Tritium Behavior in The Primary Coolant of Bebble and Prism Type Gas Cooled Reactor

Dae-sik Yook and Kunjai Lee
KAIST, 373-1, Kusong-dong, Yusong-gu, Taejeon, 305-701, KOREA

In 2004, the Korea Atomic Energy Research Institute (KAERI) launched a nuclear hydrogen program in which it aimed to develop and demonstrate by 2019 a mass producing hydrogen. Preconceptual designs for both pebble and block-type HTGR cores are being performed. Because the main purpose of these reactors is to produce heat-induced hydrogen, none of the radioactive nuclide must containin any generated hydrogen. Furthermore, because tritium is the only radionuclide that can permeate from the primary circuit through the heat exchanger walls into the secondary circuits where it causes unwanted contamination, this nuclide is of particular interest in relation to high-temperature gas-cooled reactors. This study is based on the conceptual design parameters of a gas turbine-modular helium rector (GT-MHR) which is 600 MW_{th} and a PBMR which is 300MW_{th} because these types of reactors are reference reactors of the nuclear hydrogen program. Tritium is produced in the HTGR by ternary fission and by activation reactions among trace impurities of the reflector grahphite and control materials that contain Lithium and boron. In addition, a HTGR-specific tritium source is given by the helium coolant itself in the form of the neutron-absorbing nuclide ^{3}He, which has an abundance of extremely low isotopes. Compared with these sources, the contributions of other tritium-producing reactions with nuclides such as ^{9}Be or ^{12}C are negligible. The tritium production rate is easily obtained by using the simple differential equation and the result is shown in Table 1.

Table 1. Comparison of the tritium production rate according to the reactor type(Ci/yr)

Reactor type	Thermal Power (MW_{th})	Units	Tritium Source				
			Ternary fission	^{3}He	^{6}Li	^{10}B	Total
Pebble	300	Ci/yr	1254	77.8	277.2	12.9	1621.9
		%	77.3	4.8	17.1	0.8	100
Block	600	Ci/yr	2508	45.5	735.1	1355	4643.6
		%	54.0	1.0	15.8	29.2	100

The tritium diffusion from the fuel to the primary coolant via SiC layer is evaluated by using the Tam's model. To evaluate the diffusion of tritium in the solid of the graphite as the relector, the second Fick's law and the Arrhenius equation are used in this study with spherical and cylindrical coordinates. For the pebble-type reactor, which has a spherical coordinate, the solution was obtained as follows:

$$F(t) = 1 - \sum_{n=1}^{\infty} \frac{6}{\pi^2 n^2} \exp(-Dn^2\pi^2 t / a^2) \qquad (1)$$

a is the thickness of the graphite, and D (cm^2/sec) is the diffusion coefficient. For the central reflector, which has cylindrical coordinates, this solution was obtained as follows:

$$F(t) = 1 - \sum_{n=1}^{\infty} \frac{4}{a^2 \alpha_n^2} \exp(-D\alpha_n^2 t) \quad (2)$$

$$J_0(a\alpha_n) = 0 \quad (3)$$

where the a_n values are roots of Eq. (3) and $J_0(x)$ is the Bessel function of the first kind of zero order. The roots of Eq. (3) are tabulated in the tables of the Bessel functions. The fractional release from each source to the helium coolant was summarized in table 2 on the assumption that the maximum temperature is 1079℃ for the pebble type reactor and 1218℃or the prism type reactor. And figure 1 and 2 shows the tritium activities in the primary coolant of Pebble and Prism type gas cooled reactor with the time lapsed. In case of the Pebble type reactor, even though ternary fission is the largest source and the fuel temperature is very high, the release of tritium from the fuel kernel to the helium coolant is difficult because of the SiC layer and the relatively thick of graphite. In case of the Prism type reactor, fuel compacts is just set in the fuel assembly so the tritium permeated through the SiC layer will be released to the He coolant. The total amount of tritium in the helium coolant with respect to diffusion to be 102.3 Ci/yr (approximately 6.3percent of total production rate) for the pebble-type reactor and 1279.6 Ci/yr (approximately 29.5percent of total production rate) for the block-type reactor. And the These results suggest that the specific activities of tritium in the coolant will become a few μCi/g (in case of pebble) ~ hundreds of μCi/g (in case of Prism) levels even if changes in the total helium inventory depend on the variation of the core's design.

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Table 4. Tritium release from each source to the He coolant (unit : %)

Reactor type	Ternary fission	^3He	^6Li	^{10}B
Pebble	0.8	100	5.0	-
block	46.2	100	7.3	14.3

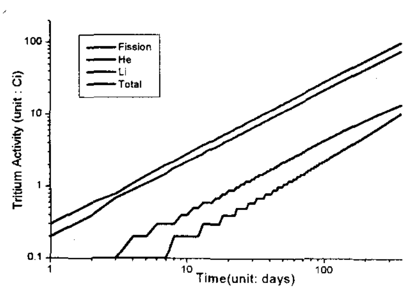

Fig 1. Tritium activity diffused from each source term in the primary coolant of Pebble type reactor

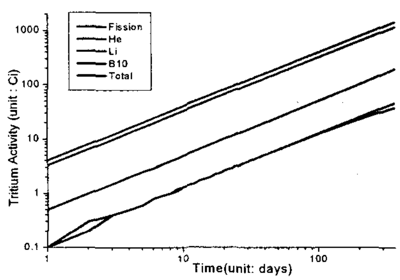

Fig 2. Tritium activity diffused from each source term in the primary coolant of Prism type reactor