Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Comparison study on the deposition of sodium impurities in cold traps

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1. Introduction

In the operation of a sodium-cooled fast reactor (SFR), it is essential to control the impurities of liquid sodium during or after operation. The impurities may have harmful effects on the operation because the pollutants, such as in form of hydrides, oxides, metallic compound, metallic or carbon particles, can lead to a corrosion of the structural material, block the passages, or deteriorate the efficiency of the coolant [1]. A cold trap, as a typical purification unit for sodium coolant, should therefore be optimally designed and operated after or during the operation of the SFR. In this study, a few reported cold traps were compared and investigated, especially from the aspect of the deposition mechanism on the sodium impurities.

2. Description of cold trap

Sodium cold traps have been used since the 1950s. The primary objective of their use is to remove the oxide impurities from the sodium. Fig. 1 shows a conventional design for a cold trap. Polluted sodium enters the top of the cold trap, and then flows down into it, where packing material such as a stainless steel wire mesh exists. The trap coolant air, on the other hand, is forced to flow from the bottom of the vessel upward. The temperature of the sodium is lowered during this process, and impurities are trapped on the surface of the packing material owing to the solubility changes according to the lowered temperature. The purified sodium moves back upward and out of the cold trap.

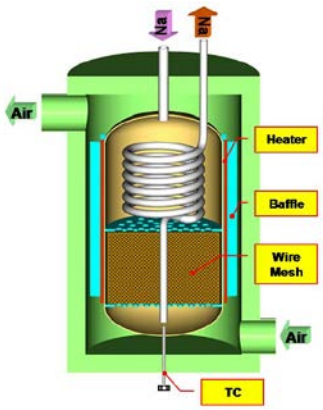

Fig. 1. Conventional design for a cold trap

3. Deposition mechanisms of sodium impurities

Although it has been a long time since cold traps have been used for sodium purification, there are a few studies on the deposition mechanism of impurities and on the related mass transfer. Most researches have focused on the operation or trapping efficiency of the traps [2, 3]. Regarding the mechanisms and location of sodium impurity deposition, a crystallization mechanism has been proposed, and the difference in deposition location between sodium oxide and hydride has been investigated [4, 5].

3.1. Crystallization mechanism of impurity deposition

When sodium is cooled in a cold trap, sodium hydride and oxide (Na_2O, NaH) are formed through a crystallization mechanism, where both nucleation and growth should be considered. In the case of sodium oxide, homogeneous nucleation is difficult to occur because the nucleation and growth kinetics are relatively slow. It was reported that the diffusion of oxygen atoms in the diffusion boundary layer appears to be a limiting step of the crystal growth. In the case of sodium hydride, however, homogeneous nucleation is easier to occur because the nucleation and growth kinetics are faster [4]. The differences in the activation energies for both cases support this, as shown in Table 1 [5].

Table 1. Activation energies (E) and order of crystallization process (n) of sodium oxide and sodium hydride [5]

Process	Nucleation		Growth	
Impurity	Na_2O	NaH	Na_2O	NaH
E(kJ/mol)	-60	-450	-45	-43.6
n	5	10	1	2

3.2. Impurity deposition both on packing material and side wall

It was experimentally concluded that in a cold trap with a conventional design, sodium hydride is crystallized mainly on the cold wall inside the trap, whereas sodium oxide is crystallized on the wire mesh packing [5]. Both hydride and oxide can be deposited on the packing material. The difference in deposition locations also supports that the mechanism and kinetics for hydride and oxide are different from each other.

4. Conclusions

When determining the structure or operation method of a cold trap, or calculating its capability such as the efficiency and capacity, it is very important to understand the impurity deposition mechanism of a cold trap. Calculation of the required quantity of packing material such as a wire mesh therefore largely depends on whether we neglected or considered the impurity mechanism, i.e., crystal nucleation and growth, for each impurity.

Acknowledgment

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (No. 2012M2A8A2025635)

REFERENCES

[1] K.R. Kim *et al.*, "Theoretical analysis on the sodium purification for cold trap design and performance measurement", Journal of Industrial and Engineering Chemistry, Vol.4, 1998.

[2] F. Zhao and Xioarong Ren, "Optimal performance analysis of a sodium cold trap", Nuclear Engineering and Design, Vol.239, 2009.

[3] M.G. Hemanath *et al.*, "Theoretical experimental performance analysis for cold trap design", Nuclear Engineering and Design, Vol.240, 2010.

[4] J.L. Courouau *et al.*, "The various sodium purification techniques", IWGRF-98IWGFR-98, Aix-en-Provence, France, 1998.

[5] N. Khatcheressian et al., "Development of a mass transfer model for sodium purification system in a fast breeder reactor", FR13, Paris, France, 2013.