Preliminary Study on the Development of MIDAS/GCR to Simulate the Plate-out Phenomena from a HTGR.

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1. Introduction

In HTGR, the dominant removal mechanism of the condensable fission product gas is a 'plate-out' on various kinds of surfaces over the primary coolant loop. The plate-outs are complex phenomena that are dependent on the mass transfer rate from the coolant to the fixed surface, the adsorption and desorption of the gas fission product, the material of the surfaces, the operation temperature, the fission product species, etc.

In a normal operation, the important information on a plate-out is the amount and the distribution and the type of isotope. This information is applied to construct a safety engineering system, to calculate the necessary shielding and to estimate the impact on the environment. The status of a model development and available data are performed extensively but the data still has a large uncertainty.

The objective of this study is to compare the condensation model of a gas fission product in the MIDAS for a PWR with the PADLOC model for a HTGR developed by GA [1] and to perform a feasibility calculation on OGL-1 with MIDAS.

The results of the model review on MIDAS and PADLOC, the feasibility calculation results on OGL-1 with MIDAS and the phenomena to be implemented into MIDAS to simulate the plate-out phenomena from HTGR are identified and listed.

2. Description of the Actual Work

2.1 Review of the Plate-out model in MIDAS/PADLOC

In MIDAS, the driving force for making the fission product gas condense to the surface is determined by two parameters such as the mass transfer coefficient and the difference of the fission product concentration between the atmosphere and the surface. The concentration of the saturated fission product on the surface can be predicted by the saturated vapor pressure value at the surface temperature and the ideal gas law.

The mass transfer coefficient of the fission product species to the surface is calculated based on the mass diffusivity of the steam in air. Therefore, for the HTGR system using helium as a coolant, the mass diffusivity value of steam in air has to be replaced by the mass diffusivity value of specie in helium.

The binary mass diffusivity of a non-polar gas at a low density can be predicted by using 'Chapman-Enskog' equations. By using the above binary mass diffusivity for all gas species, the mass diffusivity of species in a bulk gas mixture can be derived.

But the problem is how to determine the Lennard-Jones potential parameter values for all the fission product species. It is because such Lennard-Jones parameter values are not available at present. Therefore, it is necessary that the Lennard-Jones parameter values for all the fission product species be implemented not only for a PWR but also for a HTGR.

The PADLOC consists of two mass balance equations fpr the bulk and for the thin boundary and one nonlinear correlation, which causes the two separate concentrations for the thin boundary layer and for the surface to inter-connect. The concentration at the surface is calculated with this nonlinear correlation .

The PADLOC adopts the same driving force as that of MIDAS for a plate-out. But the method to establish the surface concentration is different from that of MIDAS.

Consequently the two codes are using a similar approach to model the plate-out phenomena. But PADLOC considers one more phenomenon to model a plate-out. That is the consideration of a decay and the generation of a fission product.

The PLAIN, which was developed by JAERI considers a inner diffusion of silver at a high temperature of about 600°C. Whether these phenomena should be implemented or not depends on the validation results from MIDAS against other codes or an experiment.

2.2 Feasibility calculation on OGL-1 test with MIDAS

A feasibility calculation has done with two purposes. The first is to test whether the MIDAS for a PWR can simulate an entire experimental system where the components such as the heat exchanger and the heater are interconnected or not. The second was to identify the insufficient models or absent phenomena from the fission product gas condensation model included in MIDAS.

In the OGL-1 test, the gas temperature was changed from 700°C to 30°C. The measurement was done after the end of a 500 hrs operation. The information on the experimental facility, the boundary conditions and the measured data was limited to that of a published paper [2]. Although only limited data was available for preparing the input for MIDAS, the calculation results showed similar representative fission product plate-out characteristics as that of the OGL-1.

From figure 1, the silver was condensed in a high temperature zone of about 500°C. But the cesium and cesium iodide were condensed at a low temperature zone of about 300°C. The reasons for showing a non condensing zone at 1 and 6 were attributed to the omission of a core bundle for a condensing and the function of a filtering in preparing the input for MIDAS.

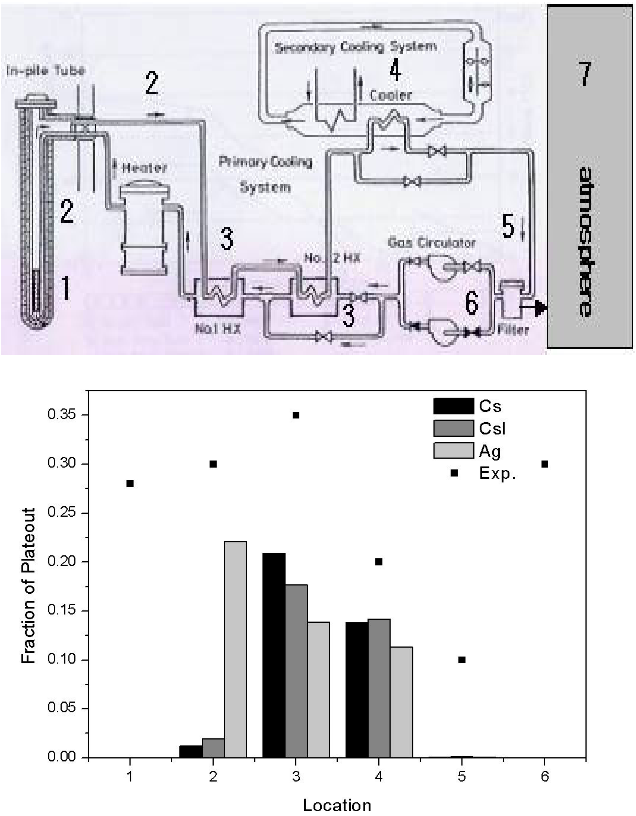

Figure 1. OGL-1 experimental circuit and the predicted Distribution of the fission product plateout in the circuit.

4. Conclusion

The review of the plate-out models and the feasibility calculation of the OGL-1 experiment by using MIDAS were performed under the frame of a preliminary study to develop the MIDAS/GCR for a HTGR.

It is considered that this preliminary study contributes to identifying the insufficient models or absent phenomena in MIDAS to successfully simulate the fission product plate-out phenomena over the HTGR loop. The identified models and the phenomena to be implemented are as follows;

1) Model the destruction and generation of fission product species by a radioactive decay.
2) Implement the adsorption and de-sorption of a fission product gas on the wall.
3) Model the irreversible chemical reaction of the fission product with a wall element (Fe,Cr Ni).
4) Model the Lift-off (Re-suspension) phenomena.
5) Update the material properties such as the single and binary mass diffusivity, Lennard Jones potential parameters and vapor pressure for all the species.
6) Model the diffusion of Ag into the metal pipe inside.
7) Identify the plate-out distribution features according to the material types of a pipe such as steel, inconel-625, incoloy-800, hastelloy-x, austenitic SS type 316.
8) Develop a special method to treat the long problem time such as (1 year or 10 year) as a tractable.

These identified model and phenomena will be implemented into the MIDAS. The implemented MIDAS/GCR will be validated against the calculation result from the PADLOC or the other experimental result.

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