Thermosyphon Phenomenon as an alternate heat sink of Shutdown Cooling System for the CANDU reactor

Kim, Jonghyun*, Lee, Kwangho**, Oh, Haechol**, Jun, Hwangyong**
* *Gnest.Inc.*
** *Nuclear Power Lab, KEPRI*
381 Manyondong Seo-gu Daejon, jh6119@gnestinc.com

1. INTRODUCTION

During the outage(overhaul) of the CANDU plant, there is a period when the coolant is partially drained to the reactor header level and the coolant is cooled and depressurized by Shutdown Cooling System(SDCS) other than PHTS pump. In the postulated accident of the loss of SDCS-the PHTS pump failure, the primary coolant system should be cooled by the alternate heat sink using the thermosyphon pheonomenon(TS) through the steam generator(SG)

This study was aimed at verification and analyzing the core cooling ability of the TS. And the sensitivity analysis was done for the number of SGs used in the TS.

As an analysis tool, RELAP5/CANDU was used.

2. THE LOSS OF SDCS DURING PARTIALLY DRAINED STATE

If SDCS fails to remove the decay heat during the partially drained state, the channel coolant begins to boil and the fuel sheaths get damaged. (Fig.1 and Fig.2)

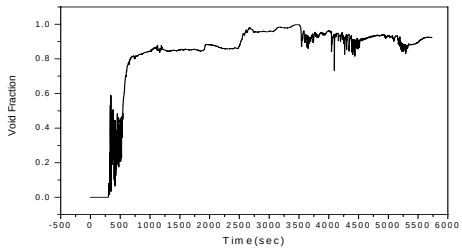

Fig.1 Coolant void fraction after the loss of SDCS

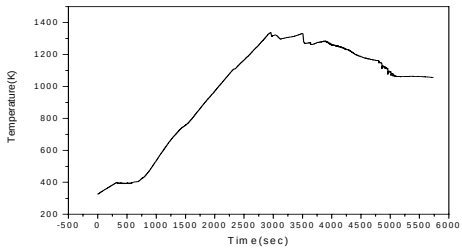

Fig.2 Fuel sheath temperature after the loss of SDCS

3. THE INDUCING OF THERMOSYPHON PHENOMENON

As an alternate cooling method, the operator should feed the PHTS & secondary side of SG and induce the TS using the SG.

There is no forced flow in the coolant loop. The driving force is only the coolant density difference between the hot reactor outlet header (ROH) and the cold reactor header (RIH) resulted from the heat transfer in the SGs(Fig 3). The better the heat transfer in the SGs, the larger the density head.

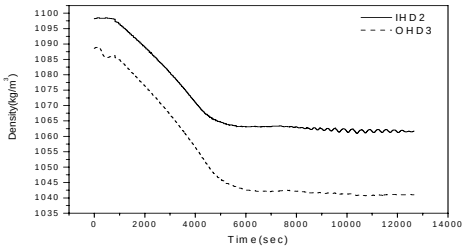

Fig.3 Coolant densities of RIH & ROH due to the TS

The coolant flow per pass which had been decreased to 27kg/s right after the PHTS pump failure was recovered to 45kg/s due to the TS. (Fig.4)

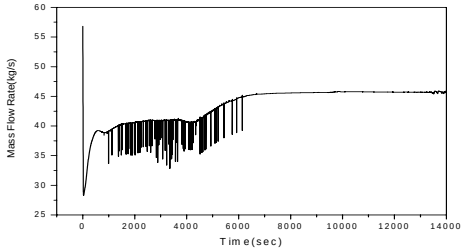

Fig.4 Coolant flow rate due to the TS

4. THE RESULTS OF THERMOSYPHON

And the channel coolant did not boil and fuel sheath temperature was maintained under the safety criteria of 800℃. (Fig.5 and Fig.6) These two figures are the results for the case of secondary side of both SGs per loop were fed.

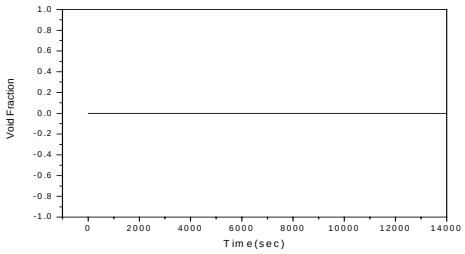

Fig.5 Coolant void fraction during the TS

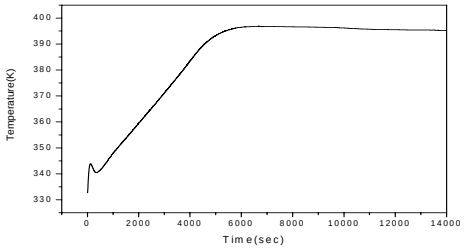

Fig.6 Fuel sheath temperature during the TS

The case of one SG per loop fed brought the different channel flow rate and different fuel sheath temperature between the upstream pass of fed SG and downstream pass of fed SG. However, the void fraction and fuel sheath temperature showed the similar results with the case of both SGs fed and assured the fuel channel integrity. (Fig.7, Fig.8 and Fig.9)

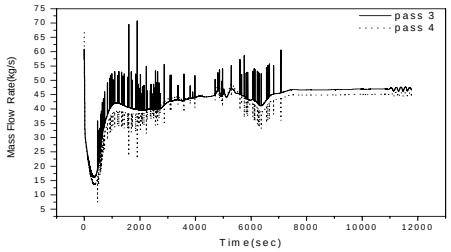

Fig.7 Coolant flow rate during the TS with one SG/loop fed

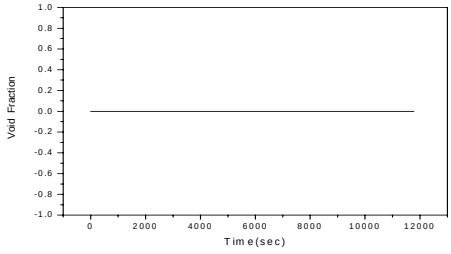

Fig.8 Coolant void fraction during the TS with one SG/loop fed

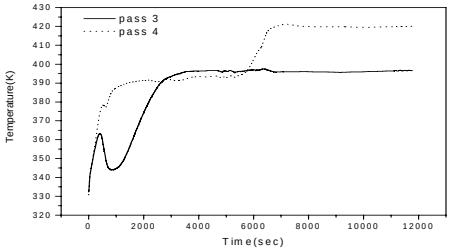

Fig.9 Fuel sheath temperature during the TS with one SG/loop fed

5. CONCLUSION

During the shutdown - partially drained operation of the CANDU reactor, the loss of SDCS will result in the coolant boiling and fuel overheat. However, the alternate decay heat sink of thermosyphon through the SG can prevent the damage of the reactor core. And thermosyphon with the secondary side of only one SG per loop fed is enough to circulate the primary side coolant naturally.

The result of this study was used for the Wolsong NPP PSA.

6. ACKNOWLEDGMENT

This study was done by the support of MOST (Ministry of Science and Technology) in the project “Development of Risk Monitoring Technology for PHWR Using Defense in Depth Method”

7. REFERENCES

1. Son, youngseok et al., Dongui univ., 2005, “Therm al hydraulic accident analysis during the low powe r-shutdown operation at KSNP”
2. ISL.Inc, 2003, “RELAP5/Mod3.3 Code Manual V ol. I&II”
3. M.Y.Ohn, Gnest Inc., 2005, “Thermal hydraulic an alysis methodology following a loss of shutdown cooling”
4. A.K.Nayak et al., Applied Thermal Engineering, 2 005, “ A numerical study of boiling flow instabilit y of a reactor thermosyphon system”
5. M. Y. Ohn, Gnest inc., 2005, “Thermosyphoning in the CANDU Reactor"