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# Partial load study for KALIMER in once-through mode of a superheated steam generator

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## 1. Introduction

A power plant is designed for incorporation into a utility's grid system and follows the load demand through the steam generator, intermediate heat exchanger(IHX), from the nuclear core. During the load-following transients, various plant parameters must be controlled to protect the reactor core and other components in the plant. The heat rate is balanced in each of the heat transport systems, and the systems are operated within their design conditions. In order to evaluate the temperature effects at the part load operation conditions, a computer code was developed. 4 types of plant operation concepts were designed, and the results of the calculations are presented in this paper.

## 2. Methods and Results

The heat balance of 1200 MWe KALIMER system at 100% power level is shown in Fig.1. The heat transport and connected systems of the reactors mainly consist of the primary heat transport system(PHTS), intermediate heat transport system(IHTS), steam generator system. The PHTS is a pool based system and transports the generated heat from the core to the IHX's. The heat is transferred to steam generators through the IHTS loops.

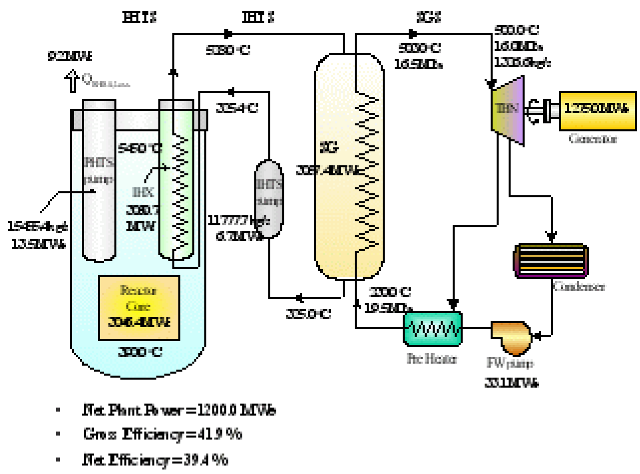


Fig. 1.Heat balance of 1200 MWe KALIMER at rated power.

To control the reactor power level the control system must maintain the required coolant temperatures and coolant flows according to a predetermined temperature-flow vs. power program. This program can be either a constant coolant flow with a temperature increase through the rector proportional to the power or a variable coolant flow with an almost constant temperature variation. There are some constraints to be considered in programming temperature and flow.

- Core inlet temperature should be less than 420 °C for the mechanical integrity of core inlet structures.
- Sodium flow rate should be greater than 50% in the primary system and 35% in the intermediate loop to prevent thermal stratification in the pool and pipes[1]
- Steam temperature at turbine inlet should be constant to minimize thermal load on the turbine.
- Temperature differences on the tube sheet ends of the steam generator and the IHX should be maintained relatively constant
- Feed water temperature should be greater than 150 °C to prevent sodium freezing.

### *2.1 Mathematical Method of solving the problem*

The followings are five equations governing the three heat transport systems. And there are 13 unknowns in these equations.

$$Q = \dot{m}_p C_p (T_{p,h} - T_{p,c})$$
$$Q = \dot{m}_i C_p (T_{i,h} - T_{i,c})$$
$$Q = \dot{m}_{fw} (h(T_s, P_s) - h(P_{fw}, T_{fw}))$$
$$Q = UA_{IHX} \Delta T_{LMTD,IHX}$$
$$Q = UA_{SG} \Delta T_{LMTD,SG}$$

$$Q, T_{p,h}, T_{p,c}, T_{i,h}, T_{i,c}, T_s, P_s, T_{fw}$$
$$\Rightarrow A_{IHX},\ A_{SG},\ \dot{m}_p, \dot{m}_i, \dot{m}_{fw}\ (100\%\ condition)$$

$$A_{IHX},\ A_{SG},\ \dot{m}_p, \dot{m}_i,\ Q, T_s, P_s, T_{fw}$$
$$\Rightarrow \dot{m}_{fw}, T_{p,h}, T_{p,c}, T_{i,h}, T_{i,c}\ \ (part\ load\ condition)$$

For the calculation of 100% condition eight unknowns are given as design parameters, then five unknowns are derived from the above five equations. Two heat transfer area results from the derived five unknowns with other input parameters are used for the calculation of system temperatures during the part load condition.

### *2.2 Results*

To generate the reference data for operation logic design, constant steam temperature(500°C), constant primary flow(100%) and constant intermediate flow(100%) conditions were given.

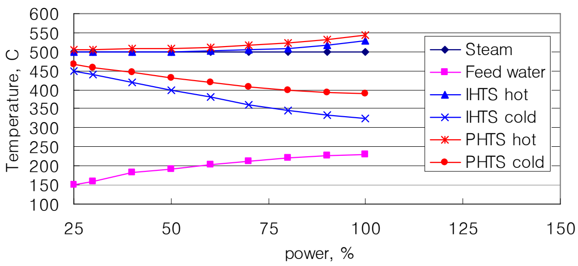


Fig. 2. Temperatures vs. plant load in reference condition

From Fig.2 it can be seen that core inlet temperature at 25% power level reaches 465°C. In order to reduce this temperature it is necessary to decrease primary flow. However there is another limitation in reducing the flow rate because of the possibility of thermal stratification in the primary system due to low flow rate. Some design options were proposed for a partial load study as follows.

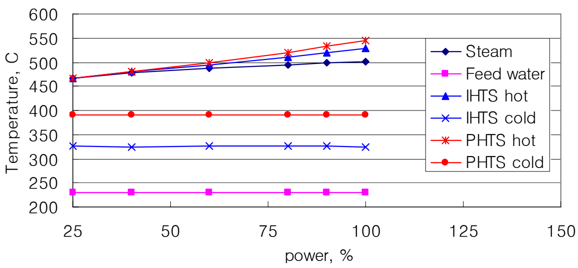


Fig. 3. Temperatures vs. plant load in constant core inlet temperature condition

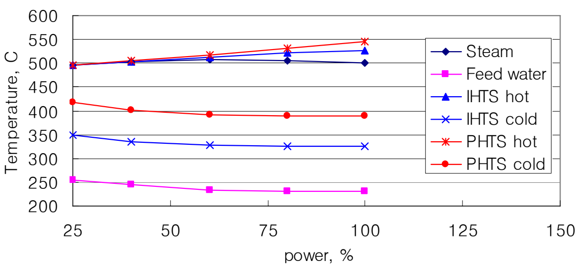


Fig. 4. Temperatures vs. plant load in linear variation of core outlet temperature condition

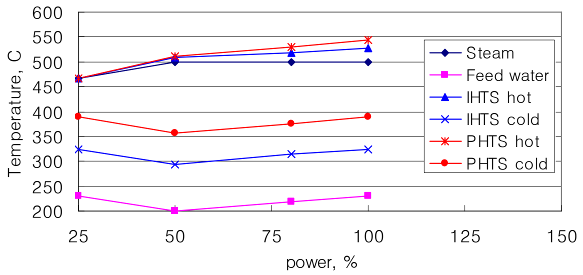


Fig. 5. Temperatures vs. plant load in partially constant steam temperature condition

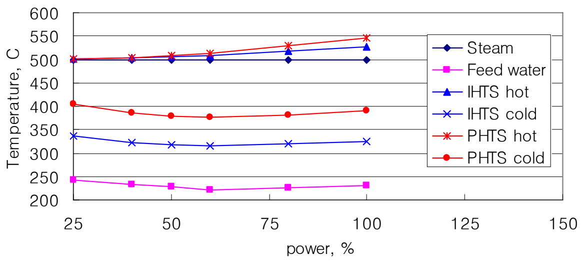


Fig. 6. Temperatures vs. plant load in constant steam temperature condition.

## 3. Conclusions

A computation tool for partial load study has been developed. In the case of constant steam temperature, low primary flow is needed. However there is a possibility of thermal stratification at a low power level. In the case of constant core inlet temperature, though steam temperature decreases as low power level decreases, it is possible to maintain constant cold leg temperature on the IHX and the steam generator's tube sheet. In the case of linear variation of core outlet temperature, steam temperature changes with little overshooting as power level decreases. In the case of partially constant steam temperature, though there is a merit to maintaining constant steam temperature partially, there is change in cold the leg temperature of the systems.

## REFERENCES

[1] Yeon-Sik Kim, Yoon-Sub Sim, Eui-Kwang Kim, Steam Generator Thermal Sizing and Preliminary Plant Operation Logic for KALIMER, Korea Energy Engineering J Vol.8, No.3, p.377-389, 1999.