



# **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

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



# Large LOCA: Assumption Examples

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



# **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**

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





# **LLOCA + LOECC: Assumption Examples**

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



# **Dose and Release Limits from C6**

## **Rev.1**

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



# 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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