6.4 Availability of steam generator against thermal disturbance of hydrogen production system coupled to HTGR

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ABSTRACT

One of the safety issues to couple a hydrogen production system to an HTGR is how the reactor coolability can be maintained against anticipated abnormal reduction of heat removal (thermal disturbance) of the hydrogen production system. Since such a thermal disturbance is thought to frequently occur, it is desired against the thermal disturbance to keep reactor coolability by means other than reactor scram. Also, it is thought that the development of a passive cooling system for such a thermal disturbance will be necessary from a public acceptance point of view in a future HTGR-hydrogen production system.

We propose a SG as the passive cooling system which can keep the reactor coolability during a thermal disturbance of a hydrogen production system.

This paper describes the proposed steam generator (SG) for the HTGR-hydrogen production system and a result of transient thermal-hydraulic analysis of the total system, showing availability of the SG against a thermal disturbance of the hydrogen production system in case of the HTTR-steam reforming hydrogen production system.

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1. Introduction

High temperature heat of about 1000°C offered by an HTGR is expected to be available for industrial chemical process such as a hydrogen production. HTGR-hydrogen production system would play an important roll to resolve global CO_2 emission problem, because the system can produce hydrogen as a clean energy source without CO_2 emission, which is different from the conventional fossil burning system.

Nuclear heat from the HTGR will be transferred to the hydrogen production system by helium gas. This heat will be utilized at a hydrogen production high temperature chemical reactor at first, and then at heat exchangers such as a steam generator (SG), installed in series in the helium loop.

One of the safety issues to couple the hydrogen production system to the HTGR is how the reactor coolability can be maintained against anticipated abnormal reduction of heat removal (thermal disturbance) of the hydrogen production system. Since such a thermal disturbance is thought to frequently occur, it is desired against the thermal disturbance to keep reactor coolability by means other than reactor scram. Also, it is thought that the development of the passive cooling system for such a thermal disturbance will be necessary from a public acceptance point of view in a future HTGR-hydrogen production system.

2. System arrangement and SG

Japan Atomic Energy Research Institute (JAERI) has been constructing the High Temperature Engineering Test Reactor (HTTR) at the Oarai Research Establishment. The HTTR will attain its first criticality in 1997. The HTTR is the first HTGR in Japan with thermal output of 30MW and a reactor outlet coolant temperature of 950°C at high temperature test operation.

JAERI is planning to couple a steam reforming hydrogen production system to the HTTR through helium-to-helium intermediate heat exchanger (IHX). Figure 1 shows flow scheme of the HTTR-steam reforming hydrogen production system. The hydrogen production system comprises a steam reformer (SR), a super heater (SH), a SG, etc..

The IHX is designed to transfer 10MW of a part of the reactor thermal output to the hydrogen production system. The secondary helium heat will be removed by the SR, the SH and the SG in sequence. At the SR, approximately 4MW of the secondary helium heat will be utilized for steam reforming reaction to produce hydrogen from process gas which is a mixture of steam and methane. Steam reforming reaction is an endothermic chemical reaction and occurs at 600°C or above. Downstream the SR in the helium loop, the rest of the secondary helium heat will be utilized to generate superheated steam through the SH and the SG. Then, the secondary helium gas will be returned to the IHX after 10MW of heat removal at steady state in normal operation.

Regardless of the SG inlet helium temperature, the SG outlet helium temperature will be a saturation temperature of steam because of large latent heat of steam. If the SG inlet helium temperature increases, the quality of steam increases naturally under constant pressure, and therefore the SG outlet helium temperature remains constant. As can be understand, this SG has a feature that its outlet helium temperature is controlled in passive manner in normal operation.

JAERI has been conducting a study about the SG to be a passive safety system in order to mitigate a thermal disturbance of the hydrogen production system. In our design, the SG has a large volume steam drum so as not to lose storage water to keep reactor coolability. We are trying to realize this cooling function of the SG in passive manner by making use of natural circulation of water and natural convection of air.

3.Transient analysis of the HTTR-hydrogen production system

Figure 2 exemplifies a transient response of helium gas temperatures at abnormal decrease of process gas flow rate at the

HTTR-steam reforming hydrogen production system shown in Fig.1. The analysis was made by the IRIS (Integrated tRansient thermal-hydraulIcs computer code System for HTGR with heat utilization system) code developed by the authors[1]. At the SR feed process gas flow rate 20% stepwise decrease, the SR and the SH outlet helium temperatures increase about 10°C slowly, as expected. However, the SG outlet helium temperature remains almost constant. Therefore, the IHX outlet primary helium temperature is found to remain almost constant. This result suggests that the SG has an availability to keep the reactor coolability without causing reactor scram during thermal disturbance of the hydrogen production system.

Therefore we propose that thermal disturbance of the hydrogen production system to be connected to the future HTGR should be mitigated by the SG so as to keep reactor coolability, passively.

4.Conclusions

The following conclusions were delivered from the present study.

(1) Thermal-hydraulics analysis of the HTTR-steam reforming hydrogen production system using the IRIS code shows that the SG has an availability to keep reactor coolability without causing reactor scram during a thermal disturbance of the hydrogen production system.

(2) Therefore, we propose that reactor coolability should be maintained during a thermal disturbance by the SG in passive manner in the future HTGR-hydrogen production system.

Reference

1) HIRANO, M. and HADA, K., JAERI-M 90-071, (1990).

The IRIS code was developed by the authors based on the THYDE-HTGR code described in reference 1).

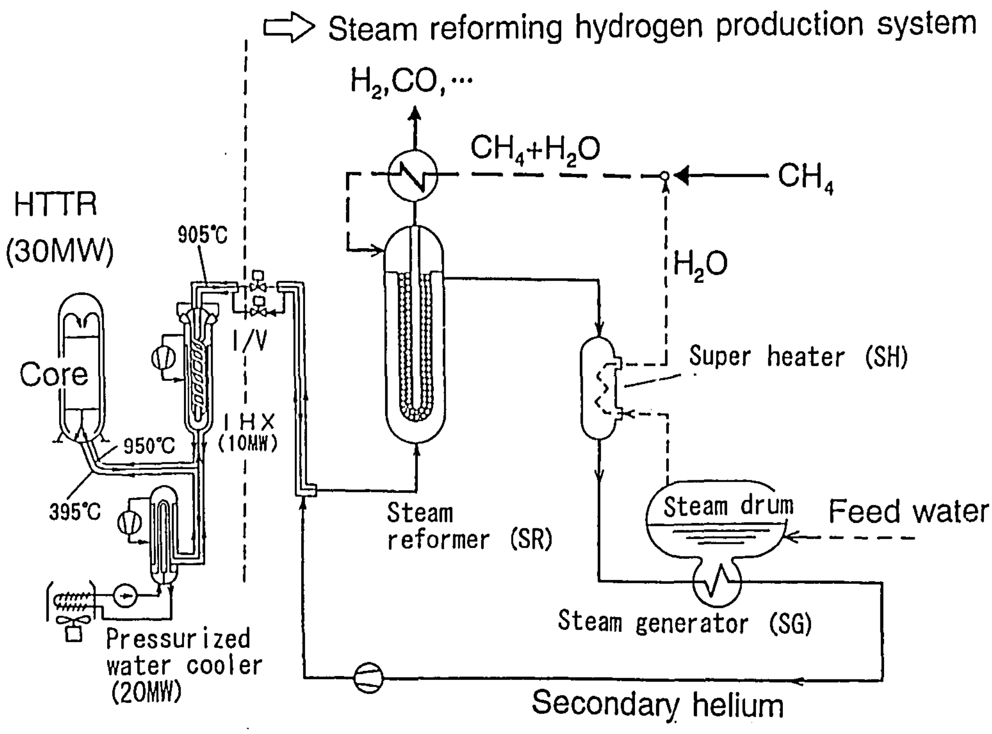

Fig.1 Flow scheme of the HTTR-steam reforming hydrogen production system.

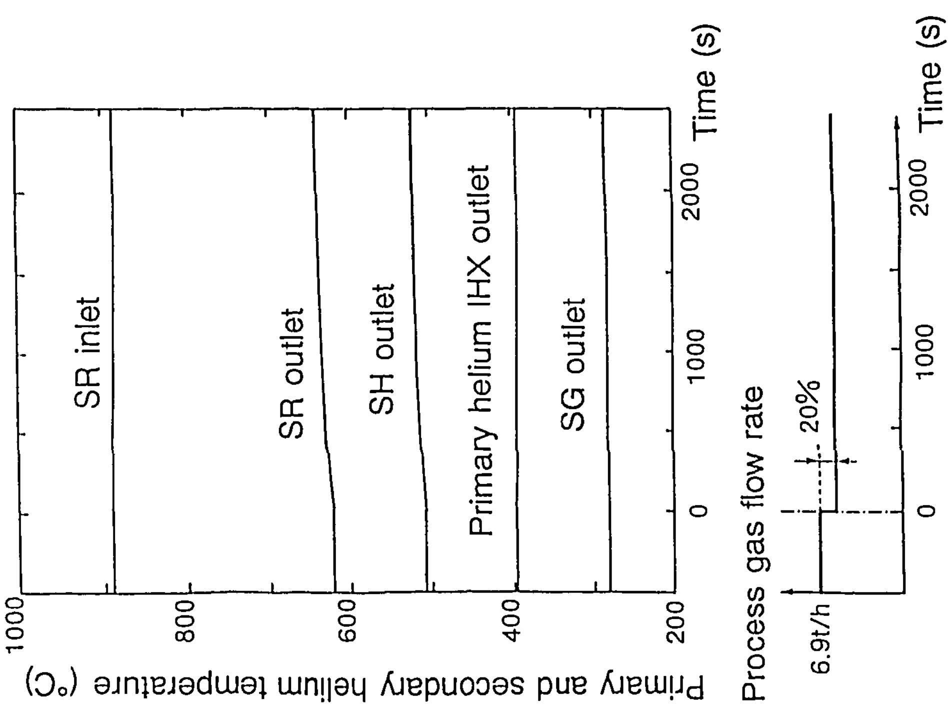

Fig.2 Helium gas temperatures at the HTTR-steam reforming hydrogen production system by transient thermal hydraulic analysis.