PRELIMINARY STUDY OF THERMAL HYDRAULICS SYSTEM FOR SMALL PRESSURIZED-WATER REACTOR BASED ON ACPR50S REACTOR TECHNOLOGY

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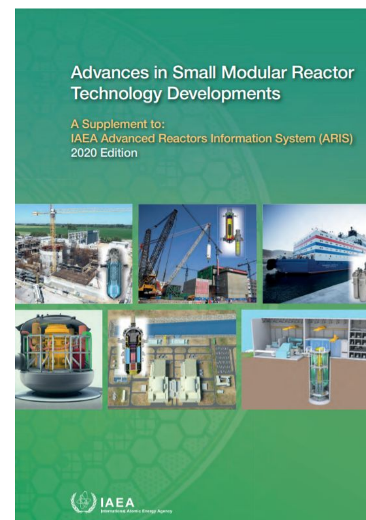
CONTENTS

1. INTRODUCTION

1.1. Development trend of Small Modular Reactor (SMR), Floating Nuclear Power Plant (FNPP) in the world

- Small modular reactors (SMRs) are being developed by many countries in the world because of the many advantages of these type reactors compared to power reactors.
- According to IAEA statistics in 2020, there are more than 70 SMR designs being developed for difference applications.
- SMR designs have been built and operated such as: KLT40S (Russian Federation), HTR-10 (China), HTTR-30 (Japan).

Akademik Lomonosov Floating Nuclear Power Plant



SMR book of IAEA

1. INTRODUCTION

1.1. Development trend of Small Modular Reactor (SMR), Floating Nuclear Power Plant (FNPP) in the world

- One of the applications of SMR is used for floating nuclear power plants (FNPP). Floating nuclear power plants are of interest to countries with long coastlines that need economic development in remote and isolated areas and offshore islands such as Russia, China, and Korea, Indonesia, etc.
- China is particularly interested in floating nuclear power plants, the first plant in China use ACPR50S reactor technology which developed by China General Nuclear Energy Corporation (CGNPC).

Floating nuclear power plant based on the BANDI-60 reactor of Korea

Floating nuclear power plant based on the ACRP50S reactor of China

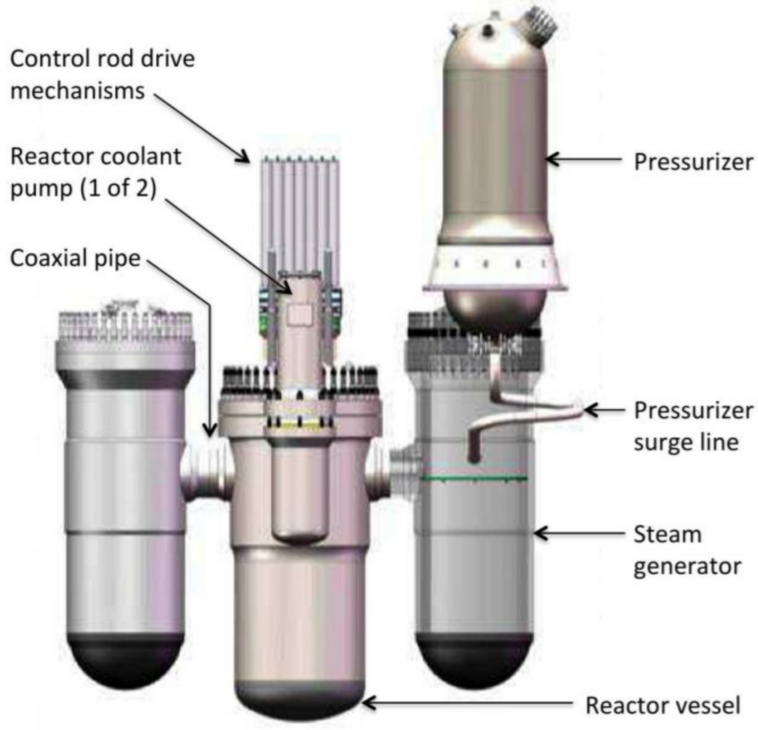
1. INTRODUCTION

1.2. Objective and Purposes

- **Objective:** Thermal hydraulics system of a pressurized water reactor similar to ACPR50S.

- **Purposes:** Steady-state simulation of a PWR reactor primary loop design based on ACPR50S technology.

- **Calculation tool:** RELAP5 code.
- The data used in these calculations are referenced from the MATPRO (A Library of Materials Properties for Light-Water-Reactor Accident Analysis).

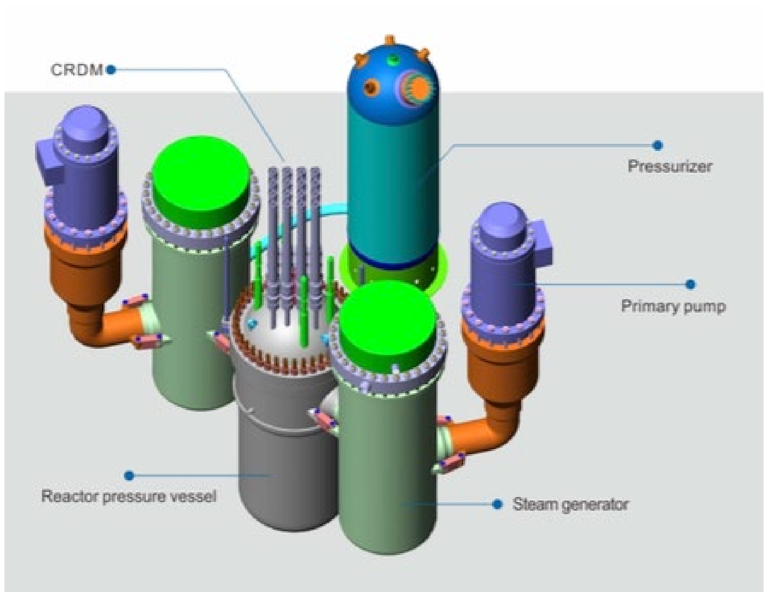


ACPR50 primary system elevation view. (ACPR50S is expected to be similar)

2. METHODOLOGY

Thermal hydraulics Parameters

Parameters in core of ACPR50S reactor



Thermal hydraulics system of ACPR50S reactor

Parameters	ACPR50S
Core of reactor	
Active diameter	1,51 m
Active height	2,00 m
Thermal power	200 MWt
Pressure of system	15,5 MPa
Number of assembly	37
Number of fuel rods in a assembly	264
Coolant temperature inlet	572.45 K
Coolant temperature outlet	594.95 K
Fuel rod	
Outer diameter of cladding	10,0E-3 m
Inner diameter of cladding	9.75E-3 m
Thickness of cladding	1.524E-4 m
Gap between fuel pellet and cladding	6.096E-4 m
Fuel rod length	2,0 m
Fuel pellet diameter	8.53E-3 m
Fuel pellet height	1.02E-2 m
Heat transfer area	6.75E+2m^2

2. METHODOLOGY

Thermal hydraulics Parameters

Reactor Vessel

Parameters	Value
Pressure design	15.5 MPa
Temperature design	616.5 K
Total height of reactor	7.2 m
Outer diameter of reactor vessel	2.2 m

Circulation pump

Parameters	Value
Number of pump	2
Type	Vert.-Centrifugal
Mass flow rate, m^3/s	0.6
Rotational speed, rad/s	124.5
Pump head, m	84.4
Moment of inertia, kg/m^2	6455
Torque, $pa.m^3$	1084

Steam Generator

Parameters	Value
Total heat exchange	200 MWt
Primary side	
Mass flow of steam at net power	67.04 kg/s
Outer diameter of tube	2.22E-2 m
Thickness of tube	1.11E-3 m
Total heat transfer area	5.32E2 m^2
Secondary side	
Temperature of feed water	490 K
Steam pressure	4.85 MPa

2. METHODOLOGY

Calculation model

The main components include: reactor core (PIPE 335); Lower plenum (BRANCH 322), Upper plenum (PIPE 356), bypass (PIPE 320), downcommer (PIPE315), 2 hot legs (102 and 202), 2 cold legs (116 and 212), 2 recirculation pumps (113 and 209), 2 steam generators, pressurized (PIPE 150).

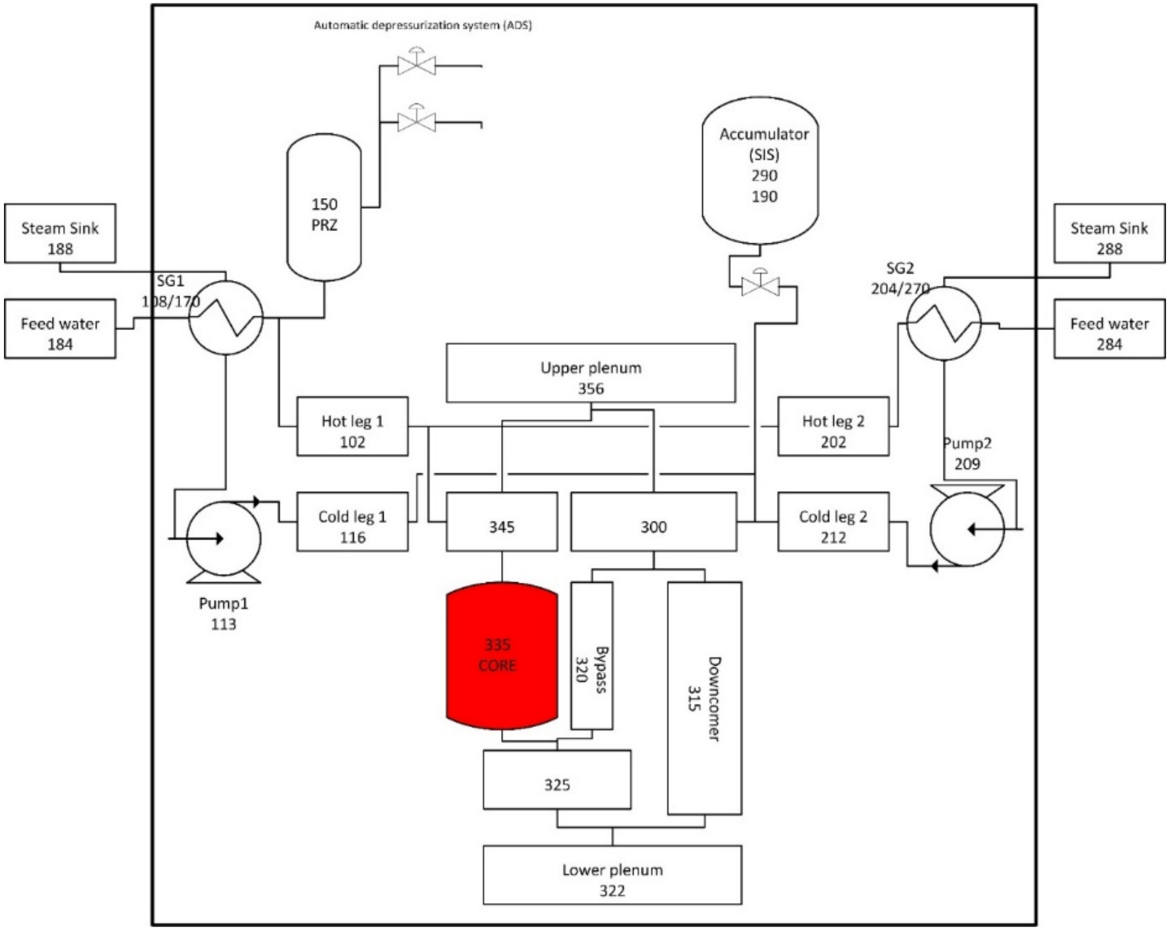
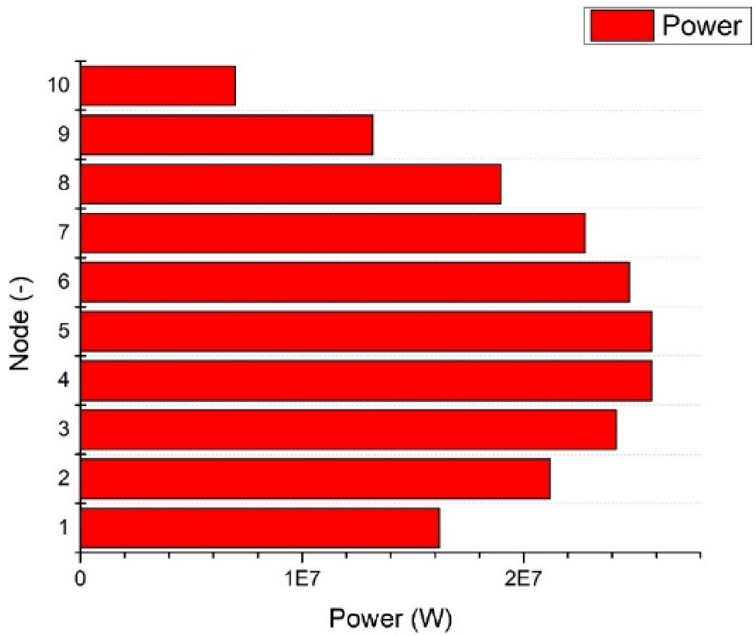


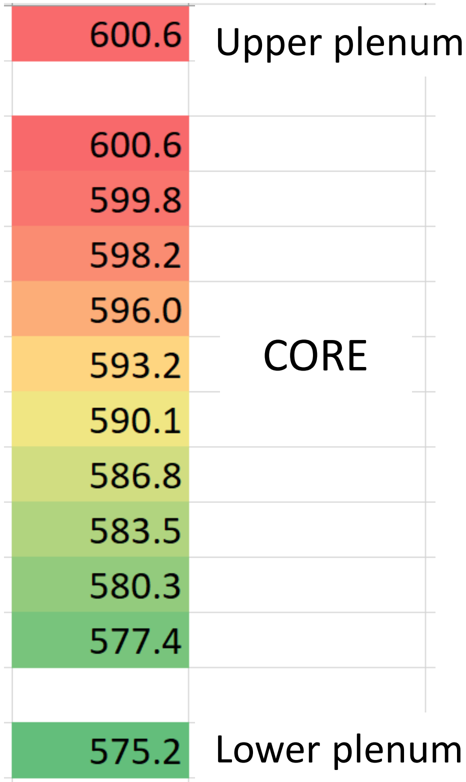
Diagram of thermal hydraulics system of the PWR reactor in RELAP5

3. RESULTS AND DISCUSSION

The thermal hydraulics evolution of the PWR was investigated in 10000 seconds using the RELAP5 code, the model has reached a steady state, and the parameters have not changed significantly.

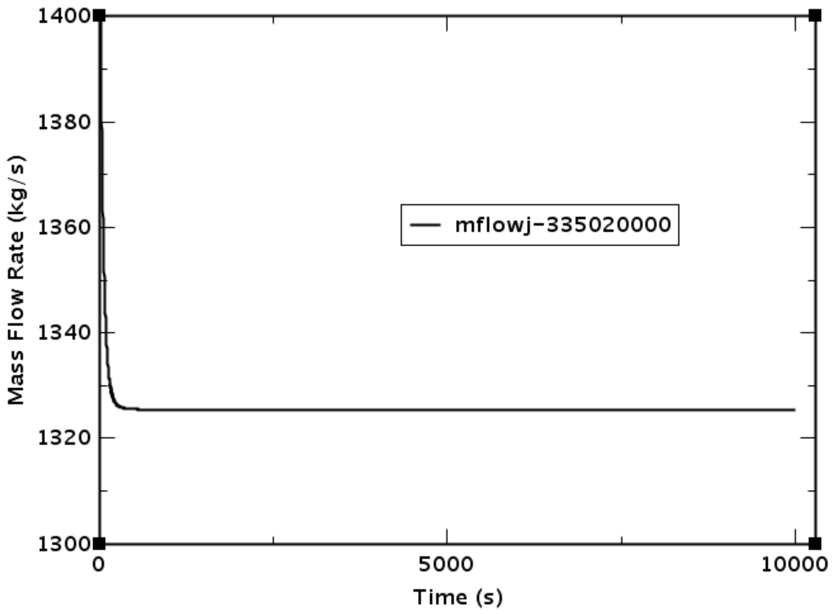


Power distribution along the active height of core reactor

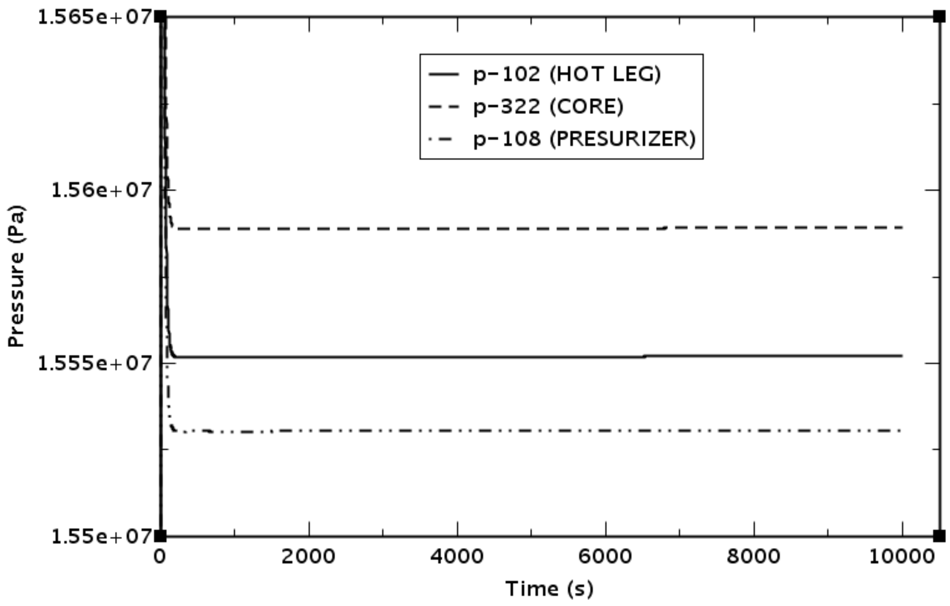


Temperature distribution along the active height of core reactor

3. RESULTS AND DISCUSSION

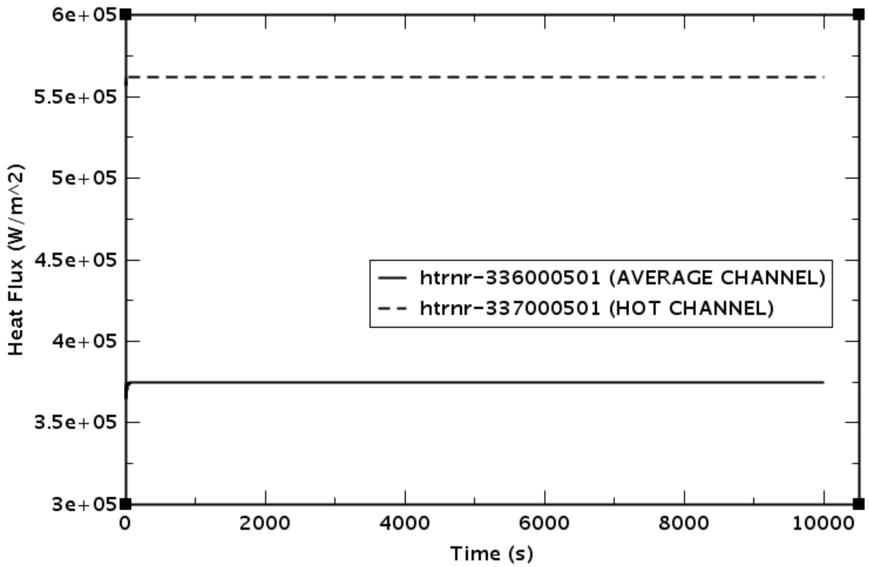


Mass flow rate (mflowj) through the reactor core (335)

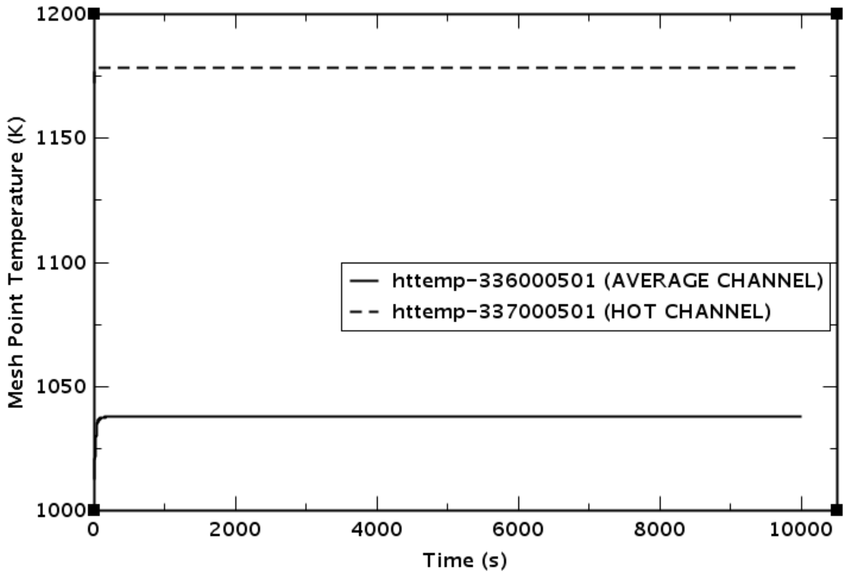


Pressure in primary loop

3. RESULTS AND DISCUSSION

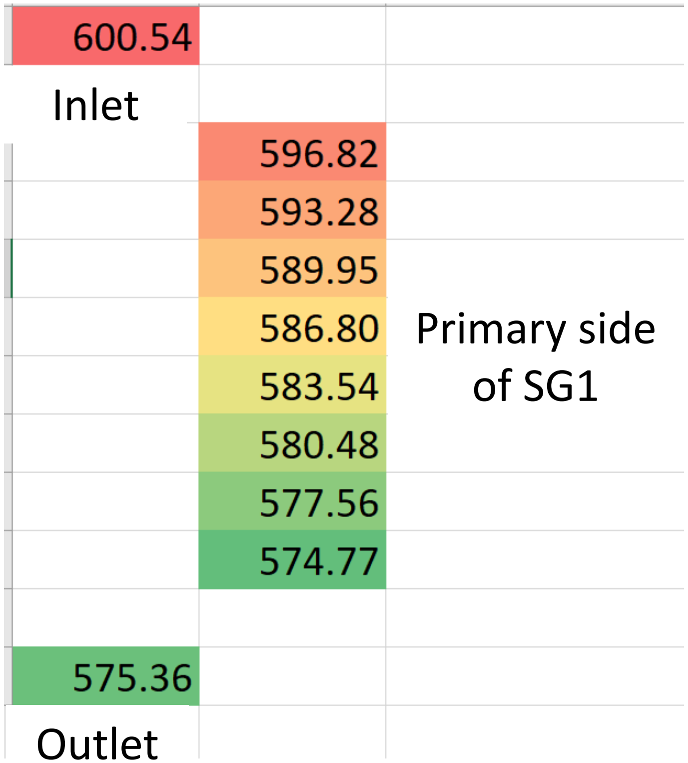


Heat flux transfer from fuel to coolant

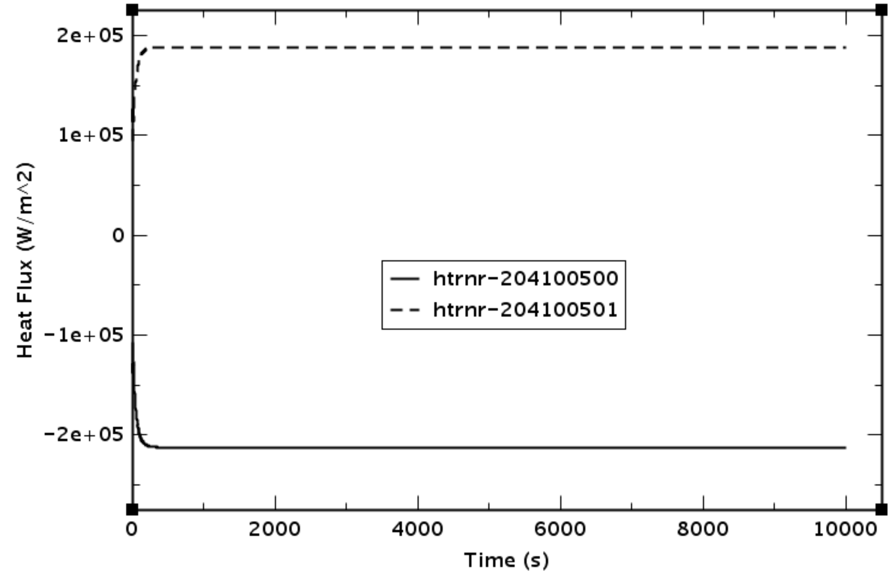


Temperature at center fuel pellets

3. RESULTS AND DISCUSSION

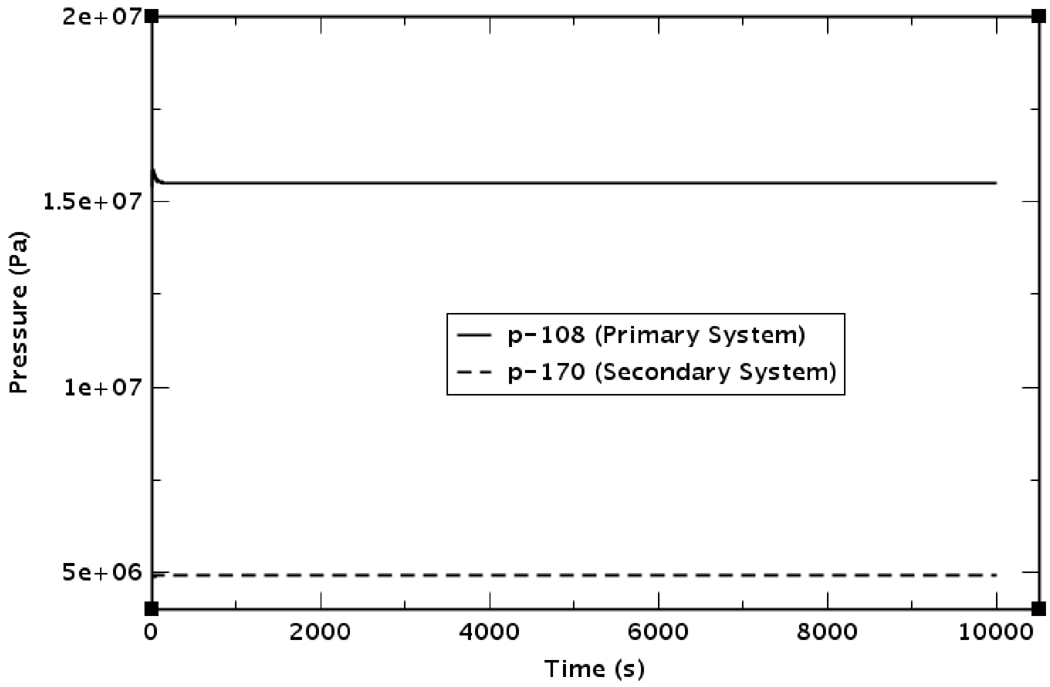


Temperature distribution at primary side of first steam generator



Heat flux of middle steam generator 212558 W/m²

3. RESULTS AND DISCUSSION



Pressure difference between primary loop and secondary loop

3. RESULTS AND DISCUSSION

Compare simulation results with PWR design parameters with ACPR50S reactor

Parameters	Units	Target value	Simulation value	Different
Reactor power	MW	200	200	0%
Pressure of primary loop	MPa	15.5	15.5	0%
Mass flowrate through reactor core	Kg/s	1436.8	1325.0	7.78%
Coolant temperature inlet	K	572.45	575.2	0.48%
Coolant temperature outlet	K	594.95	600.6	0.95%
Pressure of secondary loop	MPa	4.85	4.85	0%
Temperature of feed water	K	490	490	0%

4. CONCLUSION

The report presented the calculation using program RELAP5 to simulate the primary loop of a PWR reactor based on ACPR50S technology in steady-state operation:

- ✓ The important components are modeled including: reactor core, reactor vessel, main circulation pump, steam generator;
- ✓ The system has reached a steady state condition;
- ✓ The simulated results are consistent with target data of the PWR reactor design based on ACPR50S technology, the difference of important parameters is not large, except for the mass flow rate through the reactor core (7.78%), but this difference is still acceptable in thermal hydraulics simulation for nuclear power plants.

Based on these results we continue to perform simulations for the entire floating nuclear power plant (FNPP) using the PWR pressurized water reactor based on ACPR50S technology. In future studies, we will conduct simulation and safety analysis in accident case.

Reference

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THANK FOR YOUR ATTENTION!