

Gas Accumulation according to Pressure and Temperature Variations

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1. Introduction

Various reasons can cause unexpected accumulation of gas in the reactor safety system. Representatively, the gas accumulation can be occurred by following reasons [1]. (1) By pressure drop, the cavitation can be occurred. (2) By variations of temperature and pressure, the dissolved gases can be separated.

The accumulated gas can damage some parts of safety system in the nuclear reactor, such as pipelines and pumps. It also reduces cooling performance and increases unreliableness of accident analysis [2]. In order to prevent the unexpected situations and remove gases effectively, it is necessary to understand the gas accumulation phenomena.

In the current study, the gas accumulation due to the dissolved gas separation occurred by variations of temperature and pressure in the stationary water is discussed.

2. Experimental apparatus

The experimental apparatus consists of a pressurizer, a gas accumulator, and a gas volume measuring tank (GVMT), as shown in Figure 1. The pressure condition is adjusted using the cartridge heater installed inside the pressurizer. Temperature condition is adjusted using the band heater installed in the gas accumulator. When the gas dissolved in the water contained in the gas accumulator and the GVMT is separated by the variations of temperature or pressure, it is accumulated in the GVMT. The amount of accumulated gas is measured by the scale installed on the front of the GVMT. The volume of water contained in the gas accumulator and the GVMT is 5.565 L.

3. Experimental conditions

The experiment was conducted in three main conditions; (1) gas accumulation due to pressure change in isothermal condition, (2) gas accumulation due to temperature change in isobaric condition and (3) gas accumulation according to temperature and pressure change procedures. For the condition (3), it was observed whether the gas accumulation occurred or not and how much accumulated gas remained finally, by changing procedures of four steps; heating, cooling, pressurization, and depressurization. The detailed conditions of the experiment (3) are shown in Table 1.

The initial conditions for all experiments were set to the temperature of 20 °C and the atmospheric pressure.

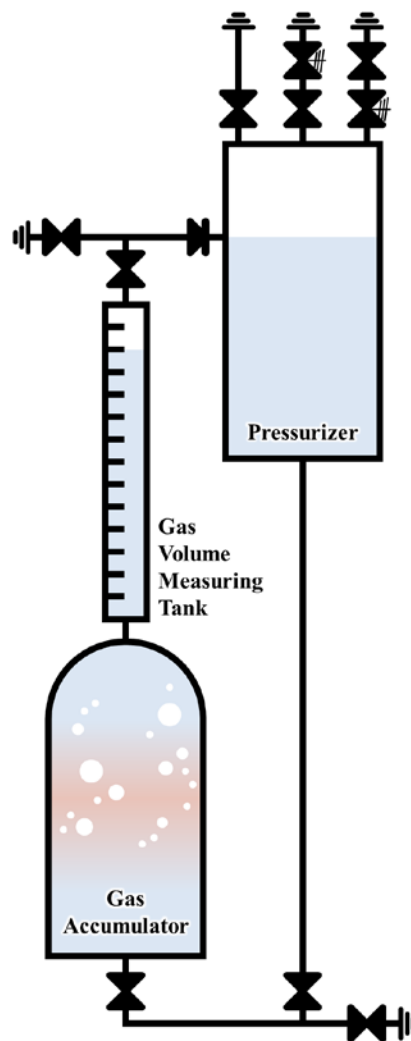


Fig. 1. Schematics of experimental apparatus.

Table 1. Detailed procedure for variations of temperature and pressure in experimental conditions (3).

No.	Procedure step			
	1	2	3	4
3.1	Heating (A → B)	Pressurization (B → C)	Depressurization (C → B)	Cooling (B → A)
3.2	Heating (A → B)	Pressurization (B → C)	Cooling (C → D)	Depressurization (D → A)
3.3	Pressurization (A → D)	Heating (D → C)	Depressurization (C → B)	Cooling (B → A)
3.4	Pressurization (A → D)	Heating (D → C)	Cooling (C → D)	Depressurization (D → A)

4. Results and discussions

Figure 2 shows an isoconcentration line which indicates same concentrations as the initial condition (red line) and a box which indicates the temperature and pressure conditions at which the experiment was conducted. The experimental results can be described using this plot.

4.1. Gas accumulation due to pressure change

The isothermal experiments were conducted at 20 °C. The water inside the test section was pressurized from atmospheric pressure. After the pressure reached at target value, it was remained for enough time. Thereafter, the water was depressurized for return to the initial condition.

During pressurization and depressurization, the gas accumulation did not occur. Based on Figure 2, pressurization and depressurization processes are expressed by the line A ↔ D. The concentration of gas is always larger than initial condition. Therefore, the dissolved gases are never separated and accumulated.

4.2. Gas accumulation due to temperature change

The isobaric experiments were conducted under the atmospheric pressure. The water was slowly heated with a 100W band heater and kept the constant temperature until no further gas was generated after reaching the target temperature. As shown in Figure 3, the higher the water temperature, the faster the gas was separated and accumulated.

Not all accumulated gases were dissolved and more than 50 percent of the gases remained when the water is cooled back to the initial condition. The accumulated gas remained about 52.94 % in the 65 °C experiment and 68.75 % in the 75 °C experiment. These results suggest that it is not easy to dissolve the separated gases again without a mechanical mixing.

4.3. Gas accumulation according to temperature and pressure change procedures

The experiments 3.1 and 3.2 were begun by heating the water in initial conditions to 80 °C. After the separation and accumulation of gases in heated condition, the water was pressurized to 5 bars. The gases accumulated by the heating process were not fully dissolved through the depressurization and cooling processes. About 43.53 % of the gas remained when the depressurization process was preceded the cooling process. About 52.78 % of the gas remained when the cooling process was preceded the cooling process.

The experiments 3.3 and 3.4 were begun by pressurizing the water from atmospheric pressure to 5 bars. After waiting sufficient time, the water was heated to 80 °C. When the depressurization process was preceded the cooling process, about 2.84 mL of gas was accumulated. Besides, when the cooling process was preceded the cooling process, no gas accumulation occurred.

These differences occur by the following reasons: In Figure 2, the process of A → D → C → D → A does not cross the isoconcentration line. In other words, there is no moment when the concentration of the dissolved gas becomes lower than that of the initial condition. On the other hand, the A → D → C → B → A process passes the isoconcentration line among the depressurization step (C → B). As a result, the separation and accumulation of dissolved gases occur when the concentration is lower than the initial conditions. In addition, it is very hard to dissolve the accumulated gases again without a mechanical mixing.

5. Conclusions

The separation and accumulation of dissolved gas by variations of temperature and pressure was observed in stationary water, quantitatively. As the experimental results, gas accumulation can occur when the concentration is lower than the initial conditions. To avoid the gas accumulation, appropriate procedures of changing temperature or pressure should be established.

REFERENCE

- [1] Nuclear Energy Institute, Guidelines for Effective Prevention and Management of System Gas Accumulation, NEI 09-10 (Rev 1a-A), Dec., 2010.
- [2] Nuclear Regulatory Commission, Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems, NRC Generic Letter 2008-01, Jan. 2008.

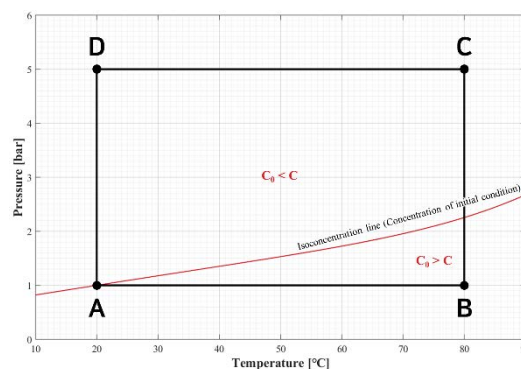


Fig. 2. Isoconcentration line of nitrogen.

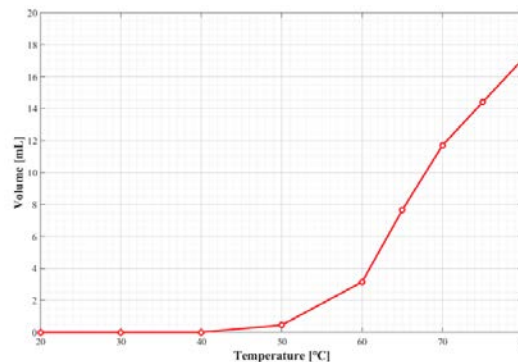


Fig. 3. Gas accumulation volume by temperature