Long-term Cooling Capability of KALIMER-600 PDRC

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1. Introduction

The safety graded decay heat removal system (SGDHRS) of KALIMER-600 is currently reviewed in the view point of long-term cooling capability. The SGDHRS is one of the main safety functions which must be assured for all operating conditions under design basis events of the plant. The system is operated by natural circulation flow which consists of a DHX (Decay Heat eXchanger) suspended in the cold pool of the primary system, an AHX (Air Heat eXchanger), and piping system connecting two heat exchangers. As a part of the analysis for the long-term cooling capability of the reactor, a LOHS (Loss Of Heat Sink) was analyzed using two types of DHX's using the MARS-LMR system analysis code [1].

2. Analysis of Long-term Cooling effects

KALIMER-600 is a pool type sodium-cooled fast reactor with the thermal power of 1538 MW and it uses metallic fuel of U-TRU-10%Zr for a core [2]. The plant has an inherent safety characteristic owing to the design to have a negative power reactivity coefficient during all operation modes and it has a passive safety characteristic due to the design of a passive decay heat removal circuit (PDRC).

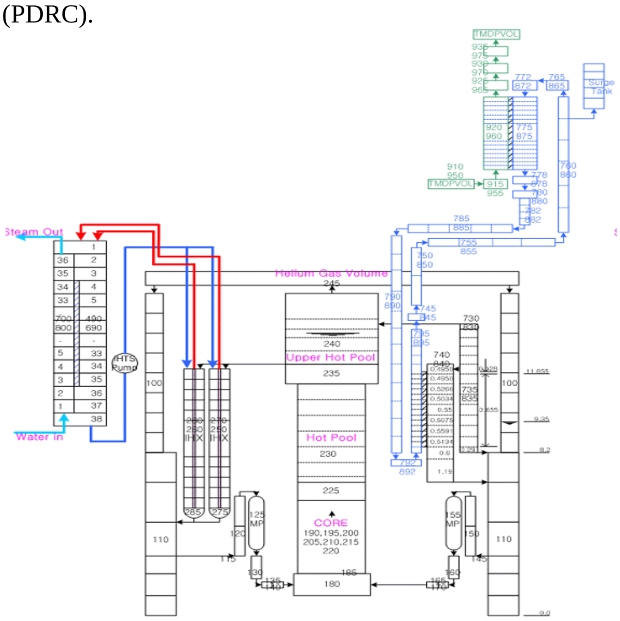

Figure 1. MARS-LMR nodalization for SFR 600 MWe

The figure 1 shows the MARS-LMR nodalization for the system. In the primary system two main pumps take sodium from the pool and discharge it into inlet pipes. Then the flow is entered into the inlet plenum feeding fueled driver subassemblies. The sodium is heated through 7 core regions and mixed in an outlet plenum of the reactor. Then the sodium goes IHX (Intermediate Heat eXchanger) inlet through lower hot pool nodes. In the IHX, the sodium transfers its heat to the sodium of the intermediate loop. The primary sodium leaving the IHX dumps directly back into the cold pool.

The transient calculation results are shown in figures 2 and 3. The LOHS is caused by a loss of feedwater to all SG's or all pumps trip in IHTS (Intermediate Heat Transport System). In this simulation, a loss of feedwater to SG's is assumed to occur at 10 seconds. RPS (reactor protection system) senses slowly the accident because the effect of the event transported to the RPS by way of IHTS. So the reactor scram occurs at the 76.65 seconds. After the pump trip the coolant temperatures go rapidly up and the maximum temperature of hot rod of 690 ℃ is calculated at 252 seconds.

The operation of PDRC's with overflow of hot pool to cold pool is started from about 3,000 seconds. The coolant flow through the global path into DHX, cold pool, and core is activated then. The cold sodium is injected into the inlet plenum and the core temperatures are temporarily dropped, however, the decay power from the reactor is still higher than the heat removed by the PDRC as shown in figure 3.

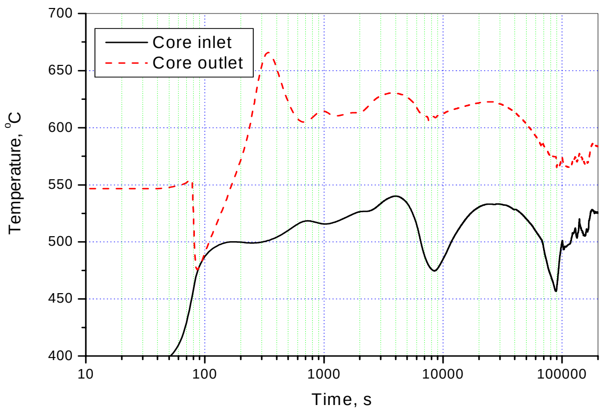

Figure 2. Core I/O temperatures behaviors (Overflow)

The temperatures go down when the heat removal by the PDRC exceeds the core decay power. The temperatures are again decreased around 35,000 seconds. The excess cooling by the PDRC causes the decrease of the level of hot pool and the core outlet temperature is maintained at about 580 ℃ then. The temperature of 580 ℃ is still high to connect other decay heat removal system of non-safety grade.

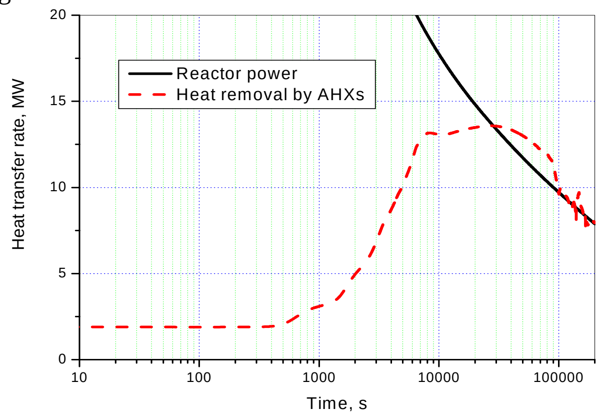

Figure 3. Decay heat removal (Overflow)

To explore an alternative for the final less temperature, we assume that the DHX is submerged into the hot pool. This concept is not required the overflow of hot pool to cold pool whereas the heat loss to atmosphere during a normal operation is more than the former concept because of the submerging DHX. The transient calculation results are shown in figures 4 and 5.

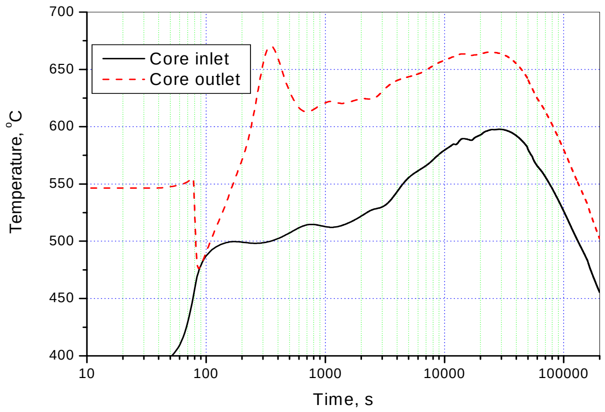

Figure 4. Core I/O temperatures (DHX submerged)

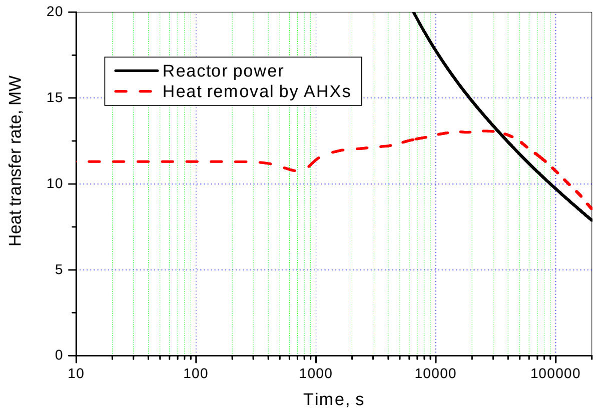

Figure 5. Decay heat removal (DHX submerged)

All behaviors except the decay heat removal rate by PDRC are generally similar to the former results. The temperatures begin to drop when the heat removal by PDRC exceeds the core decay power. The decrease of the core I/O temperatures is continued because the heat removal is more than the heat production in the core after that time.

3. Conclusion

The long-term cooling capability for the PDRC of KALIMER-600 sodium cooled fast reactor is simply investigated through the calculation of the LOHS accident. The current PDRC design satisfies the safety limit of temperature of 700 ℃, however, the design is required more improvements to reach the temperature condition to connect the non-safety graded residual heat removal system for safe shutdown in the accident conditions. Alternatively a submerged DHX concept is proposed and the long term cooling capability is analyzed. The concept is calculated with contentment.

ACKNOWLEDGMENTS

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REFERENCES

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[2] Dohee Hahn et al., "Advanced SFR design concepts and R&D activities", *Nuclear Engineering and Technology*, Vol.41, No.4, 2009.