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Reactor Physics Tests for the Full Power Operation of HANARO

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1. Introduction

The initial criticality of HANARO was achieved on the Feb. 8th of 1995. As HANARO is a unique reactor, there were difficulties to get a license to its full power operation, in which the design power of HANARO is 30 MW. There were two operation license conditions that limited the operation power to 80% of the design power. They were resolved in 2003 and the power ascension tests were conducted for the full power operation. This paper presents the several reactor physics tests for the power ascension to the full power of HANARO.

2. Experiments

There were many tests to confirm the overall performance of HANARO. Several physics parameters such as control rod worth, isothermal temperature defect, power defect, and xenon worth are correlated. These parameters were measured in serial order at the same core condition.

2.1 Control Rod Worth

The reactivity worth of the CARs (Control Absorber Rods) is measured using the reactivity computer which solves the inverse point kinetic equation with the sampled neutron signals coming out of the 3 fission chambers installed for the reactor regulation system of the reactor. As the reactivity has to be measured at the equal position of all CARs and HANARO does not have any reactivity compensators such as boron, the reactivity changes are measured up to 50 mm higher than its critical position. Fig. 1 shows the comparison of measured and calculated integral worth of the CARs.

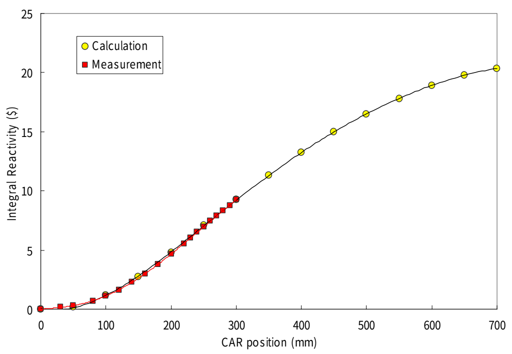

Fig. 1. The control rod worth

2.2 Isothermal Temperature Defect

The isothermal temperature coefficient is composed of the fuel, coolant, and moderator temperature coefficient. Each coefficient cannot be measured separately in HANARO. The isothermal temperature defect is measured by increasing the temperature of all components of the reactor simultaneously, in which the heat source is the kinetic energy of the primary cooling pump. HANARO uses light water as coolant and shielding material. There is light water in the reactor pool and the supplementary pool. It is required to separate each pool to reduce the temperature rising time of the coolant. The lowest temperature is limited by the environmental condition. The required time is dependent on the condition. The highest temperature is 50 ^{o}C, which is a limit of the reactor pool temperature. The coolant temperature and the critical positions of the CARs are required to get the defect. During the time, the reactor is operated automatically at 10 kW power level for precluding the xenon effect. Fig. 2 shows the measured temperature defect.

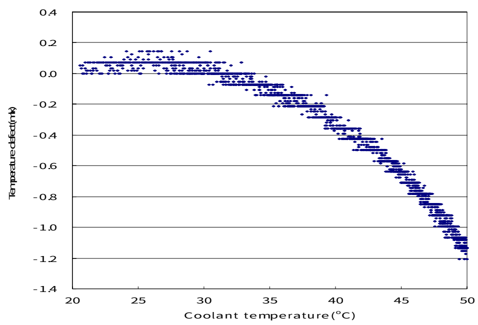

Fig. 2. The measured isothermal temperature defect

2.3 Power Defect

The power defect is the change in reactivity taking place between zero power and full power.

As the reactor power ascends, the temperature rise of the fuel, cladding, coolant and moderator affects the core reactivity. The power rising step is planned in consideration of the restriction of the neutron power log rate to keep it below the shutdown set point. The reactor power is raised from a zero power to 30 MW stepwise as shown in Fig. 3.

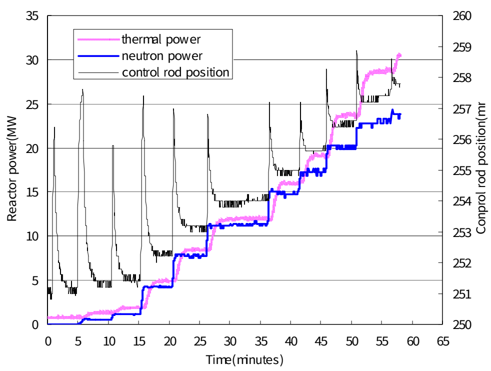

Fig. 3. Power history during the power defect measurement

The data such as the control rod position, neutron and thermal power, and the coolant inlet and outlet temperature are recorded every second. The reactivity worth due to the power rise is calculated from the change of the control rod position. The core inlet and outlet temperature data are used to compare the experimental result with the calculated value of the power defect.

The neutron power approaches the target power rapidly but the thermal power approaches slowly. It takes about 2～3 minutes that the thermal power approaches the target power. The basis of the reactor power is the thermal power when the power is higher than 1 MW and it is the neutron power when the power is less than 1 MW. The measured control rod worth is used to obtain the reactivity worth and the isothermal temperature defect is also used to compensate for the experimental result. The power defect is obtained by a summation of the reactivity worth measured from every power change stepwise. The compensated power defect from 10 kW to 30 MW is -2.19 mk[1].

2.4 Xenon Worth

Xenon is very important in the operation of a research reactor. The xenon worth can be measured from the reactivity change according to the reactor power history. When the control rod positions are measured to get the xenon characteristics, factors that affect the control rod position except xenon are as follows; fuel depletion, temperature change at the core inlet, power defect, and samarium. Fuel depletion effect is compensated for by the long term operation measurement. The effect of a temperature change at the core inlet is obtained from the measurement of the isothermal temperature coefficient. Power defect from a power dependent temperature change at the fuel and coolant should be measured for evaluating the xenon worth, also. Samarium effect is difficult to measure separately. As the samarium effect is small and slow compared to xenon, the calculated value is used.

Equilibrium xenon worth is measured at the core of 30 MW. During the experiment, the integral reactivity worth including the equilibrium xenon load is measured as 42.30 mk. As the reactivity effect by a long term operation is not measured from the abnormal power fluctuation at the core of 30 MW, the fuel depletion effect is replaced by the calculated one, 1.62 mk/FPD. The core burnup for the xenon equilibrium is 106.55 MWD and the fuel depletion effect is 5.78 mk. The reactivity worth from a change of the core temperature is -0.23 mk from the measurement of the isothermal temperature coefficient. Power defect is measured as -2.26 mk. Sm effect is 4.43 mk from the calculation. Finally, the equilibrium xenon worth is measured as 34.58 mk[2].

3. Results and Conclusion

The measured reactor physics parameters are compared with the calculated ones by the current HANARO reactor physics code system. The results are summarized below.

1) The control rod worth is measured using a reactivity computer. The measured and calculated integral worth at 300 mm are 8.48$ (63.60 mk) and 8.35$ (62.63 mk), respectively. The difference is only 1.5%.

2) The measured isothermal temperature defect is negative. The isothermal temperature coefficient is positive at the low temperature and becomes negative above 25 ^{o}C.

3) The measured power defect from 10 kW to 30 MW is -2.54 mk. When the coolant temperature effect is compensated, the power defect is -2.19 mk in which the calculated one is -2.26 mk.

4) The measured equilibrium xenon worth at 30 MW is 34.58 mk, which is lower than the calculated worth, 37.05 mk.

Each measured result agrees well with the calculated one within its specified limit. The current reactor physics code system is verified through the experiments.

Acknowledgements

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References

[1] Choong Sung Lee, et al., “Power Defect Measurement in HANARO,” *Proc. of the Int. Sym. on Research Reactor and Neutron Science*, Daejeon, Korea, April 2005.

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