Concept of the sodium cooled small fast reactor 4S and safety evaluation

Background

CRIEPI has been developing a small fast reactor (4S) which reduces the maintenance and has a long life core in cooperation with Toshiba Ltd.[*1] The core lifetime of the 4S is 30 years and refueling at the site is not needed. The reactivity feedback coefficients of the core are kept negative during the core lifetime. It can be said that the 4S has a high non-proliferation and high level of safety according to these characteristics. In addition, by introducing the decay heat removal system using natural convection, the 4S has the possibility to apply the multi-purpose application of nuclear energy of the electric power supply, the heat supply, seawater desalting, etc in the regions and islands where the power transmission infrastructure cannot be maintained enough. CRIEPI and Toshiba Ltd. schedule to conduct the pre-review of the 4S for US Nuclear Regulatory Commission (NRC). The safety evaluation of the design base and beyond design base events was shared and performed.

Objectives

Proposal of the 4S reactor concept that adopts the natural cooling decay heat removal systems. Confirmation that the 4S satisfies the safety requirement of the design criterion at the representative design base events (DBEs). Confirmation of the safety margin at the beyond design event (BDBE).

Principal Results

(1) A new 4S design was proposed as follows: there is a reflector which surrounds the core. At the upper space of the reflector, there are electromagnetic pumps and intermediate heat exchanger. The reactor vessel is designed as a tall pool-type to maximize the natural circulation power of the primary coolant (Fig.1). RVACS[*2] and IRACS[*3] that can be operated as the natural cooling system are set up as a decay heat removal system (Fig.2).

(2) (DBEs) Loss of flow event caused by the station black out (Fig.3, Primary and secondary pumps stop, Natural circulation heat removal), Reactivity insertion event caused by the cavity break at the upper part of the reflector. At these events, it was confirmed that the 4S satisfies the safety criterion by using the CERES[*4] code developed in CRIEPI.

(3) (BDBE) In assuming the scram failure at the loss of flow event or at a reactivity insertion event, the coolant at the core is not boiled and the maximum temperature of the fuel and cladding were lower than their breaking temperature.

(4) (Negligible low frequency occurrence event; NLFE) Analyses were performed for the NLFE in the residual risk region using general purpose thermal-hydraulic code. The evaluation was requested by the NRC in the past.

- RVACS performance degradation: The safety evaluation assuming a partial loss of the function of air inlet/outlet channel (The channel blockage or the destruction of the stack was assumed) was requested. It was confirmed that the 4S satisfies the safety criteria in such a hypothetical situation.
- Local fault: Center or side blockage of the core cooling was assumed as a typical local fault event, and three-dimensional thermal hydraulic analyses were performed. Prospects as follows were obtained as a result. The coolant is not boiling, and the coincidence breakage of subassembly caused by the rapid growth of the fuel failure does not occur.

Main Researcher: Yoshihisa Nishi, Ph. D.,
Senior Research Scientist, Advanced Reactor System Sector, Nuclear Technology Research Laboratory

References

Y. Nishi, N. Ueda, T. Koga and H. Matsumiya, “The concept of the sodium cooled small fast reactor 4S and the analyses of the loss of flow events,” CRIEPI Report L06011

S. Nishimura, Y. Nishi, N. Ueda and I. Kinoshita, “Analytical Evaluation of Reactor Coolability for Small Fast Reactor (4S) - Investigation of RVACS Performance under Loss of Stacks Condition-”, CRIEPI Report L05014 (in Japanese)

S. Nishimura and N. Ueda, “Analytical Evaluation of Local Fault in Sodium Cooled Small Fast Reactor (4S)- Preliminary Evaluation of Partial Blockage in Coolant Channel”, CRIEPI Report L06010 (in Japanese)

＊1：Ueda, N., et al, GENES4/ANP2003, Paper1114, Kyoto, JAPAN, 2003.
＊2：Reactor Vessel Auxiliary Cooling System, A system of the air cooling at the outside surface of the guard vessel
＊3：Intermediate Reactor Auxiliary Cooling System, A system of the cooling using the heat exchanger existing in the secondary loop
＊4：Nishi, Y., et al, ICONE-14, ICONE14-89386, Miami, Florida, USA, 2006.

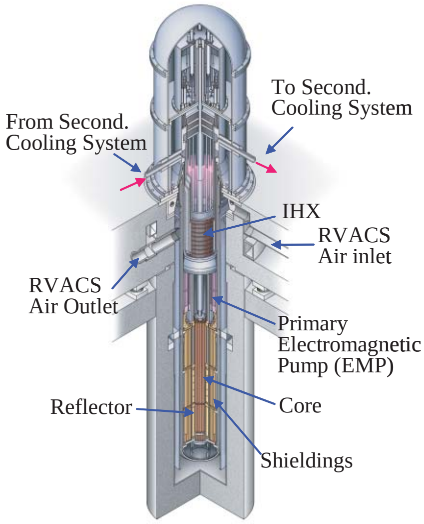


Fig.1 Primary system concept of 4S.

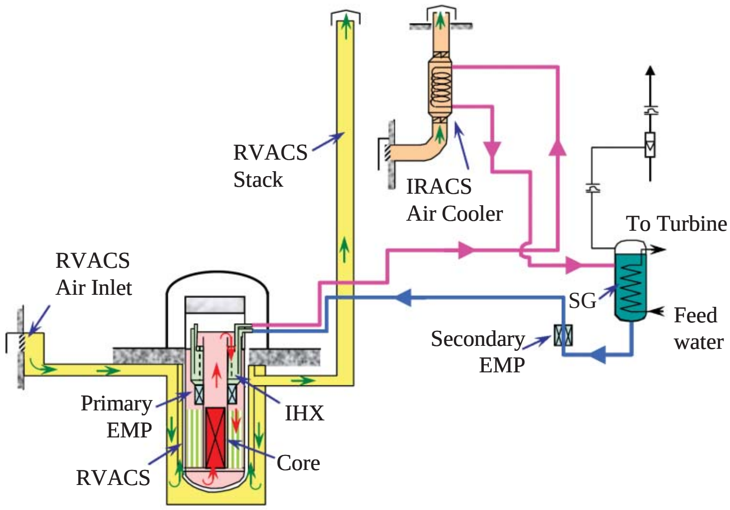
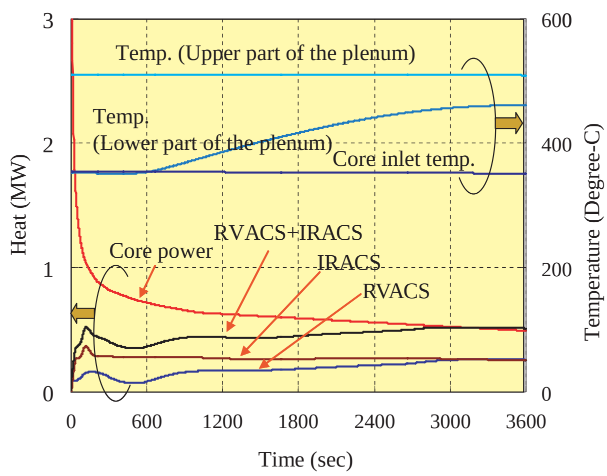
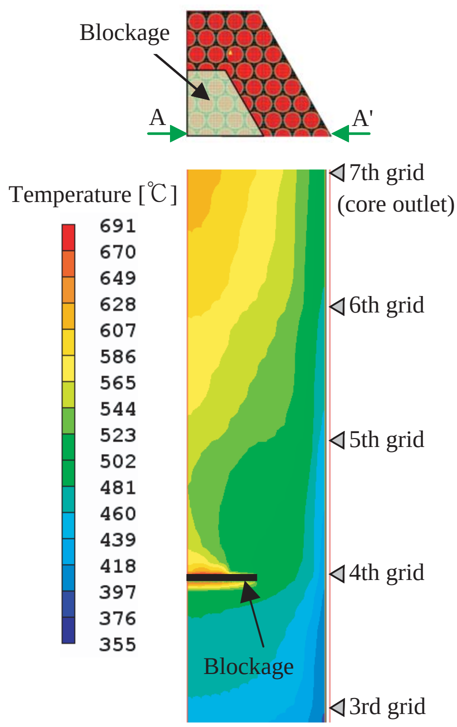


Fig.2 Concept of the cooling system.



Because the thermal capacity of the radial shieldings is large, there is no change in the inlet temperature during 3600 seconds. The total of the decay heat removal rate exceeds the core power before the plenum temperature rises. The capacity of the decay heat removal system is enough.

Fig.3 Temperature change and heat removal rate under the loss of coolant accident caused by the total station blackout



A symmetric 90° sector of fuel subassembly is analytically modeled. Although coolant temperature behind the blockage becomes the highest, the boiling of coolant does not occur.

Fig.4 Coolant temperature distribution at the A-A' vertical section in case of central blockage (24 % blockage).