3. ACR Fuel Qualification

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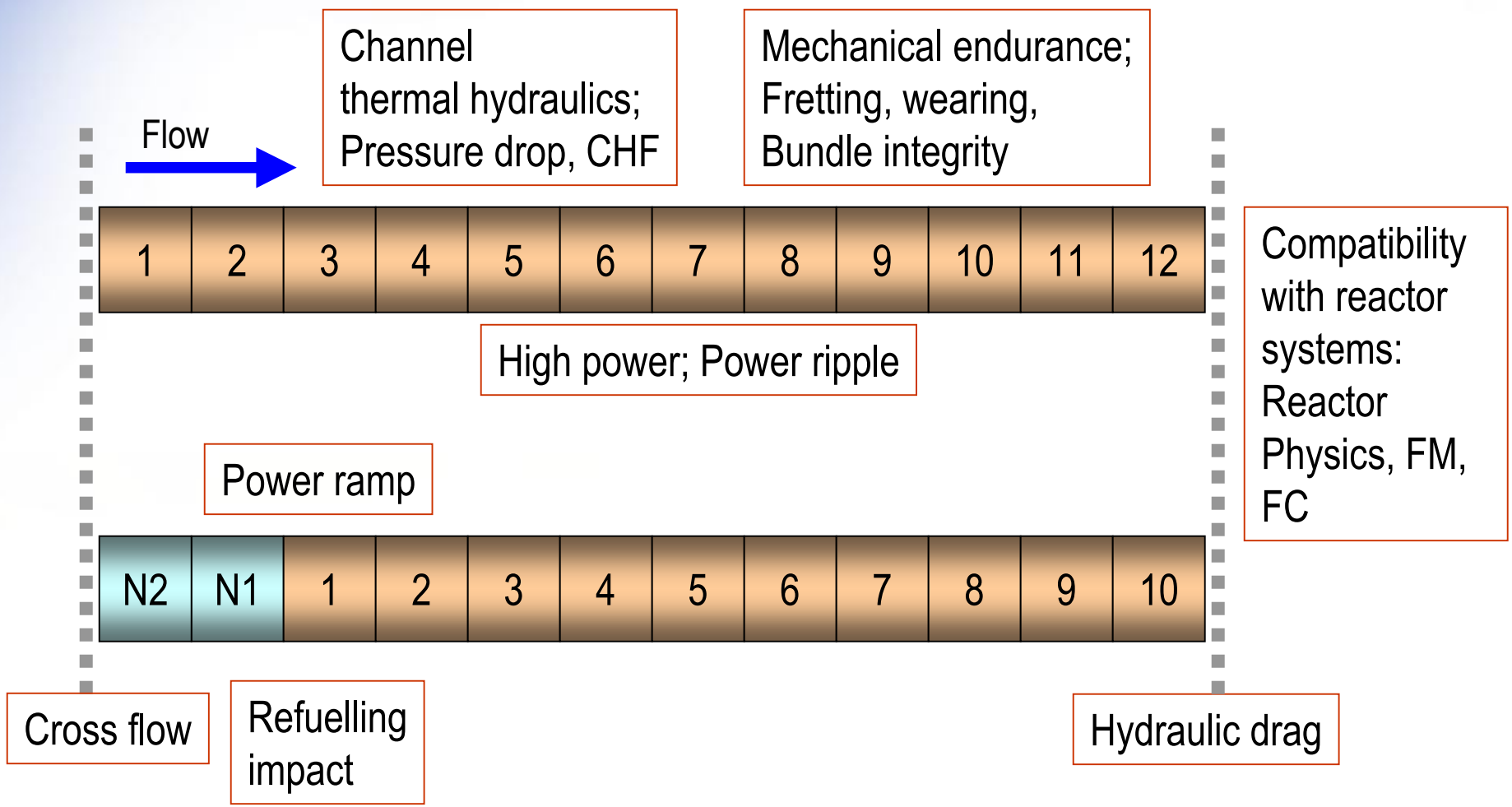
Purpose

- To confirm that all configurations permitted by design tolerances in fuel and reactor conditions will maintain fuel within specified acceptable design limits during normal operations (NOC) and anticipated operational occurrences (AOO).

Outline

- To address expected verification methods for ACR
- Scope
  - Design requirements
  - General considerations (grouping activities, verification methods, conservatism)
  - Thermal integrity
  - Structural integrity: element
  - Structural integrity: bundle
  - Compatibility with reactor systems
  - Expectation from US NRC
  - Conclusions

Design Requirements



General Considerations: Three Performance Aspects

- Thermal integrity
  - confirm that fuel clad and pellet will not overheat
- Structural integrity
  - confirm that critical components of the fuel bundle will not crack or break, nor will fuel bundle geometry lose geometric stability
- Compatibility with reactor systems
  - ensure that critical parts fit and that they have acceptable interactions with neighbours and other interfacing systems

General Considerations: Verification Methods

- Overall features of ACR fuel design are supported by operating experience
  - proven design features (e.g., thin wall clad, small diametral gap)
    - cumulative element failure rate of about 0.001% since 1997
  - CANDU utilities have ongoing fuel surveillance program
  - experience to extended burnups
    - about 230 bundles in the Bruce A power reactor, exceeding 17 MWd/kgU (about 20 bundles were examined in hot cell)
    - about 870 fuel elements in NRU, exceeding 17 MWd/kgU
      - 15 irradiations with bundle avg burnups greater than 21 MWd/kg
- New design features are verified by
  - prototype testing; available data plus planned tests
  - analytical predictions or
  - combination of both

Previous Irradiations for CANFLEX SEU and Dy-Doped Fuel

- Dimensionally acceptable for ACR fuel element verification
- Power
  - high powers for SEU; five CANFLEX SEU bundles had peak ratings above 60 kW/m
  - powers for Dy-doped fuel comparable to ACR conditions
- Burnup
  - two CANFLEX SEU test bundles (AJM, AJN) were irradiated to burnups exceeding 20 MWd/kgU
- Will be used in the qualification of ACR fuel design

CANFLEX-SEU Fabrication Dimensions

Dy-doped Fuel Fabrication Dimensions

ACR Element High Powers, Compared to Irradiations in NRU

Planned Irradiation Tests

Planned Out-Reactor Tests

- CHF test
- Pressure drop test
- Mechanical fretting endurance test
- Cross flow test
- Refueling motion test
- Sliding wear test
- Bent tube gauge test
- Bundle strength test

Planned Out-Reactor Tests

- Spacer interlocking test
- Frequency sweep test and pressure pulsation test
- Fueling machine compatibility test
- Seismic testing
- Axial collapse test
- Longitudinal ridge test

General Considerations: Conservatism

- Envelope operational and design configurations
  - most representative elements/bundles
  - bounding power envelopes
  - appropriate thermal hydraulic conditions
  - appropriate consideration for design parameters and uncertainties

Thermal Integrity

Pellet Melting

Clad Dryout

Structural Integrity: Element

Structural Integrity: Element

Internal Gas Pressure

Fission Gas Release

Clad Collapse into Axial Gap

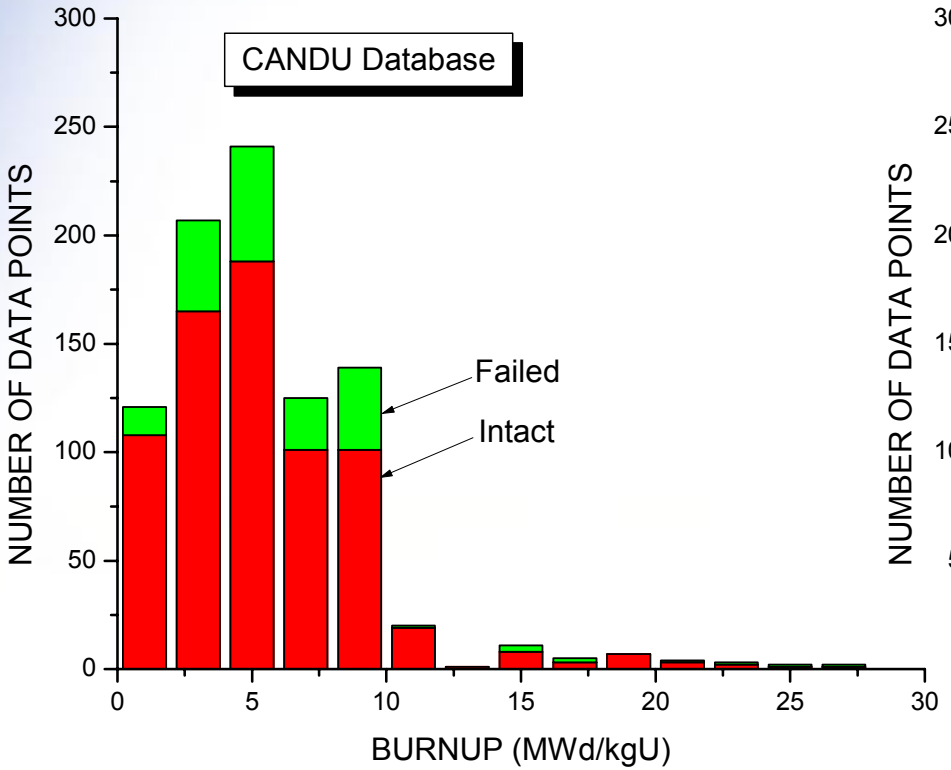
Clad Strain at Circumferential Ridges

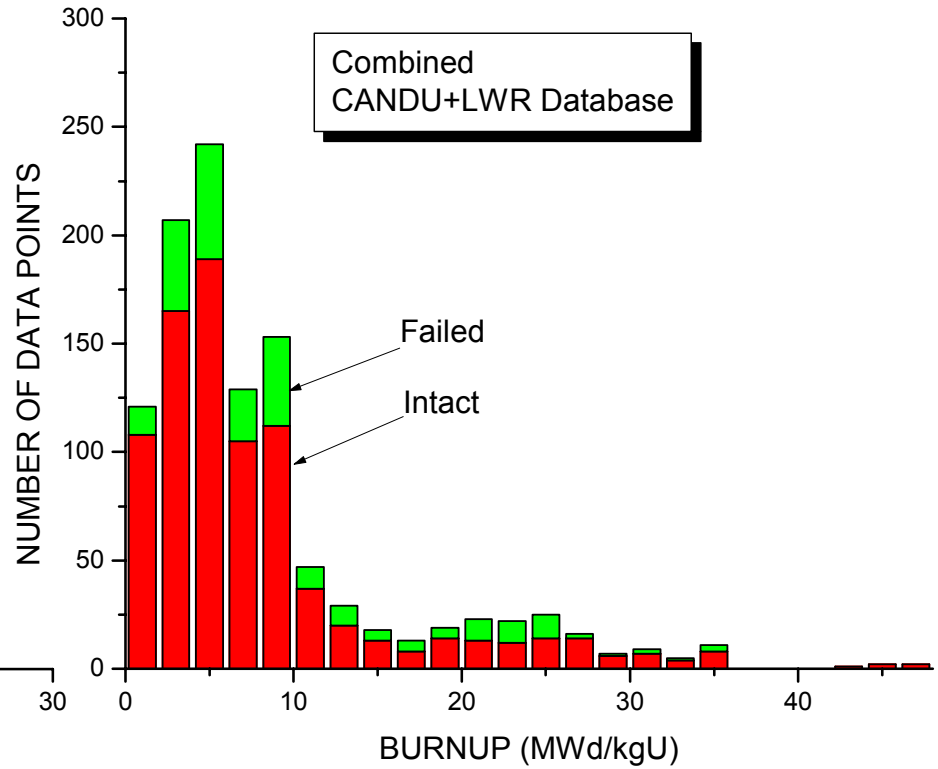
Clad Collapse into Diametral Gap (Longitudinal Ridging)

Power-Ramp Behaviour

Power-Ramp Database

Distribution of Data





Power-Ramp Failure Threshold

Hydriding

Clad Oxidation and Crud

Structural Integrity: Bundle

Structural Integrity: Bundle

Static Refueling Loads

Typical Side Stop Design

Secondary Stresses/Strains in Endplate

Buckling

Typical Bundle Compression Test Result vs. Prediction

Refueling Motion

Typical Bundle Velocity vs. Distance (Cold, Flow Visualization Test)

Fatigue Caused by Lateral Vibrations of Fuel Elements

Fatigue Caused by Axial Vibrations

Cross-Flow Endurance

Compatibility with Reactor Systems

Compatibility with Reactor Systems

Length Changes

Fretting

Fretting vs. Time

Sliding Wear

Bowing, Sag and Droop

Dimensional Compatibility with FC and FH Systems

Conclusions

- Fuel design criteria established consistent with SRP requirements
- Verification plan will show how criteria are met
- Verification plan consistent with previous qualification of CANDU fuel
- Extensive CANDU power reactor experience supports key ACR fuel design features
- Various incremental qualification activities for ACR fuel planned
  - testing, analysis, and combination
  - takes advantage of available existing test results (e.g., CANFLEX qualification results)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