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Study on the Sodium-Water Reaction Phenomena in a LMR Steam Generator for a Small Water/Steam Leak

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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, there results an important phenomenon, so called "wastage" which may cause damage to or a failure of the adjacent tubes. In general, wastage is defined as the decreasing thickness of the materials caused by the erosion or corrosion effects of the sodium-water reactions. Therefore, it is very significant to predict the wastage phenomena quantitatively from the view of designing a steam generator and its leak detection systems.[3-5] The goal of this study is to establish a means of estimating the extent of a tube wastage resulting from a small leak of water/steam into the sodium in a sodium heated steam generator, and to determine the dominant parameters affecting a tube wastage.

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 wastage. Small leaks are generally in the range of 0.1 to 50g/s (0.05 to 10g/s in Japan).

2.2 Experimental apparatus

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

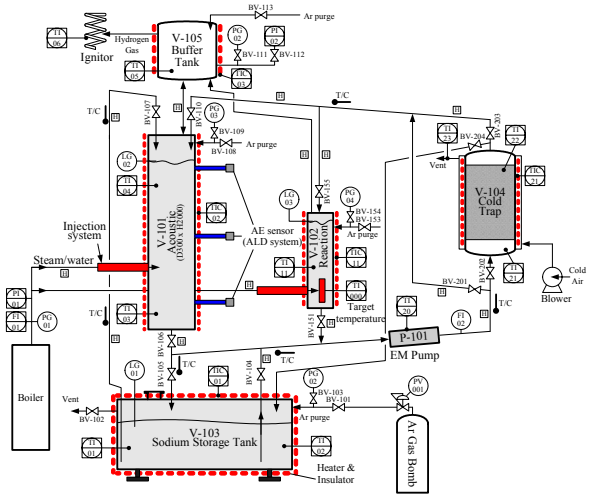

Figure 1. P&ID of an experimental apparatus

2.3 Experimental procedure and conditions

Steam is injected into sodium from a steam reservoir through the 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 has openings from 0.1 to 0.3mm in diameter and it is sealed

before the initial steam/water injection. These nozzle specimens are exposed to small leaks of steam/water in 340℃ stagnant sodium. The sodium velocity is kept stagnant throughout all of the wastage tests. After closing the injection valve, argon gas will be bubbled into the sodium through the injection nozzle in order to prevent a nozzle blockage. The injection duration will be determined from the opening and closing signals of the injection valve. Based on the previous works, the sodium level above the steam injection point is 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. The 2.25Cr-1Mo and 9Cr-1Mo steel were chosen for the test specimen material, because this material was specified for the heat transfer tubes in KALIMER. Nozzle-to-target distance (L) to nozzle diameter (D) ratios (L/D) from 15 to 100 was selected for the tests by considering the length of the reaction flame. Figure 2 shows the calculated results on the maximum length of the reaction flame according to the saturated steam temperature and the diameter of leak hole.

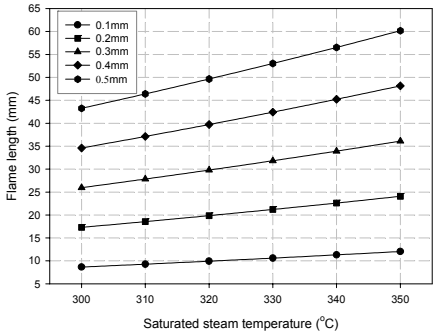

Figure 2. The relationship of the flame length with the saturated steam temperature and the diameter of leak hole

And figure 3 shows the calculated results on the steam leak rate according to the size of leak hole at a steam temperature of 300℃.

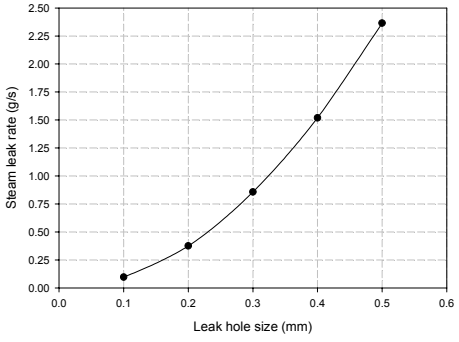

Figure 3. Steam leak rate according to the size of the leak hole at a steam temperature of 300℃

2.4 Work scope

The wok scope is to include basic investigations of the wastage mechanisms and of the sodium-water reaction phenomena associated with needle-like jets of a high pressure water into a sodium side.

3. Conclusions

A small leak sodium-water reaction test facility was designed and is being constructed. This study will be applicable to the development of the sodium-heated steam generators and to the technology of the sodium-water reactions in the KALIMER project. 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 the sodium-water reactions.

ACKNOWLEDGEMENT

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