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Evaluation of SG Blowdown time for PGSFR SWRPRS

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1. Introduction

Sodium-Water Reaction (SWR) is one of the most important economic and safety issues to be addressed in designing and operating an SFR(Sodium Fast Reactor). A steam-to-sodium leak causes a violent exothermic sodium/water reaction resulting in local temperature rise (>1,200°C) and produces hydrogen gas and highly corrosive chemicals. The SWR often induces self-enlargement (self-wastage) of the leak and rapid propagation of wastage to adjacent tubes, leading to secondary or multiple tube failures. If it is unmitigated, the hydrogen gas formation could cause a pressure increase in the intermediate heat exchanger (IHX) or the intermediate heat transport system (IHTS) and may potentially cause tubing rupture. If the effects are unmitigated, the highly corrosive chemicals formed could lead to and accelerate the corrosion problems of SG(Steam Generator) and IHX/IHTS structure.

In order to mitigate the SWR, PGSFR SWRPRS (Sodium Water Reaction Pressure Relief System) has capabilities of steam blow down and sodium dump to stop SWR. Steam blowdown operation starts from signals from plant control system based on the hydrogen concentration in the sodium or cover gas of IHTS and operator manual actions.

2. Design Requirements of Steam Blowdown Time

SWRs are classified micro, small, intermediate and large by leakage rate of water/steam into sodium. IHTS pressure rises abruptly by SWR from the intermediate and large leak and actuates the rupture disk to dump the sodium in the IHTS. However small leak generates corrosive sodium water reaction jets for the time being and give damages to adjacent tubes.

In order to stop the small leakage before the propagation of tube failures to adjacent tubes, steam blowdown operation should be completed before the burn through of adjacent tubes.

2.1 Burn through time

Various wastage correlations [1, 2, 3] with small leak rates were reported based on steam injection experiments. For 9Cr–1Mo steel, the correlation of wastage rate (W_R) and burn through time(t_b) were derived from experiments with leakage rate G(g/sec), to target spacing L(mm).[3]

$$W_R = \frac{3.63}{L^{1.37}} e^{-0.265(\ln\frac{G}{6.25})}$$

$$t_b = \frac{tube\ thickness}{W_R}$$

By application of the above model to the PGSFR SG tubes and by converting the water/steam leakage rate to hydrogen concentration, burn through times were calculated as shown Fig.1.

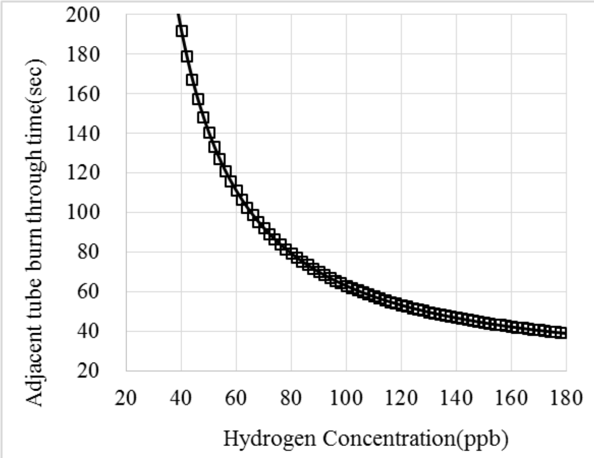

Fig. 1. Burn through time of adjacent tubes of PGSFR SG with respect to hydrogen concentration

2.2 Hydrogen detection time

PGSFR hydrogen detector is developed based on EBR-II experiences [4]. The detector is located inlet and outlet sodium nozzle of steam generator and response time is around 12 seconds and the maximum traveling time of hydrogen from the water/steam leakage point to the location of hydrogen detector is estimated around 12 seconds. By the sum of sensor response time and traveling time, the hydrogen detection time is assumed as 24 seconds.

2.3 Operation time of pumps and valves

For the blowdown of water/steam of infected loop, feed water pump and IHTS pump be stopped and feed water valve and steam line isolation valve be closed. The shutdown of PGSFR feed water pump and IHTS pump are to be achieved within 5 seconds after receiving signals. The feed water valve and steam line isolation valve are designed to be closed within 5 seconds.

2.4 Blowdown time

The setpoint of hydrogen concentration for the automatic actuation of SG blowdown for PGSFR are assumed as base concentration plus 80 ppb. From the Fig.1, the burn through time at 80 ppb hydrogen concentration is 77 seconds. The blowdown time should be less than 43 seconds in considering hydrogen detection time 24 seconds and pump/valve operating time 10 seconds.

3. Steam Generator Water/Steam Blowdown

3.1 MARS code model

MARS-KS[5] computer code is applied for the evaluation of the water/steam blowdown from the steam generator and pipings of feed water. Steam generator, feed water pipes and steam pipes were modeled as Fig.2 for the evaluation of water/steam blowdown evaluation. Sodium side of SG were modeled by 3xx components and water/steam side modeled by 5xx components.

During normal operation sodium and feed water are maintained at constant flowrate as shown in Table. 1 and after SG blowdown starts sodium flow drop to zero and water/steam is dumped to water dump tank.

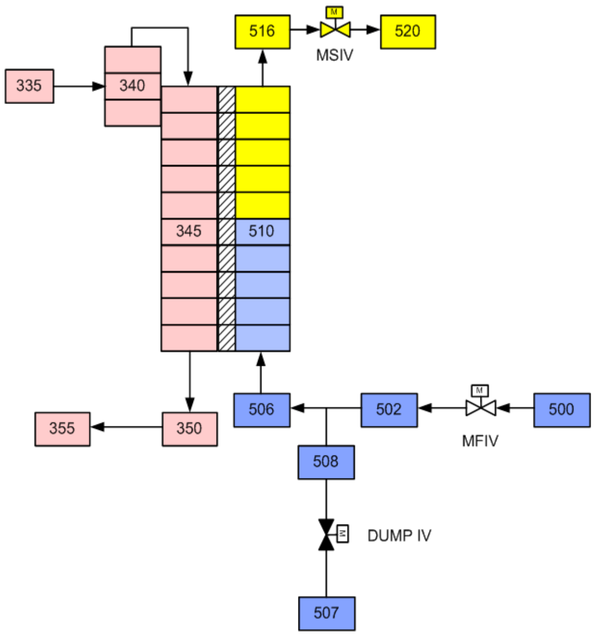

Fig. 2. Mars code model for water/steam blowdown analysis

Table. 1. Steady state results and heat balance target

	sodium			Feed water and Steam		
	Inlet (℃)	Exit (℃)	Mass flow (kg/s)	FW Temp (℃)	Steam Temp (℃)	Mass flow (kg/s)
MARS Results	528.1	331.1	782.62	240	504.6	86.7
Heat Balance	528.0	332.0	782.15	240	503.0	86.7

3.2 Water/Steam Blowdown Evaluation

The blowdown time is dependent on the dump line and isolation valve size and dump line length. For the design of PGSFR water/steam dump line evaluation, the dump line length was assumed 50m.

Blowdown analysis were done by use of MARS two phase model with choking flow for dump lines with 4,5,6,8 inch diameter pipe and valve[6] from normal operation steam pressure 16.7 MPa to 1.5 MPa on the SWRPRS operating procedures. From the evaluation, steam pressure of 4inch diameter dump line took 39.3 seconds which is less than 43 seconds and the larger diameter took the less time as shown Fig.3.

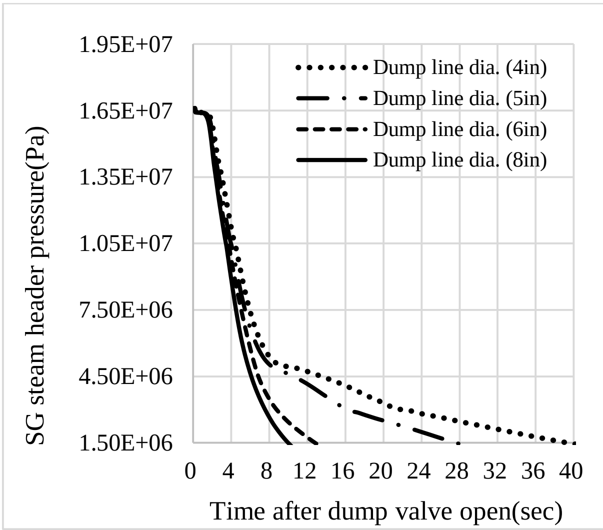

Fig. 3. Blowdown time for various dump line diameter

4. Conclusions

Through the study of hydrogen detection time and SG tube burn through time and component operation time, design requirement for blowdown time requirements were established. Based on the requirements, the diameter of pipes and valves of the blowdown line should be equal to or larger than 4 inch for PGSFR.

ACKNOWLEDGEMENT

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