The Remedy for the Instability in LZCS of CANDU Reactor

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1. Introduction

The instability of Liquid Zone Control System (LZCS) of the CANDU reactor, after refueling the reactor power and water level in upper side zone being out of control for some period, is common problem for the CANDU reactor all over the world. The root cause and the remedy of the instability have not been known even in the Canada. Through a set of simulating experiment, the hydrodynamic mechanism and the cause of the instability were proven.

Also two remedies for the instability were suggested, one is to increase the flow area in the Tube Support Plate (TSP) and the other is to adjust the inflow and outflow of the light water and helium.

The former is adequate for new plant and the latter is for existing plant.

2. LZCS

The Liquid Zone Control System is one of several reactor regulating systems (RRS). Neutron absorption is controlled by varying the light water inventory in the fourteen cylindrical compartments within the reactor. The volumes of demineralized light water in these compartments can be controlled either simultaneously or independently. The pressure of the compartment inside can be kept constantly the He gas upper light water.

The controlled range of reactivity from all compartments empty to all compartments full is about 7mk. There is an outflow of approximately 0.45L/s of water from the bottom of each compartment and a controlled inflow of from 0L/s to 0.9L/s. This permits a maximum reactivity rate of change of approximately 0.1mk/s.

3. Instability

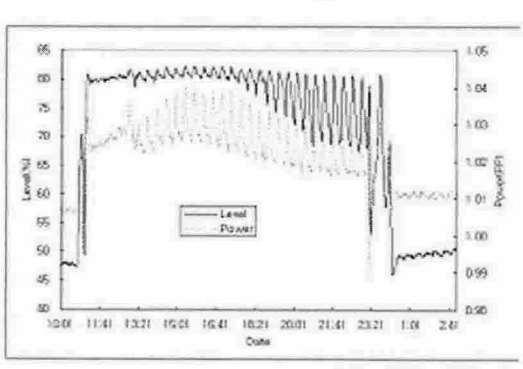

Figure 1. Level and Power after refueling G19 in Wolsung-2 (2002-10-30 10:00 ~ 2002-10-31 02:48)

As show Figure 1, the type of instability is after water level rise suddenly to 80%, it's cycling or sudden drop. And zone power is similar water level. It is on the opposite of the stable operation.

This instability has happened to upper-side zone (# 1, 6, 8, 13) mainly.

4. Experiments and Results

An experimental facility, which almost had same dimension as a real LZCS except the deviation from commercial product, was designed and installed to simulate the LZCS.

In the experiment, helium gas was replaced by air. The inlet and outlet of the helium and water are located in the same manner as the real one. However, instead of the helium and light water flow tubes, three vacant tubes are installed in side the compartment. The tubes contribute just to equalize the equivalent diameter to the real one.

By adjusting the inflow and outflow of water and air, the instability experiment was performed at the water level about 80%. When the water level is above the TSP and some flow conditions are met, the up-flow air can't pass through the water above the TSP, instead the up-flow air accumulated below the plate, which resulted in the separation of light water into two regions, one above the TSP and the other below the TSP. As the time passed by the air bubble enlarged and the water column above the TSP grows and the water column below the TSP shrinks. The shrink and growth of the water column resulted in the transport of the water from the bottom to the top of the compartment. Finally the light water was expelled from the core to the outside of the fuel boundary. A set of experiment was performed to find out the stable conditions of the inlet and outlet flow rate of the water and the air and summarized in Fig 2.

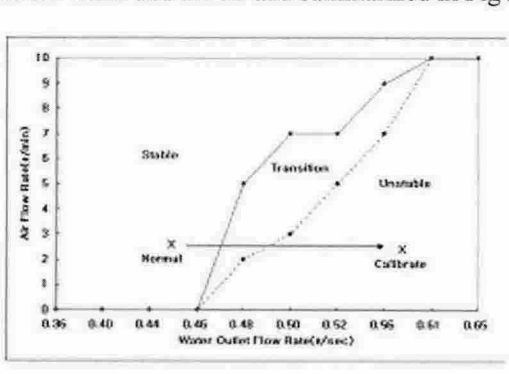

Figure 2. The Stability Map for the Water and Air.

5. The Cause of the Instability

When the water level is over the TSP (about 70~75%), there happen a water hold-up on the TSP. Because the flow area gets narrow in the TSP (See Fig 4), to happen like this phenomenon.

That is, helium from the bottom of compartment doesn't pass through the TSP and is made layer below the TSP. Also, a part of water from the top of compartment doesn't pass through the TSP and becomes hold-up above the TSP.

Therefore, the reactivity worth is attenuated by absence of light water as volume of helium layer. In addition, because a part of hold-up water above the TSP is pushed out of Fuel-boundary, the reactivity worth is attenuated.

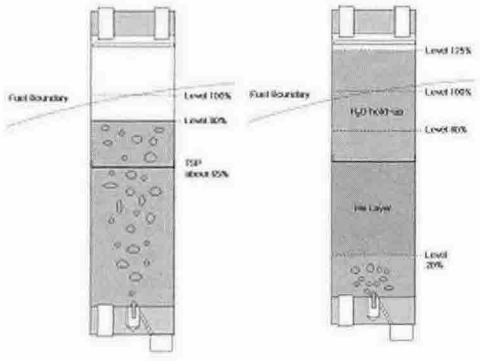

Figure 3. A comparison between stable (left) and unstable (right) situation.

6. The remedy of the Instability

We tried that flow area of helium and water increased 10% at the TSP (In fact, the area of the TSP is decreased) so that helium and water pass through the TSP smoothly.

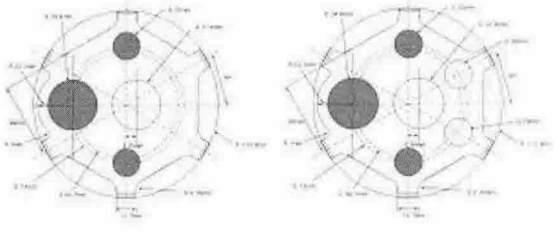

Figure 4. Design of TSP (zone # 1, 6, 8, 13). The 3 black holes are tube and the white spaces are flow area. The left is real one and the right is remedied.

Then, it made a second experiment on the instability at the same condition and method with first experiment. Only, the flow area of the TSP was increased in 10%.

The result of second experiment, the instability didn't happen at the same flow rate of water and air as first experiment.

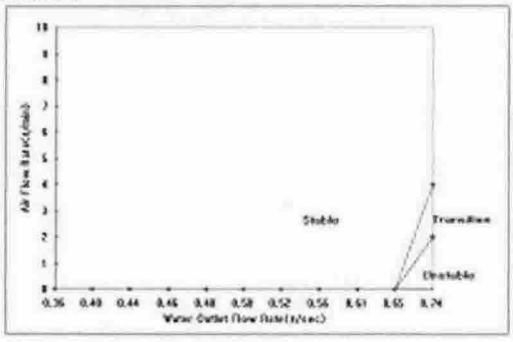

Figure 5. The Stability Map for the Water and Air (The flow area of the TSP was increased in 10%).

7. Conclusions

Tow things can be proposed to remedy the LZCS instability. One is to increase the flow area of the TSP. And the other is to adjust the inflow and outflow rate of the water and helium. The former can increase the water inflow from the TSP and result in preventing the air from the accumulation below TSP (Fig 3). The latter can assure the stable operation of LZCS as shown Fig 2. However, the former remedy may not be adequate for the existing plant since it needs a lot of hardware change. Therefore, this is recommended for the new plant, while the latter for the existing plant since it needs a little hardware and software change without the modification of the components inside calandria.

8. Reference

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