

Toward the Robust and Resilient Nuclear System for the Highly Improbable Event

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Preliminary Analysis of TMI-2 Severe Accident using CINEMA Computer Code

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Introduction

□ TMI-2 Accident (USA, March 28, 1979):

Total Loss of Feed Water with Stuck Open PORV

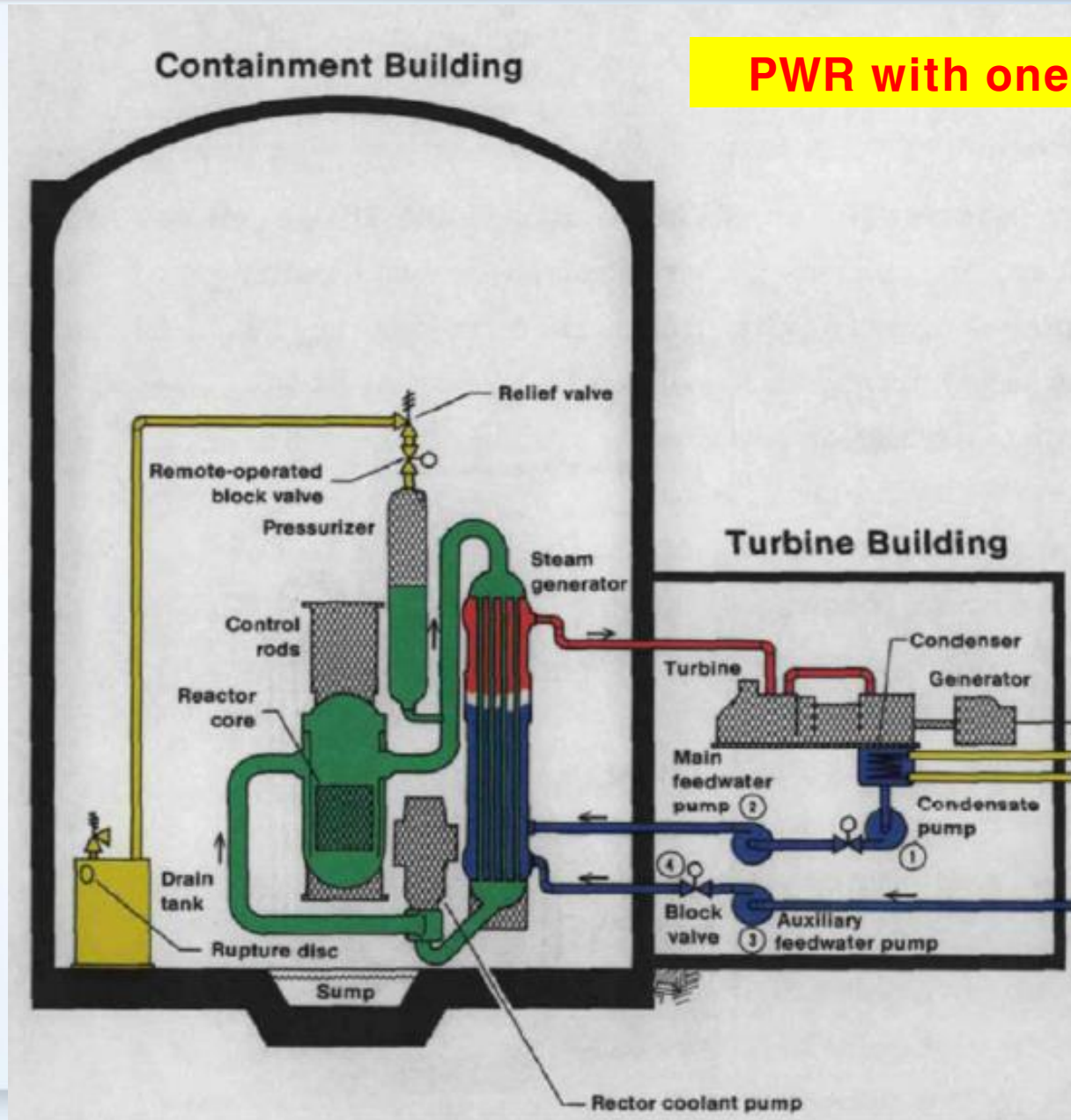
- Multiple Failure

- Accident Progression: 0. sec. (Initiating Event) --- Total Loss of Feedwater
13 sec. to 101 min --- Loss of Coolant
101 min. to 174 min. --- Initial Core Damage
174 min. to 315 min. --- Quenching & Core Damage
5h 15 min to 1 month --- Recovery attempts
- Main Accident Region: **Mechanical Failure & Operator Action Miss**
 - Stuck Open PORV: Loss of Coolant Accident
 - Misread the sign of LOCA: Stop of HPSI by Increase of High Pressurizer Liquid Level



TMI-2 Plant

PWR with one-through SG



Plant Data of TMI-2

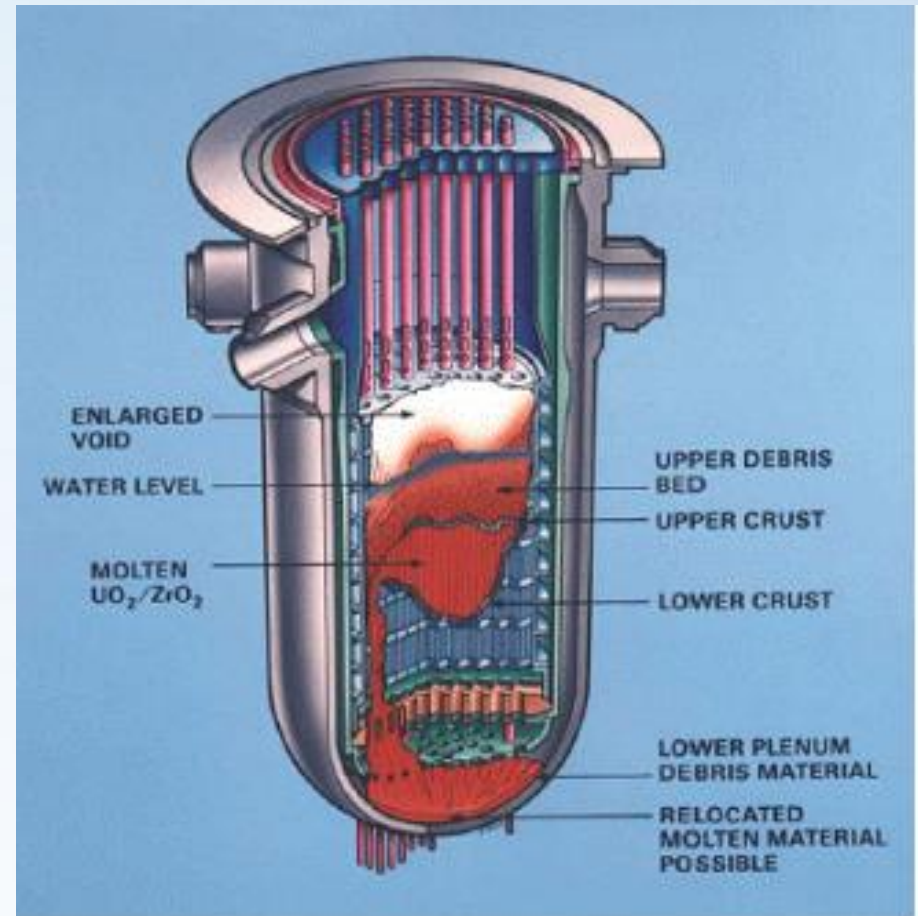
Reactor	Data	Core & Fuel Assemblies	Number
Design Heat Output	2,272 MWt	Fuel Assemblies	177
Vessel Coolant Inlet Temperature	292 °C	Fuel Rods per Fuel Assemblies	208
Vessel Coolant Outlet Temperature	320 °C		
Core Coolant Outlet Temperature	321 °C	Control Rod Guide Tubes per Assembly	16
Average Core Fuel Temperature	649 °C		
Core Operating Pressure	15 MPa		

Detailed TMI-2 Accident Scenario

- 0 sec: Turbine and main feedwater pump trip (**Total Loss of Feed Water**)
- 3 sec: Pressurizer PORV valve opening, no closing (**SBLOCA**)
- 8 sec: Reactor scram
- **122, 278 sec: HPSI Actuation, Stop of HPSI by Operator**
- 480 sec: Auxiliary feedwater startup
- 552 sec: Core boiling begins
- **4,440 sec: Shutdown B-loop RCPs (end of phase 1)**
- 6,184 sec: Core uncover (Increase of fuel cladding temp.)
- 7,442 sec: Cladding oxidation begins (T= 1,000 K)
- 7,719 sec: Cladding failure (T=1117 K)
- **8,520 sec: Close of the PORV line block valve (Operator Action)**
- **9,014 sec: Fuel melting**
- **10,400 sec: Restart one B-loop primary pump (end of phase 2)**
- 11,580 sec: Shutdown of the B-loop primary pump
- **12,000 sec: Start of primary system feed and bleed (Operator Action)**
- **13,440 sec: Core material slumping (end of phase 3)**
- **18,000 sec: General emergency declared (end of phase 4)**

End State in TMI-2

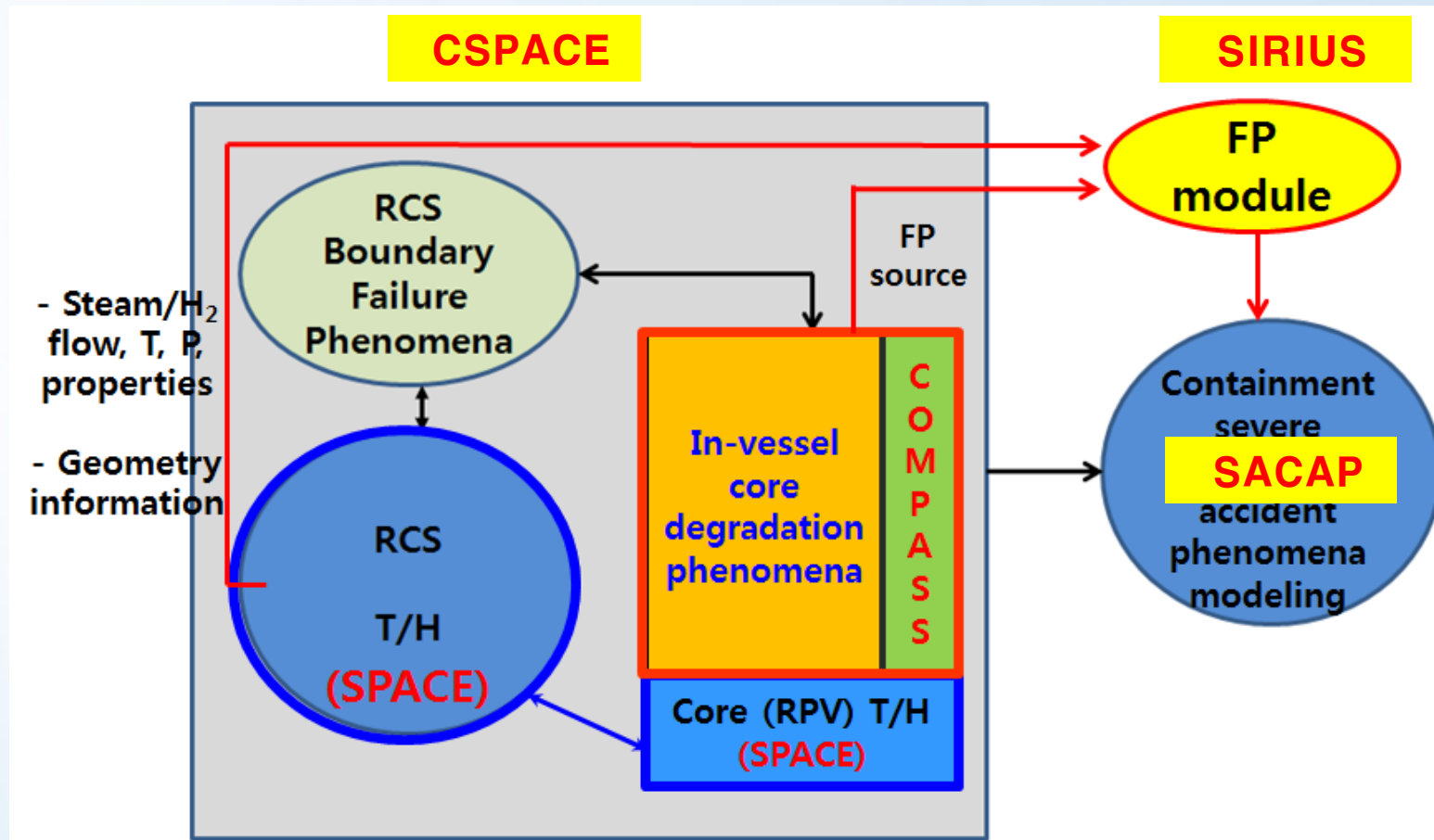
- Melting of **45 % Core Material** (62 tons): Molten Pool Formation in Core
- Melted Material **Relocation to the Lower Plenum of Approx. 19 tons**: Side Relocation
- **No Reactor Vessel Failure by Operator Action**: Water injection to the Core



TMI-2 End State

CINEMA Development in Korea

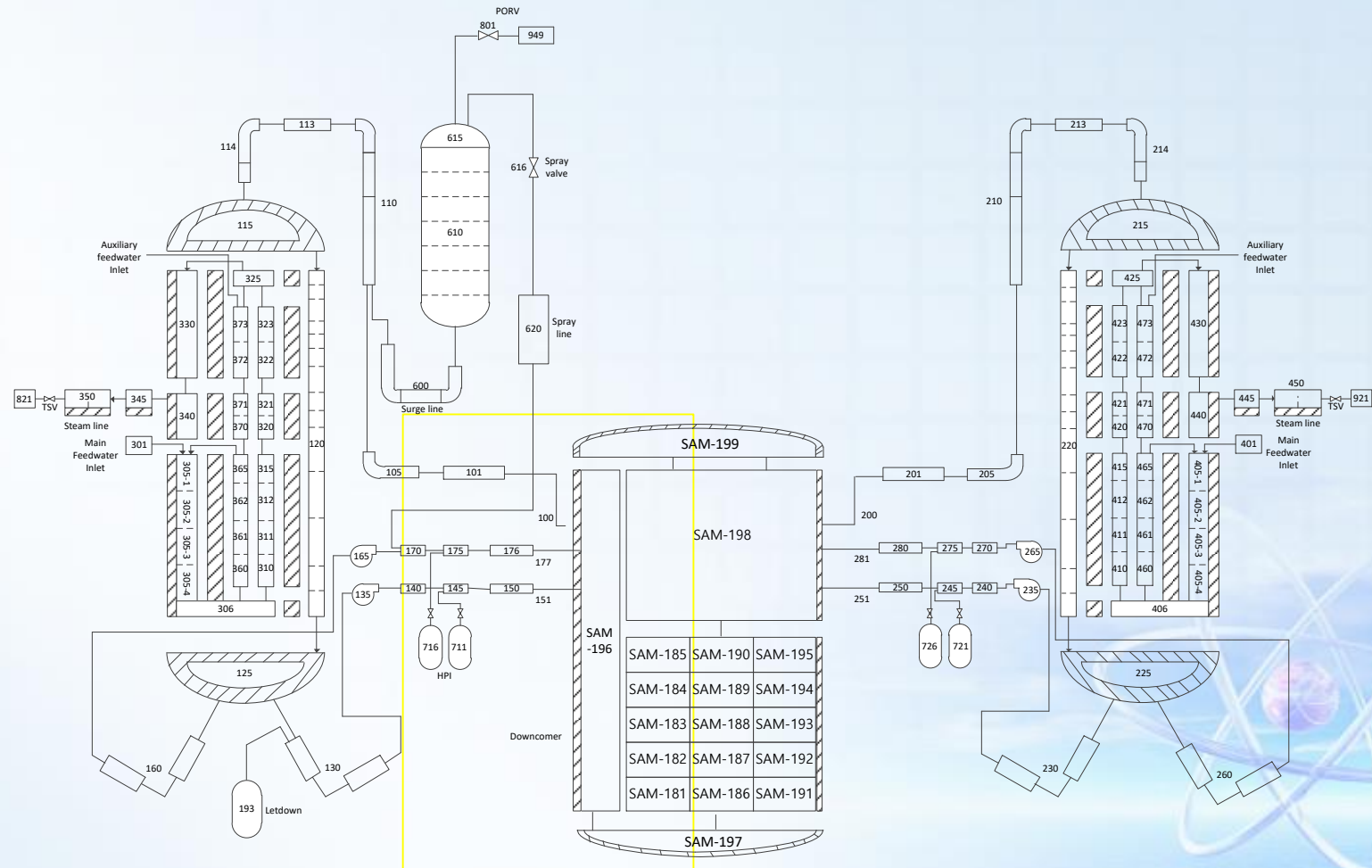
- ❖ An integrated severe accident analysis computer code (**CINEMA**) has been developed by the collaboration in Korea.



- **CINEMA: Code for INtegrated severe accidEnt Management Analysis**

CINEMA Nodalization for TMI-2

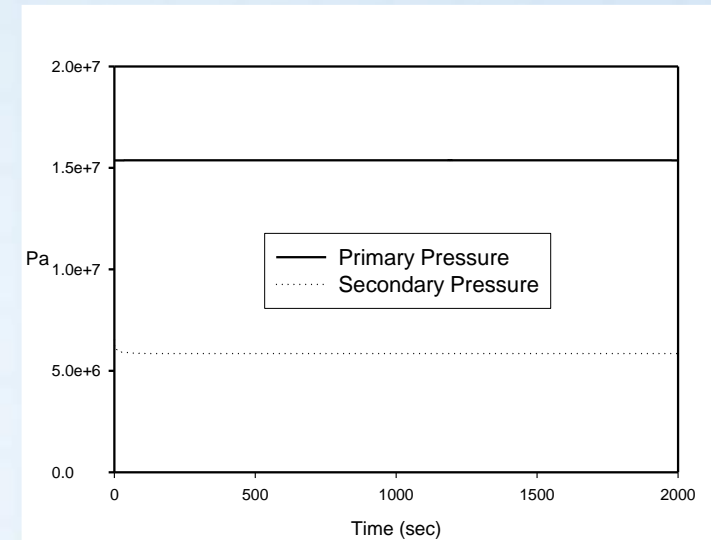
- ❖ Using TMI-2 Design Data
- ❖ Based on SCDAP/RELAP5 Input



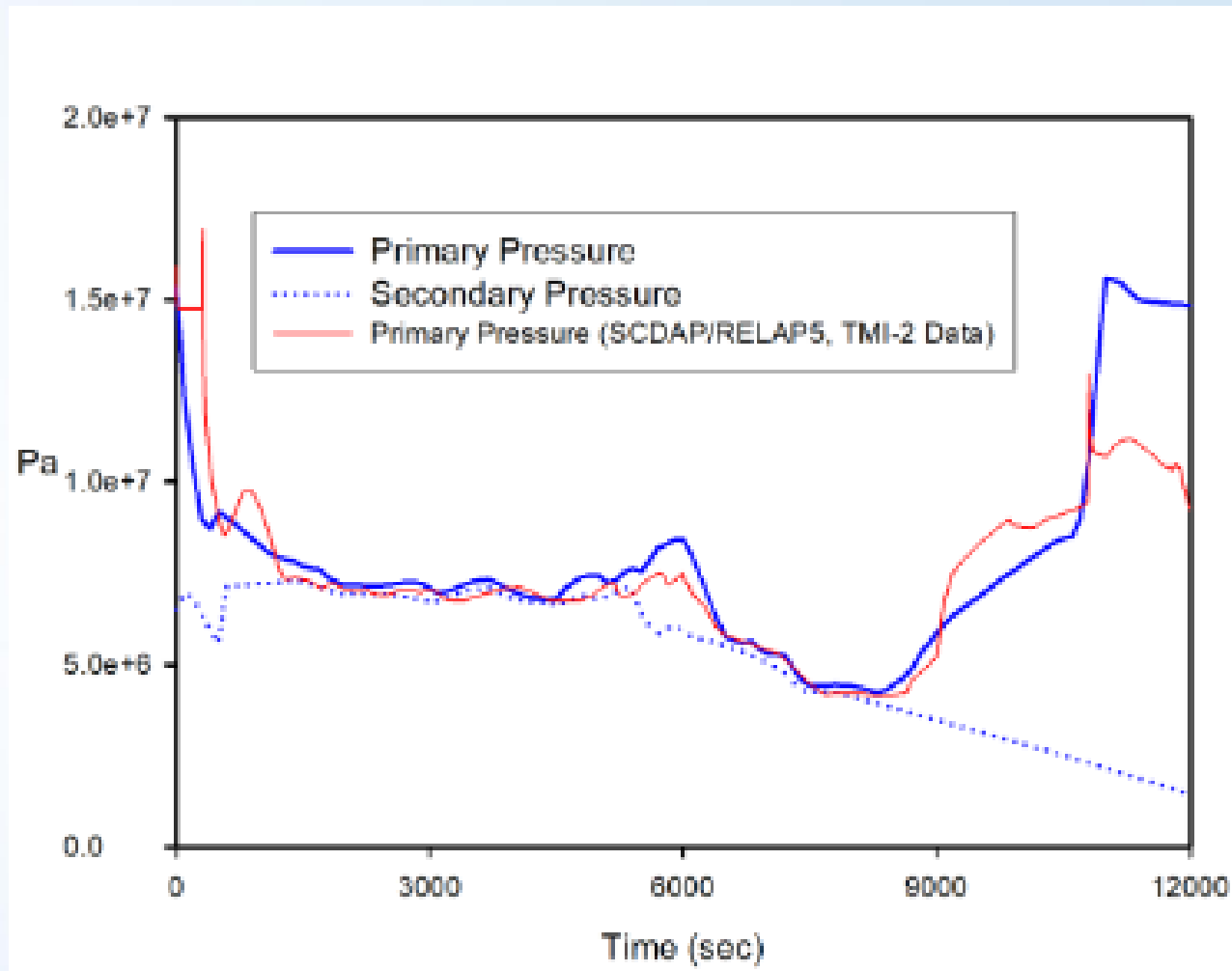
CINEMA-CSPACE Nodalization

Steady State Results

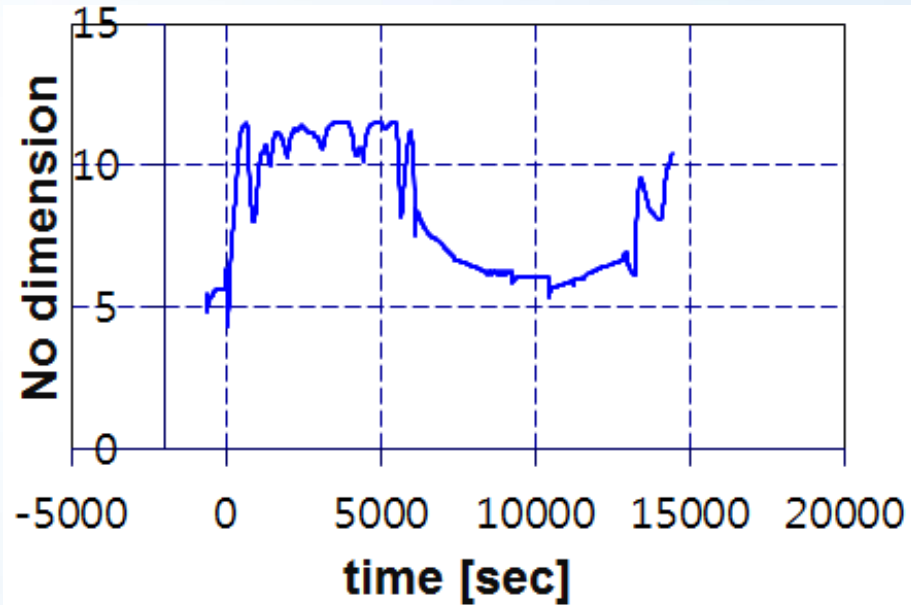
Parameter	Plant Operating Condition	CINEMA Results
Reactor Power (MW)	2700.0	2700
Primary System Pressure (MPa)	15.2	15.3
Cold Leg Temperature 1A (K)	561.0	571.0
Cold Leg Temperature 2A (K)	548.0	571.0
Hot Leg Temperature Loop A (K)	592.0	598.0
Hot Leg Temperature Loop B (K)	592.0	598.0
Feedwater Temperature (K)	513.0	513.0
SG A Pressure (MPa)	7.31	5.85
SG B Pressure (MPa)	7.24	5.85
SG A Steam Temperature (K)	586.0	578.0
SG B Steam Temperature (K)	585.0	579.0



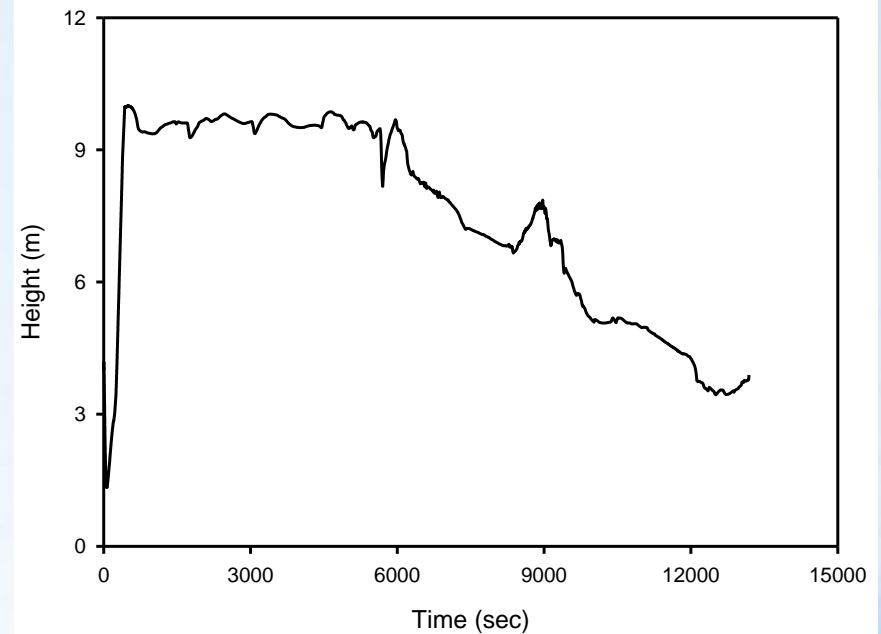
Pressurizer Pressure



Pressurizer Water Level

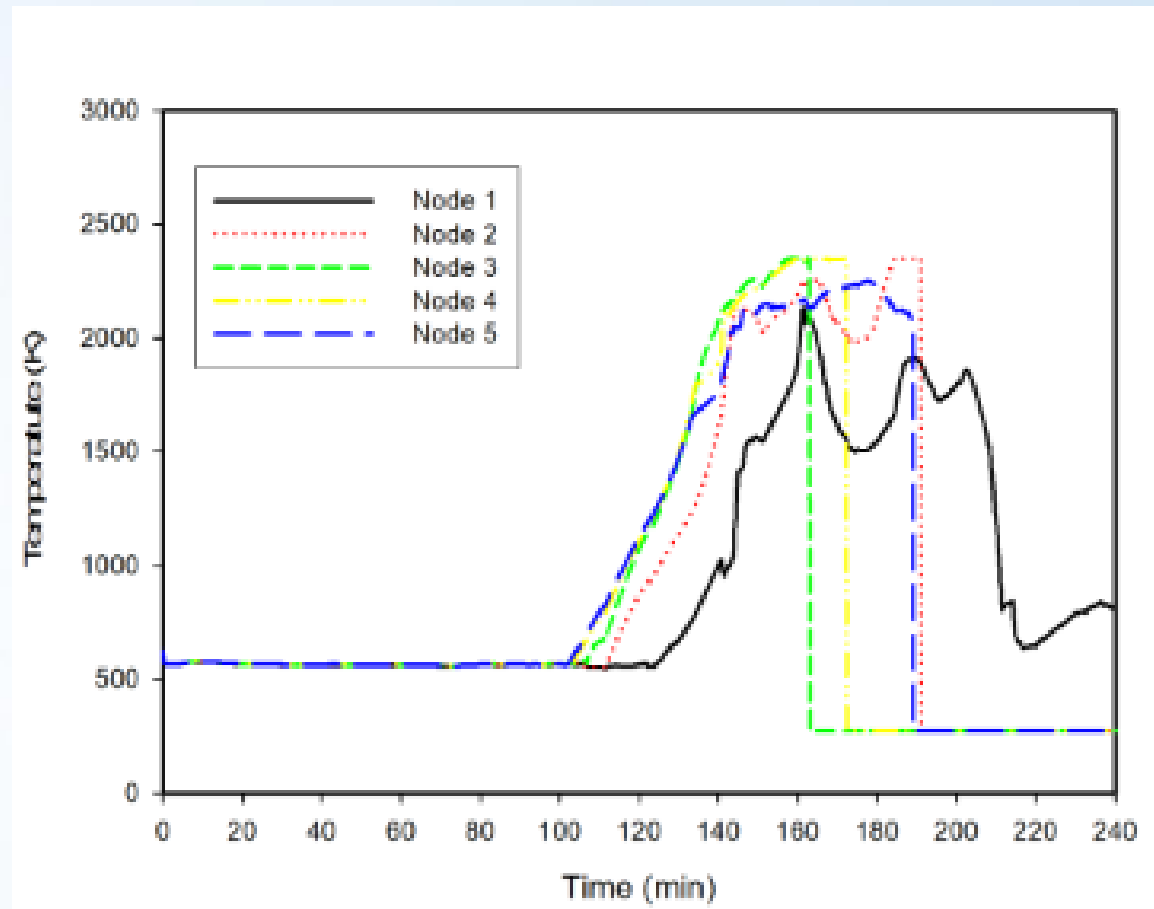


MELCOR Results

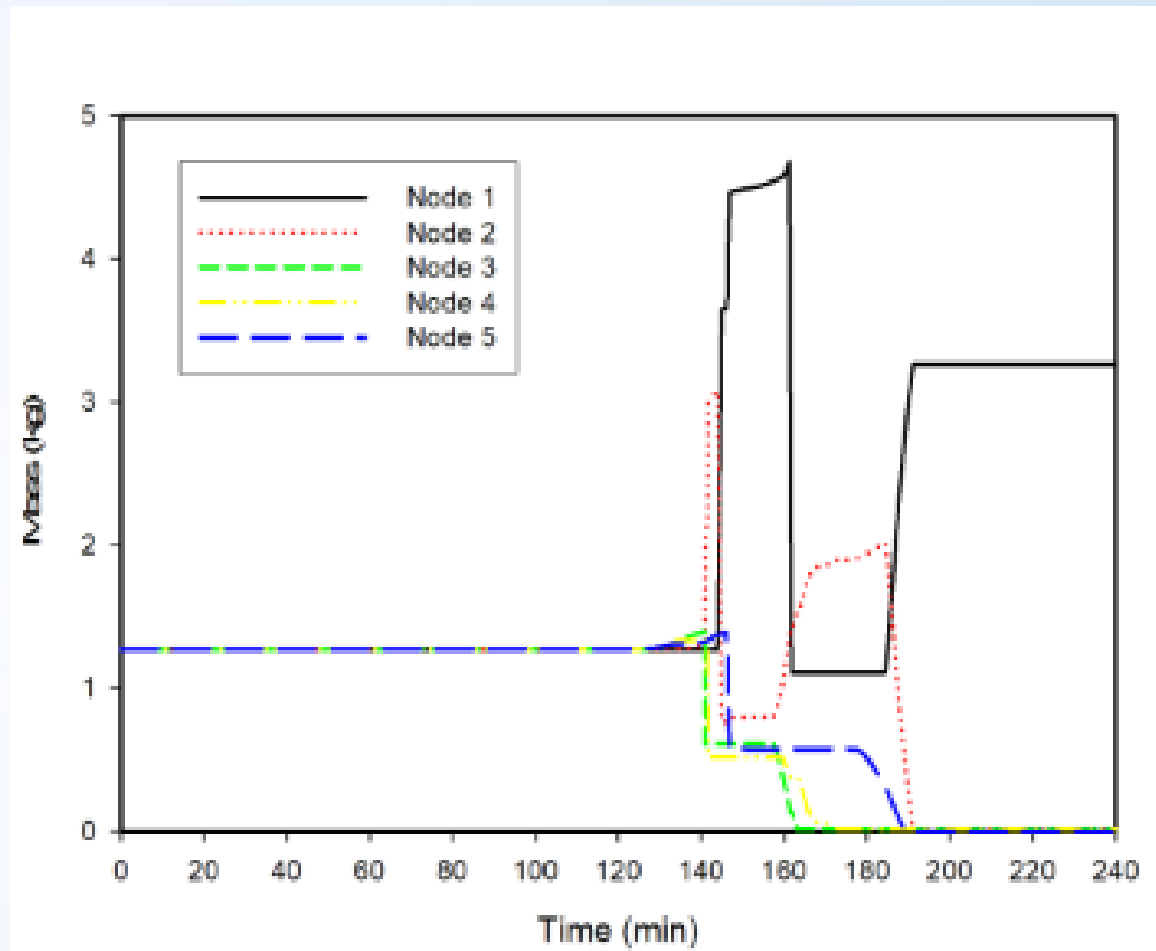


CINEMA Results

Fuel Cladding Surface Temperature




Fuel Cladding Mass Distribution



Conclusions



- ❑ The CINEMA results are similar to the TMI-2 data in general, with the exception of a rapid increase in the pressure at 170 minutes, which is a result from **deficiency** of CSPACE model on **a melted fuel relocation and quenching process**.
 - ❑ More CINEMA model development and analysis for a melted fuel relocation and quenching process in the core and lower plenum are necessary to accurately simulate the TMI-2 severe accident.
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Thank You!



중대사고 · 중수로안전연구부
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