Evaluation of plant status by the fuel range water level indicators of Unit-1

1. Principle of the fuel range water level indicators

A typical fuel range water level indicator used in BWR plants is illustrated in Figure 1. It measures the reactor water level by measuring pressure difference (H_s – H_r) of two instrumentation piping systems (reference condensing water chamber side piping, hereafter described as reference leg, and reactor side piping) while keeping the water head H_s in the reference water head at a certain fixed value.

If the water level in the reference leg decreases due to evaporation, etc., the H_s, which should be constant, is reduced. But, what is measured (or rather observed) is only the pressure difference, it cannot be distinguished whether H_s has decreased or H_r has increased. As a consequence, the apparent reactor water level seems to have increased (Figure 2). Figure 3 illustrates vertical positioning of the fuel range water level indicator in the drywell (D/W). When only the water level in the instrumentation piping on the reference leg decreases, the reactor water level may be indicated as having increased by L_1 (about 7m) in the figure at the maximum. On the contrary, when only the water level in the instrumentation piping on the reactor side decreases, the reactor water level may be indicated as having decreased by L_2 (about 3.3m) in the figure at the maximum. It should be noted that the water levels in the piping outside the D/W will be maintained with little changes, because the ambient temperatures are kept low.

2. Assumptions made in the analysis

The following contradictions have been noticed in the analysis results made public so far (MAAP results on May 23th, 2011).

- Once the reactor water level dropped to the bottom of active fuel (BAF), the water head in the fuel region was considered not to have been formed. But the fuel range water level indicator (Channel-A) showed the level was at the top of active fuel (TAF) +0.45m at 21:30 on March 11th.
- No water was injected thereafter, nevertheless the water level increase was indicated (Figure 4).

These suggest that, when the fuel range reactor water level indicator (Channel-A) was restored at 21:30, the water head in the reference leg had already been decreased (Figure 5-1).

One possibility for the water level decrease in the reference leg can be gaseous leakage from the reactor vessel. If it occurs, steam leaks into the D/W, the D/W atmosphere temperature increases and the water in the piping is heated up. In addition, when the reactor pressure decreases, the saturation temperature of water in the instrumentation piping decreases and thus evaporation is facilitated.

Possible paths of gaseous leakage from the reactor vessel to the D/W are the in-core instrumentation dry tube (Figure 6) or the main steam line flange gasket. The in-core instrumentation dry tube can be damaged when fuel temperatures are elevated. The main steam line flange gasket may lose its airtightness at temperature of about 450 deg C. In the new MAAP analysis, therefore, two gaseous leakages (0.00014m^2 and 0.00136m^2) have been assumed at the timings when the core damage started and when the reactor gas temperature reached 450 deg C.

(Note) Causes of change of water levels indicated on the fuel range water level indicators

The fuel range water level indicator (Channel-A) indicated TAF +0.45m at 21:30 on March 11th; this slightly increased thereafter until 22:20 and reached TAF+0.59m, where it remained until 23:24. It increased again to TAF+1.3m at 00:30 on March 12th and stayed there until about 06:30. The Channel-B indicator, on the other hand, indicated TAF+0.53m at 01:55 on March 12th and stayed there. The fuel range reactor water level indicators (Channel-A and Channel-B) started to decrease at 06:30 on March 12th and thereafter. And after about 12:30 on that day they remained roughly constant. The following items are relevant examinations into the status of the reactor water levels and the fuel range water level indicator piping.

(1) Water levels indicated from 21:30 on March 11th to 00:30 on March 12th

As discussed above, when the fuel range water level indicator (Channel-A) showed TAF+0.45m at 21:30 on March 11th, the actual reactor water level is considered to have been below BAF and therefore the water level in the reference leg is considered to have decreased at that timing (Figure 5-1). The reactor water level increase seen on the chart over this time period would be considered to have been caused by gradually decreasing water in the reference leg by evaporation, since no water was being injected during this time period.

In the MAAP results, fuel melting had already occurred during this time period and the reactor gas temperatures were elevated. Therefore, gaseous leakage from the reactor vessel seems likely to have occurred. If gases leaked and the D/W temperature increased, the water temperature in the reference leg could exceed its saturation temperature and the water level therein could evaporate, thus indicating higher values on the indicator.

The reason has not been identified why the fuel range water level indicator (Channel-A) increased again after 22:20, until then it had remained at a constant value for a while. The water level and saturation temperature of the water in the reference leg could have been changeable due to the changes of the pressure containment vessel (PCV) temperature and reactor pressure, if gaseous leakage had occurred from the reactor vessel.

(2) Water levels indicated from 00:30 to about 06:30 on March 12th

There is a possibility that the water level changes could not have been detected and the indicator value could have stayed at an elevated value. The reasons therefore could be: the water level in the reference leg decreased to the level of PCV penetration, while the reactor water level dropped below BAF and reached the level of the tap position of the reactor side piping (TAF– about 5.5m) (Figure 5-2).

According to the new MAAP results, the reactor vessel ruptured at about 01:50 on March 12th. But the accident progression scenario may depend on the analytical model, because there is a limitation in simulating complicated phenomena like fuel relocations of molten fuel after core damage. Therefore, the analysis results may not mean that the reactor vessel was ruptured during this time period.

It should be noted that the Channel-B fuel range water level indicator showed a lower value than that of Channel-A by about 0.80m. One possible reason for this is the water level decrease in the Channel-B reference leg was less than that of the Channel-A piping due to the larger water inventory in the former piping because its piping routing in the D/W was longer than that of Channel-A by about 3m in the horizontal direction.

(3) Water levels indicated after 06:30 on March 12th

It can be considered that the PCV temperature increased, for instance, because the molten fuel fell on the pedestal due to reactor vessel rupture, the water in the reactor side piping started to evaporate and was evaporated before the D/W penetration (Figure 5-3). If this is true, the pressure difference is increased between the reference leg and reactor side piping, and the water level indicators show decreasing values regardless of the actual reactor water level.

Once the water level changes in the instrumentation piping terminated at about 12:30 on March 12th, constant values might have been indicated thereafter on the water level indicators.

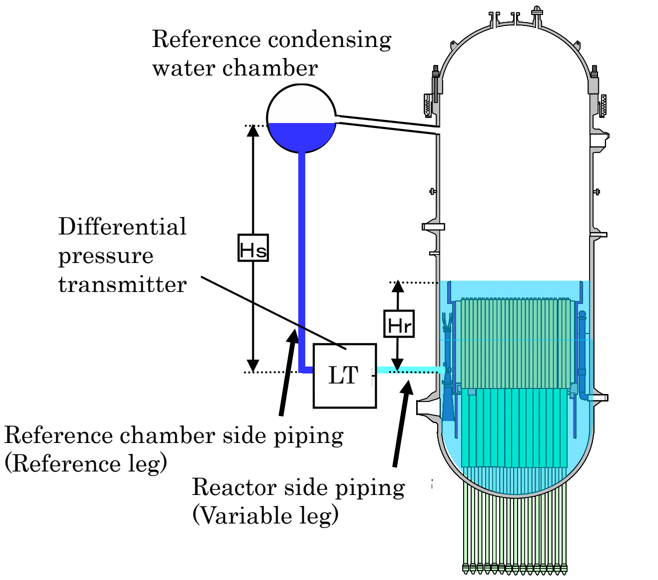

Figure 1 Fuel range water level indicator

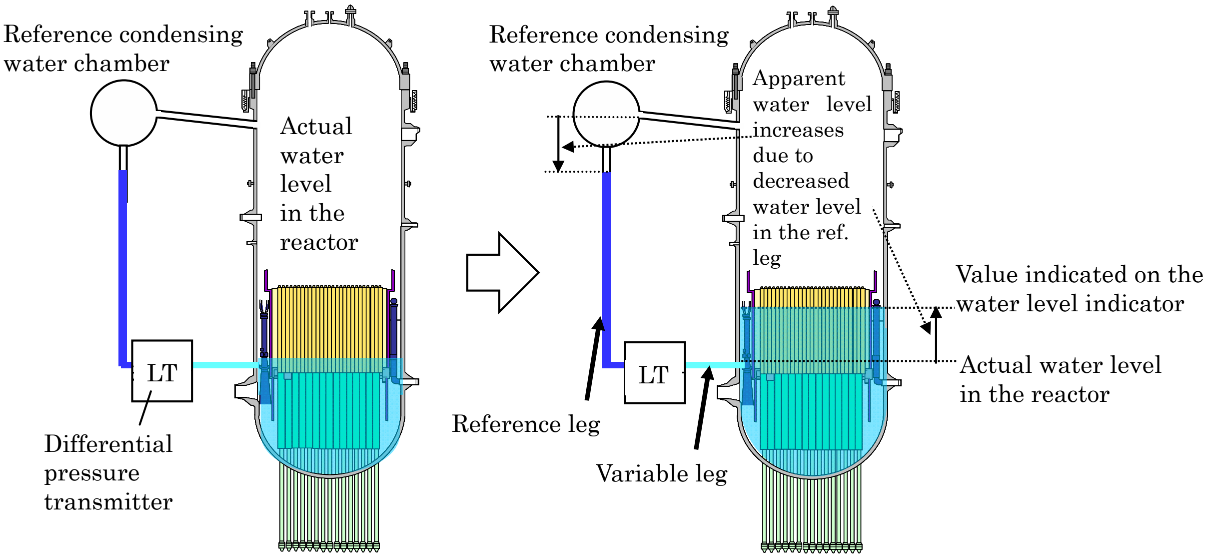

Figure 2 Water level indicated when the water level decreased in the instrumentation piping

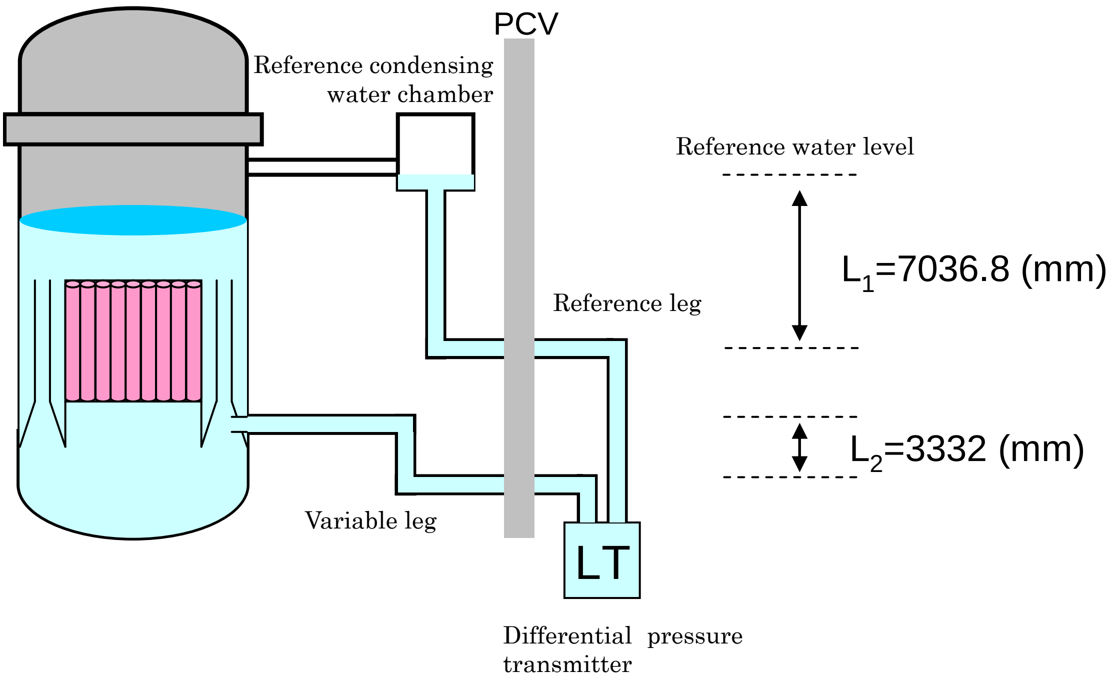

Figure 3 Vertical positioning of fuel range water level indicator in the D/W

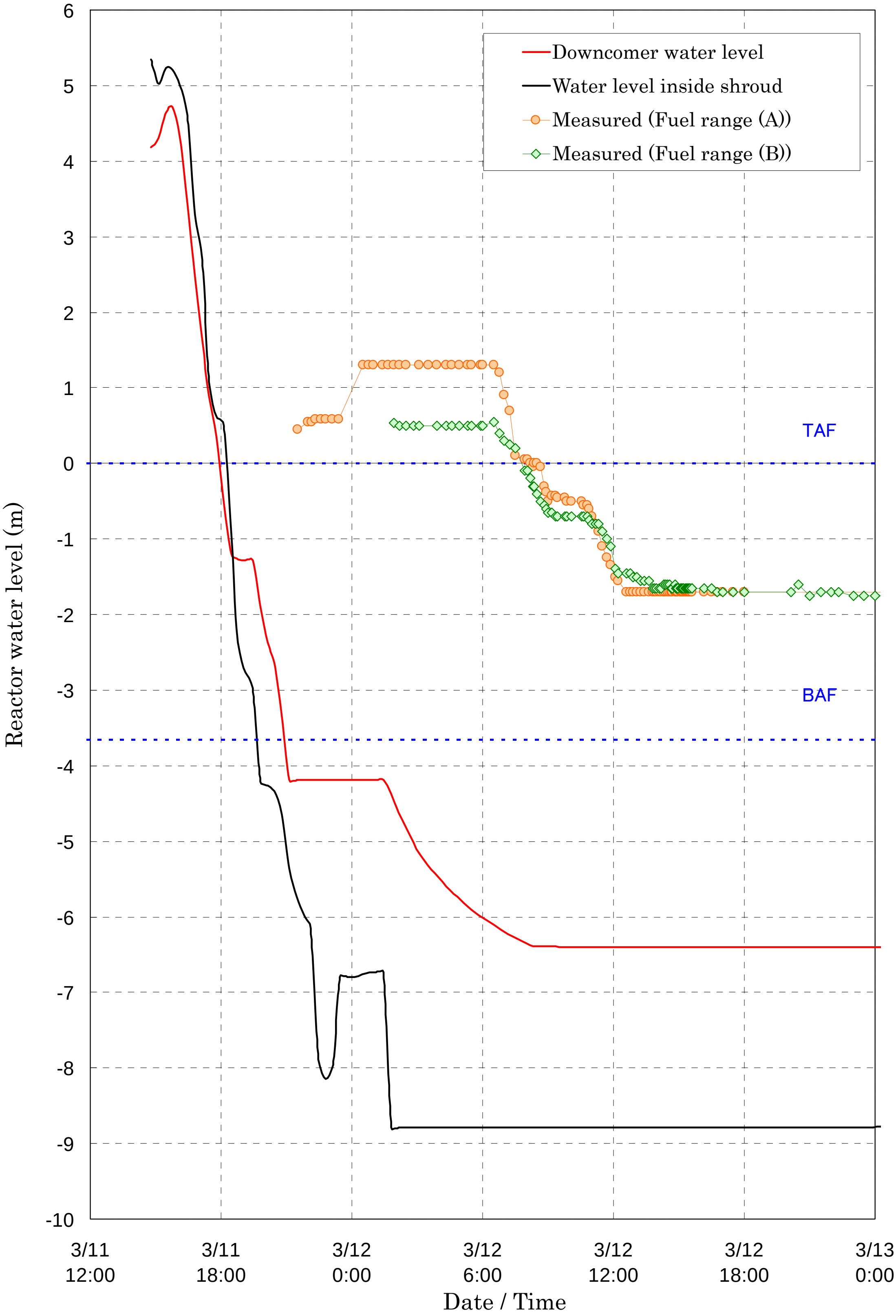

Figure 4 Water level changes on the fuel range reactor water level indicators

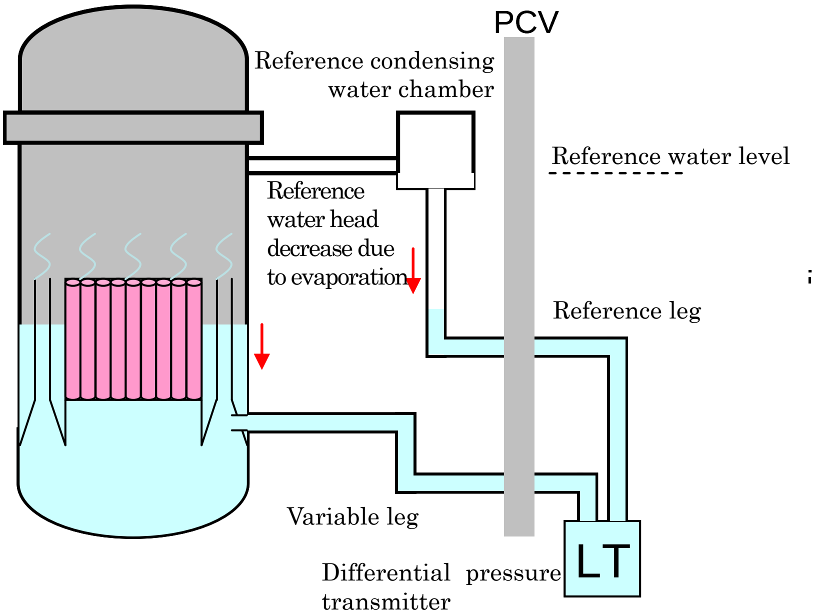

Figure 5-1 Water level changes of the reactor and fuel range water level indicators (from 21:30 on March 11th to about 00:30 on March 12th)

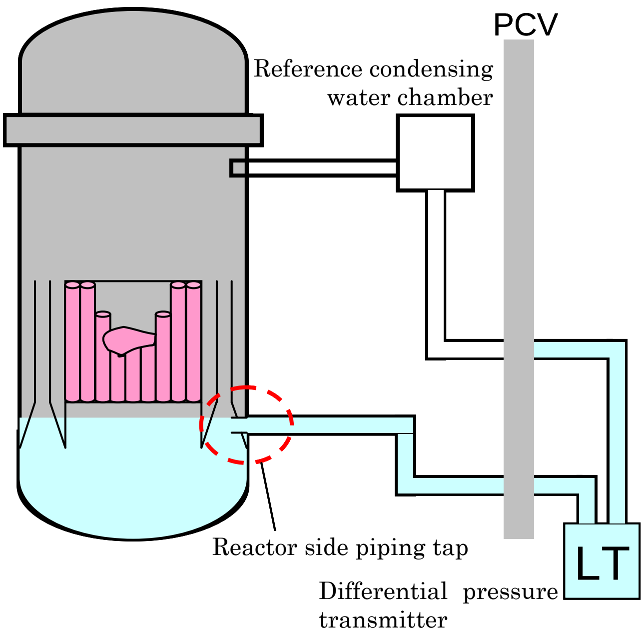

Figure 5-2 Water level changes of the reactor and fuel range water level indicators (from about 00:30 to about 06:30 on March 12th)

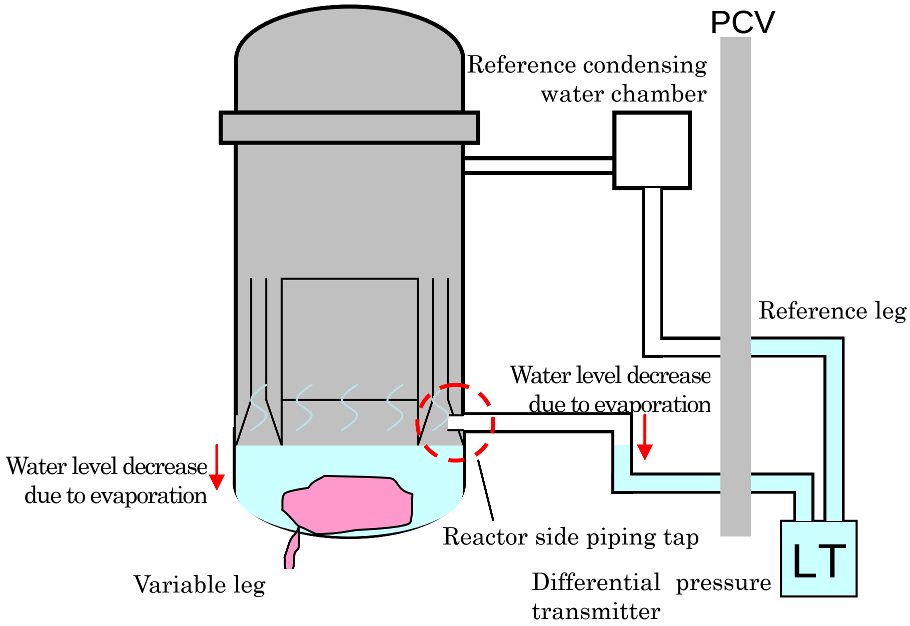

Figure 5-3 Water level changes of the reactor and fuel range water level indicators (after about 06:30 on March 12th)

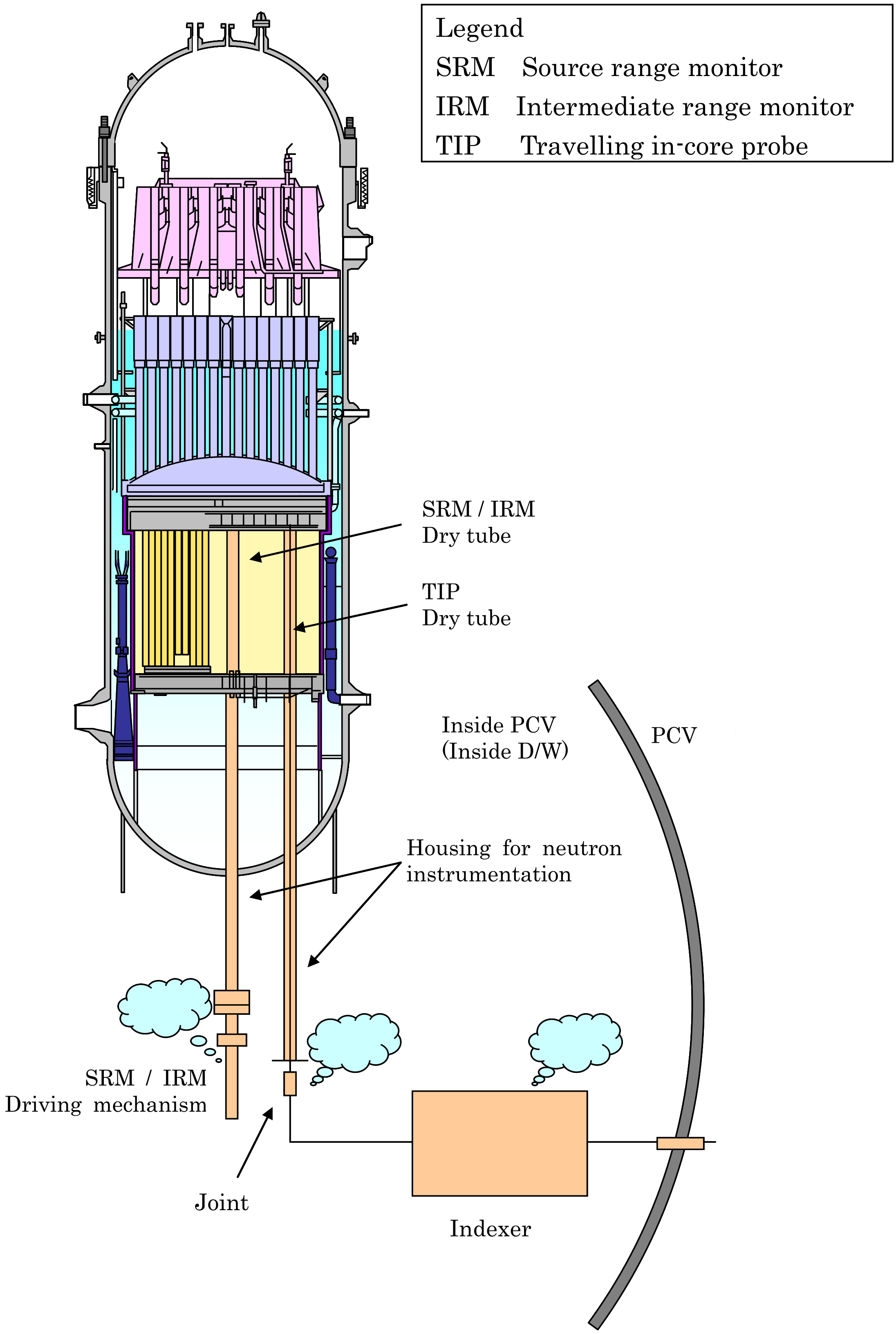

Figure 6 Leak path through the in-core instrumentation system