Evaluation of Natural Circulation Capability in KORI 1 and KORI 3&4

Yong Jin Cho,a Sang Kyoon Lee,a In Goo Kim,a Chong Bae Lee,b
a Korea Institute of Nuclear Safety, P.O.Box 114, Yusong, Daejeon, Korea
b Korea Hydro and Nuclear Power Company, SamsungDong, Kangnam-Gu, Seoul, Korea

1. Introduction

The regulatory requirements (BTP RSB 5-1) applied to RHRS were identified, compare the design of RHRS to that of other operating plants and establish the methodology of natural circulation cooldown according to regulatory requirements. The typical plants, Westinghouse 2-loop (Kori Unit 1) and 3-loop (Kori Unit 3&4) plants have been analyzed the NPP using the above methodology in order to confirm its margin.

2. Analysis Methodology

The methodology used in YGN3&4 was adopted for this study and the brief system status during analysis were listed in Table 1. RELAP5/MOD3 was used to this study. The Kori 1 and Kori 3&4 nodalization were listed in Figure 1 and 2.

Table 1. Assumptions for Major System and Equipment

System/Equipment	Status
Off-site Electrical Power	Unavailable
RCP, CVCS	Unavailable
Pressurizer Pressure, Level, and Heater Control	Unavailable
Steam Bypass Control	Unavailable
Main Feedwater System	Unavailable
CEDM Cooling Fan	Unavailable
Reactor Protection System	Available
Emergency DG, HPSIS	One Train Available
Steam Line PORV	1 PORV per S/G Available
AFWS	1 Train Available
RWST, CST	Available
RCGVS	1 Train Available (If qualified)

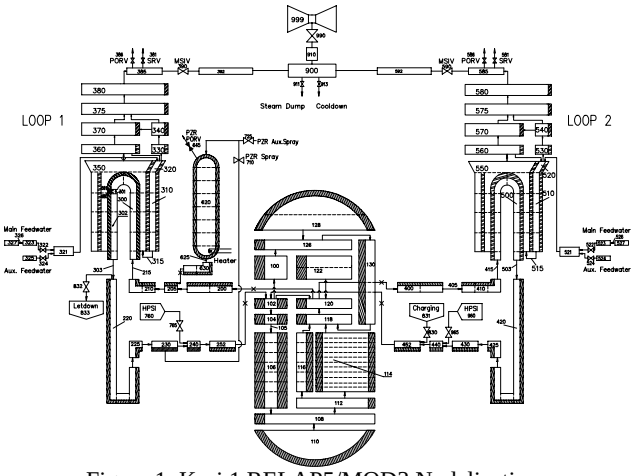

Figure 1. Kori 1 RELAP5/MOD3 Nodalization

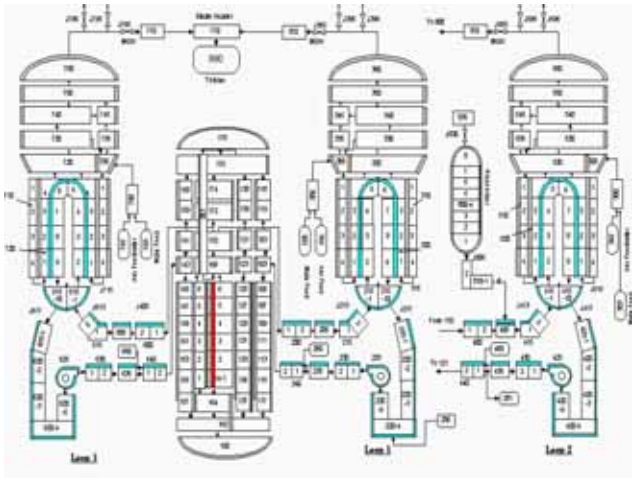

Figure 2. Kori 3&4 RELAP5/MOD3 Nodalization

3. Analysis Results

3.1 Kori 1 without pressurizer PORV

Kori 1 is Westinghouse 2-loop nuclear power plant and has pressurizer PORV and steam generator PORV as a primary and secondary depressurization device. The PORVs are actuated by instrument air and unfortunately, the instrument air system of Kori 1 is not safety grade and the system cannot be actuated by emergency diesel generator. This means that Kori 1 has no devices for depressurization and heat removal.

The analysis results of the case without PORV shows that NSSS can not be depressurized although the coolant temperature of NSSS was reduced below 400^{o}F due to auxiliary feedwater system and steam generator PORVs. In this case, steam generator PORV can be operated by manual. This case shows in Figure 3 and 4.

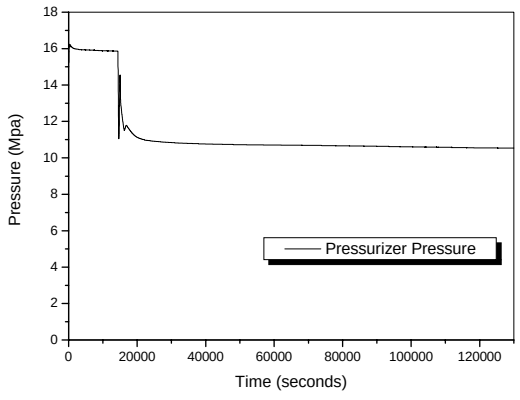

Figure 3. Pressurizer Pressure (Kori 1 w/o PZR PORV)

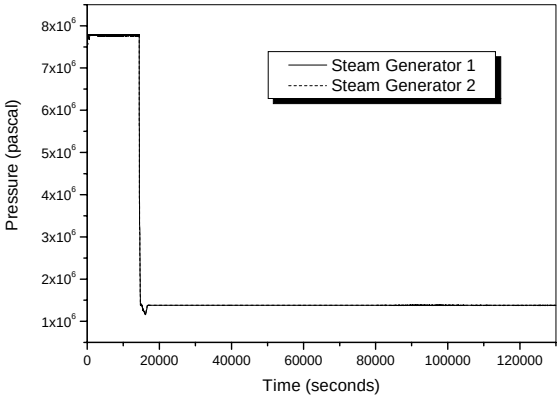

Figure 4. SG Pressure (Kori 1 w/o PZR PORV)

3.2 Kori 1 with pressurizer PORV

In the case that Kori 1 pressurizer PORVs can be operated by operator remotely, the NSSS can be cooled until pressure and temperature of RCS become cold shutdown conditions. The results show in Figure 5 and 6. In view of reactor upper head vapor, vapor fraction of upper head became one and this means that vapor in upper head can threaten continuous natural circulation due to vapor trapping in U bend in the top of steam generator tube. But the slow depressurization of NSSS can prevent the void generation in reactor upper head.

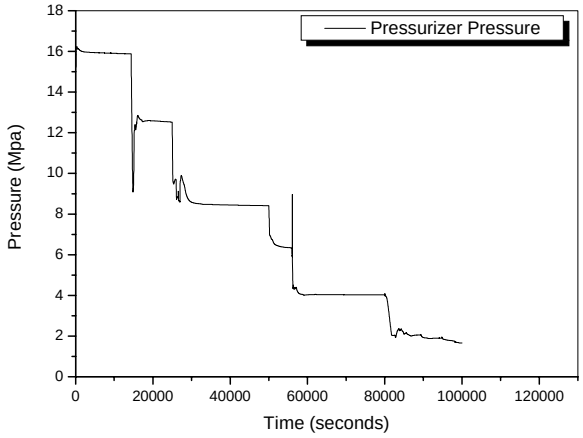

Figure 5. Pressurizer Pressure (Kori 1 w/ PZR PORV)

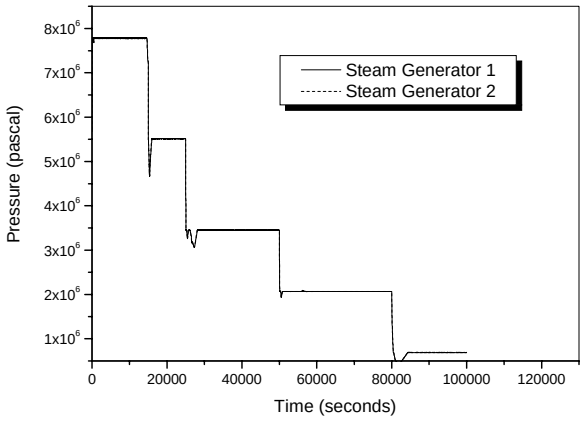

Figure 6. SG Pressure (Kori 1 w/ PZR PORV)

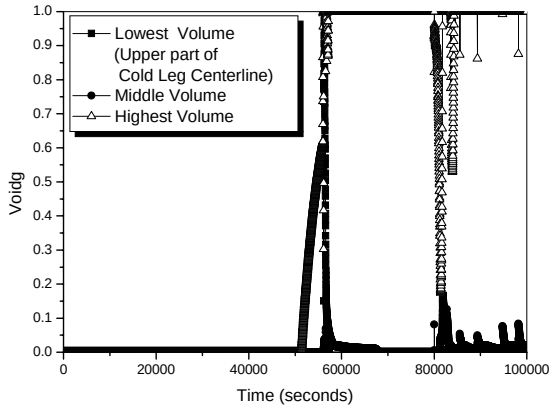

Figure 6. Reactor Upper head Void (Kori 1 w/ PZR PORV)

3.3 Kori 3&4 with PORV

The differences of Kori 3&4 PORVs compared to Kori 1 are that the actuating power source is safety grade electricity. In any plant conditions, pressurizer PORVs and steam generator PORVs can be used for certain purposes. The pressurizer PORVs were used in Kori 3&4 case. As described in Kori 1 with PORV case, this Kori 3&4 results show that successive cooldown was achieved using safety injection, pressurizer PORVs and steam generator PORVs. This results shows in Figure 7 and 8.

4. Conclusions

The natural circulation capability of Westinghouse 2 loop and 3 loop NPPs were evaluated and the following conclusions were made.

1) Kori 1 has no natural circulation capability under current design.
2) Kori 3&4 has natural circulation capability under current design except reactor head vapor removal.
3) If pressurizer and steam generator PORVs actuating power were improved, Kori 1 can have natural circulation capability.
4) Emergency Operating Procedure related to natural circulation should be improved in order to prevent reactor vessel upper head voiding during cooldown and depressurization without RCGVS (Reactor Coolant Gas Vent System).

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