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TUBE INLET ORIFICE DESIGN OF A ONCE-THROUGH STEAM GENERATOR CONSIDERING OPERATION STRATEGIES

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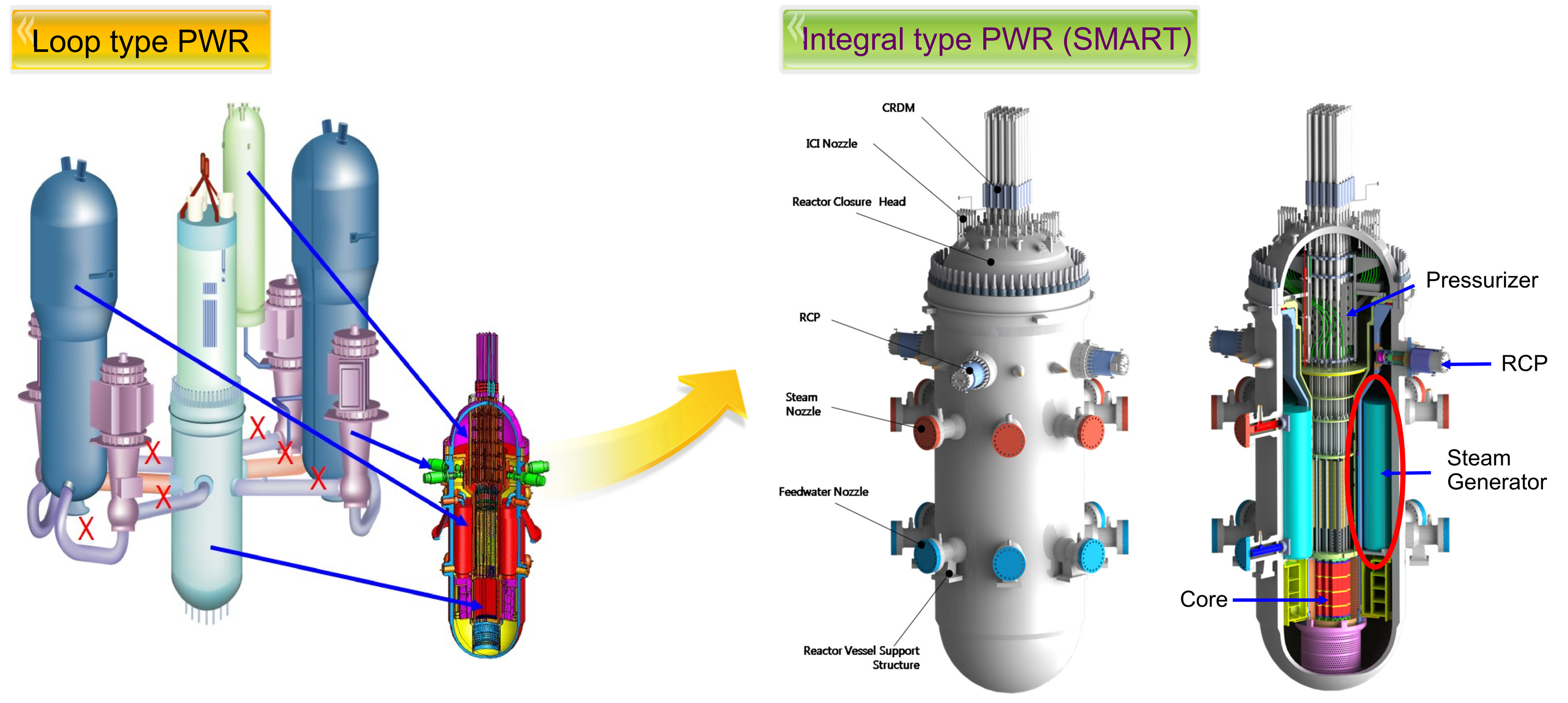
INTRODUCTION

Integral-Type Pressurized Water Reactor (PWR)



Helically Coiled Tube Once-Through Steam Generator (OTSG)

- In-vessel steam generator
- Compact design and simple flow path arrangement
- Primary coolant flowing down outside the tubes and secondary feedwater flowing up inside the tubes (counter-flow operation)
- Superheated steam generation (no steam separator)

◆ **Motivation**

- Flow oscillation due to the phase change of the feedwater from subcooled water to superheated steam
- Orifice installation at the tube inlet for flow stabilization
- Prediction of the operating point according to the operation strategy for the tube inlet orifice design

◆ **Objective**

- To investigate constant thermal power operation strategies and to compare the orifice design results of the different operation strategies

ANALYSIS METHOD

ONCESG

- Design and analysis code for a once-through steam generator using helically coiled tubes
- Three major heat transfer regions: economizer, evaporator & superheater

Operation Strategies

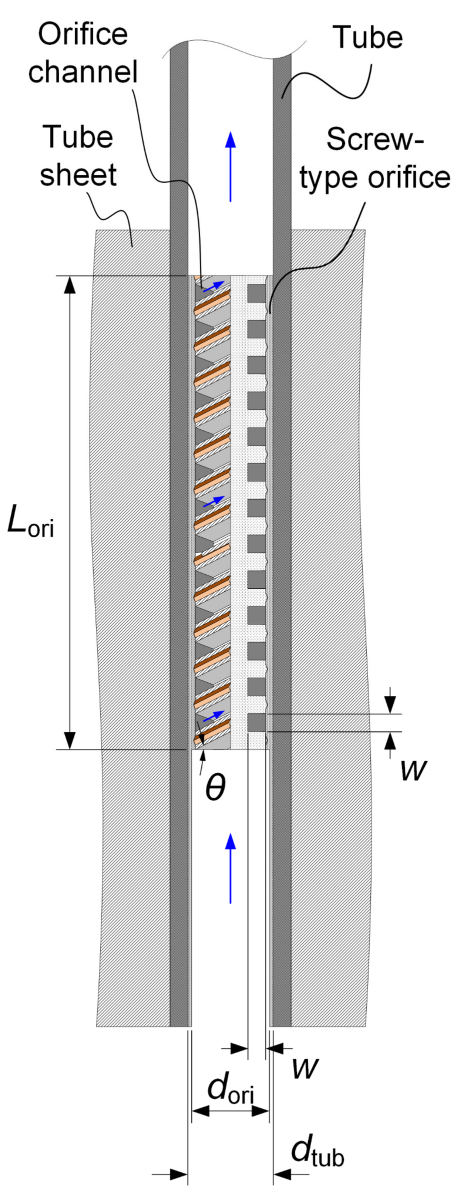
- Secondary coolant inlet temperature control
- Secondary coolant flow rate control
- Secondary coolant outlet pressure control

Orifice Length Criterion

- Screw-type tube inlet orifice

$$L_{ori} \geq L_{ori\_min} = \frac{K_{ori\_min}\rho_e v_e^2 - K_i \rho_i v_{c\_1}^2 - K_e \rho_{c\_2} v_{c\_2}^2}{\left[f/w + 0.1/(\pi D_{avg}) \right] \rho_{c\_1} v_{c\_1}^2} \sin\theta,$$

$$K_{ori\_min} = 2\left[\kappa_{min}\left(\Delta P_{two} + \Delta P_{sup}\right) - \Delta P_{sub} \right] / \left(\rho_e v_e^2\right)$$



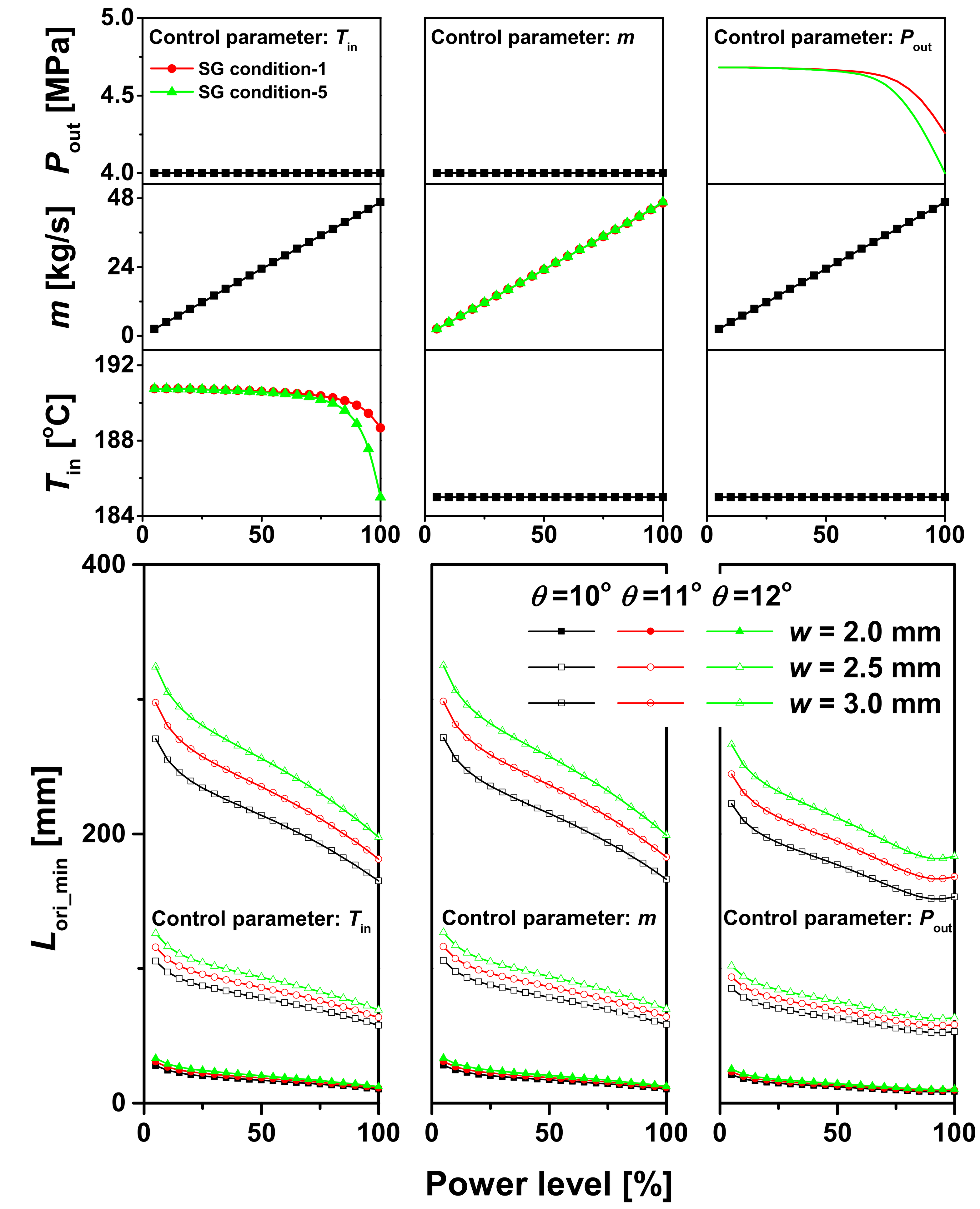
OTSG Design

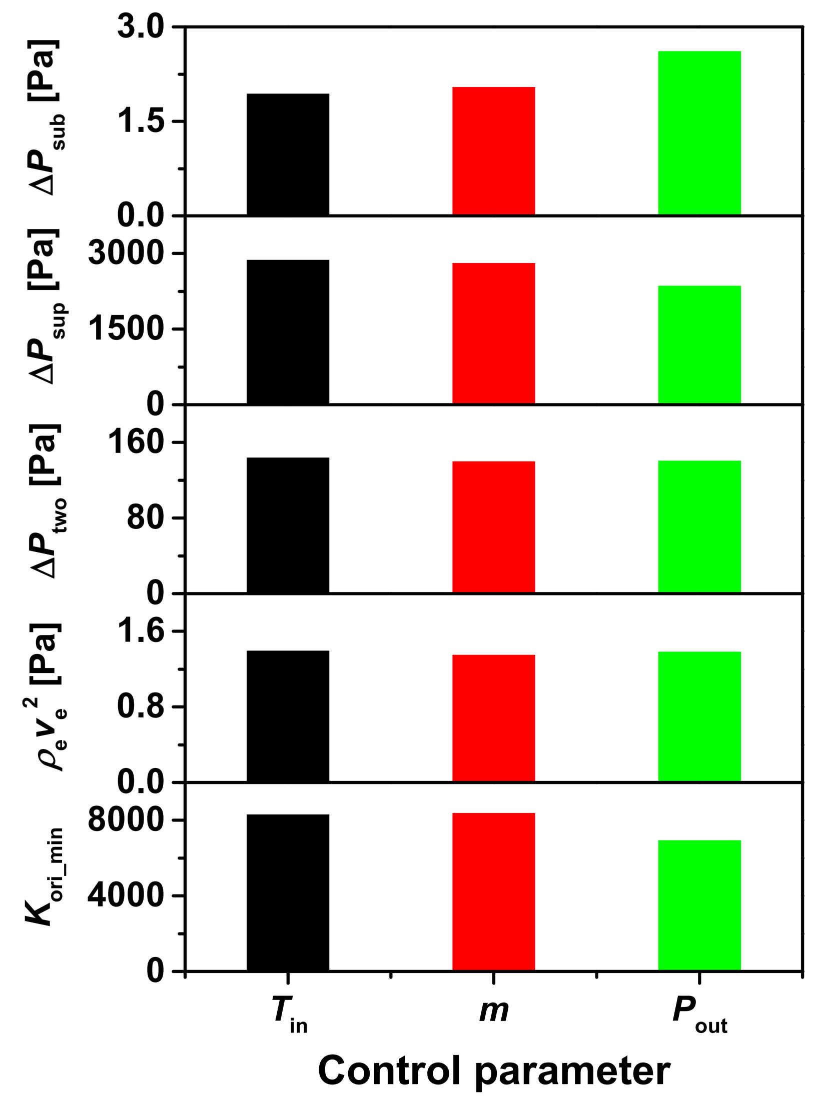
- Marine Reactor X (MRX) OTSG design data
- Steam generator conditions

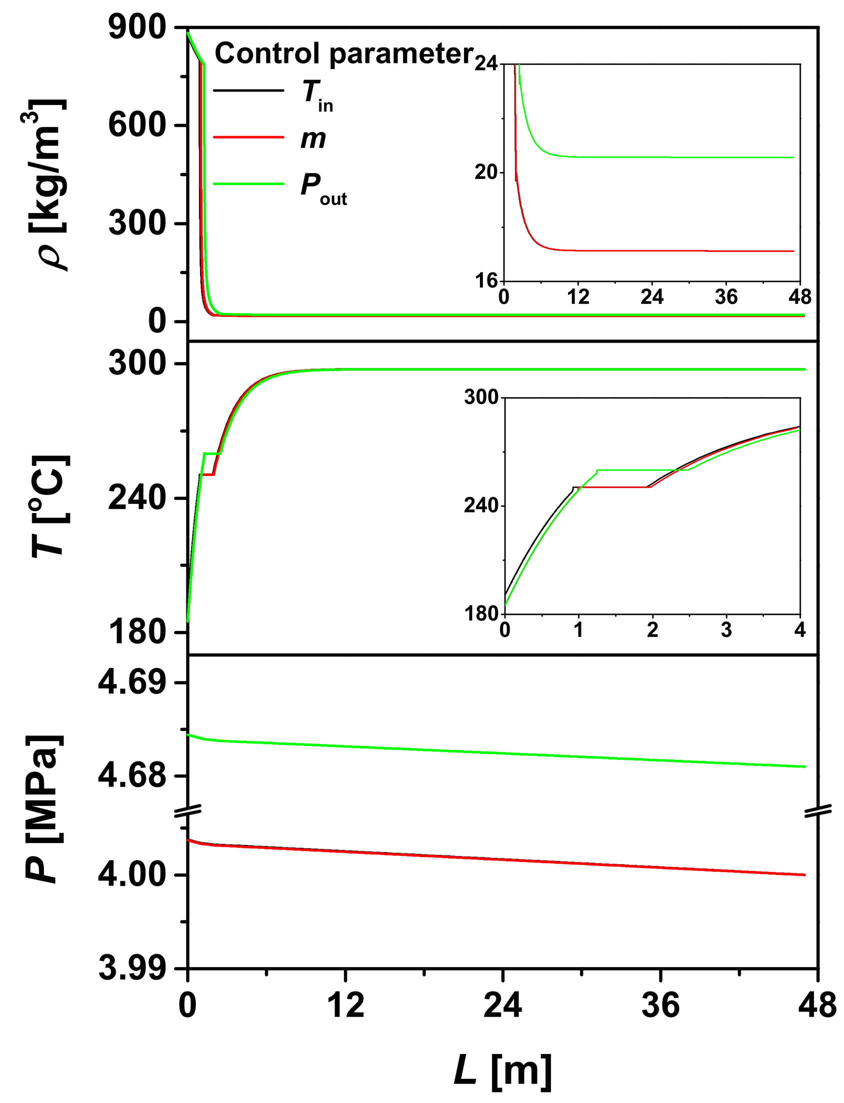
SG condition	1	2	3	4	5
Plug. ratio, α [%]	0.0	2.6	5.2	7.7	10.3
No. of tubes, N [ea]	388	378	368	358	348

RESULTS AND DISCUSSION

Control Parameters & Orifice Design Comparison







CONCLUSIONS

- The T_{in} control operation, m control operation, and P_{out} control operation allow a relatively high T_{in}, a relatively low m, and a relatively high P_{out} compared to the other different operation strategies, respectively, except when the OTSG operates at the design condition.
- The P_{out} control operation provides a relatively high secondary coolant pressure and results in a reduced orifice length because the flow instability becomes less severe under high pressure.