Design Features of Regional Energy Reactor, REX-10

Jong-Won Kim [a*], Yeon-Gun Lee [a], Sung-Won Lim [a], Hyeong-Min Joo [b], Byeong-Ill Jang [b], Moo-Hwan Kim [c], Goon-Cherl Park [a]
[a] *Dept. of Nuclear Engineering, Seoul National Univ., Seoul, Korea*
[b] *Dept. of Nuclear Engineering, Hanyang Univ., Seoul, Korea*
[c] *Dept. of Mechanical Engineering, POSTECH, Pohang, Korea*
[*] *Corresponding author: riaa99@snu.ac.kr*

1. Introduction

Recently, today's global pattern of energy supply is not sustainable. The provision of affordable energy services is a fundamental prerequisite for economic growth and development. In addition, the environmental problems such as energy crisis, global warming and acid rain are issued and more demand for reliable electricity supply increases. As one of the realistic solutions, the extension of the peaceful uses of nuclear energy has been suggested. Small and medium nuclear reactors with non-electric applications arise as an alternative energy source. The main non-electric applications are defined as district heating, desalination (of sea, brackish and waste water), industrial heat supply, ship propulsion and the energy supply for spacecraft. RERI (Regional Energy Research Institute for the Next Generation) is to develop a small-scale electric power system by an environmentally-friendly and stable small nuclear reactor. The newly designed REX-10 (Regional Energy Reactor, 10MWth) has been developed to maintain system safety in order to be placed in a densely populated region, or island, etc. The REX-10 reactor system was designed based on SMART, however, the operation mode and the system pressure and capacity were determined properly for a regional energy reactor. In this study, the design characteristics of REX-10 and the related researches will be introduced.

2. Regional Energy Reactor, REX-10

Regional energy reactor, REX-10 is a small-size nuclear reactor developed by RERI. A number of issues will be considered in an increasingly competitive and regional energy market such as enhancing reactor safety, minimizing environmental impact, improving nuclear power generation economics and improving resource utilization. In particular, since this reactor will be located relatively near the residential area such as an apartment complex, an island etc., REX-10 should have highly enhanced safety features compared with current nuclear power plants. Moreover, the thorium fuel cycle with a 20-year lifetime is considered for non-proliferation and the economical efficiency is ensured by the unmanned automatic control.

REX-10 is an integral type PWR as shown in Fig. 1. These integral reactor concepts are characterized that the entire primary systems such as core, pumps, main heat exchangers (steam generators), pressurizer, etc. are arranged in a single pressure vessel. Thus, large break LOCA can be excluded. Unlike SMART, REX-10 is designed to remove the heat from nuclear fuel by natural circulation and to be operated with low system parameters compared with traditional PWR. In order to increase the natural circulation capacity, there is a long riser in the upper part of the core. In addition, the passive safety was enhanced by adopting self-pressurized built-in steam-gas pressurizer. The nitrogen gas is used for initial pressurization and the additional pressure is generated by steam from the primary coolant. The steam generator is a type of helical-coiled tube bundle based on SMART. Proliferation-resistance of fuel is a very important feature for the REX-10. Thus, the thorium fuel is the best candidate fuel for a small power reactor.

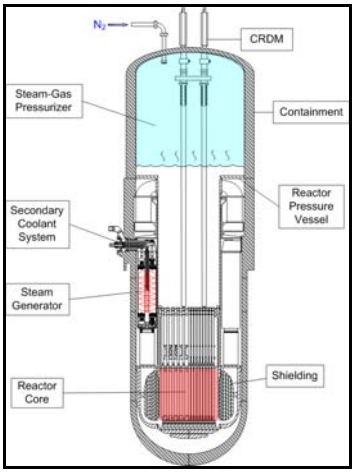

Fig. 1. Schematic Diagram of REX-10

3. Design Characteristics of REX-10

The detail design parameters of REX-10 are determined considering system pressure, total thermal power and natural circulation system. Table I shows the detail design parameters of REX-10.

Table I: Design Parameters of REX-10

Primary circuit	Operation pressure	2.0 MPa
	Thermal power	10 MW_{th}
	Cooling mode	Natural circulation
	Coolant flow	64.9 kg/s
	Core inlet temp.	165 ℃
	Core outlet temp.	200 ℃

Steam generator	Type	Helical-coiled Once-through
	Steam temp.	198.3 ℃
	Steam pressure	1.5 MPa
	Feed water temp.	99.6 ℃
	Feed water flow rate	4.37 kg/s

3.1 Natural Circulation

RTF(REX-10 Test Facility) is designed to study the characteristics of natural circulation in REX-10. The experimental facility is composed of a primary loop and a secondary loop. Figure 2 shows the schematic diagram and picture of REX-10. The sizes of RTF are determined from REX-10 using Ishii' scaling law.

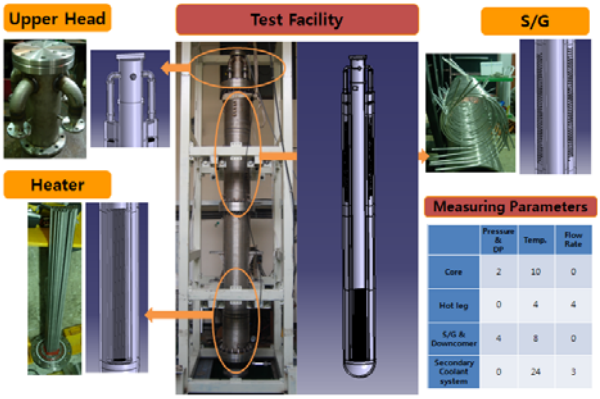

Fig. 2. RTF(REX-10 Test Facility)

The primary loop consists of electric heaters, hot legs, a heat exchanger and a pressurizer. First, electric heaters, which are 12 mm in diameter and 1 m in height, are located in a lower part of the facility. Electric heaters generate 200 kW maximum. Secondly, hot legs, which are between a riser and a heat exchanger, are designed to measure a primary flow rate. A flowmeter is installed in a vertical tube of the hot leg. Thirdly, a heat exchanger consists of 12 helical coils. Each helical tube is 3/8 inch in diameter and about 4 m in length.

Some cases of natural circulation experiments with various heater powers, pressures, secondary flowrates are performed. However, it is important to consider the natural circulation behavior of various pressures because the district heating reactor is to guarantee the safety in normal or emergency situations. Thus, the additional experiment will be performed and the numerical analysis will be also carried out to verify the experimental results.

3.2 Steam-gas Pressurizer

The structure of the steam-gas pressurizer is relatively simple, however, thermal-hydraulic phenomena such as evaporation and condensation in the steam-gas pressurizer are very complex. The condensation heat transfer coefficients in the presence of noncondensable gas at high pressure were obtained from the previous research. Based on these results, the experimental facility is designed to simulate the thermal hydraulic performance of the steam-gas pressurizer in REX-10 as shown in Fig. 3.

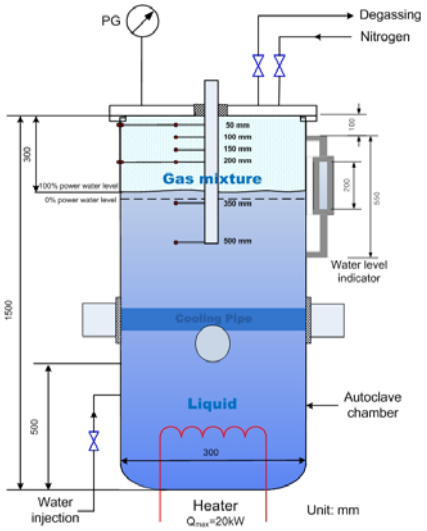

Fig. 3. Schematic Diagram of Steam-gas Pressurizer Test Facility

In near future, the performance test which is related to the power and feed water flow rate will be carried out. In addition, the transient case such as feedwater line break will be performed so that the experimental results will be used to estimate the thermal-hydraulic behavior of a steam-gas pressurizer in REX-10.

4. Conclusions

This paper introduced the design objectives and characteristics of regional energy reactor, REX-10. In near future, the fundamental design technologies such as natural circulation, steam-gas pressurizer are expected to establish by developing system design code and performing benchmarking experiments.

REFERENCES

[1] International Atomic Energy Agency, "Design approaches for heating reactors," IAEA-TECDOC-965, 1997
[2] International Atomic Energy Agency, "Nuclear heat applications: Design aspects and operating experience," IAEA-TECDOC-1056, 1998
[3] M. H. Chang, et al., "Basic design report of SMART," KAERI/TR-2142, Korea Atomic Energy research institute, 2002
[4] Doo Jeong Lee, et al., "A Study of Passive and Inherent Safety Design Concepts for Advanced Light Water Reactors," KAERI/CM-112/96, Korea Atomic Energy research institute, 1996
[5] Tae-Wan Kim, "Development of Steam-Gas Pressurizer Model based on Two-Region Nonequilibrium with Noncondensable gas," Ph.D. Thesis, Seoul National University, Seoul, 2005