



## **2. ACR Fuel Design & Safety Criteria**

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# Introduction

- **Section 4.2 of US-NRC Standard Review Plan (SRP) applies to Fuel System Design**
- **Objectives of the SRP review are to provide assurance that:**
  - **fuel system is not damaged as a result of normal operation and anticipated operational occurrences**
  - **fuel system damage is never so severe as to prevent control rod insertion when it is required**
  - **number of fuel rod failures is not underestimated for postulated accidents**
  - **coolability is always maintained**
- **Design bases for fuel must reflect these objectives**
- **Objectives are satisfied by defining acceptable damage criteria for fuel system damage, fuel rod failure, and fuel coolability**



# Introduction

- **ACR fuel design acceptance criteria are based on known damage mechanisms for CANDU fuel**
- **Criteria organized into three groups to ensure:**
  - **thermal integrity (“T” series)**
  - **structural integrity (“S” series)**
  - **compatibility with interfacing systems (“C” series)**
    - **needed for on-power fuelling capability of ACR / CANDU**
- **Criteria meet the SRP 4.2 objective that the fuel system is not damaged as a result of normal operation and anticipated operational occurrences**



# Introduction

- **Criteria for postulated accidents are based on SRP 4.2 design bases/ requirements**
- **ACR design acceptance criteria have been mapped to SRP 4.2 categories:**
  - fuel system damage
  - fuel rod failure
  - fuel coolability
- **Criteria related to postulated accidents are not discussed in this presentation**



# Fuel Design Criteria: Mapping to SRP 4.2



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## **Fuel Design Criteria: Mapping to SRP 4.2**

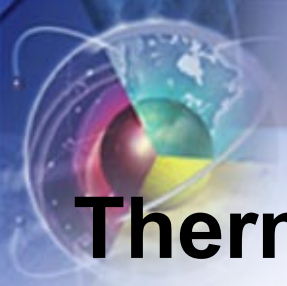


# Thermal Integrity Criteria

- **Thermal integrity criteria (“T” series) address damage mechanisms related to thermal conditions**
  - pellet overheating
  - clad overheating
- **Related SRP 4.2 requirements are:**
  - fuel system damage
    - dimensional changes & clearances
  - fuel rod failure
    - overheating of fuel pellets
    - overheating of cladding



# Thermal Integrity Criteria: Pellet Overheating



# Thermal Integrity Criteria: Clad Overheating



# Thermal Integrity Criteria: Clad Overheating



# Structural Integrity Criteria

- **Structural integrity criteria (“S” series) address damage mechanisms related to structural/ mechanical conditions**
  - internal gas pressure
  - stress, strain or loading limits
  - fatigue cycles
  - power ramps
  - hydrides
  - oxides and crud



# Structural Integrity Criteria

- **Related SRP 4.2 requirements are:**
  - **fuel system damage**
    - **stress/ strain/ load**
    - **fatigue cycles**
    - **oxidation, hydriding & crud**
    - **dimensional changes & clearances**
    - **fuel rod internal gas pressure**
  - **fuel rod failure**
    - **internal hydriding**
    - **pellet clad interaction (PCI)**





# Structural Integrity Criteria: Internal gas Overpressure



# Structural Integrity Criteria: Stress, Strain



# Structural Integrity Criteria: Loading Limits



# Structural Integrity Criteria: Loading Limits



# Structural Integrity Criteria: Loading Limits



# Structural Integrity Criteria: Loading Limits



# Structural Integrity Criteria: Fatigue Cycles



# Structural Integrity Criteria: Fatigue Cycles

- **Application**
  - fatigue analysis shall be based on fatigue-life data for applicable loading and material conditions
  - effects of temperature and irradiation, if significant, shall be taken into account
  - effect of mean stress/ strain of cyclical load shall be factored in
  - a safety factor of 2 on strain amplitudes or a factor of 20 on the number of cycles, shall be used
    - these factors are also stated in US NRC SRP 4.2





# Structural Integrity Criteria: Power Ramps



# Structural Integrity Criteria: Hydrides



# Structural Integrity Criteria: Hydrides



# Structural Integrity Criteria: Oxides and Crud

- **Damage mechanism**
  - external cladding oxidation can
    - reduce the residual metal cladding thickness and strength
    - increase cladding and pellet temperatures
    - if excessive, can “flake out” and cause debris in coolant
  - impact on strength is covered by the appropriate criteria in “S” series
  - impact on temperatures is covered by the appropriate criteria in “T” series
  - flaking is not a fuel damage issue (requirement on coolant clean up/ filtering)
  - crud can also increase cladding and pellet temperatures (adds to requirement of coolant clean up)



# Structural Integrity Criteria: Oxides and Crud



# Compatibility Criteria

- **Compatibility criteria (“C” series) address the damage mechanisms related to**
  - dimensional compatibility and changes
  - wear
- **Related SRP 4.2 requirements are**
  - fuel system damage
    - dimensional changes & clearances
    - fretting wear at contact points
  - fuel rod failure
    - fretting of fuel cladding



# Compatibility Criteria



# Compatibility Criteria





# Verification

- Covered in the presentation by Ki-Seob Sim



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