Wastage Behavior of Modified 9Cr-1Mo Steel Tube Material by Sodium-Water Reaction (II)

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1. Introduction

The Korea Advanced LIquid MEtal Reactor (KALIMER) steam generator is a helical coil, vertically oriented, shell-and-tube type heat exchanger with fixed tube-sheet. The conceptual design and outline drawing of the steam generator are shown in Figure 1. Flow is counter-current, with sodium on the shell side and water/steam on the tube side. Sodium flow enters the steam generator through the upper inlet nozzles and then flows down through the tube bundle. Feedwater enters the steam generator through the feedwater nozzles at the bottom of steam generator.[1] Therefore, if there is a hole or a crack in a heat transfer tube, a leakage of water/steam into the sodium may occur, resulting in a sodium-water reaction. When such a leak occurs, so-called "wastage" is the result which may cause damage to or a failure of the adjacent tubes. [2-3] If a steam generator is operated for some time in this condition, it is possible that it might create an intermediate leak state which would then give rise to the problems of a multi-target wastage in a very short time. [5-6] Therefore, it is very important to predict these phenomena quantitatively from the view of designing a steam generator and its leak detection systems. The objective of this study is a basic investigating of the sodium-water reaction phenomena by small water/steam leaks. For this, wastage tests for modified 9Cr-1Mo steel tube material were conducted, and an empirical formula of the wastage rate for this material was obtained from the results.

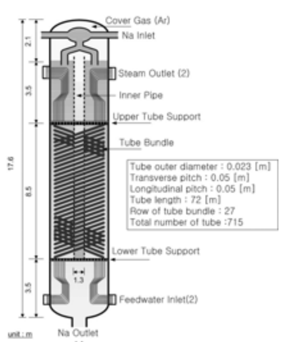

Figure 1 KALIMER-600 Steam Generator

2. Experimental

2.1 Experimental apparatus

The tube material wastage tests at KAERI were conducted in a small leak sodium-water reaction test facility-2. A schematic diagram is shown in Figure 2. It consists of a reaction vessel, sodium and steam supply system, and a sodium dump tank. The reaction vessel is a 13.8-in.-diameter by 25.6-in.-long stainless steel vessel.

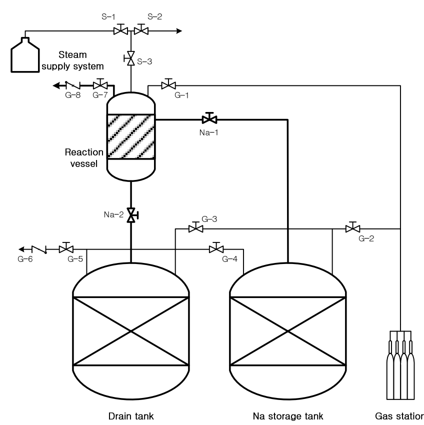

Figure 2 Experimental apparatus

2.3 Experimental procedure and conditions

Circular type defects were used in these tests whose diameter ranged from 200~300 micrometers. The targets of an actual tube shape and size were also used. Figure 3 shows the steam injection nozzle and target assembly. These assemblies were exposed to small leaks of steam in 400 and 450℃ stagnant sodium. Steam was injected to the target from a steam supply system through this assembly at a 150kg/cm^2 pressure and 350℃ temperature. During the tests, any hydrogen with entrained sodium was vented from the reaction vessels to the atmosphere through a vapor trap.

Figure 3 Nozzle and target assembly

3. Results and Discussion

Single-target wastage tests were conducted for modified 9Cr-1Mo steel in a small leak sodium-water reaction test facility-2. The wastage data obtained in the stagnant sodium systems are shown in Figure 4. It showed that the tube spacing and sodium temperature had a significant effect on the tube material wastage rate. And it showed that the wastage rate increased as the leak rate increased.

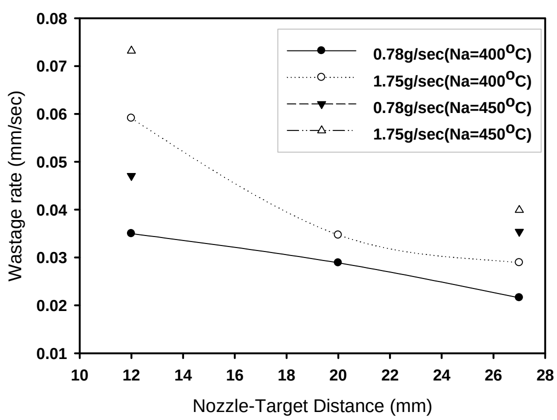

Figure 4 Relation between wastage rate and leak nozzle to target distance

Also an empirical formula of the wastage rate for the modified 9Cr-1Mo steel was obtained as equation (1) from the results.

$$W_R = \left(\frac{T_{Na}}{400}\right)^{2.5}\left[0.001869\left(\frac{Q_{Steam}}{1.75}\right)^{1.1}(34 - L_{N-T}) + 0.018\right] \quad (1)$$

Figure 5 shows the wastage rate of the modified 9Cr-1Mo steel calculated from equation (1) corresponding to the leak nozzle to target distance with the sodium temperature of 400 and 450℃. As shown in Figure 5, the numerical result (blue, short dash line) for the wastage rate agrees well with the experimental results. Even though some data have relatively large deviations from the numerical prediction, most of them are distributed within 10% of the mean values.

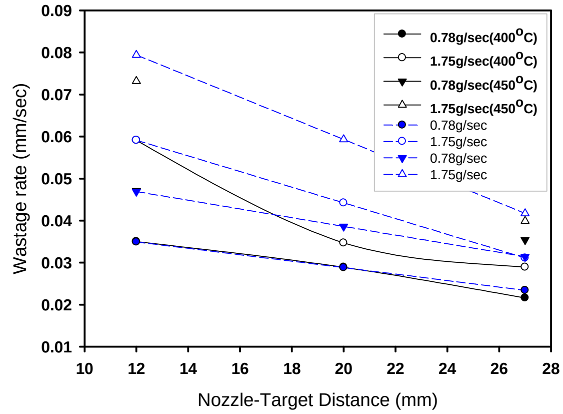

Figure 5 Comparison of the wastage rate

3. Conclusions

A series of tests were conducted to clarify the wastage behavior of modified 9Cr-1Mo steel as a steam generator tube material for KALIMER-600. It confirmed that the sodium temperature and tube spacing had a significant effect on the tube material wastage rate. And it showed that the wastage rate increased as the leak rate increased. Also an empirical formula of the wastage rate was obtained for the modified 9Cr-1Mo steel from the results. The data obtained from this study will be used to prepare the design criteria and to verify the safety analysis code for a demonstration plant steam generator from the point of view of sodium-water reactions.

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NOMENCLATURE

W_R = Wastage rate (mm/sec)
Q_{Steam} = Steam mass flow rate (g/sec)
L_{N-T} = Nozzle to target distance (mm)

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