Safety Analysis Approach for ACR

Part 2: Application

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Recap of Event Classification

- Three categories of events:
  - Design basis events
  - Severe accidents
  - Severe core damage accidents
- Three classes of design basis events
  - Classes 1, 2 and 3
- Two classes of severe accidents
  - Classes 4 and 5
- Acceptance criteria and targets assigned to each class or category based on safety margins commensurate with the likelihood of the class/category (risk-based approach)

Events and Acceptance Criteria

- Acceptance criteria for various category of events
- Examples of events and acceptance criteria
  - Design Basis Events:
    - Class 1 : Total Loss of Class IV Power
    - Class 3 : Large LOCA
  - Severe Accidents:
    - Class 5: Large LOCA with Loss of ECC

Acceptance Criteria – Design Basis Events

- Class 1:
  - Dose: CNSC C-6 Rev. 1 Class 1 limits
  - Fuel: no calculated failures
  - Fuel Channel: no Pressure Tube (PT) failures
  - Overpressure/pressure boundary integrity:
    - Level B limit for first shutdown system to trip
    - Level C limit for second shutdown system to trip

Acceptance Criteria – Design Basis Events

- Class 2:
  - Dose: CNSC C-6 Rev. 1 Class 2 limits
  - Fuel: no calculated failures (in non-failed channels)
  - Fuel Channel: no PT failures (in non-affected channels)
  - Overpressure/pressure boundary integrity:
    - Level C limit for first shutdown system to trip
    - Level D limit for second shutdown system to trip
  - Containment: Peak pressure not to exceed design pressure
  - Other: Calandria remains intact

Acceptance Criteria/Targets – Design Basis Events

- **Class 3:**
  - **Acceptance Criteria:**
    - **Dose: CNSC C-6 Rev. 1 Class 3 limits**
    - **Fuel: limit failures**
    - **Fuel Channel: no channel failures (in non-affected channels)**
      Overpressure/pressure boundary integrity: Level C/D (as for Class 2)
    - **Containment: Peak pressure not to exceed design pressure (LOCA)**
      No damage to containment structure (MSLB)
      Hydrogen concentration to remain below flammability limit
    - **Other: Calandria remains intact**
  - **Performance Target:** no widespread PT ballooning

Acceptance Criteria and Performance Targets – Severe Accidents

- Classes 4 and 5:
  - Acceptance Criteria:
    - Dose: Class 4 and Class 5 limits respectively of CNSC C-6 Rev. 1
  - Performance Targets:
    - Fuel: limit failures
    - Fuel Channel: no fuel channel failures (in non-affected channels)
      ensure sufficient moderator subcooling if PT sags into CT contact
    - Containment: Peak pressure not to exceed design press (LOCA)
      Structural integrity of containment ensured to a degree that consequential damage to reactor systems could not result (MSLB initiated)
      Hydrogen concentration to remain below DDT (deflagration to detonation transition) limit
    - Other: Calandria remains intact

Targets for Severe Core Damage Accidents

- Severe Core Damage (SCD) accident targets are in terms of frequency (from PRA)
- Summed frequency of SCD events is $<10^{-5}$ per year and summed frequency for accident sequences leading to large releases of radioactivity is $< 10^{-6}$ per year
- Summed frequencies include also external events except seismic (a seismic margin assessment will be performed for earthquakes)
- Targets to be demonstrated by Level 2 PRA

Example of Application to Class 1 Event: Total Loss of Class IV Power

- Acceptance Criteria:
  - Dose Class 1: 0.5 mSv effective dose
    5 mSv lens of eye
    20 mSv skin
  - Overpressure/pressure boundary integrity:
    - Level B limit for first shutdown system to trip
    - Level C limit for second shutdown system to trip
- Performance Target:
  - First trip to prevent the onset of fuel clad dryout
  - Backup trip to maintain
    - Pre-trip fuel clad temperature below 600°C *and*
    - Duration of pre-trip dryout less than 60 seconds
  - Perform detailed fuel assessment to demonstrate fuel integrity if analysis target not met

Example of Application to Class 1 Event: Total Loss of Class IV Power

- Methodology (conservative)
  - Conservative CHF calculation
  - Licensing limit on channel power
  - Initial reactor power 102%
- Examples of Assumptions (conservative)
  - 2 Shutoff Rods (SORs) unavailable
  - Reactor Regulating System (RRS) operating and frozen (operating is more conservative as power goes down for this transient)
  - ASDVs, CSDVs not credited

Large LOCA : Acceptance Criteria

- Dose: Class 3: 30 mSv effective
  300 mSv lens of eye
  1,200 mSv skin
- Fuel Integrity: Limit fuel failures and maintain core coolability
- Fuel Channel Integrity:
  - No Channel Failure
  - No widespread PT ballooning (Target)
- Containment:
  - Peak pressure not to exceed design pressure
  - Hydrogen concentration below flammability limit

Large LOCA : Methodology Examples

Channel Flow	As calculated by CATHENA
CATHENA Single Channel Power	Licensing limit channel power
Gap Conductance	Most conservative lower bound used

Large LOCA: Assumption Examples

Credited Trip	Second
Recombiners	One assumed failed
Local Air Coolers on Class III Power	Minimize heat removal capability (single failure)

LLOCA + LOECC: Acceptance Criteria

- **Dose:**

  Class 5: **250 mSv effective**

  1,500 mSv lens of eye

  5,000 mSv skin

LLOCA + LOECC : Performance Targets

- Fuel Integrity:
  - Maintain core coolability
  - Limit fuel failures
- Fuel Channel Integrity:
  - No channel failures
  - Adequate moderator subcooling if PT sags into Calandria Tube contact
- Containment:
  - Peak pressure not to exceed design pressure
  - Hydrogen concentration below DDT limit

LLOCA + LOECC: Methodology Examples

Channel Flow	Average channel flows assumed
CATHENA Single Channel Power	Maximum Time Average channel power with ripple
Gap Conductance	More reasonable value used

LLOCA + LOECC: Assumption Examples

Credited Trip	First
Recombiners	All assumed available
Local Air Coolers on Class III Power	All air coolers assumed available

Dose and Release Limits from C6 Rev.1

Requirements	Event Class				
	1	2	3	4	5
Effective dose (mSv)	0.5	5	30	100	250
Lens of the eyes (mSv)	5	50	300	1,000	1,500
Skin (mSv, averaged over 1 cm^2)	20	200	1,200	4,000	5,000

Conclusion

- ACR uses risk-based approach
- It features a rigorous approach to safety analysis; in particular:
  - Very conservative analyses for design basis events
  - Detailed models for the analysis of both design basis events and severe accidents
- It also includes the treatment of severe core damage accidents in Level 2 PRA
- The structure of event categories/classes and respective acceptance criteria and targets is fully consistent with international practice


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