Analysis for design of passive safety injection line in IPSS

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1. Introduction

After the Fukushima accident, the importance of passive safety system has been more than emphasized. To enhance the passive safety system of nuclear power plants, the integrated passive safety system (IPSS) was proposed with passive safety features of the decay heat removal, safety injection, in-vessel retention and ex-vessel cooling, containment cooling by gravitational way from outside of the containment, filtered venting and pressure control system for the containment [1].

The current safety system of nuclear power plants cannot deal with loss-of-coolant accidents during the circumstance of station black-out (SBO), total loss of AC electric power. However, application of IPSS allows nuclear power plants to solve the combined accidents by its characteristics, only operated by natural phenomena.

In order to achieve ultimate safety from the IPSS, analysis for currently operating nuclear power plants should be considered.

Hence, in this research, analysis for the effectiveness of passive safety injection of IPSS was conducted for OPR1000 with using MARS code.

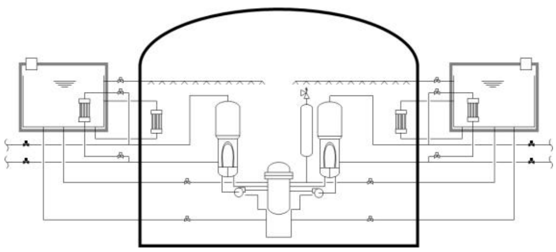

Fig. 1 Integrated Passive Safety System in OPR1000 [2]

2. Application of MARS for PSIS in IPSS

With an assumption of the direct vessel injection through a drain to the core, MARS evaluated the effectiveness of the passive safety injection based on large break loss-of-coolant accident in OPR1000.

MARS, a multi-dimensional thermal-hydraulic system code, was developed for analyzing two-phase flow phenomena in pressurized water reactors under the accident [3]. For our analysis, the code calculated hypothetical break-out at cold leg 1A for each case of emergency core cooling by (1) different pipe size of injection from passive safety injection system (PSIS) and (2) high pressure / low pressure safety injection system (HPSI/LPSI). Safety injection tanks (SITs) are set to be operated in both cases for mitigation in early phase of the break in this code. HPSI/LPSI starts to operate after 37 seconds of the accident. However, PSIS starts to inject the water at 87 seconds, after the SITs stop to operate. In case (1), the effectiveness was simulated with various pipe diameter from 3 inches to 8 inches in order to find appropriate mass flow rate.

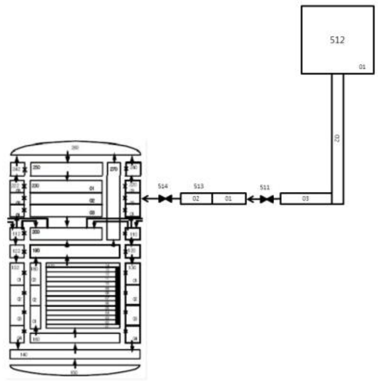

Fig. 2 Nodalization of passive safety injection system

3. Results and Discussion

The injection rate of emergency coolant from PSIS on case (1) is given in Fig.3. From an assumption of one drain PSIS system, the average amount of emergency coolant is defined by diameters of the injection pipe from 3 to 8 inches.

Originally, OPR1000, case (2) use HPSI and LPSI for mid/long term emergency core cooling through each two drains, respectively. After 37 seconds from the break-out, the amount of whole ECCS reaches to 321.307 kg/s in average.

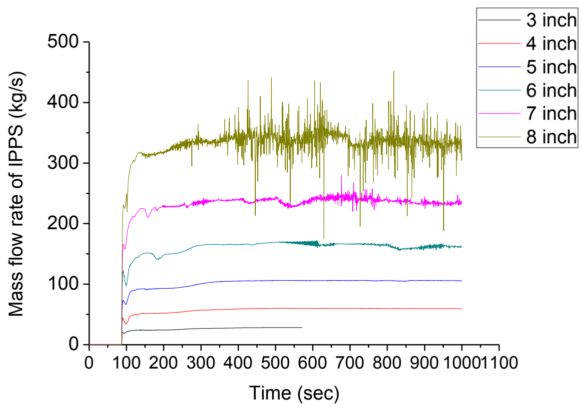

Fig. 3 Mass flow rate of Case (1), PSIS

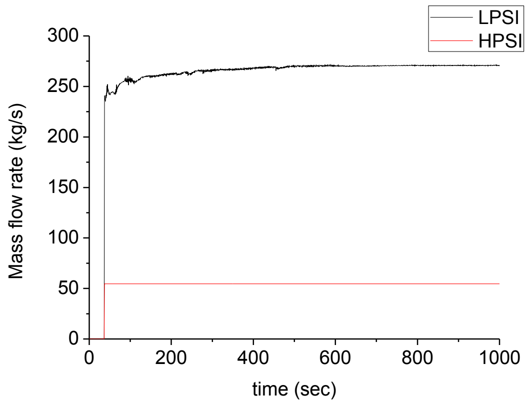

Fig. 4 Mass flow rate of Case (2), HPSI and LPSI

The efficiency of PSIS and HPSI/LPSI developed in below from defining changes of cladding temperature.

Fig.5 shows that only case (1)-(a) progressed to melt-down with insufficient water injection rate of 26.302 kg/s in average. By contrast, other cases having larger injection diameters prove that PSIS is the sufficient method to deal with LBLOCA even comparing with HPSI/LPSI.

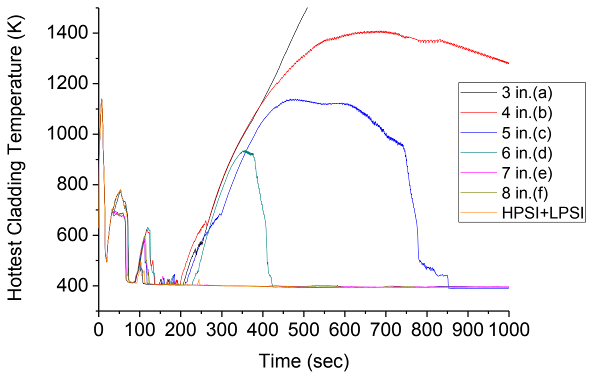

Fig. 5 Peak cladding temperature for each case

After the earlier steep temperature drop, the highest temperature of cladding in case (1)-(b) achieved 1409.6℃K at 683.5 seconds, which avoids the design basis of core melting temperature around 1477℃K. From increasing diameter of the pipes, temperature peak after 200 seconds decreased. Finally, from case (1)-(e) with 7 inches diameters and 233.273 kg/s of flow rate shows appropriate mitigation performance compared with case (2) of HPSI and LPSI.

Overall, the results prove that decreasing the core temperature and preventing melt-down in passive manner, are successfully achieved by using PSIS.

4. Conclusions

In this study, application of PSIS for OPR1000 was evaluated. Following the results were simulated by MARS, we verified that PSIS can be the successful supplement for safety roles that HPSI and LPSI does in OPR1000. Even though, the result is strictly bounded to OPR1000, it gives us a prospect that PSIS of IPSS can cope with LBLOCA in the failure of active safety systems induced by SBO on other PWR. On the other hand, this simulation was evaluated with a hypothesis of direct vessel injection. Therefore, further study is needed for passive safety injection through cold legs to OPR1000 and other PWRs and those comparisons.

REFERENCES

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