Study on Verification of Natural Circulation for Small Scale Reactor with Passive System

Sung Won Lim, In Young Kim, Yong Won Choi, Un Chul Lee
Dept. Nuclear Engr. Seoul Nat'l Univ., Shillim-dong, Kwanak-gu, Seoul, 151-744
Tel:1-82-2-880-8332 , Fax:1-82-2-889-2688 , Email : sw54176@snu.ac.kr

1. Introduction

As a development of industry, energy demands are greatly increased and environmental problems such as energy crisis, global warming and acid rain are issued. With this fact, eastern European countries have already led the development and operation of many nuclear district heating power plant. And a study on small scale reactor for multi-purpose regional energy system is started in Korea. This reactor is induced natural coolant circulation and passive systems to enhance safety. And economical efficiency is improved with remote control system. [1]

From the viewpoint of design characteristics for regional energy reactor, the thermo-hydraulic analysis of natural circulation system is needed. So, small scale reactor that induced natural coolant circulation is nodalized and analysis is done with RELAP.

2. Natural Circulation Heat Removal on power reactors

The study is conducted to verify natural circulation of small scale reactor. And for the single phase flow, total NC mass flow W_{NC} is related to reactor power Q, the height differences between the heat source (core) and heat sink (SG) ΔH and K. K is a function of total pressure drop due to loss and friction through the coolant path and mass flow.

$$W_{NC} \propto Q^{1/3} \Delta H^{1/3} K^{-1/3} \quad (1)$$

$$K = \sum K_i + \sum \frac{f}{D_h} \Delta L \quad (2)$$

Due to the height differences between the core and SG is limited by RPV size, W_{NC} also related to RPV size. So, single phase natural circulation core cooling is recommended for a small reactor. And low pressure drop design is also important such as wider rod-to-rod spacing fuel bundle. In fact P/D (pitch to diameter ratio) in IMR and IRIS is 1.4 which is larger than that of conventional PWR, not only thermal hydraulic but also neutronic reason. [2]

3. Nodalization of small scale reactor

Small scale reactor is induced natural coolant circulation and integrated design. So, without primary coolant pump natural circulation is formed on all power level. And steam generator is accommodated in reactor pressure vessel. Related with small scale reactor, Schematic diagram and some parameters are determined. The diagram is shown as Fig. 1 and parameters are tabulated as Table. 1.

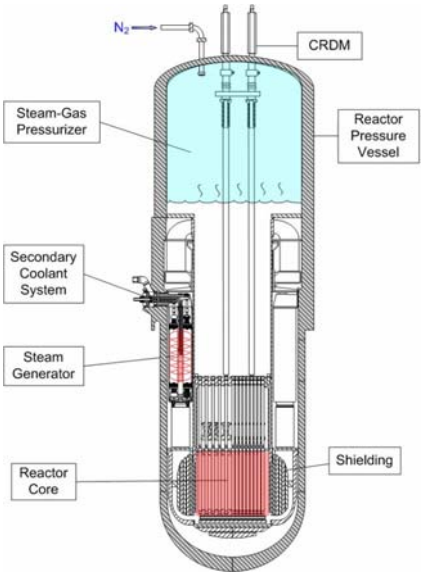

Fig. 1. Schematic Diagram of small scale reactor

Table 1. Design parameters of small scale reactor

Overall	
Thermal Power	10 *MWth*
Service Years	20 *yr*
Fuel	UO_2+Th
Geometry	
RPV outer diameter	2.272 *m*
RPV height	6.18 *m*
Core height	4.635+1.545 *m*
Primary Circuit	
Coolant medium	Water
Cooling mode	NC
Operating pressure	2.0 *MPa*
Secondary Circuit	
SG type	Helical-coiled
Number of SG	1 (overall)

But small scale reactor is under developing, some detail designs and parameters are not confirmed yet. So, some parameters such as heat transfer area and loss coefficient are scale down with SMART and KHNP. With these design parameters, small scale reactor nodalized as Fig. 2.

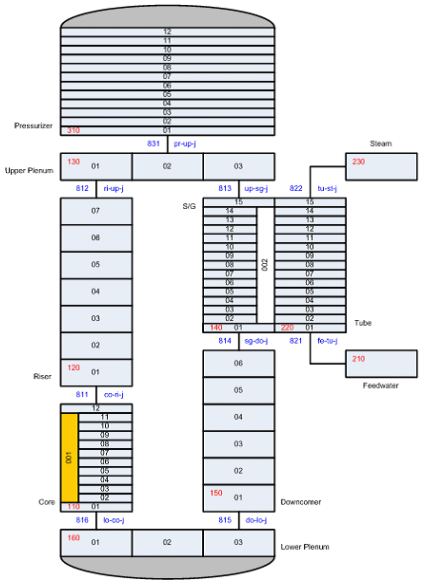

Fig. 2. Nodalization of small scale reactor

4. Verification of Natural Circulation

As a nodalization, coolant is heated by core and rises up and moves to SG. Moving through SG, coolant transfer heat to secondary side and goes down and moves to core region. With heating and cooling, coolant get natural circulation driving force and form natural circulation path.

With nodalization and RELAP, natural circulation is stabilized at about 1000sec. The temperature on steady state is 458.9377 K and 485.7155 K at core inlet and core outlet respectively. Coolant flow rate on steady state is 76.6kg/s and its pressure on primary circuit is 1.994MPa.

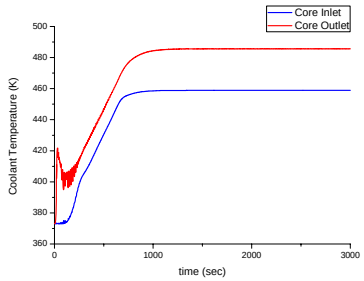

Fig. 3. Coolant temperature on steady state

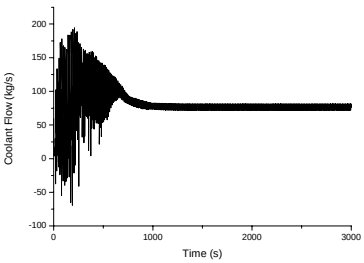

Fig. 4. Coolant flow rate on steady state

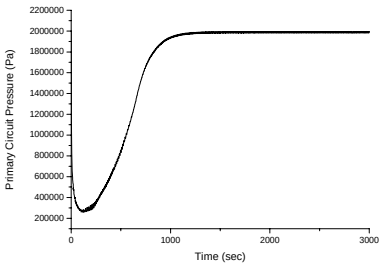

Fig. 5. Primary circuit pressure on steady state

5. Conclusion

In this study, the natural circulation of the small scale reactor is verified. And the geometry and parameters are enough to cooling the core with natural circulation. But as written in text, some detail designs and parameters are not confirmed yet. So, some parameters that used in this study can help to determine the real design parameters. Also the nodalization and input data for RELAP could be a basement for further study on safety system design and safety analysis.

REFERENCES

[1] Ministry of knowledge economy, “Study on small-scale reactor based multi-purpose regional energy system”, Feb 2009

[2] Hisashi Nonokata, “A comparative overview of thermal hydraulic characteristics of integrated primary system nuclear reactors”, Nuclear Engineering and Technology, Vol38 No.1, Feb 2006