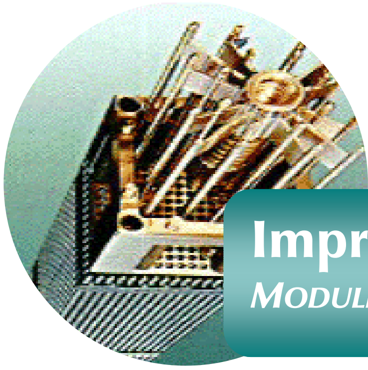


Improving Nuclear Fuel Reliability:

MODULE NO. 4 FAILURE CHARACTERIZATION AND MITIGATION

With the occurrence of a failure in-core, whether it is a fuel rod, reactivity control element or other component, a number of activities must be initiated to:

a) Confirm the failure event

b) Characterize the failure

c) Manage the failure during operation

d) Inspect the failure at the end-of-cycle

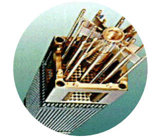
e) Determine the factors contributing to the failure.

Not only will such activities help to minimize the impact of the failure on subsequent plant operation, but they will help prevent similar failures in the future.

Establishment and implementation of an effective failure characterization and mitigation program are critical if the adverse impacts on plant operation, and ultimately plant economics, are to be minimized when failures do occur.

This module addresses the basic principles and key features of a modern fuel characterization and mitigation program. The objectives of the standard Failure Characterization and Mitigation Module are as follows, but the training sessions may be customized to meet your specific needs. This module can be conducted in one to two days.

- Describe and Discuss Radiochemistry Indicators
  - Isotope generation in the fuel pellet, release to the fuel/clad gap and release to coolant
  - Isotopes and ratios of isotopes used in failure confirmation and characterization
    - Differences between noble gases and water borne isotopes; significance of Cs, I, Xe, Kr, Np, etc. isotopes; absolute activity levels and corrections; Ssix (noble gases); (DE)I-131, contamination indicators; actinide release; spiking phenomena; AY/λ vs. λ plots; various noble gas, Cs, iodine ratios and cross-ratios; defect maps, etc.
    - Utility best practices for failure identification
    - The Fuel Reliability Index (FRI)
    - Examples from NAC Stoller's experience
- Describe and Discuss Characterization of Failures In-core
  - Quantitative techniques available for the estimation of the number of failures in-core, defect size, primary vs. secondary defects, burnup (in-house correlations, analytical tools such as CADE, CHIRON, etc.)
  - Limitations and uncertainties in techniques
  - On-going activities during operation (e.g., sampling rates, additional failure indications, difficulties in primary failure event identification with multiple failures present)
  - Examples from NAC Stoller's experience



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- Describe and Discuss Techniques for Managing Failures In-core
  - Degradation processes affecting fuel and cladding (impacts ability of component to meet operational requirements)
  - Effects of power changes on failed fuel including strategies to minimize power shocks and levels; local power suppression (BWR)
  - Other means to reduce activity levels in-core and degradation rate (e.g., derate unit, increase letdown)
  - Operational impacts of degraded fuel
    - Increased frequency of demineralizer change-out
    - Increased containment activity levels (increases time from shutdown to head removal, increased doses to operators)
    - Hot particle control
    - Increased decontamination efforts, waste generation, etc.
  - Examples from NAC Stoller's experience
- Describe and Discuss End-of-Cycle Fuel Inspections
  - Scope – failed fuel and sound fuel
  - Minimum scope for failed fuel
    - Detailed visual inspections (in situ and fuel rod removed from assembly)
    - All failed fuel, even if in discharge batch
  - Optional scope includes ECT/UT for defect localization and oxide/crud
  - Documentation package
    - Identify condition
    - Provide apparent/contributing factors
    - Identify extent of condition
    - Provide corrective actions
- Describe and Discuss Root Cause Evaluations
  - Interdisciplinary to ensure that all contributory factors are identified
    - Manufacturing records review
    - Operating and chemistry records review
    - Analysis of post-irradiation inspection results
    - Examination/testing of archive samples
    - Comparisons with other failures
    - Laboratory or hot cell examinations
  - Importance of an active dialogue with the fuel supplier
  - Ensure that results are fed back into design evaluation, new fuel inspection programs, etc. to minimize recurrence