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

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1. Introduction

The development of a sodium-heated steam generator with safety and reliability is an essential requirement from the viewpoint of the economic efficiency of a sodium-cooled fast reactor. In most cases, these steam generators, which are in the process of development or operating, are of a shell-in tube type, with a high pressure water/steam inside the tubes and low pressure sodium on the shell-side, with a single wall tube as a barrier between these fluids. 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. [1-4] When such a leak occurs, so-called "wastage" is the result which may cause damage to or a failure of the adjacent tubes. 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 were conducted.

2. Experimental

2.1 Definition of a small leak

A small leak is one in which a coherent reaction jet of a size capable of impinging on one or two heat transfer tubes is formed, causing damage to them mainly by a wastage. Small leaks are generally in the range of 0.1 to 50g/sec (0.05 to 10g/sec in Japan). [7]

2.2 Experimental apparatus

The tube materials wastage tests at KAERI were conducted in a small leak sodium-water reaction test facility-2. A schematic diagram is shown in Figure 1. It mainly consists of a reaction vessel, sodium and steam supply system, and a drain system. The reaction vessel is a 13.8-in.-diameter by 25.6-in.-long stainless steel vessel; the sodium feed line is a 1/2-in. stainless steel tube. During the tests, any hydrogen with entrained sodium was vented from the reaction vessels to the atmosphere through a vapor trap.

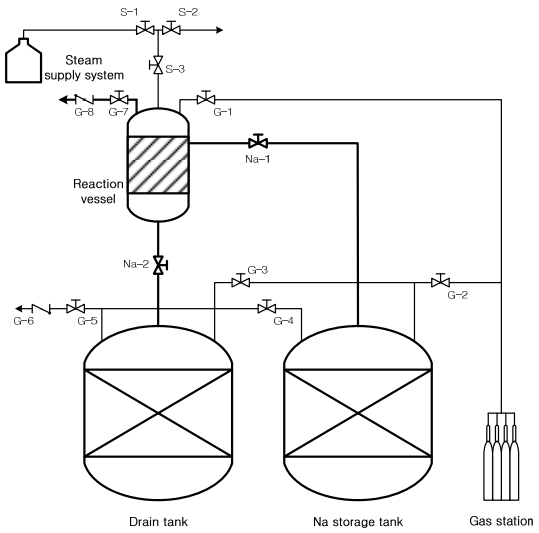

Figure 1 Experimental apparatus

2.3 Experimental procedure and conditions

Circular type defects were used in these tests whose diameter ranged from 200~400 micrometers. The targets of an actual tube shape and size were also used. Figure 2 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. Modified 9Cr-1Mo steel was chosen for the test specimen material because this material was specified for the heat transfer tube for a KALIMER-600 steam generator. Based on previous works, the sodium level above the steam

injection point was established as variable. This is because it has been proven that the effect of the sodium level on the wastage is negligible so long as the target tube is submerged in the sodium.

Figure 2 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. Tests were made to determine the effect on the modified 9Cr-1Mo steel wastage rate from the water leak rate, a leak nozzle to target distance, and sodium temperature. The wastage data obtained in the stagnant sodium systems are shown in Figure 3. It showed that the tube spacing and sodium temperature had a significant effect on the tube material wastage rate. Also it showed that the wastage rate increased as the leak rate increased.

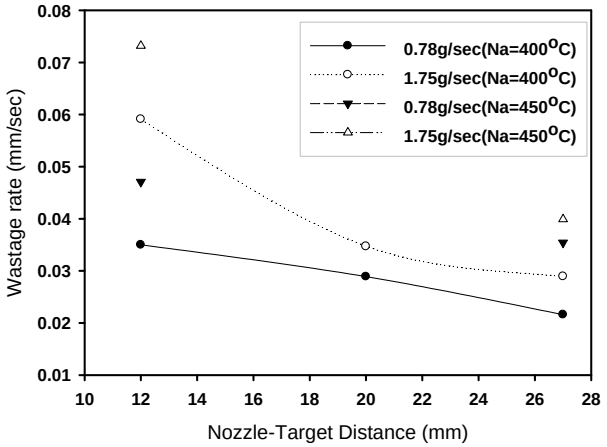

Figure 3 Relation between wastage rate and leak nozzle to target distance

Figure 4 is the target shapes which were damaged from this experiment.

Meanwhile, a series of Na-CO_2 reaction tests were carried out in order to compare wastage behavior from the sodium-water reaction.

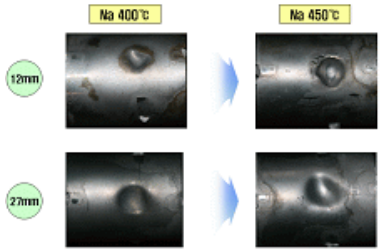

Figure 4 Wastage patterns of target tubes

Test results showed that the damage from the target surface did not appear. But with different sodium-water reaction test results, the reaction products were stuck plentifully on the nozzle and target assembly. Figure 5 shows a nozzle-target assembly shape after the respective reactions.

Figure 5 Assembly image of after a Na-H_2O (left) and Na-CO_2 (right) reaction

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. The data obtained from this study will be used to prepare the design criteria and design analysis procedures for these steam generators from the point of view of sodium-water reactions.

ACKNOWLEDGEMENT

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