Safety Analysis Methodology

Zoran Bilanovic
ACR Safety Engineering

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Outline

- Analysis approach
- Physics / Thermal-hydraulics methodology
- Fuel and fuel channel methodology
- Containment methodology
- Atmospheric dose and dispersion methodology

Analysis Approach - 1

Limit of the Operating Envelope (LOE):

- **The Limit of the Operating Envelope (LOE) is the basis for ACR safety analyses for design basis events**
- **This approach requires that initial and boundary conditions be set to simultaneously conservative, or pessimistic values, taking into account the objective of the analysis**
  - **A particular bounding assumption is linked to a specific safety analysis objective**

Analysis Approach - 2

- **Bounding assumptions include:**
  - Initial and boundary conditions (the plant state parameters)
  - Key modeling parameters
- **Key modeling parameter selection is based upon:**
  - Sensitivity analyses during validation
  - Previous experience
  - Limited sensitivity analyses to ensure the dominant model uncertainties are accounted for

Bounding Assumptions Example

Containment analysis for peak pressure and pressure dependent signal:

	Analysis Objective	
	Peak Pressure	**Pressure Dependent Signal**
Containment leakage	No leakage	Beyond design
Surface area of structures	Low estimate	High estimate
Air cooling	Low	High
Additional heat sources	Motors, lights, pipes	None
Instrument air	Maximum air ingress	No air ingress

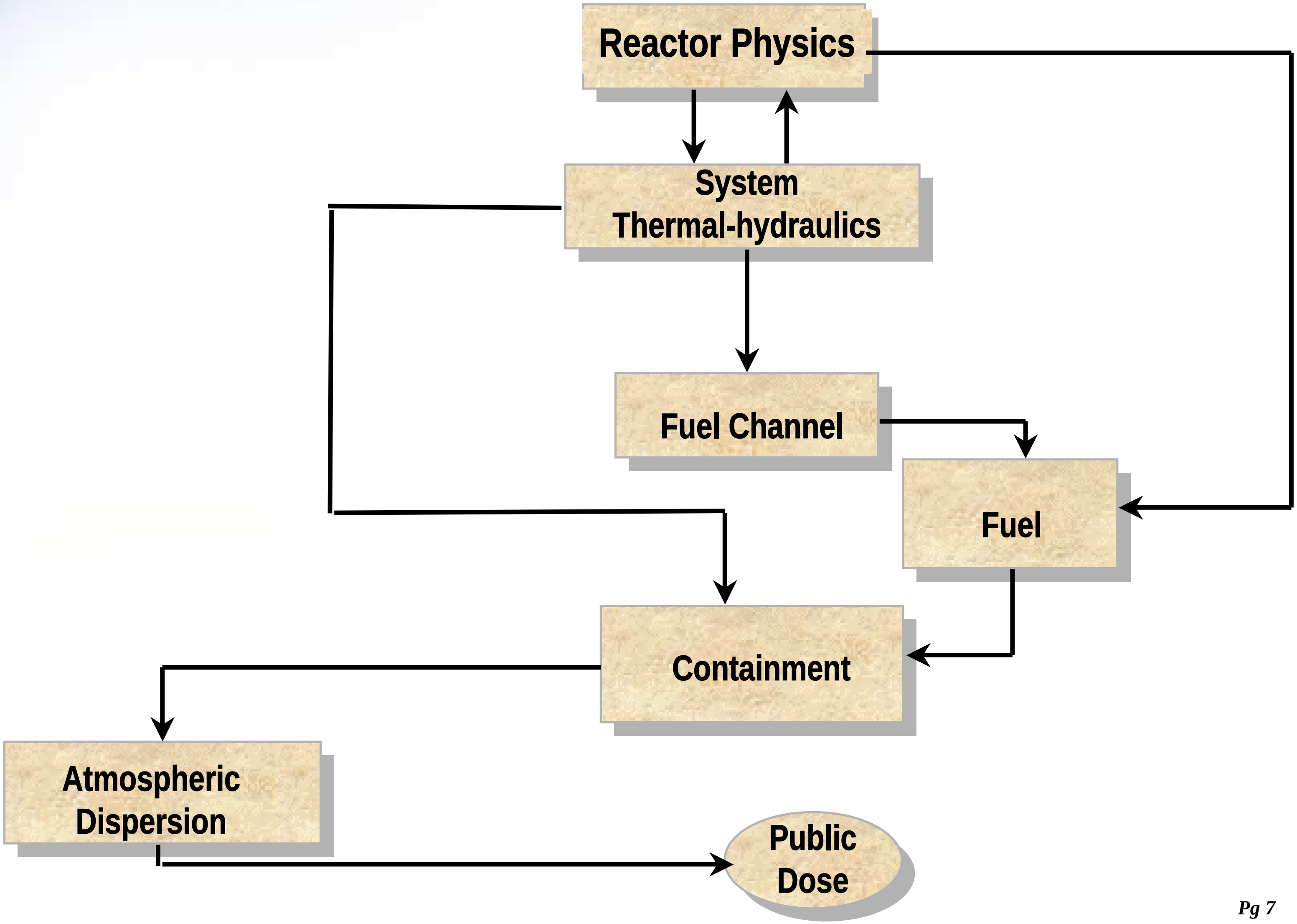
Analysis Approach Example

Large LOCA

Safety Concerns:

- Public dose related to fission product releases from the fuel
- Core coolable geometry related to fuel channel integrity
- Containment integrity

Discipline Links



Physics / Thermal-Hydraulics Objectives

- To determine the reactor power transient
- To determine the thermal-hydraulic response of the Reactor Cooling System, Steam and Feedwater System, and ECC System for all design basis events
- To provide boundary conditions for subsequent analyses such as fuel / fuel channel and containment

Physics / Thermal-Hydraulics Analysis Methodology

- Coupled thermal-hydraulic code CATHENA with physics codes CERBERUS and WIMS-AECL to determine power transient for loss of coolant accidents
- Perform circuit analysis to determine the system response (e.g., event sequences, trip time, core refill)
- Circuit analysis results provide boundary conditions for downstream fuel and fuel channel, as well as containment analysis

Examples of Physics / Thermal-Hydraulic Analysis Assumptions – Large LOCA

- Conservative initial reactor conditions (102% power after a long shutdown)
- Conservative (slow) shut-off rods (SOR) drop times
- 3 of 3 trip logic
- Limiting instrumentation delay times
- Two most effective SORs assumed unavailable
- CHF set to appropriate conservative values

Fuel and Fuel Channel Analysis Objectives

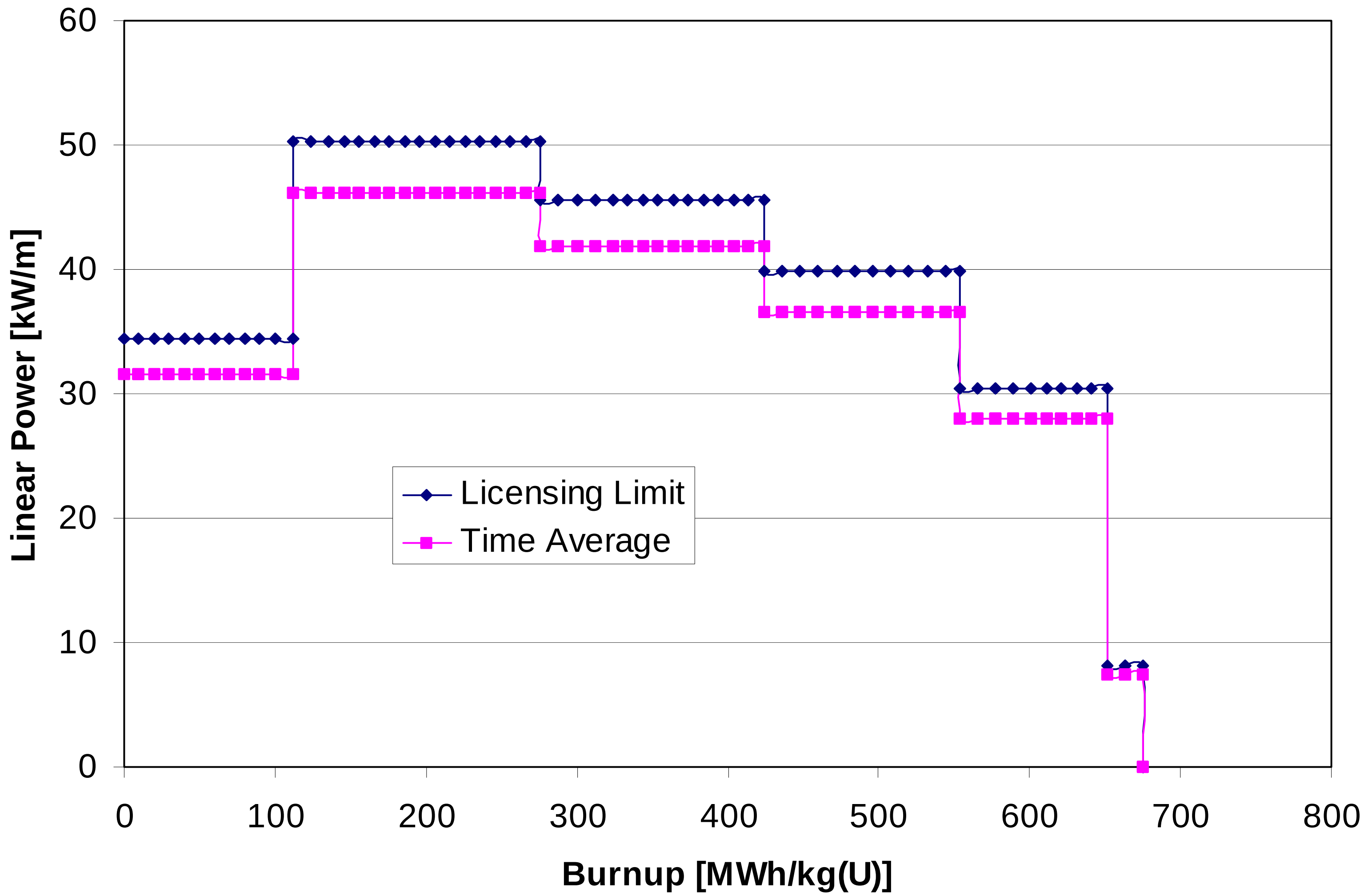
- Establish the number and timing of fuel failures
- Determine the fission product release into containment
- Determine the amount of hydrogen generated into containment
- Demonstrate fuel channel integrity

Examples of Fuel and Fuel Channel Analysis Assumptions – Large LOCA - 1

Maximize fuel and pressure tube temperatures:

- Licensing limit channel power
- Maximized power / burnup history (maximizes fission product inventory within the fuel and within the fuel-to-clad gap)
- Maximize reactor power uncertainties (102% full power)
- Second reactor trip credited
- Gap conductance
- Appropriate conservative CHF correlations

Examples of Fuel and Fuel Channel Analysis Assumptions – Large LOCA - 2



Examples of Fuel and Fuel Channel Analysis Assumptions – Large LOCA - 3

Maximize fission product release:

- Maximized power/burnup history to maximizes fission product inventory within the fuel and within the fuel-to-clad gap
- Conservative fuel failure criteria
- Assume that once the first fuel element fails, all other elements in that ring fail
- Temperature transient for the hottest fuel element in the ring is used

Examples of Conservative Fuel Failure Criteria

Fuel integrity for Design Basis Events:

1. **Uniform clad strain no greater than 5% for clad temperatures less than 1000°C**
2. **Uniform clad strain no greater than 2% for clad temperatures greater than 1000°C**
3. **Oxygen concentration no greater than 0.7 weight percent over half the clad thickness**
4. **No beryllium-braze penetration at bearing pad and spacer locations**

Containment Analysis Objectives

- To determine the maximum containment pressure and temperature following LOCA and Main Steam Line Break (MSLB)
- To determine the differential pressure across the Reactor Building (R/B) internal walls
- To establish the timing of containment pressure dependent signals (e.g., containment isolation, reactor trip)
- To determine the hydrogen concentration and distribution inside containment
- To predict the radionuclide behavior inside R/B and predict releases

Containment Analysis Methodology

- Assumptions to maximize R/B pressure and temperature
- Assumptions to minimize R/B pressure and temperature
- Assumptions to maximize releases

Examples of Containment Analysis Assumptions – Large LOCA - 1

Maximize R/B pressure and temperature

- **Used in peak pressure/temperature calculations:**
  - Underestimate heat sinks (e.g., minimize the number of Local Air Coolers (LACs), higher cooling water temperature, reactor building wall and structures, reserve water tank, etc.)
  - Zero leakage from containment
  - Early containment isolation

Examples of Containment Analysis Assumptions – Large LOCA - 2

Minimize R/B pressure:

- **Used to determine the R/B high pressure trip initiation, containment isolation, etc.**
  - Greater than design leakage
  - Overestimate heat sinks (e.g., all local air coolers, lower cooling water temperature, R/B wall and structures)
  - No instrument air discharge
  - Slow containment isolation

Examples of Containment Analysis Assumptions – Large LOCA - 3

Maximize releases:

- **Greater than design leakage**
- **Low R/B pressure transients:**
  - Releases via ventilation duct before isolation
  - To delay containment isolation
- **High R/B pressure transients:**
  - Releases mostly due to leakage
  - Use assumptions to maximize R/B pressure to maximize releases

Dose Analysis Objectives

- **Determine radiological doses to a member of the public at, or beyond the site boundary**
- **Demonstrate public safety by compliance of doses with reference dose limits**

Dose Assessment Methodology

- Methodology for handling weather data and calculating doses:
  - Public dose consequences can be calculated using every weather condition recorded, had the accident occurred at any time over the period of weather data collection
  - Determine the worst dose estimate at a certain cut-off criterion:
    - Cutoff at 90% frequency
  - Reports dose distributions at various consequence percentiles around a power plant, and provides extensive information to identify the location of greatest risk after an accident

Summary

- The Limit of the Operating Envelope (LOE) is the basis for ACR safety analyses for design basis events
- This approach requires that initial and boundary conditions be set to simultaneously conservative, or pessimistic values, taking into account the objective of the analysis
- Bounding assumptions include initial and boundary conditions and key modeling parameters
- Key modeling parameters selection is based upon:
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