applicable Design Limits for Stability

Design Limits selected by BWR Fuel Vendors

- Cladding and channel stress and strain, including:
  - creep deformations
  - annealing of irradiation hardening
  - pellet cladding mechanical interaction
- Cladding fatigue
- Cladding oxidation
- Dimensional changes (fuel rod growth, cladding collapse)
- Increased fission gas release and fuel rod internal pressure
- Fuel centerline melting

These design limits establish all required detailed fuel evaluations for stability

Feasibility Study Results – Fuel T/M Evaluation

- Stability design limits were selected
- These generic limits were translated into preliminary fuel design limits
- Feasibility analyses indicated that a single limit could bound all design limits
  - Analysis showed that annealing of irradiation hardening is the limiting requirement
  - Small amount of annealing occurs, but has negligible effect on cladding properties
  - Implies that a limit on peak clad temperature and duration of instability event is required

Summary

- Using SRP 4.2 as the basis, stability design limits for protecting the fuel have been defined
- These design limits have been used in a feasibility study
  - Annealing of fuel irradiation hardening has been identified as the most limiting requirement
    - ↳ This requirement can be met by limiting the peak cladding temperature and duration of the instability event
    - ↳ The peak cladding temperature is controlled by limiting the oscillation magnitude
    - ↳ The oscillation magnitude is controlled by proper selection of the stability scram setpoint

Based on these results, the fuel rods are not predicted to fail and there are negligible changes to fuel rod properties

Conclusions

Conclusions

- The BWROG approach is consistent with current regulatory requirements
- The use of a New Stability Limit is feasible
- This approach is expected to provide:
  - A solution for all D&S plants
  - Acceptable setpoints using existing D&S hardware/software
  - A solution that is applicable for fuel from all BWR fuel vendors
  - Flexibility to accommodate future fuel design changes and operating domain expansions
  - Permanent closure to BWR D&S stability issues

Future Activities

Milestones

Task	Date
NRC concurrence on new stability limit approach . . .	Today
Plan for licensing submittal	1Q 03
Complete technical work	3Q 03
Present results to NRC	4Q 03
Submit LTR for NRC review	4Q 03
NRC approval	2Q 04

NRC Comments and Feedback

Proposed Contents of LTR - Backup

- Revised stability bases and new limit
- Define stability event parameters (oscillation magnitude, period, and duration)
- Application to Options III, I-D, II with existing stability hardware/software
- Confirmation of applicability to all fuel vendors

Backup Material

Standard Review Plan Section 4.2

Specified Acceptable Fuel Design Limits

Review of Regulatory Considerations

All design limits are described in SRP Section 4.2

- Objectives
  - Fuel system is not damaged as a result of normal operation or AOOs
  - Control rod insertion not prevented
  - Fuel rod failures not underestimated
  - Coolability is maintained
- Design Bases
  - "Design bases for the safety analysis address fuel system damage mechanisms and provide limiting values for important parameters such that damage will be limited to acceptable levels."

SRP 4.2 Fuel System Design Criteria

a. Stress, strain, or loading limits on fuel bundle components and control rods
b. Cumulative number of strain fatigue cycles on fuel rods and structural members
c. Fretting wear at contact points on fuel rods and structural members
d. Oxidation, hydriding, and buildup of crud
e. Dimensional changes such as rod bowing or irradiation growth
f. Fuel and burnable poison rod internal gas pressures
g. Hydraulic loads for normal operation should not exceed holddown capability of the fuel assembly
h. Control rod reactivity must be maintained

November 5, 2002 New Stability Limit Slide 31

SRP 4.2 Fuel Rod Design Criteria

a. Hydriding (due to internal hydrogenous material)
b. Cladding collapse
c. Fretting (a gradual process that would not be effective during brief duration of AOO or accident)
d. Overheating of cladding (more detail later)
e. Overheating of fuel pellets (centerline melting)
f. Excessive fuel enthalpy (reactivity insertion accidents from zero or low power)
g. Pellet/Cladding Interaction
h. Bursting (LOCA issue)
i. Mechanical fracturing (from externally applied forces, such as seismic or LOCA events)

November 5, 2002 New Stability Limit Slide 32

SRP 4.2 Fuel Coolability

- Fuel coolability applies to postulated accidents, and considers the following criteria:
  a. Cladding embrittlement
  b. Violent expulsion of fuel
  c. Generalized cladding melting
  d. Fuel rod ballooning
  e. Structural deformation