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KAERI Korea Atomic Energy Research Institute

Modeling of Drop Tests of Reactor Shutdown System using RELAP5

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Background and Objectives

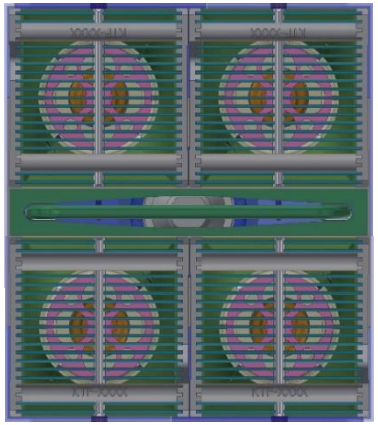
- Background
  - Developing a new Reactor Shutdown System (RSS) for research reactors
    - ✓ Plate type fuels
    - ✓ Upward flow in the reactor core
    - ✓ Thermal power from 10 to 30 MW
  - Installed a facility for performance and endurance tests of the RSS
  - Manufacturing the prototype of the RSS
  - Carry out performance and endurance tests this year

- Objectives
  - Develop a RELAP5 modeling on drop tests of the Control Plate Assembly (CPA)
  - Assess the effects of design variables on the drop speed and time of CPA
    - ✓ Weight of CPA
    - ✓ Flow area of the return pipe from the guide tube assembly to the lower plenum
    - ✓ Hydraulic load caused by the core differential pressure

Test Facility and Reactor Shutdown System

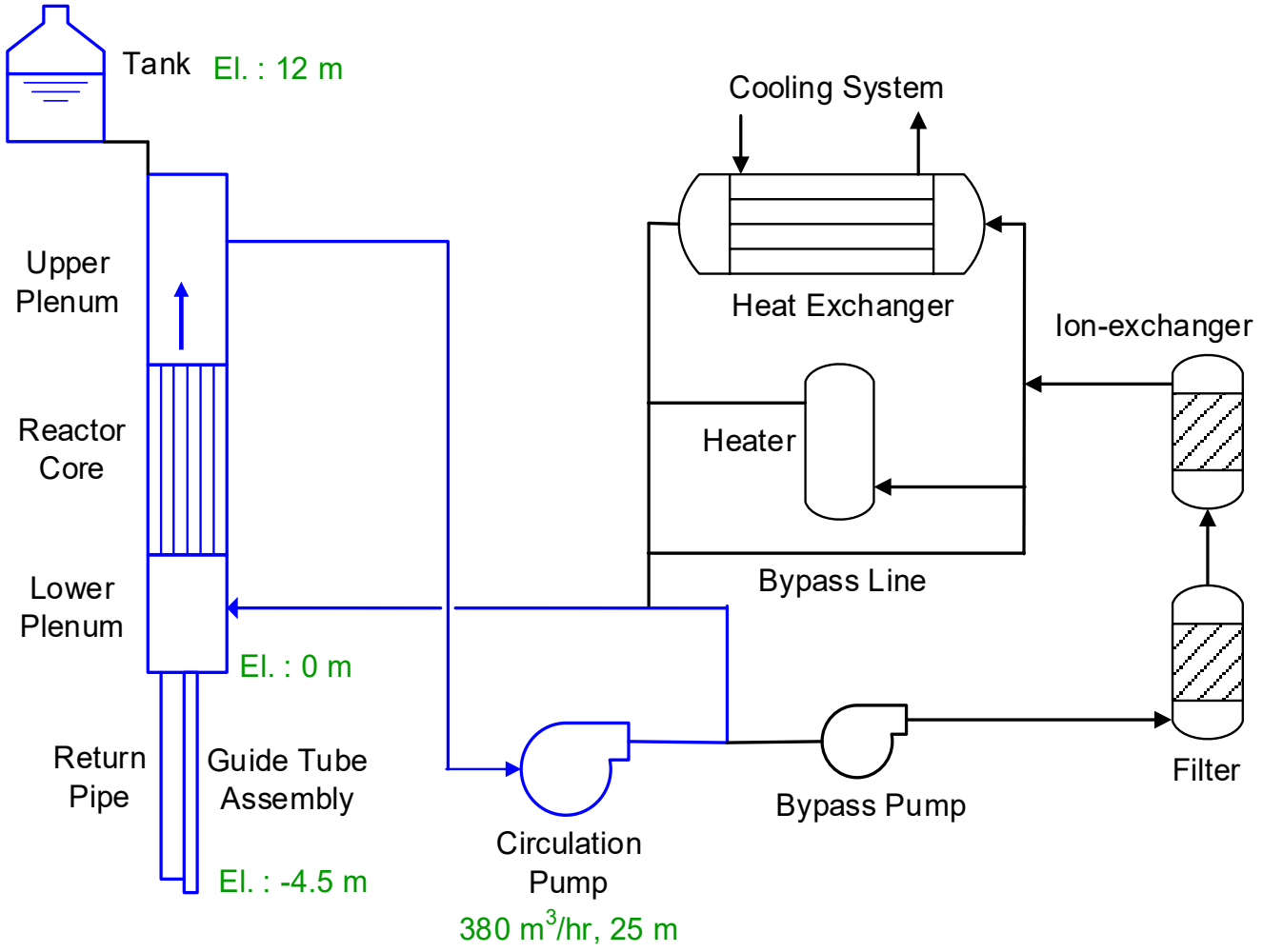
Photo of Test Section

Top view of Test Section



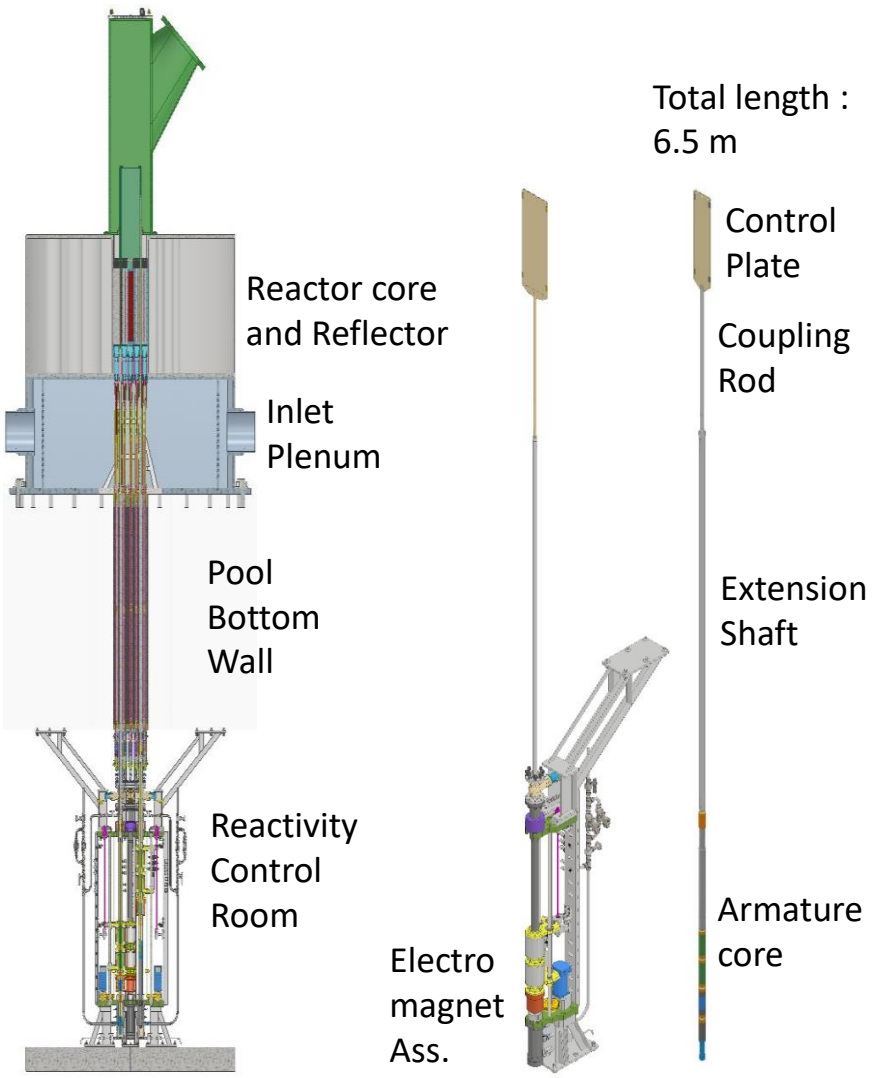
▪ Test Facility

Schematic Diagram of Test Facility



Test Facility and Reactor Shutdown System

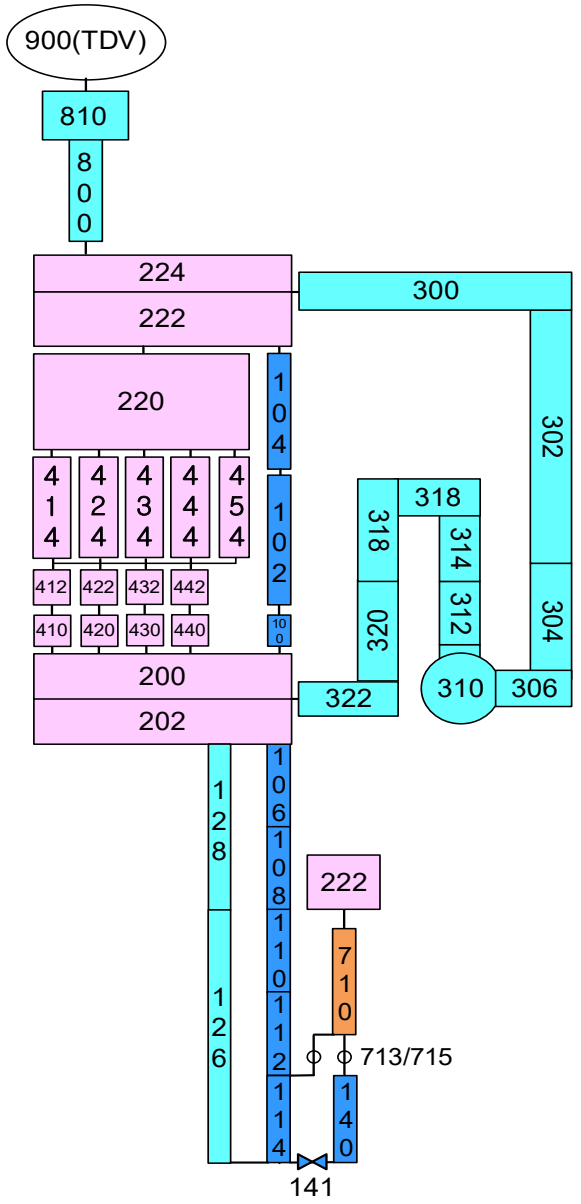
- Reactor Shutdown System
  - Control Plate Assembly (CPA)
    - ✓ Control Plate
    - ✓ Coupling Rod
    - ✓ Extension shaft
    - ✓ Armature core
  - Guide Tube Assembly (GTA)
    - ✓ Guide for moving the CPA
  - Electromagnet Assembly (EA)
    - ✓ Hold the CPA in normal operation
    - ✓ Release the CPA in emergency condition
  - Control Drive Assembly (CDA)
    - ✓ Move up and down the electromagnet assembly in power operation
- Functions of RSS
  - Regulate the reactor power in normal operation
  - Shutdown the reactor in emergency



Modeling of Test Facility and Drop of CPA

- Node Diagram of RELAP5 for Test Facility

Nodes	Hydraulic Components of RELAP5	Descriptions
200, 202	Branch	Lower plenum
410~444	Single volume, Pipe	Grid plate, 4 Fuel assemblies
454	Pipe	Gap flow path
220~224	Branch	Upper plenum
300~322	Pipe, Pump	Primary fluid system
800, 810	Pipe, Branch	Water tank, pipe
100~114, 140	Single volume, Pipe	Flow path between the CPA and GTA
713, 715	Time dependent junction	Drop speed of CPA
141	Solenoid valve	Simulating the hydraulic damping by varying the flow area
126, 128	Pipe	Return pipe from the GTA to the lower plenum



Modeling of Test Facility and Drop of CPA

- Modeling on the Drop of CPA
  - Force Balance

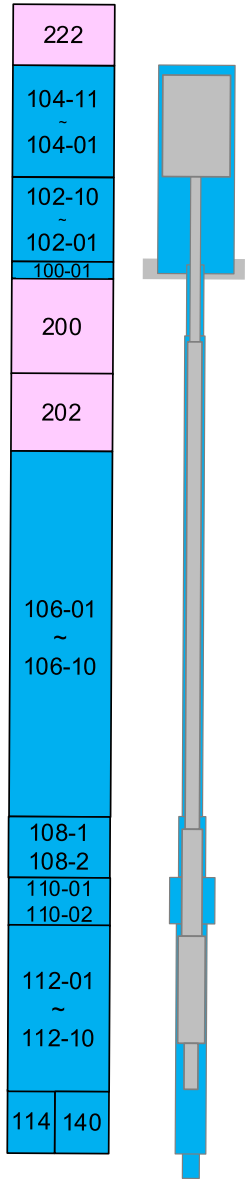
$$M_s \frac{dv(t)}{dt} = M_s g + \sum P_i(t)A_i - \sum P_j(t)A_j$$

M_s : Mass of CPA

$\sum P_i(t)A_i$: downward hydraulic force

$\sum P_j(t)A_j$: upward hydraulic force

	Node No.
Downward Hydraulic Force	104-11
	104-01
	200-01
	106-10
	110-02
Upward Hydraulic Force	102-10
	114-01
	140-01



  - Drop Speed

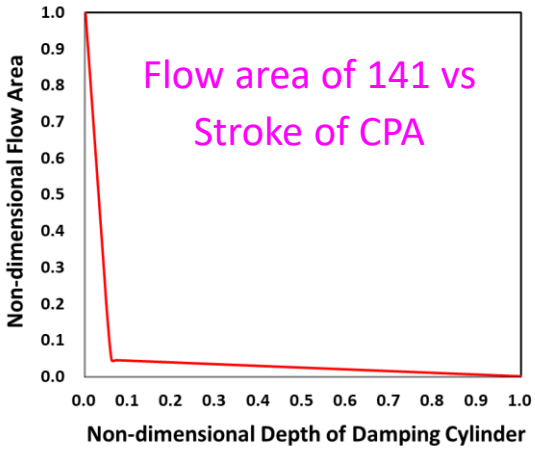
$$v(t) = \frac{1}{M_s}\int_0^t M_s g + \sum P_i(t)A_i - \sum P_j(t)A_j \, dt$$

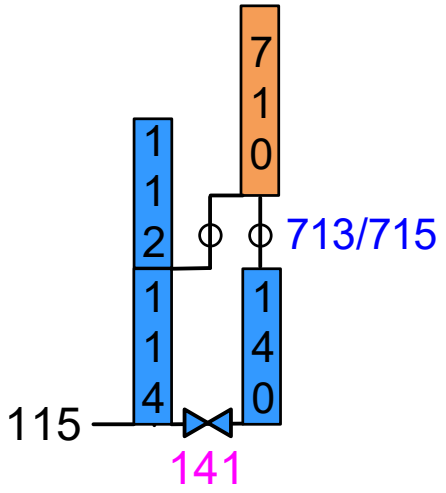
→ Input of 713/715 TDJ

  - Drop Distance

$$l(t) = \int_0^t v(t)dt$$

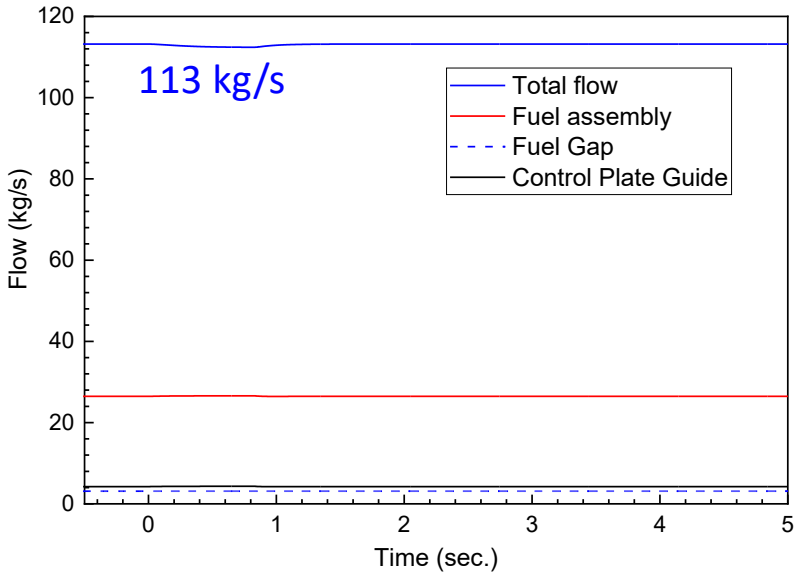
  - Modeling of Hydraulic Damping
    - ✓ Varying the flow area of 141 node



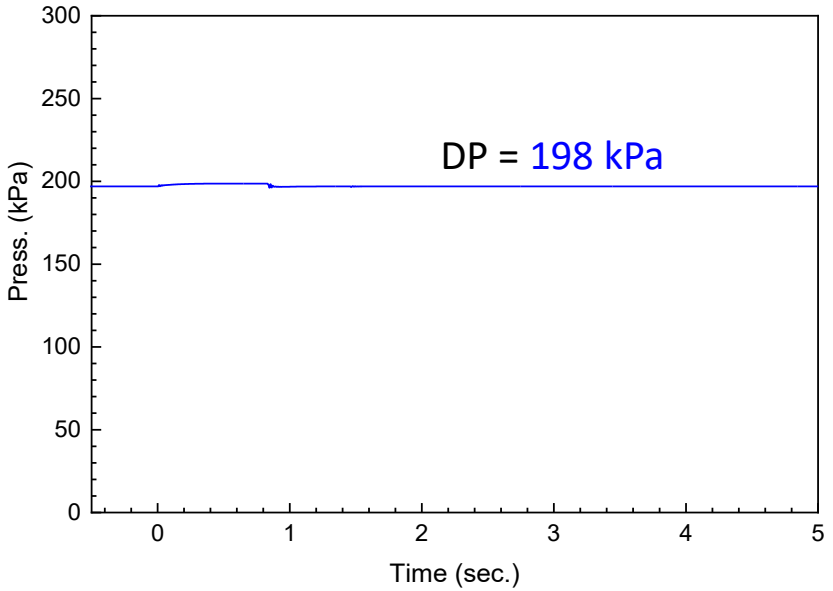


Simulation of Drop Tests of CPA

- Normal Forced Flow Condition
  - Total flowrate = 113 kg/s, Core DP = 198 kPa
  - Mass of CPA = 37 kg, Dia. of return pipe = 16.52 mm
  - CPA starts to drop : 0.0 sec.
  - Pump continues to run.



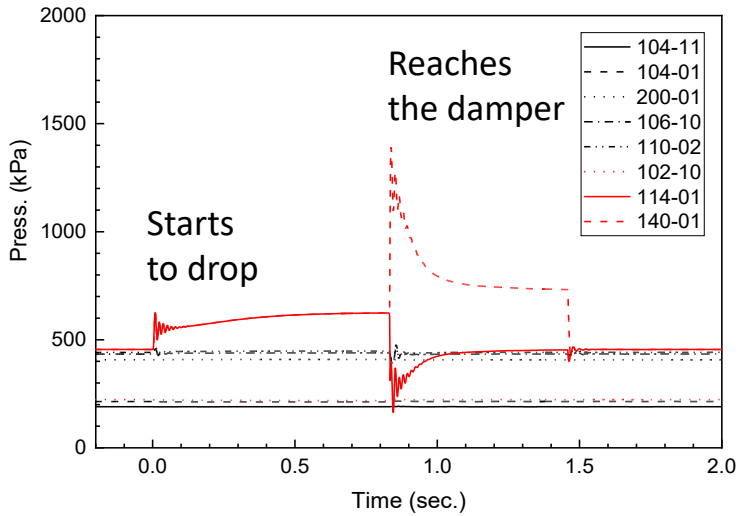
Flowrates at Test Section



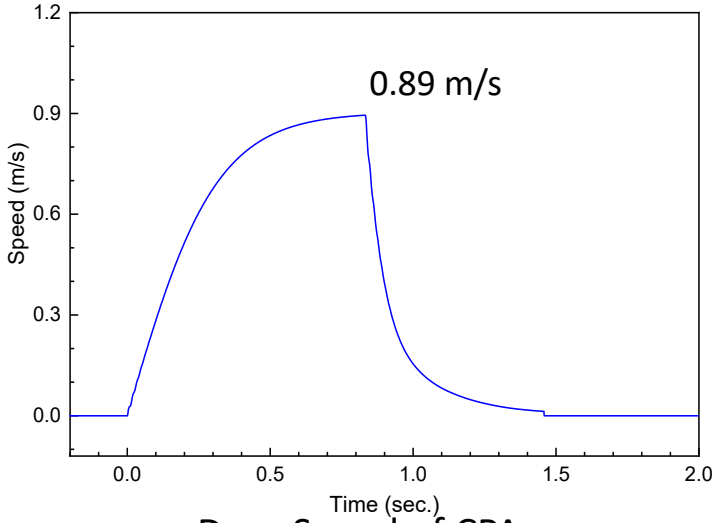
Core Differential Pressure

Simulation of Drop Tests of CPA

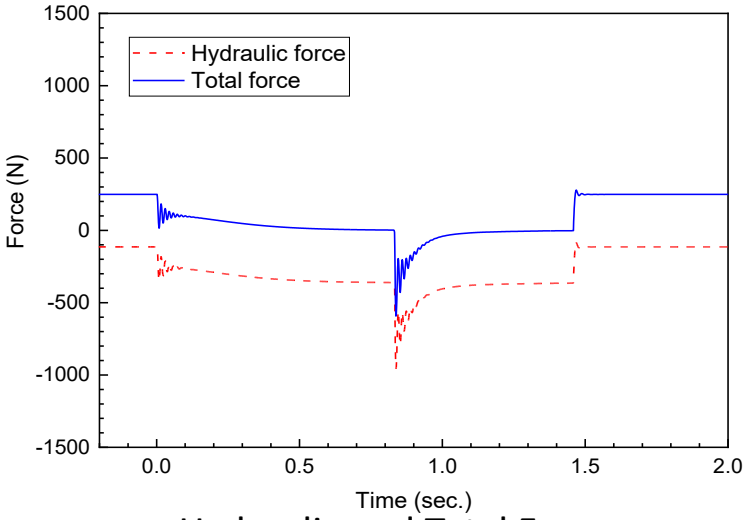
- Normal Forced Flow Condition



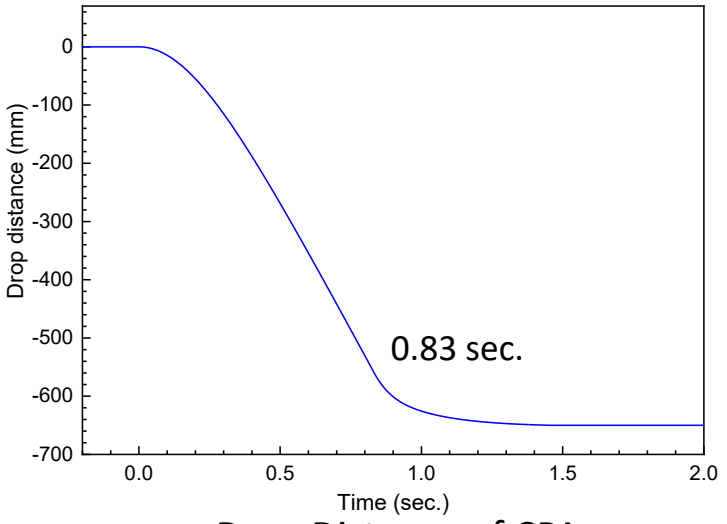
Pressures for Calculating Hydraulic Force



Drop Speed of CPA



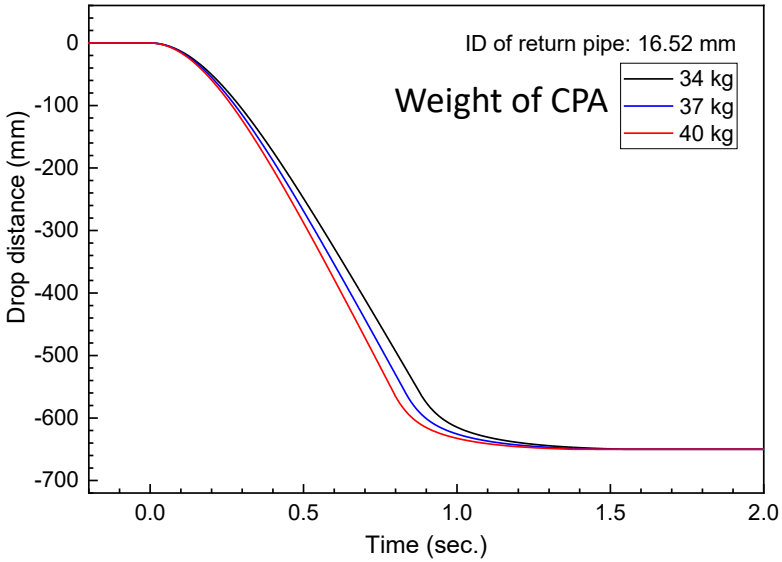
Hydraulic and Total Force



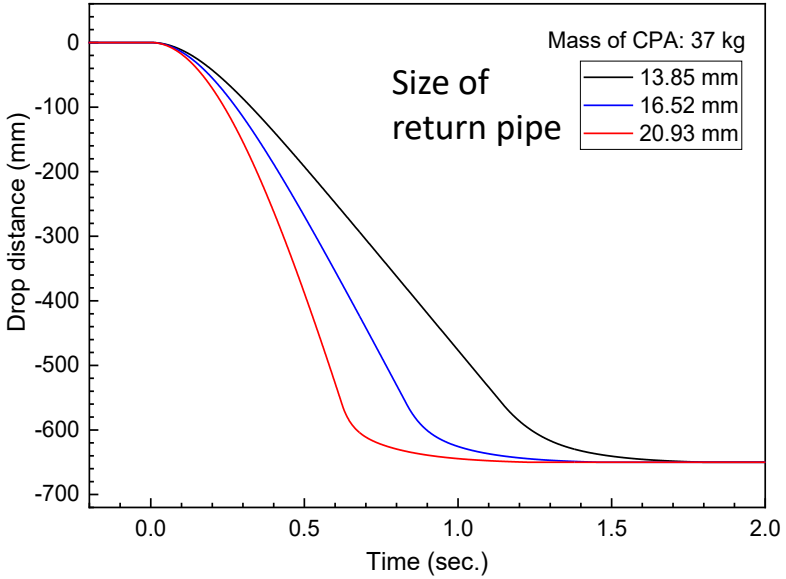
Drop Distance of CPA

Simulation of Drop Tests of CPA

- Normal Forced Flow Condition



Drop Distance of CPA



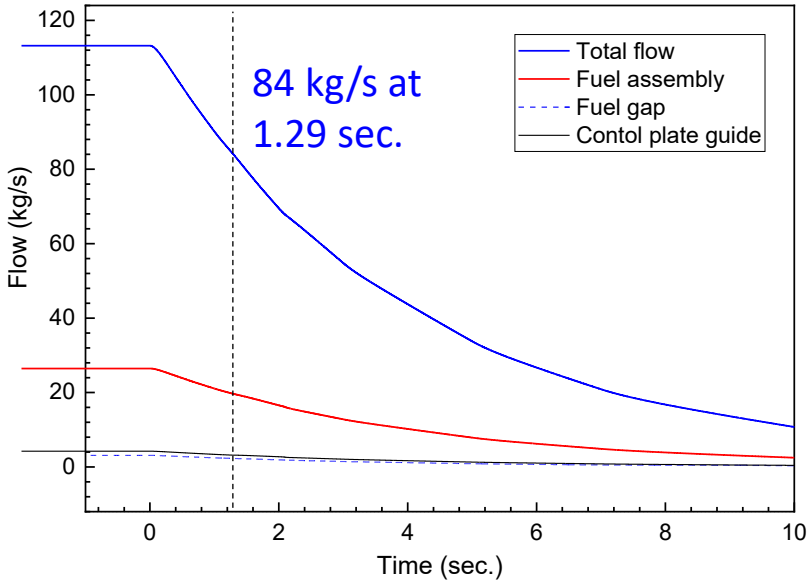
Drop Distance of CPA

ID of return pipe	16.52 mm	Drop Time
Mass of CPA	34 kg	0.88 sec.
	37 kg	0.83 sec.
	40 kg	0.79 sec.

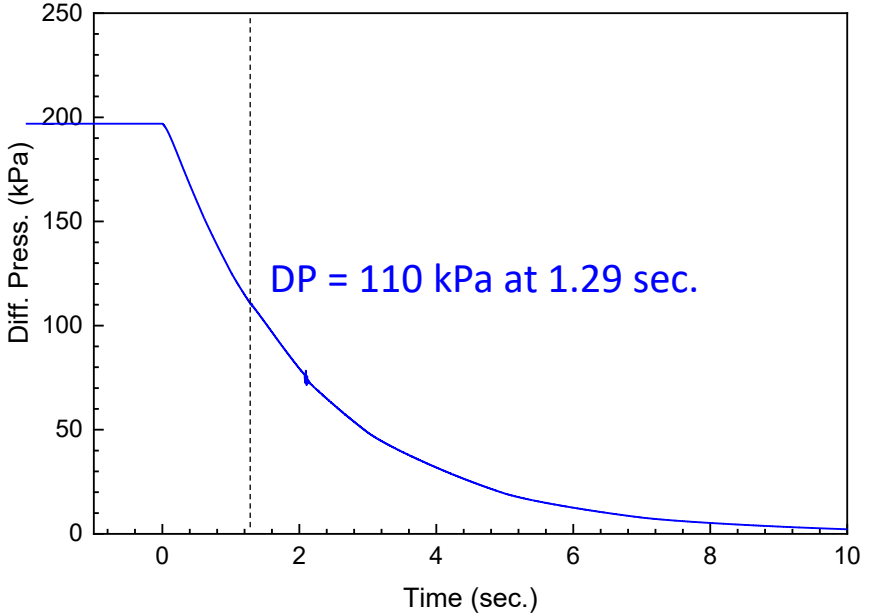
Mass of CPA	37 kg	Drop Time
ID of return pipe	13.85 mm	1.14 sec.
	16.52 mm	0.83 sec.
	20.93 mm	0.62 sec.

Simulation of Drop Tests of CPA

- Pump Trip Event
  - Initial total flowrate = 113 kg/s, core DP = 198 kPa
  - Mass of CPA = 37 kg, Dia. of return pipe = 16.52 mm
  - Pump turned off : 0.0 sec.
  - Flowrate reaches the low flow trip setpoint : 0.74 sec. (85% of normal flowrate)
  - CPA starts to drop : 1.29 sec. (trip delay time of 0.55 sec.)



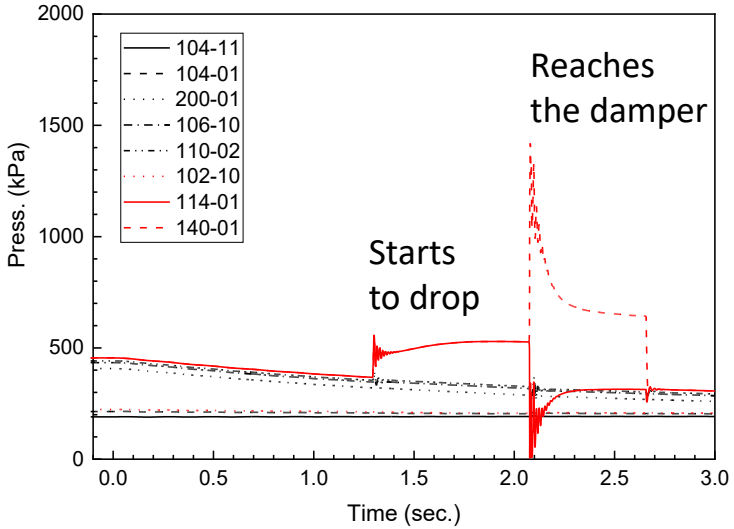
Flowrates at Test Section



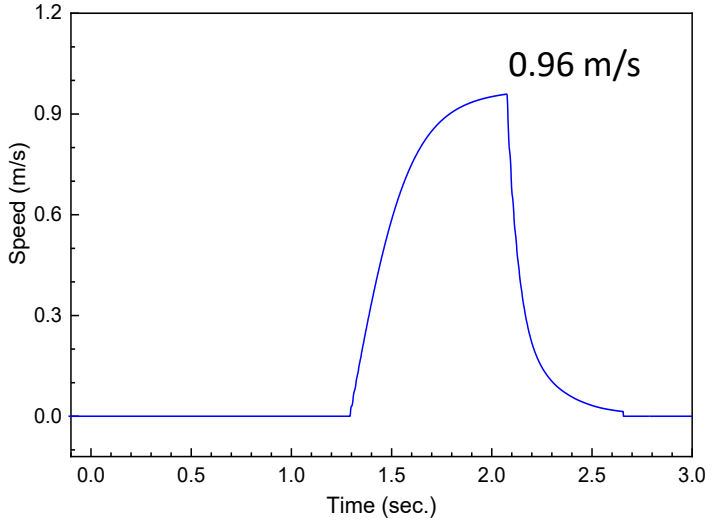
Core Differential Pressure

Simulation of Drop Tests of CPA

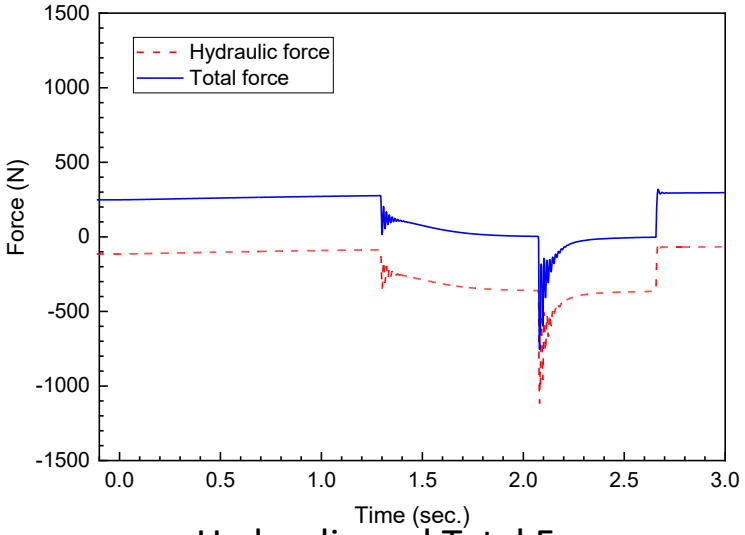
- Pump Trip Event



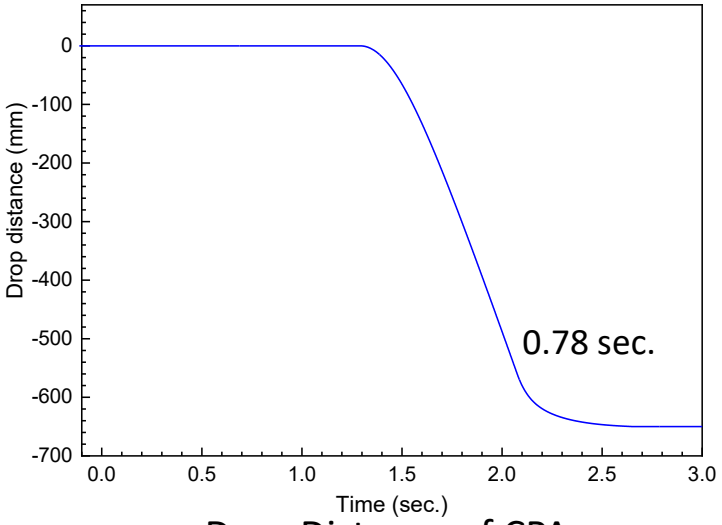
Pressures for Calculating Hydraulic Force



Drop Speed of CPA



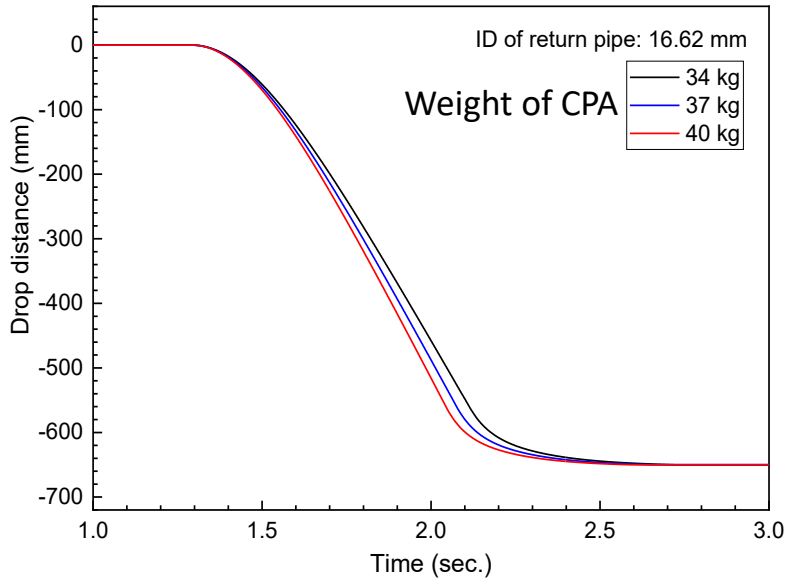
Hydraulic and Total Force



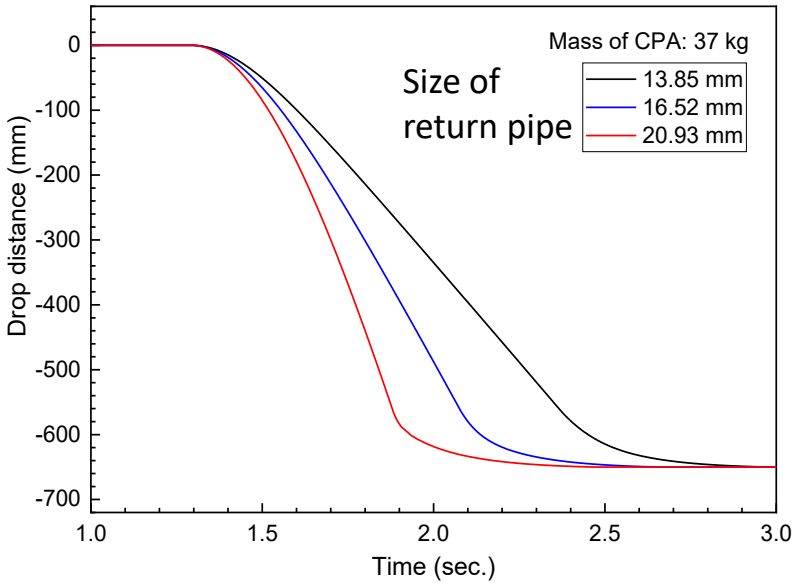
Drop Distance of CPA

Simulation of Drop Tests of CPA

- Pump Trip Event



Drop Distance of CPA



Drop Distance of CPA

ID of return pipe	16.52 mm	Drop Time
Mass of CPA	34 kg	0.82 sec.
	37 kg	0.78 sec.
	40 kg	0.75 sec.

Mass of CPA	37 kg	Drop Time
ID of return pipe	13.85 mm	1.07 sec.
	16.52 mm	0.78 sec.
	20.93 mm	0.59 sec.

Simulation of Drop Tests of CPA

- Effects of hydraulic load on the drop time

		Forced Flow Cases	Pump Trip Cases
ID of return pipe	16.52 mm	113 kg/s, 198 kPa	84 kg/s, 110 kPa
Mass of CPA	34 kg	0.88 sec.	0.82 sec.
	37 kg	0.83 sec.	0.78 sec.
	40 kg	0.79 sec.	0.75 sec.

		Forced Flow Cases	Pump Trip Cases
Mass of CPA	37 kg	113 kg/s, 198 kPa	84 kg/s, 110 kPa
ID of return pipe	13.85 mm	1.14 sec.	1.07 sec.
	16.52 mm	0.83 sec.	0.78 sec.
	20.93 mm	0.62 sec.	0.59 sec.

Conclusions

- A RELAP5 modeling on drop tests of the reactor shutdown system was developed in order to assess the effects of design variables on the drop time of CPA.
- The weight of CPA and the size of return pipe were investigated in the normal forced flow condition and the pump trip event.
- The trend of drop speed and distance of CPA is predicted reasonably.
- The drop time decreases obviously as the weight of CPA and the size of return pipe increase.
- The drop times of CPA in the pump trip cases are slightly shorter than in the forced flow cases due to the lower core differential pressure.
- The RELAP5 modeling will be verified experimentally and improved in the future.

Thank for your attention