Hydrogen Behavior at a Subcomparment in The Containment Building

U.J. Lee and G.C. Park

Seoul National University

ABSTRACT

For hydrogen management in severe accidents with degraded nuclear core of PWR's, several experiments have been performed in the SNU hydrogen mixing facility. The objectives are understanding the extent of hydrogen mixing and analyzing the effects of factors which dominate uniform or non-uniform mixing at compartments in the containment building. The facility represents on a 1/11th linearly scaled model of the YGN unit 3&4, hydrogen was simulated by helium. Because there are the gaps between safety injection tank and compartment layers in the containment, the test facility was constructed in three dimentinal mode for analyzing of mixture behavior through the gaps. From the experimental results we could conclude that overall hydrogen concentration distributed uniformly in the free volume of the test compartment, but fluctuated in the gaps. This paper is focused on experimental result from several experiments.

1. INTRODUCTION

1.1. BACKGROUND

Up to now many experiments for hydrogen management have been conducted around the world. Most of them were experiments for macroscopic phenomenon analysis in the containment building. The experiments, that is, were conducted for the purpose of the analysis of hydrogen concentration distribution by global flow loops of hydrogen in the containment building. The key matter of concern for the experiments was such as containment-wide natural circulation, stratification in some compartment, effective mixing by spray system or diffusion fans, etc. But, the experiments analyzing effect of obstacles and geometry of flow path in a compartment were so few.

If obstacles exist in the way of hydrogen behavior in a compartment which hydrogen diffuses through, they would cause concentration gradient of hydrogen in the compartment. A local concentration peaking as a result of non-uniform concentration distribution would lead to hydrogen deflagration and moreover bring about a flame flow path. Consecutive hydrogen deflagration may cause damage to the safety system which will operate in accidents.

Therefore hydrogen behavior should be considered profoundly of a compartment in which concentration peaking by local non-uniform distribution of hydrogen would occur

1.2. SNU TEST CONSIDERATION FOR HYDROGEN BEHAVIOR

YGN unit 3&4 in Korea is a prototype of Korean type reactor. There are two gaps between safety injection tank and two layers in which safety injection tank in the containment building of YGN unit 3&4 is located. The layers, that is, are compartment layers at 154ft and 169ft in elevation. The gaps are ring-shaped and 27.8cm in width.

In the accidents hydrogen produced in the containment would move from the subcompartment under the 154ft layer through the 154ft gap to the upper parts. If a hydrogen deflagration takes place at the subcompartment over the 154ft layer in the accidents, the flame may propagate to the subcompartment under the 154ft layer through the 154ft gap. Because of the flame propagation, the behavior of hydrogen through the gaps should be considered carefully. Besides hydrogen deflagration at the gaps may result in rupture of grids holding safety injection tank. The flame propagation downward, as it were, may cause severe accidents.

2. THE SNU TEST FACILITY

For the purpose of the analysis of hydrogen behavior through the gaps, the compartment chosen as test domain is a control volume including safety injection tank and two gaps in the actual plant. Two layers and safety injection tank were set up in the test facility as shown in Fig.[1]. With consideration for the randomness in direction of hydrogen injected to 154ft gap, we conducted experiment I and II according to the injection direction of hydrogen. Experiment I and II were conducted independently according to injection direction as shown in Fig.[2].

Size of cylindrical mixing chamber is about 100cm in diameter and 180cm in height and free volume is about 1.34×106cm3, safety injection tank is about 25cm in diameter and 115cm in height. All structure materials constituting the test facility are stainless steel of 1.5mm in thickness. The sampling lines are a urethane tube of 1.4mm in inner diameter. As shown in Fig.[2] sampling lines and thermocouples were installed in experiment I and II.

A important feature of the experiment was pre-heating of the mixing chamber steel structures to about 80℃ before the experiment. If this were not done, the steel structures would act as too efficient heat sink in the total experiment term.

3. EXPERIMENT CONDITIONS AND RESULTS

3.1 THE TEST CONDITONS

The conditions of experiment I and II are identical with the exception of the injection position of mixture injected into the mixing chamber. Major test conditions are as follows: Helium injection rate is 0.4 g/min, Steam injection rate is 8 g/min, Mixture injection velocity is 57 cm/s, Injection ratio of He to steam is 1/20 in mass and 1/3.34 in volume. Mixture injection rate is 17 lit/min, and Mixture injection position is the center of the mixing chamber bottom in Exp.I and the lower part of the mixing chamber wall in Exp.II.
From t=0 the experiments were continued up to the concentration of all sampling point to approach the steady state in the mixing chamber.

3.2 THE RESULT OF EXPERIMENT I

Objective of experiment I is analysis of mixture behavior and effect of the obstacles(154ft and 169ft layers, safety injection tank) when the mixture is injected symmetrically into the mixing chamber.
Fig.[3-a] and [3-b]. shows the results of the helium concentration measurements during experiment I

Concentration difference at each point was very little with the exception of the below of SI tank bottom since the below of SI tank was right over the injection aperture. The concentration of a sampling point(that is, channel 1) located at the 154ft gap is higher than that of other points in the subcompartment under the 154ft layer. This result was because when steam injected into mixing chamber rose from the bottom with intensive momentum to upper part, momentum of steam caused helium to flow up through the 154ft gap. Therefore we could conclude that the amount of helium diffused from the injection point is very little in comparison with that of helium raised by momentum in the subcompartment under the 154 ft layer. Fig.[3-b] shows the experiment result at the intermediate subcompartment. Because 154ft gap was a path injected from the lower subcompartment, the helium concentration at the gap was higher than other detection points and the concentration distribution of other point with the exception of the gap showed small difference

3.3 THE RESULT OF EXPERIMENT II

Objective of experiment II was analysis of mixture behavior and effect of the obstacles(154ft and 169ft layers, safety injection tank) when the mixture is injected unsymmetrically into the mixing chamber.
Fig.[4]&[5] shows the results of the helium concentration measurements during experiment II

There are some differences in helium concentration distribution according to the sampling point in comparison with experiment I. This is due to unsymmetric injection into the mixing chamber. An unsymmetric injection brought about a unsymmetric gas behavior in axial direction and unsymmetric flow-off of the mixture to the upper subcompartment through the 154ft gap around the safety injection tank. This mixture behavior circulated air in the subcompartment under 154ft layer and drew into the air in the subcompartment over the 154ft layer. The air inflow from the upper subcompartment, as a result, gave rise to concentration gradient in the lower compartment. This unsymmetric air inflow was also noticed from the concentration distribution of the 154ft gap. As shown in Fig.[4] and [5] helium concentration in the 154ft gap with sampling point 1, 5, and 9 fluctuated largely as time goes on, the fluctuation width was about max. 4 percent in volume. A phenomenon of this concentration fluctuation was also detected at the gap with sampling point 1, 6, and 11 in the intermediate subcompartment.

4. CONCLUSIONS

Through the experiments injected symmetrically and unsymmetrically into the test chamber we could understand the behavior of helium mixture according to the effects of obstacles at subcompartments in the SI tank compartment.

In the experiment I in which helium mixture was injected symmetrically concentration difference at each point was very little. The helium concentration measured at the intermediate subcompartment was very low. In the experiment II in which helium mixture was injected unsymmetrically we could conclude that the injected mixture caused air in lower compartment under the 154ft to circulate through 154ft gap, thus helium concentration at the gap fluctuated largely, this concentration fluctuation may cause helium concentration peaking in a moment.

From the experiments conducted above hydrogen behavior at the gaps in the SI tank compartment should be considered carefully because local concentration peaking by non-uniform path of hydrogen may occur.

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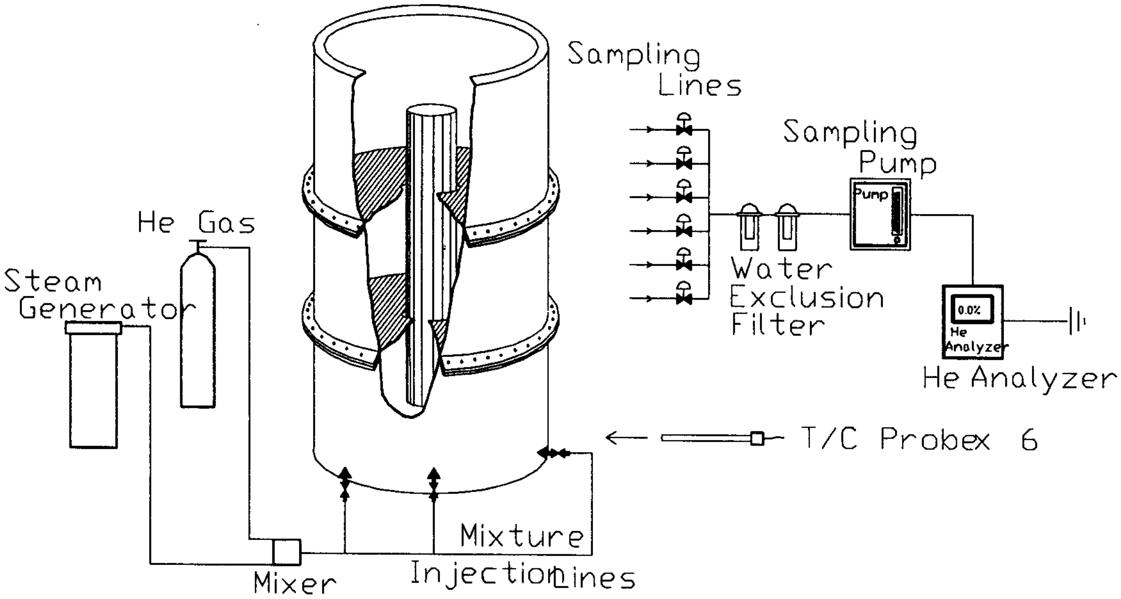
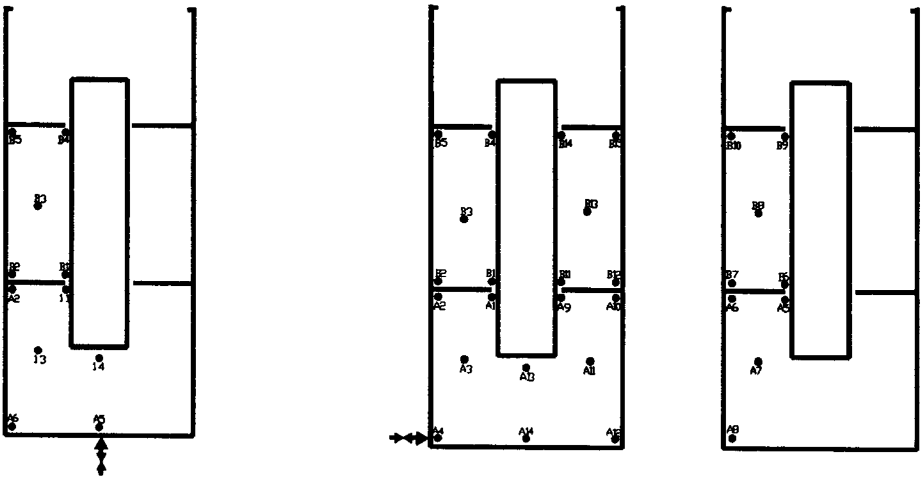


Fig. [1]. Entire Scheme of The SNU Test Facility



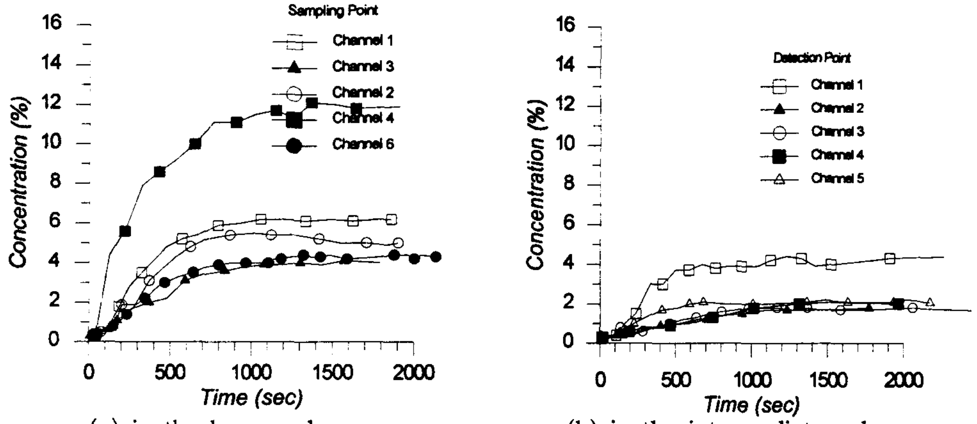
View of x direction

View of y direction

(a). Sampling Points of Exp. I

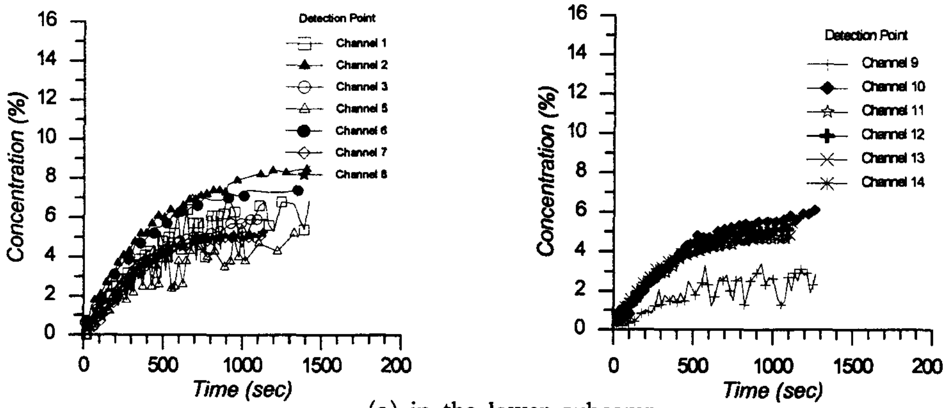
(b). Sampling Points of Exp. II

Fig. [2]. Sampling Point of Experiment I and II

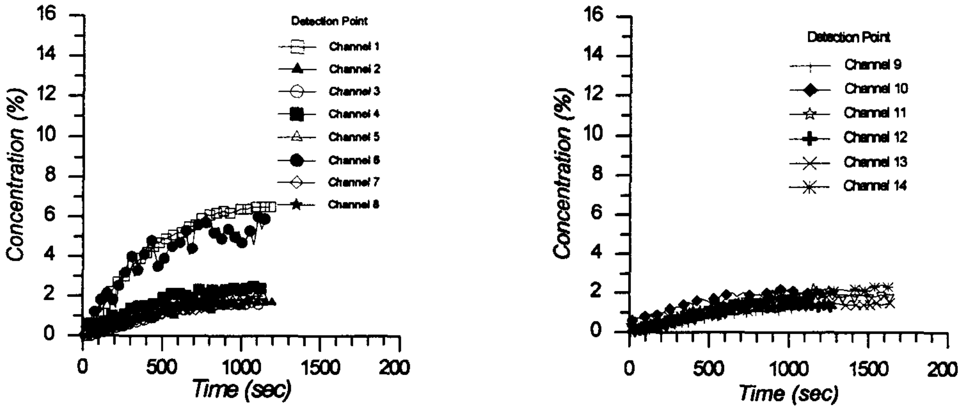


(a) in the lower subcomp. (b) in the intermediate subcomp.

Fig.[3]. Concentration Distributions of Exp.I



(a) in the lower subcomp.



(b) in the intermediate subcomp.

Fig.[4]. Concentration Distributions of Exp.II