Natural Circulation Cooling Capability in the AHR

Chae Heetaek and Park Cheol
Korea Atomic Energy Research Institute
150 Deokjin-dong, Yuseong-gu, Daejeon 305-353, KOREA
htchae@kaeri.re.kr

1. Introduction

An AHR (Advanced HANARO Reactor) based on the HANARO has been conceptually developed for the future needs of research reactors[1]. Generally, a natural convection cooling in nuclear installations is an ultimate heat removal mechanism as an inherent safety feature. This paper presents the preliminary thermal hydraulic characteristics and safety margins for a natural convection cooling in the AHR.

2. Reactor core and fuel of AHR

The AHR will be a light-water-cooled and heavy-water-reflected pool type research reactor with a 20 MW thermal power. The reactor will use a 19.75% enriched U_3Si_2 fuel of a finned rod type with the same shape as the HANARO fuel. The reactor core, surrounded by the inner wall of the reflector tank, consists of a total of 23 flow channels as shown in Fig.1. Two kinds of fuel assemblies are used. 16 out of 23 sites are assigned for 36-element hexagonal fuel assemblies, and 4 sites are for 18-element circular fuel assemblies[2]. The other 3 sites in the core can be used for the irradiation tests and RI production that require high fast and thermal neutron fluxes. The reactor core is immersed in a cylindrical water pool.

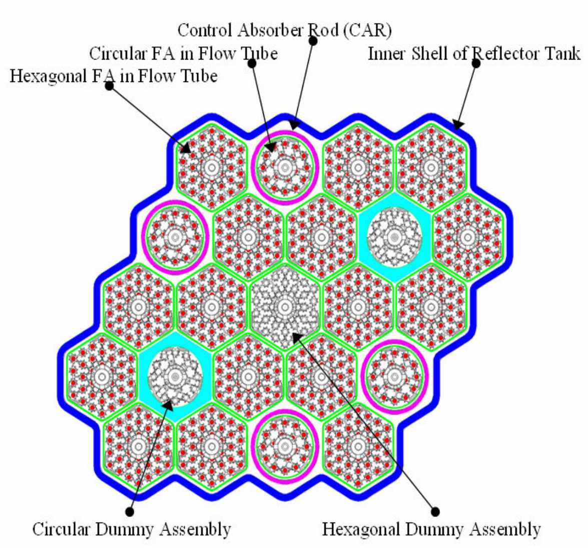

Fig. 1. Cross Sectional View of the AHR Core

3. Natural convection cooling characteristics

3.1 Natural circulation in the HANARO

The AHR is an upward flowing reactor with an open-chimney-in-pool arrangement. Reactor pool where the reactor is submerged is 4m in diameter and 12.2m in depth as shown in Fig. 2, and it can play the role of a sufficient and good heat sink when the primary cooling pump is not running. At a normal operation, the core heat is removed by the forced convective flow by two pumps in parallel and then dissipated to the secondary cooling system through two plate type heat exchangers. During a reactor shutdown, the core decay heat can be removed by the pool water recirculation via the flap valves and the natural circulation through the primary cooling system.

In order to investigate the cooling capability and the flow characteristics of the natural convection in the HANARO, the natural circulation tests were performed at various power levels. In the tests, the flow rate and temperature distributions at the primary cooling system were measured. The natural circulation flow rates were shown in Table 1 for the tests of 1.5 MW and 1.8 MW power levels. It was confirmed from the tests that the core heat could be removed by the natural circulation flow up to 6% of full power(1.8 MW) without any subcooled boiling[3].

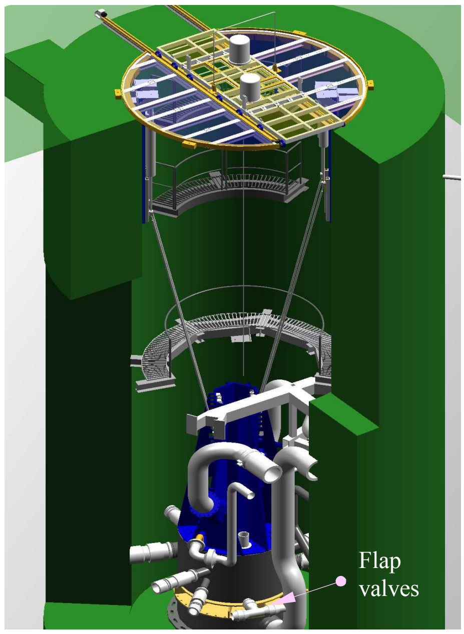

Fig. 2. In-pool reactor structures in the HANARO

Table 1. Thermal margins for natural circulation conditions

Natural circulation test		Fuel type	Design Parameter			
Test power (MW)	Core flow rate (kg/s)		ONB margin (℃)	MCHFR	Fuel temperature (℃)	
					$T_{surface}$	$T_{centerline}$
1.5	23.9	Hex.	25.7	17.8	100.8	209.9
		Cir.	21.8	18.1	103.9	216.9
1.8	27.3	Hex.	18.2	14.6	109.0	220.0
		Cir.	14.1	14.7	112.0	227.8
Design limit		Hex.	12.7	1.95	-	485
		Cir.	11.2	1.86	-	

3.2 Natural circulation in AHR

The core decay heat in the AHR will be designed to be removed only by the natural circulation of the pool water via flap valves which are located in the inlet pipe at the level of the reactor top as shown in Fig.3. The density difference between the core inside and outside pool water provides the driving force to maintain a natural circulation of the pool water. The developed flow rate of the natural circulation is determined from the momentum balance between the driving force and the system pressure losses.

The thermal hydraulic parameters under the natural circulation conditions of the AHR core were calculated by the MATRA_h code. The natural circulation flow rates from the 1.5 MW and 1.8MW test results were applied with the assumption of maintaining the same gravity driving head as that of the HANARO. The calculation results are summarized in Table 1. In the case of the 1.8 MW test, the ONB margin, the MCHR and the maximum fuel temperature were 14.1℃, 14.6 and 118.5℃ respectively, and those values satisfied the normal operation design limits. Therefore, it is supposed that the pool water natural circulation via flap valves in the AHR has enough cooling capability up to 1.8 MW (9% FP) without the ONB during a shutdown after a normal operation or upset conditions.

On the other hand, it is considered that the PCS loop natural circulation is not necessary from the HANARO operation experience even though the driving head is higher than that of the pool natural circulation. An introduction of a pool water cooling system is more effective for the decay heat removal. The design requirements for the opening conditions and location of the flap valve in the HANARO should be reviewed from the operation and maintenance points of views.

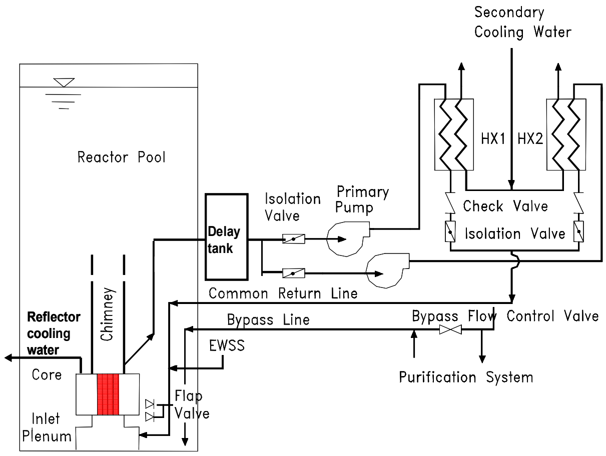

Figure 3. Schematic of the AHR Primary Cooling System (PCS)

3. Concluding Remarks

During a reactor shutdown and transients, the core decay heat is removed by a gravity driven natural circulation of pool water via flap valves in the AHR design. It was confirmed that the AHR core is capable of a cooling of up to 1.8 MW(9% FP) by the natural convection cooling without an ONB. It is necessary to reexamine the existing design requirements for the opening conditions and the locations of the flap valves by considering their operation and maintenance.

Acknowledgements

This work has been carried out under the nuclear research and development program by MOST.

REFERENCES

[1] C. Park, "Design Approach to the Development of an Advanced HANARO Research Reactor", Proc. of Int. Sym. HANARO 2005, Deajeon, Korea, 2005.
[2] C.G. Seo, et al., "Conceptual Core Design of a 20 MW Research Reactor Using the HANARO Fuel Assembly," Proc. of the KNS Spring Meeting, Kangchon, Korea, 2006.
[3] H.T. Chae, et al., "Natural Circulation Tests in HANARO," Proc. of the KNS Spring Meeting, Korea, 2001.