



3. ACR Fuel Qualification

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Presentation to US NRC
Chalk River, 2004 May 12**





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).**

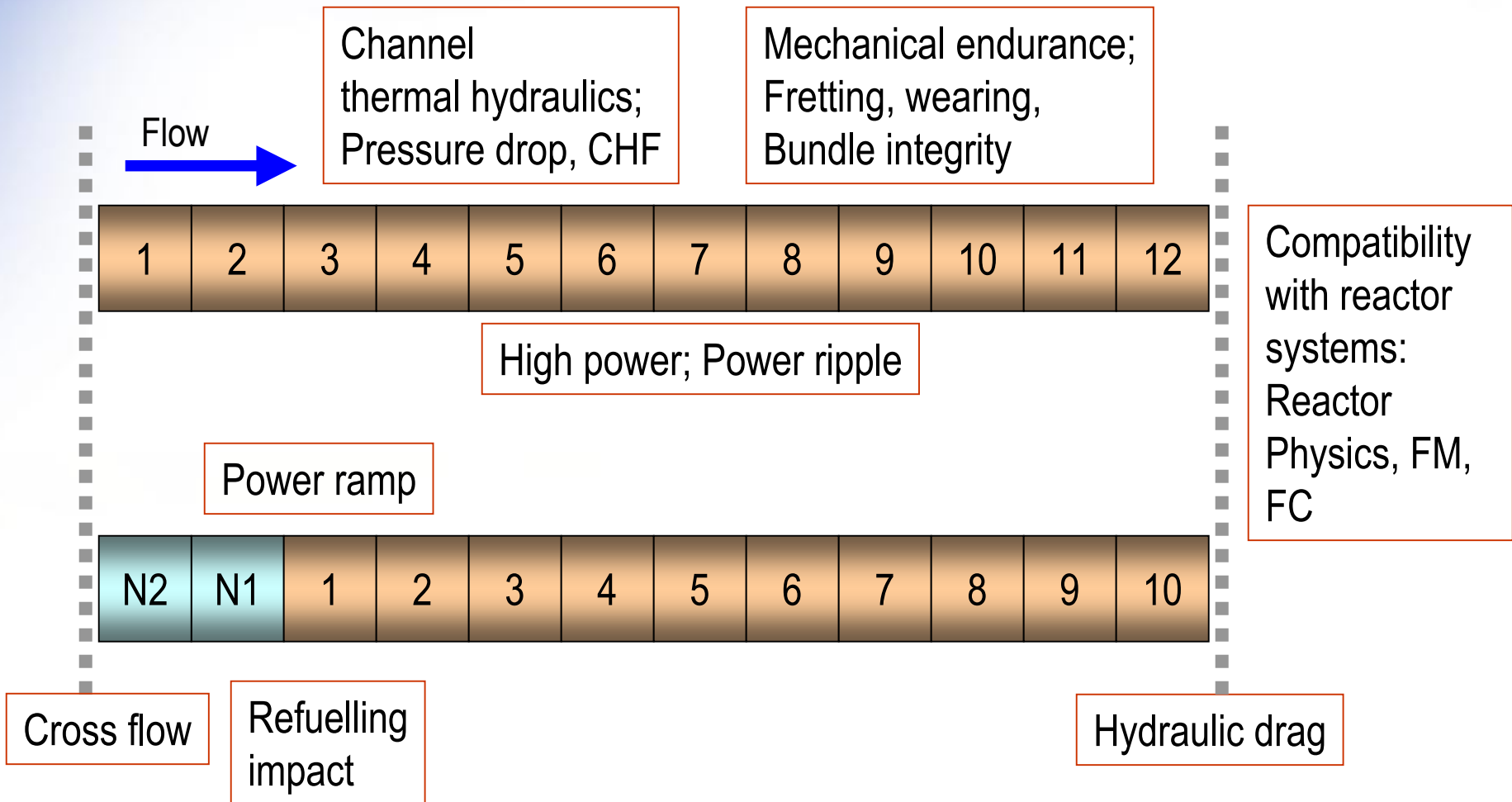


Outline

- **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

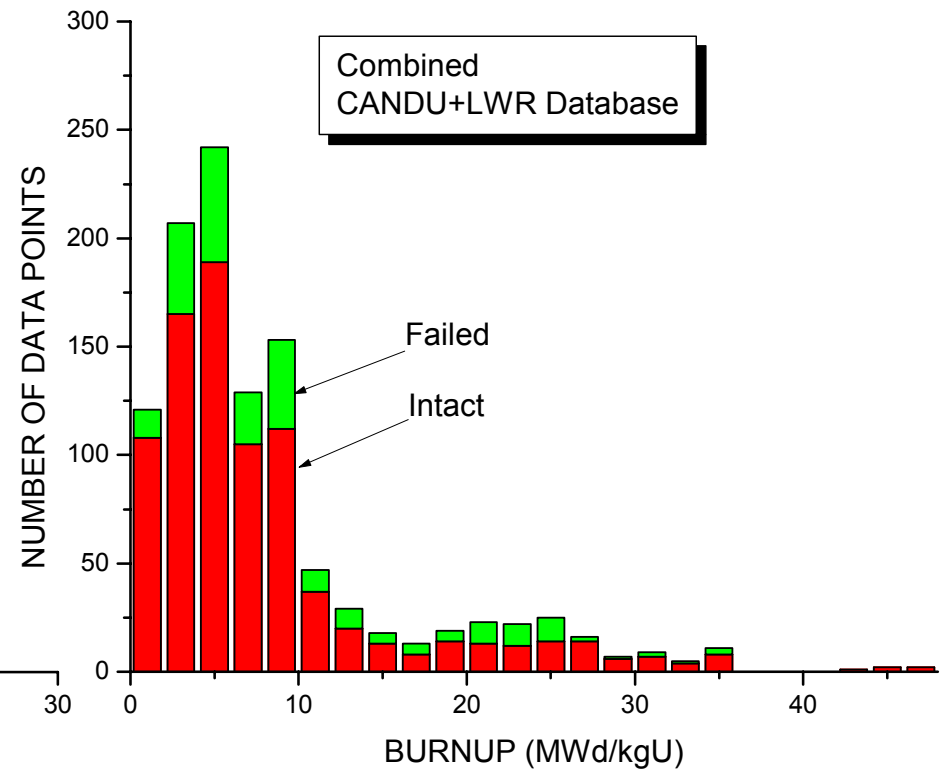
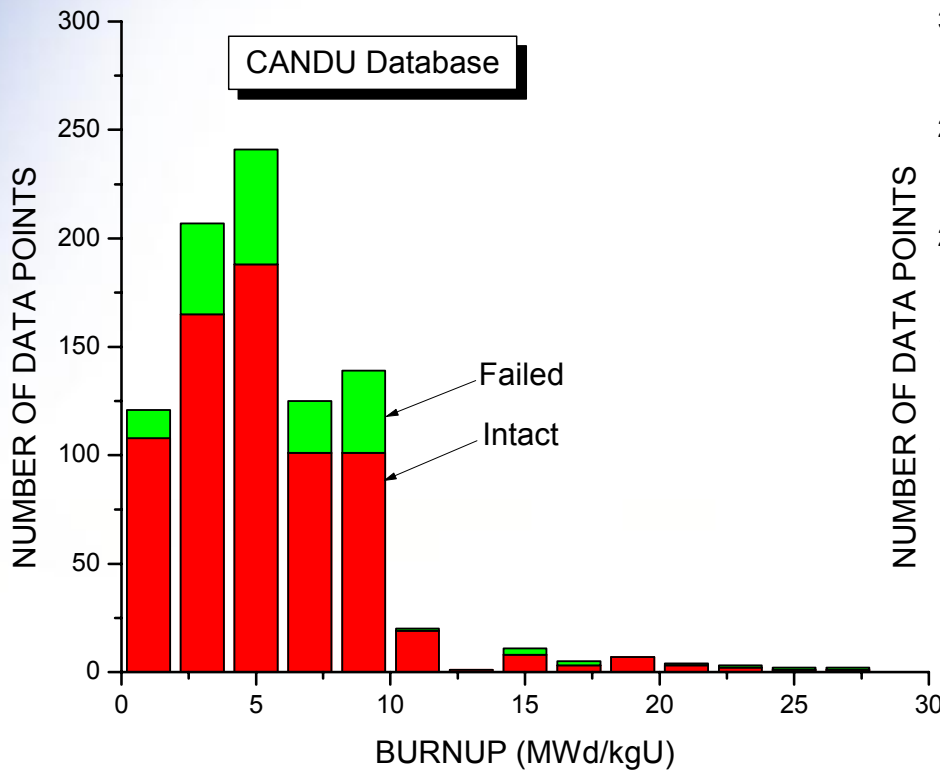


Power-Ramp Database





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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