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Safety Evaluation for Steam Generator Sodium-Water Reaction Event in PGSFR

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1. Introduction

Korea Atomic Energy Research Institute(KAERI) has been developing the Prototype Generation IV Sodium Cooled Fast Reactor(PGSFR). As a rector coolant, a sodium is used to transfer the heat from the core to the turbine. A sodium has a chemical characteristics to rigorously react the water or steam and produce the high pressure waves and high temperature reaction heat. It has an excellent characteristics as a reactor coolant. But, there is an event to be considered in the sodium cooled fast reactor design. The Sodium-Water Reaction (SWR) event can be occurred by the water or steam leakage due to Double-Ended Guillotine Break(DEGB) of the steam generator tubes. If appropriate actions to mitigate the event are not taken, the propagated high pressure waves may threathen the structural integrity of the Intermediate Heat Transport System(IHTS) and steam generator. In this paper, the integrity of the IHTS and SG by the SWR event are evaluated using the SWAAM-II[1] code. In this paper, a few changed design features are reflected compare with prior design.

2. Analysis methods

The sodium-water reaction event can be occurred in the part of manufacturing defect and improper welding point of the SG tubes. Depending on the amount of the water or steam leakage, this events are classified as AOO, DBA Class I and II.[2] In this paper, it is carried out a event for the double ended guillotine break of the one SG tube. Generated pressure point of view, it must be evaluated to the structural integrity to the items which represent an affected SG and IHX active tubes. The built pressures in this points must be satisfied with design pressures values.

When a water or steam from the SG tubes is released to the SG shell shide, high pressure waves and reaction heat due to the instantaneously expansion of the hydrogen bubble gas, which is a sodium-water reaction product, is generated and propagated through the IHTS pipes. The generated high pressure waves are most influential variable to threaten the structural integrity in the IHTS.

In PGSFR, the Sodium Water Advanced Analysis Method(SWAAM-II) code which was developed in the ANL is used for calculating the propagated pressures to the each position of the IHTS. It is capable of modeling the sodium-water reaction, growth and expansion of the hydrogen gas bubble, propagation through the loops.

Fig. 1 presents the overall configuration of one IHTS loop in PGSFR. It is composed of the one SG, two IHXs, one hot leg pipe, one cold leg pipe, one expansion tank, two rupture disks and one IHTS EM pump. The red and blue lines present a hot leg and cold leg about 20.0 inch outer diameter, respectively. The part of the two rupture disks, one expansion tank and the Sodium Dump Tanks (SDT) are out of the figure.

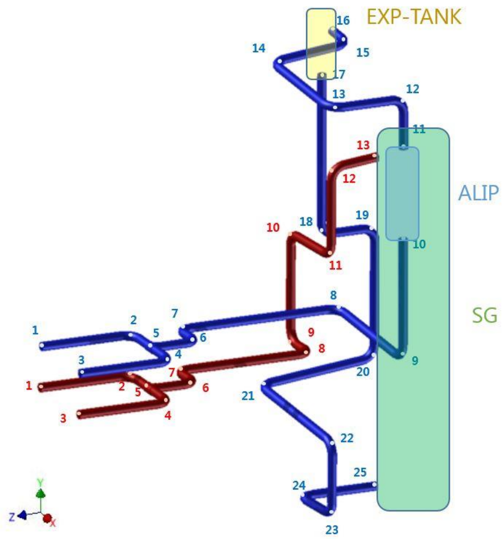

Fig. 1 The configuration of the modified IHTS in PGSFR

Fig. 2 presents the nodalization for the SWAAM-II input. [3] The pipes of 82 and junctions of 83 are used for modeling the sodium of the closed loop type IHTS. As a SWRPRS, one rupture disk with a reverse buckling type and one SDT as a pair are connected with the pipe of the hot leg and cold leg, respectively. An expansion tank filled with argon inert gas is connected with the cold leg to control and maintain the design pressure of the IHTS sodium. The numbers inside the hollowed circle represent the junction number to connect the pipes to each other. The blue and red lined rectangles boxes represent the major interested positions such as the SG inlet and outlet, expansion tank, IHX inlet, outlet and IHX active tubes. In the right side of the figure, the vertically arranged pipes and junctions represent the sodium side of the SG shell and the corresponded level positions of the SG tube filled with water or steam. The SG tube side is composed of 40 nodes and 41 junctions. As the boundary conditions, the values of 17.5 MPa, 240 °C for the inlet and 16.7 MPa, 503 °C for the outlet are applied to time dependent volumes 1 and 2, respectively.

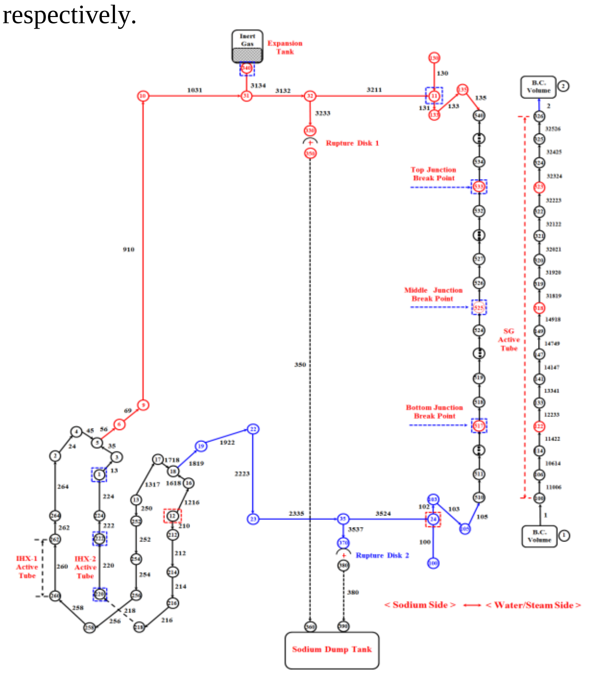

Fig. 2 The Nodalization for SWAAM-II code analysis

2.1 Assumption & Calculation

Prior to evaluate the integrity in the SG and IHX, the variables such as node length, calculation time step, the uncertainty of the rupture disk and pressure distribution to the axial direction of the SG must be determined by a sensitivity analysis. To the maximum pressure point of view, the most conservative conditions are determined by a sensitivity analysis for major variables. Fig. 3 presents the pressure behavior in the affected SG due to the one SG tube double-ended guillotine break event. Fig. 4 presents the pressure behavior in the affected IHX active tubes due to the pressure pulse propagated from the SG. Comparing with the initial peak pressure in SG, the pressure propagated to the IHX is reduced as much as it passes through the expansion tank, IHTS EM pump and connected pipes.

2.2 Results

Inside the SG, the peak pressure is a 2.26 MPa at 6.6 milisec and then gradually decreased due to the burst of the rupture disks. The peak pressure is less than the design pressure 3.5 MPa to the SG.

In the IHX tubes, the peak pressure is 0.30 MPa at 65.2 milisec. The built maximum pressure in this point is less than the design pressure 2.5 MPa to the IHX active tubes. In analysis SWR

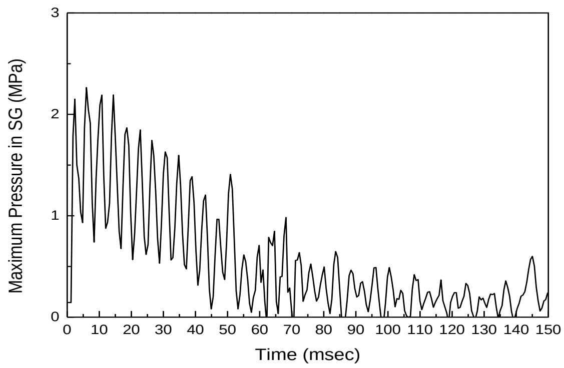

Fig. 3 The pressure behavior in the affected SG (1 DEGB)

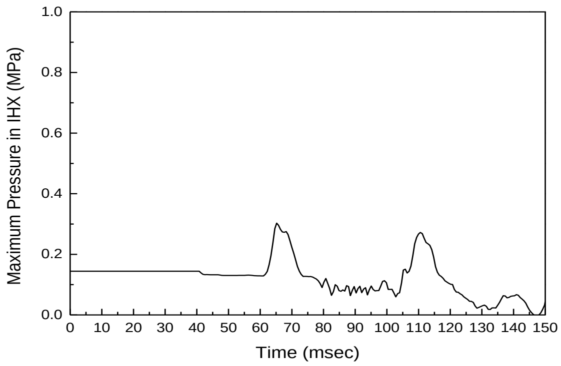

Fig. 4 The pressure behavior in the IHX tubes (1 DEGB)

3. Conclusions

To the peak pressure point of view, it is performed to evaluate the integrity of the major components due to the SWR event in the SG.

The generated maximum pressures due to the one SG tube DEGB event are within the range of the design pressure for the SG and IHX including the related pipes.

ACKNOWLEDGEMENTS

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