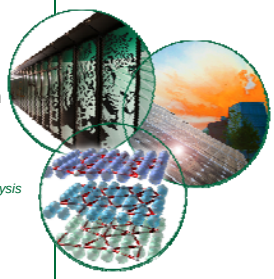
NRC RESEARCH IN SUPPORT OF BURNUP CREDIT REGULATORY GUIDANCE



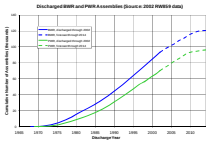
John Wagner, Cecil Parks, Don Mueller, Ian Gauld
Nuclear Science & Technology Division

Session: TH32 Spent Nuclear Fuel Criticality Analysis Issues; Thursday, March 11

The 22nd Annual Regulatory Information Conference

March 9 – 11, North Bethesda, Maryland

Introduction

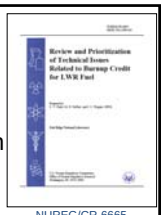


- Increasing spent nuclear fuel (SNF) inventories necessitate expanding and optimizing SNF storage and transport capacity
- Credit for fuel burnup can enable more cost-effective, higher-density storage and transport of SNF
- Potential benefits of burnup credit have motivated
  - Numerous technical studies, domestically and internationally
  - Use in storage, transport and disposal license applications
- PURPOSE: inform audience about NRC sponsored research (at ORNL) relevant to *Spent Nuclear Fuel Criticality Analysis*

Introduction

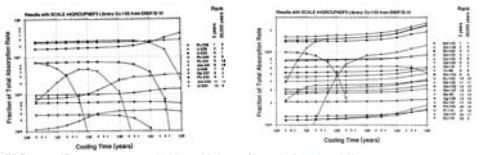
- In 1999, the US NRC initiated a research program with ORNL to develop guidance and technical bases for allowing and expanding the use of burnup credit in PWR SNF storage and transport applications
- The research program attempted to systematically address technical issues in the pursuit of expanding regulatory guidance for the use of burnup credit
- The program produced a number of publically available reports and supported revised guidance

Baseline Report, 1999



NUREG/CR-6665

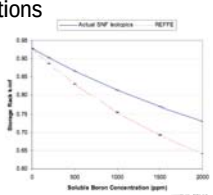
- Reviewed application areas
- Reviewed previous technical studies
- Reviewed/identified parameters/phenomenon
- Reviewed technical and licensing issues
- Proposed research and prioritization
- Status of burnup credit programs in other countries



Reactivity Equivalencing, 2000

NUREG/CR-6683

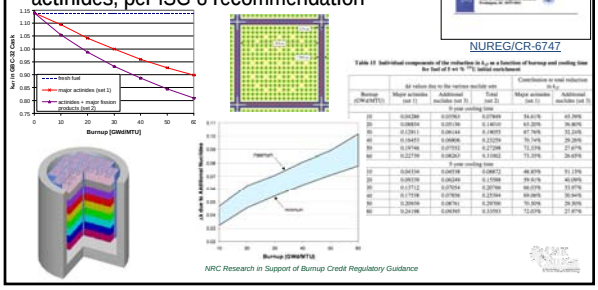
- Investigated the practice of equating the reactivity of spent fuel to the reactivity of fresh fuel, referred to as *reactivity equivalencing for PWR SFP conditions*
- Looked at normal and accident conditions, as well as various storage configurations
- Demonstrated practice to be acceptable, when used properly
- Demonstrated inaccurate and non-conservative reactivity estimates when used improperly



Computational Benchmark, 2001

NUREG/CR-6747

- Defined representative high-capacity cask
- Estimated additional reactivity margin available from fission products and minor actinides, per ISG-8 recommendation

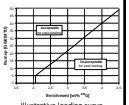


SCALE BUC Sequence, 2001

- STARBUCS sequence to automate burnup credit analyses for UO_2 SNF systems
- Performs integrated depletion analysis, cross-section processing, and Monte Carlo calculations for 3-D systems
- Relevant input options to represent
  - Irradiation conditions
  - Cooling time
  - Nuclides relevant to burnup credit
  - Axial and radial variation of burnup
  - Isotopic composition uncertainties
- Used extensively at ORNL to study burnup credit issues

NUREG/CR-6748

GBC-32 cask with horizontal burnup modeled

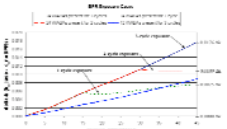


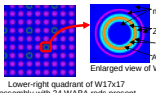
Illustrative loading curve

Burnable Poison Rods, 2002

- Investigated effect of BPRs on reactivity for various BPR designs & exposure conditions

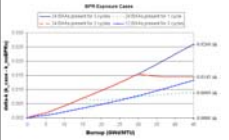
NUREG/CR-6761

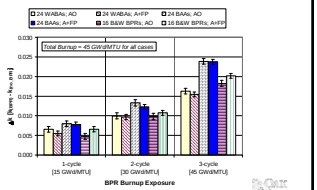




Enlarged view of WABA rod

Lower-right quadrant of W17x17 assembly with 24 WABA rods present

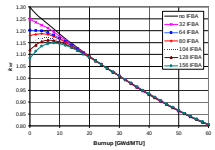


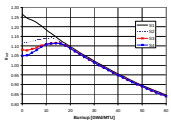


Integral Burnable Absorbers, 2002

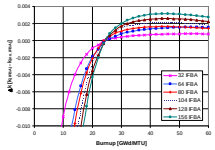
- Investigated effect of IBAs on reactivity, ZrB_2, UO_2-Gd_2O_3, UO_2-Er_2O_3, Al_2O_3-B_4C

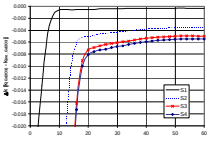
NUREG/CR-6760





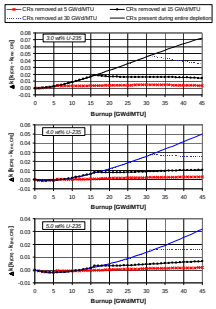
UO_2-Gd_2O_3

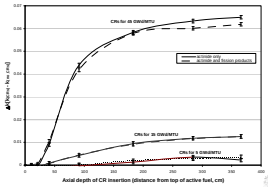




Control Rods, 2002

- Investigated effect of CRs on reactivity for CR/APSR designs & exposure conditions
- W, B&W, and CE designs considered

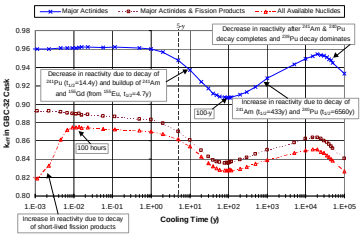


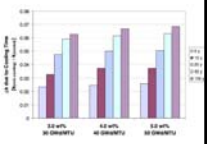


NUREG/CR-6759

Cooling Time, 2003

- Examined reactivity behavior as a function of cooling time to assess the possibility of modifying guidance recommendation

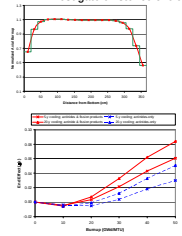




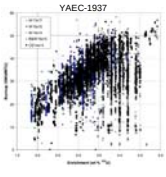
NUREG/CR-6781

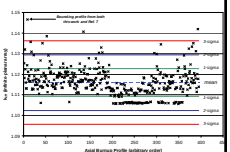
Axial Burnup, 2003

- Examined effect of axial burnup on reactivity
- Examined available database of profiles to
  - Identify profiles that maximize, k_{eff}
  - *Assess its* adequacy for use in safety analyses
  - Investigate existence of trends with fuel type and/or reactor operations



YAEC-1937





NUREG/CR-6801

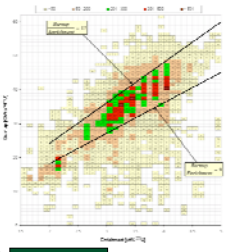
Reactivity Margins, 2003

- Examined impact of depletion & criticality analysis assumptions on loading curves

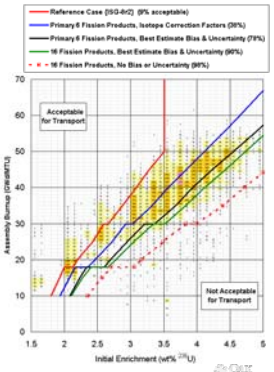
NUREG/CR-6800

Reactivity Margins, (cont'd)

- Quantified large impact of ICFs
- Confirmed need for FP credit



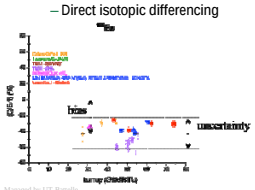
US PWR discharge data through 1998

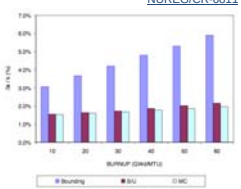


Isotopic Validation, 2003

- Examined strategies for addressing uncertainties in predicted isotopic comps.
  - Reviewed/applied methods and data
    - Bounding methods
    - Best estimate methods
      - Monte Carlo sampling
      - Sensitivity coefficient analysis
      - Direct isotopic differencing

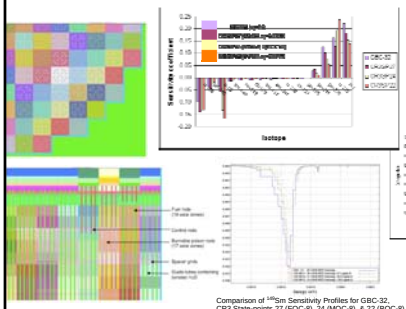
NUREG/CR-6811





Applicability of CRCs, 2008

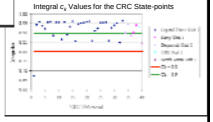
- Examined neutronic similarities between a SNF cask and 40 CRC state-points



Comparison of ^{149}Sm Sensitivity Profiles for GBC-32, CR3 State-points 27 (EOC-8), 24 (MOC-8), & 22 (BOC-8)

NUREG/CR-6951

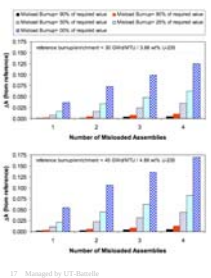
Integral c_k Values for the CRC State-points

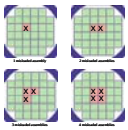


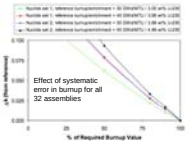
- CRCs found to be good in terms of applicability
- Issue of configuration uncertainties not addressed

Assembly Misloading, 2008

- Examined effect of fuel misloading on k_{eff}
- A variety of fuel-misloading configurations were investigated to understand impact





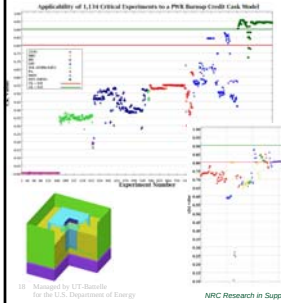


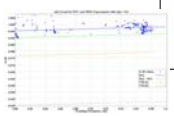
NUREG/CR-6955

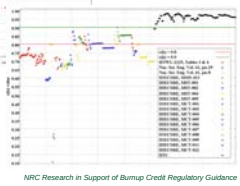
Δk effect of misloading a single fresh assembly with 5 wt% ^{235}U enrichment in different locations within the GBC-32 cask

Criticality Validation–HTC data

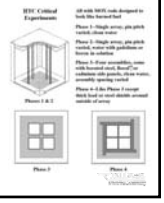
- Examined applicability/usefulness of French critical experiments (Valduc) for actinide validation
  - 156 configurations with designed to mimic 4.5 wt% ^{235}U initial enrichment fuel burned to 37.5 GWd/MTU in storage & transport conditions







NUREG/CR-6979



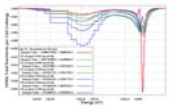
Burnup Confirmation, 2009

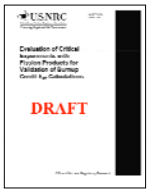
NUREG/CR-6998

- Reviewed information and issues relevant to pre-shipment burnup measurements when using burnup credit in PWR SNF storage & transport casks
- The report provides a review of:
  - Role of burnup measurements in the regulatory guidance (ISG-8) for demonstrating compliance with burnup loading criteria
  - Burnup measurement capabilities and experience
  - Accuracy of utility burnup records
  - Fuel movement and misloading experience
  - Consequences of misloading assemblies in casks designed for burnup credit
- The report also provides observations based on the review

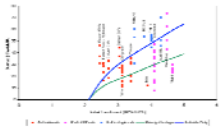
Current Focus – FP Validation

- Methods and data for criticality validation





- Methods and data for isotopic validation



Other Technical Resources

- OECD/NEA Expert Group publications
- Meeting proceedings and journal articles
- Technical reports from US DOE and other organizations
- Regulatory guidance/standards from safety authorities
- ANSI/ANS-8.27-2008: Burnup Credit for LWR Fuel

- Burnup credit bibliographies:
  - http://www.ornl.gov/sci/radiation_transport_criticality/BUCPublications..htm
  - http://www.nea.fr/html/science/wpncs/buc/index.html

Concluding Remarks

- US NRC initiated and maintained a research program to address burnup credit technical issues with the goal of allowing and expanding the use of burnup credit in PWR SNF storage and transport applications
- A great deal of work has been performed by ORNL and others in the US and abroad, particularly for PWR SNF
- Hopefully this work is and will be useful to others for
  - Learning and understanding issues
  - Reducing redundant work, thereby enabling focused efforts on remaining important technical issues

Closure – questions & discussion

- Thank you for your attendance and attention!

- Contact Info:
  - John Wagner, wagnerjc@ornl.gov