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Governing Mechanism of LZCS Instability in CANDU-6 Reactor

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1. Introduction

Since the CANDU type nuclear reactor uses natural uranium as its fuel, which means no much room for the excess of extent of reaction, one should use heavy water (D_2O) with a small neutron absorption cross-section and a big scattering cross-section as a moderator and a coolant, and overmoderate the reactor before operating it. Thus, if light water (H_2O) is inserted into the reactor core, no effects of velocity reduction are produced, but only the effects of neutron absorption (the role of the control rod) are produced. Also, due to the nuclear characteristics of natural uranium (creation of Pu), the reactor locally increases the extent of reaction (power output) after replacing fuel. Thus, a H_2O compartment should be installed in the reactor core to adjust light water's level, thereby controling local power tilt caused by the replacement of reactor fuel. This is referred to as the liquid zone control system (LZCS).

2. Methods and Results

2.1 Instability of LZCS

The instability of LZCS is attributable to light water being stationary at the top of the tube support plate (TSP). This perforated TSP, installed at the 65% of the upper exterior height from the bottom of the compartment, is designed to prevent the vibration of long, narrow tubes (allowing the inflow and outflow of He, H_2O) passing vertically inside the compartment. This perforated plate makes narrow channels, preventing light water coming down and helium gas going up from descending to the bottom of the support plate or emitting via the top, and leaving them accumulated at both the top and bottom of the support. This causes instability of LZCS. Likewise, as shown in Figure 1, only part of light water flowing in at the top goes down to the bottom, and the rest of it accumulates at the tube area.

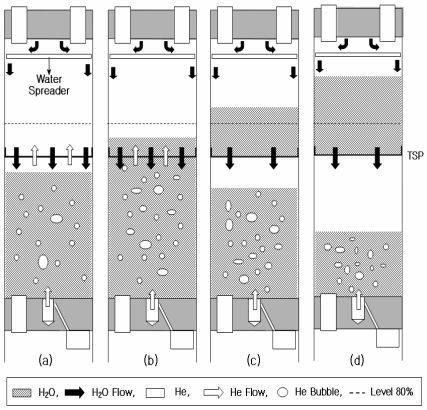

Figure 1 Stage of abnormalcy occurrence in light water and helium within the compartment

2.2 Definition of the mechanism of abnormal phenomenon

The fundamental mechanism of the abnormalcy (light water remains stationary at the top of the support) needs to be defined. This is because the mechanism should be identified so as to accurately forecast the amount of light water flowing down to the bottom of the support, and this is very crucial.

2.3 CCFL(Counter-Current Flow Limit) Model

First, the first thinkable mechanism is the CCFL (counter-current flow limit) of air and H_2O. Likewise, in the support plate where channels are made to be narrow, He and H_2O form counter-current flow, therefore limiting the amount of descending H_2O current. As observed in experiments, if this abnormalcy is created, air does not pass the support plate, but remains stationary at the bottom, and only H_2O forms a descending current flow. The CCFL experiment equation Wallis Correlation goes $\sqrt{j_g^*} + \sqrt{j_l^*} = C$. Here, C has the value of 0.75 ~ 1.0, and since air remains stationary, $j_g^* = 0$ and only j_l^* remains.

The theoretical equation provides $j_l^* = j_l \rho_l^{\frac{1}{2}} [g d_0 (\rho_l - \rho_g)]^{-1/2}$, and ρ_g is very small compared with ρ_l, it can be disregarded. Briefly expressed, it goes $j_l^* = j_l (g d_0)^{-\frac{1}{2}}$.

Here, $j_l = Q_l / A = V_l A_l / A = (1-\alpha) V_l$ and it is superficial velocity.

Calculated from this are the superficial velocity and actual velocity of H_2O passing the support plate as 0.2421 ~ 0.4304m/sec and 0.56 ~ 1.00m/sec, respectively.

These make a great difference with the TSP passage current velocity of 0.260m/sec obtained in the experiment of this research.

3. Conclusion

The next thinkable mechanism is that the light water accumulating at the top of the support plate experiences limitations in its descending current flow (the current flow flowing in below the support plate) passing the support plate due to the difference in pressure between the top and bottom of the support plate and to water levels (water pressure) in the limited number of channels. Of H_2O that simply flows into the top from outside, the amount of H_2O exceeding this limitation will accumulate at the top. Also, at the bottom of the support plate, since the emitted H_2O amount is greater than the amount of H_2O (descending current flow that passed the support plate) that passes the support plate and flows into the bottom, this will reduce as much liquid space as the difference, and fill it with air.

Likewise, this research experimentally measured the pressure difference between the top and bottom of the support plate, the descending current flow and so forth, according to the water pressure of light water (water level) accumulated at the top of the support plate, as a result, this theory was deemed to be valid.

REFERENCES

[1] “Unit 1 Shutdown Event from 05. Jan. 2001, Caused by LZC System Malfunction”, CNE-PROD CERNAVODA
[2] “Zone #1 Operating Data of Wolsong-2 (2003-11-21 ~ 22)”, Korea Hydro and Nuclear Power(KHNP)
[3] “Zone #13 Operating Data of Wolsong-2 (2002-10-30 ~ 31)”, Korea Hydro and Nuclear Power(KHNP)
[4] “Darlington NGS Unit 4 Flux Tilt Events”, COG/AECL CANDU Liquid Zone Control Workshop, Oct. 30-31, 2001
[5] “LZC system instability of Wolsung-2”, Korea Hydro and Nuclear Power(KHNP) Report, 1999
[6] “CANDU 6 Liquid Zone Control Units”, Atomic Energy of Canada Limited(AECL), Jan. 1995
[7] “Wolsung-1 Nuclear Generating Station Liquid Zone Control System”, Atomic Energy of Canada Limited(AECL), Sep. 1979
[8] “Final Safety Analysis Report Wolsung Unit 2, 3 & 4”, Korea Electric Power Corporation(KEPCO)
[9] “Zone Control Assy. 2 Zone Assembly General Arrangement (XX-31751-2-1-GA-E)”, Atomic Energy of Canada Limited(AECL)