Analysis of the Sodium-Water Reaction Phenomena by Small Water/Steam Leaks

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1. Introduction

One of the important problems to be solved in the design and construction of a sodium cooled fast reactor is to confirm the safety and reliability of the steam generator which transfers the heat from the sodium to the water. Sodium-water reaction events may occur when material faults such as a pinhole or cracks occur in the heat transfer tube wall.[1, 2] When such a leak occurs, evaporating water or superheated steam enters through a small leak into the sodium. The surface of this steam jet reacts with the surrounding sodium. Due to turbulence, sodium and particles of the reaction products are drawn at a high velocity into the jet. Impingement of these particles on an adjacent tube is followed by a combined process of a corrosion and erosion which results in a local weakening of the affected tube. If there is no reliable detection available in time, wastage will ultimately result in an additional leak in the adjacent tube. Therefore, it is very significant to predict these phenomena quantitatively from the view of designing a steam generator and its leak detection systems.[3-6] The objective of this study is a basic investigating of the sodium-water reaction phenomena by small water/steam leaks.

2. Experimental

2.1 Experimental apparatus

As shown in Figure 1, a small leak sodium-water reaction test facility was designed and constructed. It mainly consists of two test section (reaction vessels), a sodium circulation circuit, sodium and steam supply system, a sodium purification system, and a drain system. The entire loop including the reaction vessel and piping lines are filled with sodium and the high pressure steam is injected into the reaction vessels. Tests was conducted in two test rigs, one in which an investigation of the wastage phenomena of the heat transfer tube and one in which measurement for the frequency band of the reaction sound were implemented. In addition, some basic studies were conducted to help determine the mechanism producing tube wastage during a sodium-water reaction. During the tests, any hydrogen with entrained sodium was vented from the reaction vessels to the atmosphere through a vapor trap. For the leak detection, an acoustic detector (in sodium) was used.

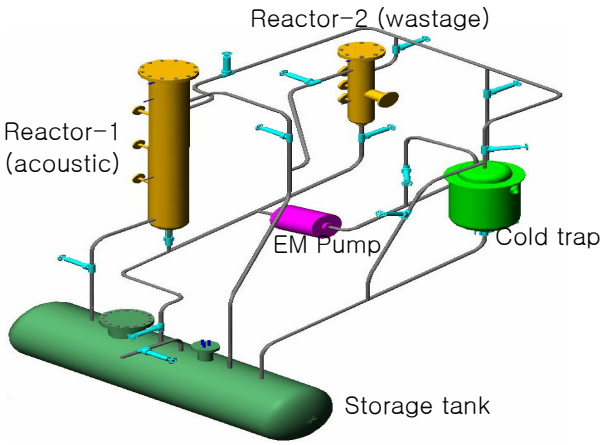

Figure 1. Experimental apparatus

2.2 Experimental procedure and conditions

Steam was injected into the sodium from a steam reservoir through an injection nozzle. The steam reservoir was designed to produce steam of up to a 214kgf/cm^2 pressure and a 370℃ temperature. The injection nozzle had openings from 0.1 to 0.3mm in diameter and it was sealed before the initial steam/water injection. These nozzle specimens were exposed to small leaks of steam/water in 300℃ stagnant sodium. The sodium velocity was kept stagnant throughout all of the wastage tests. After closing the injection valve, argon gas was bubbled into the sodium through the injection nozzle in order to prevent a nozzle blockage. The injection duration was determined from the opening and closing signals of the injection valve. Based on the previous works, the sodium level above the steam injection point was

established as variably. Because it was proven that the effect of the sodium level on the wastage is negligible so long as the target tube is submerged in the sodium. 2.25Cr-1Mo steel was chosen for the test specimen material, because this material was specified for the heat transfer tubes in KALIMER.

2.3 Experiments

2.3.1 Analysis of the reaction zone

When discussing the effect of small water/steam leaks in sodium heated steam generators the expression "flame type reaction zone" (shown in Fig. 2) is always used.

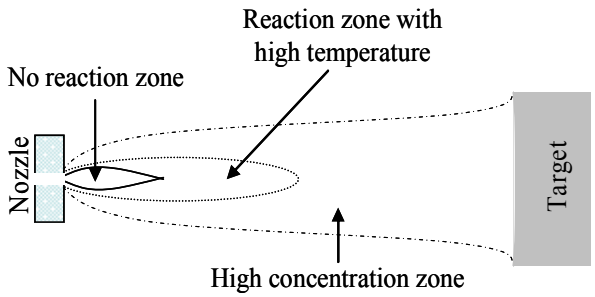

Figure 2. Typical shape of the flame type reaction zone

In order to predict the influence range of such a reaction zone, a series of tests were conducted for determining the size and temperature of the reaction flame. A measuring tool used for the influence range of the reaction flame is shown in Fig. 3.

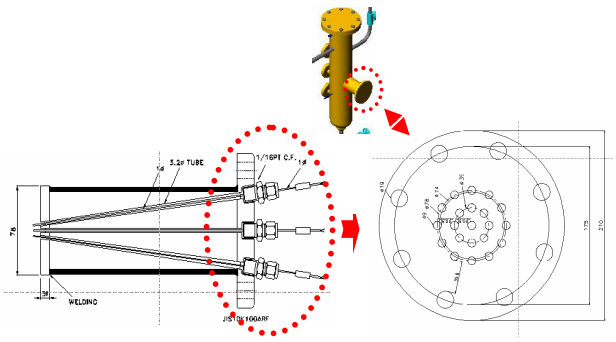

Figure 3. The reaction temperature measuring assembly

2.3.2 Investigation of the self-wastage phenomena

Another type of wastage phenomenon caused by the leakage of water/steam into the sodium is the one termed a self-wastage, which is not a wastage on the wall of adjacent tubes, but that which occurs on the inside of a leaking hole itself. This state can possibly damage the leak hole itself, which may eventually enlarge it into a much larger opening. Therefore, before it becomes a larger leak and damages the surrounding tubes, it is necessary to know the time to a sudden enlargement for the heat transfer tube material. Enlargement time of the leak hole was measured at regular intervals.

3. Conclusions

A small leak sodium-water reaction test facility was designed and constructed. And a series of tests is being carried out to investigate the wastage mechanisms and the sodium-water reaction phenomena associated with needle-like jets of high-pressure water/steam into the sodium side. The data obtained from this study will be used to prepare the design criteria and design analysis procedures for steam generators from the point of view of sodium-water reactions.

ACKNOWLEDGEMENT

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