Detection Test for Leakage of CO_2 into Sodium Loop

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1. Introduction

A sodium-and-carbon dioxide (Na-CO_2) heat exchanger is one of the key components for the supercritical CO_2 Brayton cycle power conversion system of sodium-cooled fast reactors (SFRs) [1]. A printed circuit heat exchanger (PCHE) is considered for the Na-CO_2 heat exchanger, which is known to have potential for reducing the volume occupied by the exchangers compared to traditional shell-and-tube heat exchangers [2, 3]. Among various issues about the Na-CO_2 exchanger, detection of CO_2 leaking into sodium in the heat exchanger is most important thing for its safe operation. It is known that reaction products from sodium and CO_2 such as sodium carbonate (Na_2CO_3) and amorphous carbon are hardly soluble in sodium, which cause plug sodium channels [5, 6]. Detection technique for Na_2CO_3 in sodium loop has not been developed yet. Therefore, detection of CO_2 and CO from reaction of sodium and CO_2 are proper to detect CO_2 leakage into sodium loop.
Proposed mechanism for reaction of sodium and CO_2 is as follows [7]:

$2Na(l) + CO_2(g) \rightarrow Na_2O(s, l) + CO(g)$
$Na_2O(l) + CO_2(g) \rightarrow Na_2CO_3(s)$
$2Na(l) + CO(g) \rightarrow Na_2O(s) + C(s)$
$4Na(l) + 3CO_2(g) \rightarrow 2Na_2CO_3(s) + C(s)$
$4Na(l) + CO_2(g) \rightarrow 2Na_2O(s) + C(s)$
$2Na(l) + 2CO_2(g) \rightarrow Na_2CO_3(s) + CO(g)$
$C(s) + CO_2(g) \rightarrow 2CO(g)$

In addition, Radiolysis and corrosion will undoubtedly generate CO from the reaction of sodium and CO_2 [4]. Due to the dangerous nature of CO_2 and CO to human, compartment monitoring is required [1].

This report is about the facility for the detection test for leakage of CO_2 into sodium loop.

2. Methods and Results

2.1 Experimental Facility

The facility for the detection test of CO_2 into sodium loop is shown in Figure 1. The facility consists of mechanical components (sodium melting tank, separator, filter, Na-CO_2 mixing section, sodium dump drum, sodium catch tray, CO_2 preheater, and a gas cooler) and electrical control/measurement components (sodium electromagnetic pump (EMP), sodium electromagnetic flow meter (EMF), CO_2 mass flow controller (MFC), Ar MFC, pressure transducer (PT), electrical heating coil, and electrical heating furnace). All components are connected with each other by welded pipes for sodium or by fitted tubes for gases, which are fixed with brackets at the frame and wrapped with electrical heating coils and insulators. The EMP, EMF, MFC, electrical heating coil, and electrical heating furnace are electrically controlled with control systems. The compositions of CO_2 and CO in cover gas of separator are measured using nondispersive infrared sensor analyzer (NDIR) (INFRALYT 80, SAXON JUNKALOR).

Fig. 1. Facility for the detection test for CO_2 leak into sodium loop.

2.2 Experimental Procedure

CO_2 detection experiments are going to be carried out in the facility. Electrical heating jackets and furnaces were used to heat the facility. The operation procedure for the CO_2 detection is as follows. The Na-CO_2 mixing section was placed in the facility, whose inner diameter (ID) and length were 22 mm and 700 mm, respectively, and whose one side had a hole of 1/16 in ID to be injected with CO_2 (Figure 2). The facility was heated at 200 °C, and purged with Ar for 60 min to eliminate any effects of O_2. The melting tank was charged with sodium ingot (10 kg) pressurized by Ar at 0.1–0.5 bar. The whole facility was heated up to the experimental temperature (200–500 °C). Sodium was circulated by the EMP in the facility. The flow rate of the sodium and temperatures reached a steady state. CO_2 heated at the experiment temperature in the heating storage was injected into the mixing section. When the cover gas pressure in the separator increased or the composition of CO in the separator increased, the injection of CO_2 was stopped and the experiment was

finished. The sodium used was drained into the dump drum, and the facility was flushed with Ar for ~30 min.

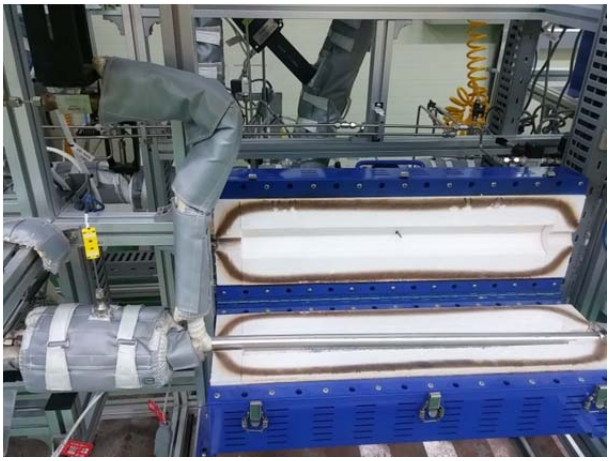

Fig. 2. Na-CO_2 mixing section equipped in the facility.

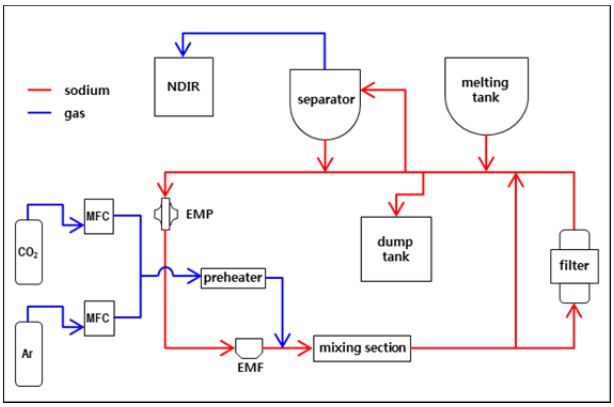

Fig. 3. Schematic diagram for the detection test of CO_2 leak into sodium loop (red: sodium; blue: CO_2).

3. Conclusions

The facility for the detection test for leakage of CO_2 into sodium loop was introduced. The test will be carried out. Our experimental results are going to be expected to be used for approach methods to detect CO_2 leaking into sodium in heat exchangers.

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