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Wastage of Steam Generator Tubes by Sodium-Water Reaction

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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. [4-5] Therefore, it is very important to predict these phenomena quantitatively from the view of designing a steam generator and its leak detection systems. For this, multi-target wastage tests for modified 9Cr-1Mo steel tube bundle by intermediate leaks are being prepared.

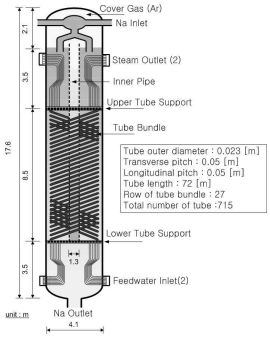

Figure 1 KALIMER-600 Steam Generator

2. The Sodium-Water Reactions

When physical contact is made between sodium and water, with an excess of water, a spontaneous violent reaction occurs, producing sodium hydroxide and hydrogen.

$$Na + H_2O \rightarrow NaOH + 1/2H_2$$

However, under small leak conditions prevailing in steam generators, the ratio of sodium to water is of the order of 10^6 and additional reactions take place:

$$2Na + H_2O \rightarrow NaOH + NaH$$

$$4Na + H_2O \rightarrow 2NaH + Na_2O$$

$$2Na + H_2O \rightarrow Na_2O + H_2$$

The relative fraction of water participating in each of these reactions is dependent on the quantity of water introduced by the leak, the sodium temperature, and the sodium pressure. However, no numerical values were reported in the literature as to the quantity of water going into any of the four above reactions. [6]

3. Experimental

3.1 Experimental apparatus

The tube bundle wastage tests at KAERI are being prepared in a sodium-water reaction test facility-2. A schematic diagram of this facility is shown in Figure 2.

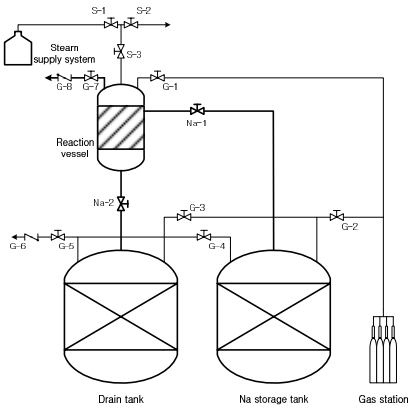

Figure 2 Experimental apparatus

It consists of a reaction vessel, a sodium storage tank, and a sodium dump tank and steam supply system. The reaction vessel is a 50-cm-diameter by 100-cm-long stainless steel vessel. And steam is supply into the reaction vessel at a 160kg/cm^2 by gas booster as shown in Figure 3.

Models of tube bundle which will be used in this experiment were made with modified 9Cr-1Mo steel pipe and those have 5×5 layer respectively. Figure 4 is show the reaction vessel installed with a model of tube bundle.

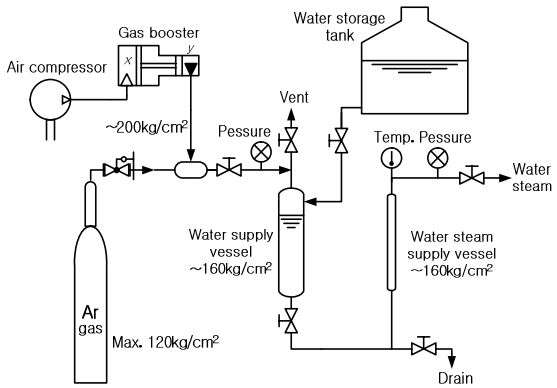

Figure 3 Steam supply system

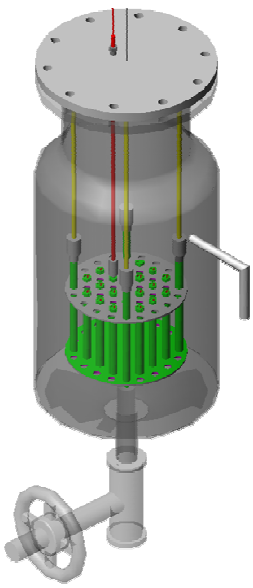

Figure 4 Reaction vessel with a model of tube bundle

3.2 Experimental conditions

Circular type defects will be used in these tests whose diameter ranged from 0.8~1.0millimeters. The targets of an actual tube shape and size will be also used. Figure 5 shows a model of tube bundle. Model of tube bundle is exposed to intermediate leaks of steam in 450℃ stagnant sodium. Steam is injected to the target from a steam supply system through this model at a 160kg/cm^2 pressure and 350℃ temperature. During the tests, any hydrogen with entrained sodium is vented from the reaction vessels to the atmosphere through a vapor trap.

Post-test examination of target tubes will be performed with an ATOS 3D Digitizer which delivers three-dimensional measurement data for industrial components such as sheet metal parts, tools and dies, turbine blades, prototype, injection modeled and casted parts.

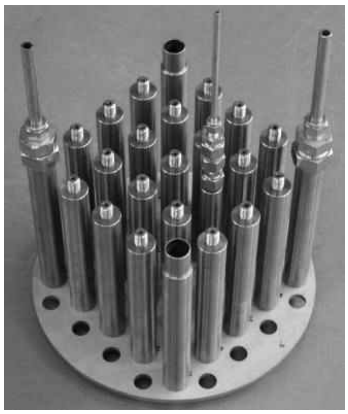

Figure 5 Model of tube bundle

4. Conclusions

A series of tests are being prepared to clarify the multi-target 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 to verify the safety analysis code for a demonstration plant steam generator from the point of view of sodium-water reactions.

ACKNOWLEDGEMENT

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