THERMAL-HYDRAULIC TRANSIENT ANALYSIS OF DEDICATED DEPRESSURIZATION SYSTEM FOR GEN-III+ PWR IN STATION BLACKOUT

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To analyze the effectiveness of the Dedicated Depressurization System (DDS) in Gen-III nuclear reactors during a station blackout (SBO), a transient model for the ACP1000 design was developed using the MELCOR code. The study focused on simulating the severe accident scenarios, evaluating the DDS's effectiveness in mitigating risks of high pressure melt ejection and direct containment heating.

Thermal-Hydraulic Transient Analysis of Dedicated Depressurization System for Gen-III+ PWR in Station Blackout

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Introduction & Motivation

- Station Blackout (SBO) is a severe accident in NPPs: leads to direct containment heating (DCH) by high pressure melt ejection (HPME) of molten corium from RPV.
- The Dedicated Depressurization System (DDS) mitigates these risks by depressurizing the RPV, reducing molten material and minimizing DCH effects.
- Motivated by the Fukushima accident, DDS is crucial in Gen-III+ NPPs to ensure reactor safety during core meltdowns.

Project Objectives

1. **Development of a transient model** for 1100 MWe ACP1000 design using MELCOR code.
2. **Severe accident process analysis** by simulation of station blackout and resulting control parameters.
3. **Validate effectiveness of DDS** through thermal hydraulic analysis of RPV and containment.
4. **Validation of MELCOR model** for future applications to other accident scenarios.

Severe Accident Transients

SBO { DEC-B accident }

1. Loss of all AC power
2. Reactor trip
3. SG safety valves open
4. SG depletion
5. Core uncovery
6. Core outlet temperature > 650°C
7. Accumulators injection
8. Cladding oxidation and fuel failure
9. Loss of core geometry
10. RPV dry-out
11. Corium relocation to lower head
12. RPV failure
13. RPV failure consequences:
14. Failure at low RPV pressure — No HPME occurs
15. Failure at high RPV pressure — HPME (DCH) occurs

DDS for ACP1000 Reactor

- Level 4 defense-in-depth.
- Set of motorized valves connected to pressurizer.
- Powered by DC batteries.
- Fast-depressurization of RCS.
- Actuated manually by operator, when core exit temperature > 650°C for more than 60 mins.
- Prevents HPME by reducing RCS pressure to less than 2 MPa and protects containment integrity.

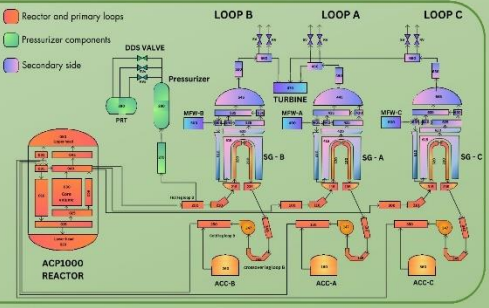
Methodology & Nodalization

Modelling Process:

MELCOR Input Packages Used For Analysis:

Input Parameters:

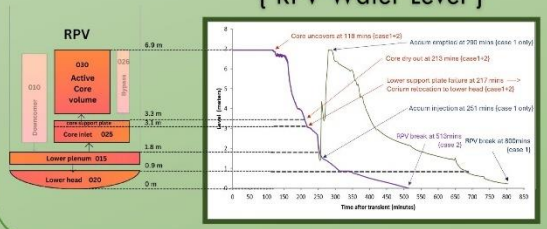
Reactor thermal power	3,050 MWth
Pressurizer pressure	15.5 MPa
Reactor coolant flow rate	68,520 m3/h
Number of fuel rods	177 x 264
Core inlet temperature	291.5 C
Core outlet temperature	381.8 C
Main steam flow rate	1,700 kg/s



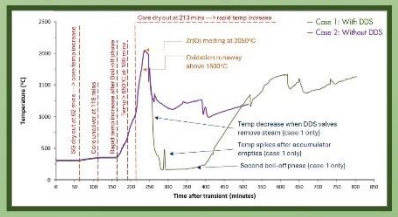
Results & Transient Analysis

- **Case 1:** DDS valves opened by operator
- **Case 2:** DDS valves not opened

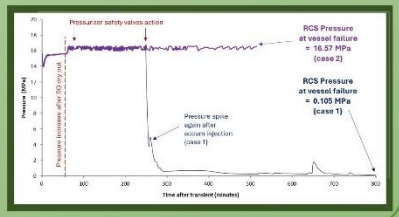
{ RPV Water Level }



{ Core Exit Temperature }



{ RCS Pressure }



Conclusions

- Station blackout without any heat removal and , leads to core meltdown and reactor vessel failure.
- Without reactor depressurization, a high pressure melt ejection (HPME) occurs. Corium releases from RPV with > 16 MPa pressure and thus containment integrity is at risk due to direct containment heating (DCH).
- The Dedicated Depressurization System can prevent HPME by lowering RCS pressure to < 2 MPa before RPV failure.

Events	Case 1: No DDS	Case 2: DDS actuated
Core uncover time	118 mins	118 mins
CET reaches 650 C	189 mins	189 mins
DDS actuation	---	249 mins
RPV failure / Lower head break	513 mins	800 mins
RCS pressure when RPV failure	16.57 MPa	0.105 MPa

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