

Estimation of causes of high contamination of RCW piping at Unit-1

1. Background

In the air dose rate measurements in the reactor building (R/B) and radioactive waste treatment building (Rw/B) of Unit-1, high radiation dose rates were observed around the piping of the reactor building closed cooling water system (RCW system) [1]. This issue is designated as Unit-1/Issue-9.

As the causes of high dose rates, a possibility has been pointed out that, since the highest dose rates were observed around the RCW heat exchangers, the molten fuel dropped to the PCV and damaged RCW piping housed in the pedestal to cool the equipment drain sump, and thus the radioactive materials were transferred into the RCW piping. If this scenario could be clarified, it may be possible to obtain relevant information on the core and PCV conditions. In this document the migration paths of radioactive materials were examined as the cause of high dose rates around the RCW piping in the Unit-1 buildings when the RCW piping had been damaged, and through comparisons with the measured results, the possibility of RCW piping damage was examined.

2. Outline of RCW system

The RCW system supplies cooling water to the auxiliary equipment, which is installed in the PCV drywell (D/W), R/B, Rw/B and turbine building (T/B), and ensures such equipment maintain their functions. As shown in Figure 1, the RCW system is composed of a surge tank, pumps, a heat exchanger, the necessary piping and instrumentation systems, and other equipment. The RCW system is a closed circuit. The cooling water, which exchanges heat with sea water in the RCW heat exchanger, is delivered to each piece of auxiliary equipment via many piping junctions, warmed up by cooling the equipment and returned to the heat exchanger. After being cooled by exchanging heat, it goes back again to the auxiliary equipment.

Refer to Chapter 10 of the Main Body of Progress Report for the usage of O.P.

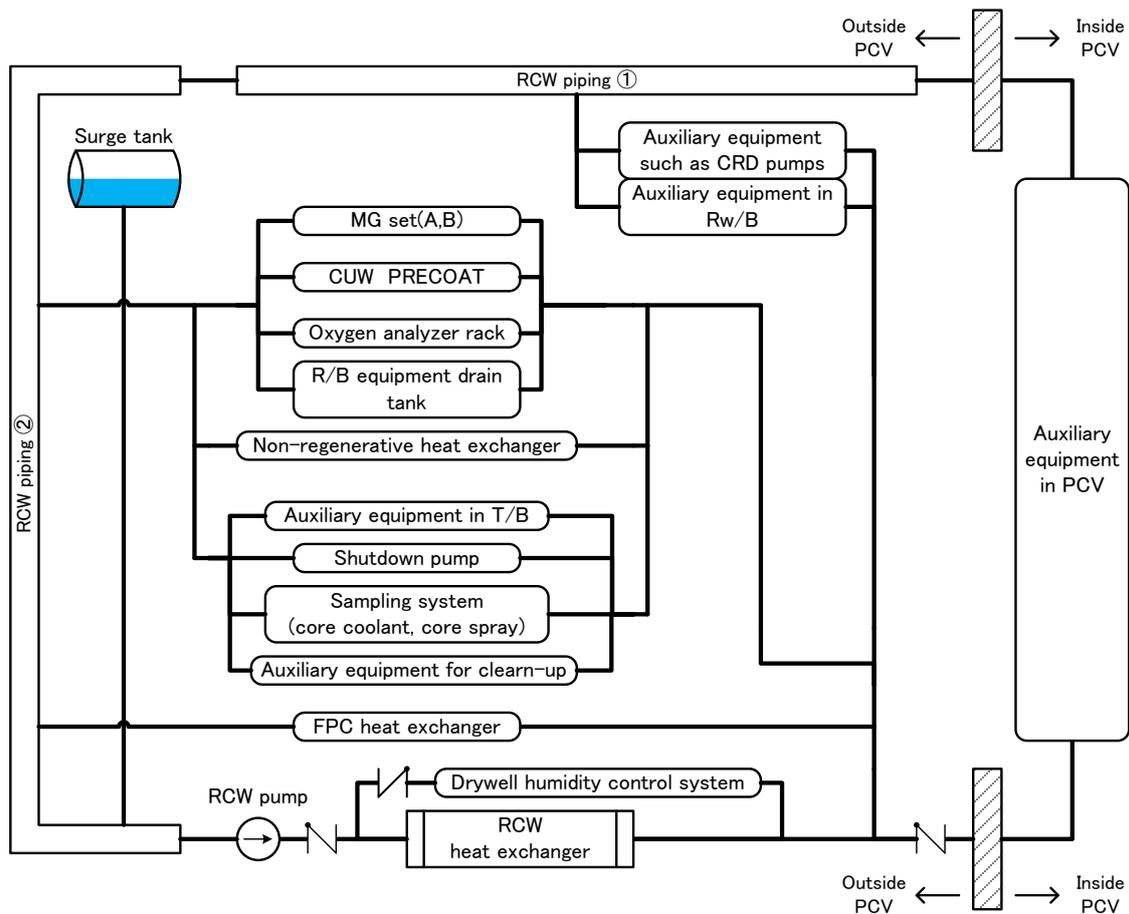


Figure 1 Key components of the RCW system
(Equipment names are shortened in the figure)

3. Air dose rate measured in the R/B and Rw/B of Unit-1

Figure 2 to Figure 6 show the air dose rates measured from April 2011 to February 2014 on Floors 1 to 4 of the R/B and Floor 1 of the Rw/B of Unit-1, which TEPCO has disclosed [1]. High dose rate spots are seen on each floor.

On the R/B Floor 1, high dose rates were measured in the southeast area (Figure 2). For this spot, a correlation with the vent line of the PCV vent (wet well (W/W) vent) is suggested [2]. Therefore, the possibility of high dose rate contamination due to RCW piping damage can be considered as low. Besides the southeast area, high dose rates (120mSv/h) were measured in the vicinity of the dry-well humidity control (DHC) system in the southwest area. The DHC is one piece of auxiliary equipment to be cooled by the RCW system.

On Floor 2, high dose rates were measured in the south area (higher than 1,000mSv/h) and in the west area (30 to 700mSv/h) (Figure 3). An extremely high dose rate was measured in the

south area, where the RCW heat exchanger was installed. In the west area, the MG set oil cooler (A) was installed, which was cooled by the RCW system. In the west area, the highest dose rates were measured in the lower area on the figure (700mSv/h) and the lowest dose rates in the left area on the figure (30mSv/h). This hints at possible impacts from the high dose rates in the vicinity of the RCW heat exchanger in the south area.

On Floor 3, high dose rates were measured in the west area (149mSv/h) (Figure 4). A possible cause is the MG set oil cooler (B) in the area, but other causes may be possible because the air dose rates in the surrounding area were low (3.5 to 40mSv/h). On Floor 4, dose rates in several tens of mSv/h were measured in the west and southwest areas, the highest value being 90mSv/h measured in the southwest area (Figure 5). The RCW surge tank which adjusts the RCW water inventory was installed in this area.

On the R/B Floor 1, a high dose rate (350mSv/h) was measured in the south area (Figure 6). In this area, a recirculating cooler for waste collection filters was installed, which was one piece of equipment to be cooled by the RCW system.

Since the RCW system has no openings toward the RPV or PCV, high dose rates are generally not observed around its piping or its auxiliary cooling equipment, but the above-mentioned air dose radiation measurements showed high dose rates around the RCW piping or its auxiliary cooling equipment in the R/B and R/B of Unit-1.

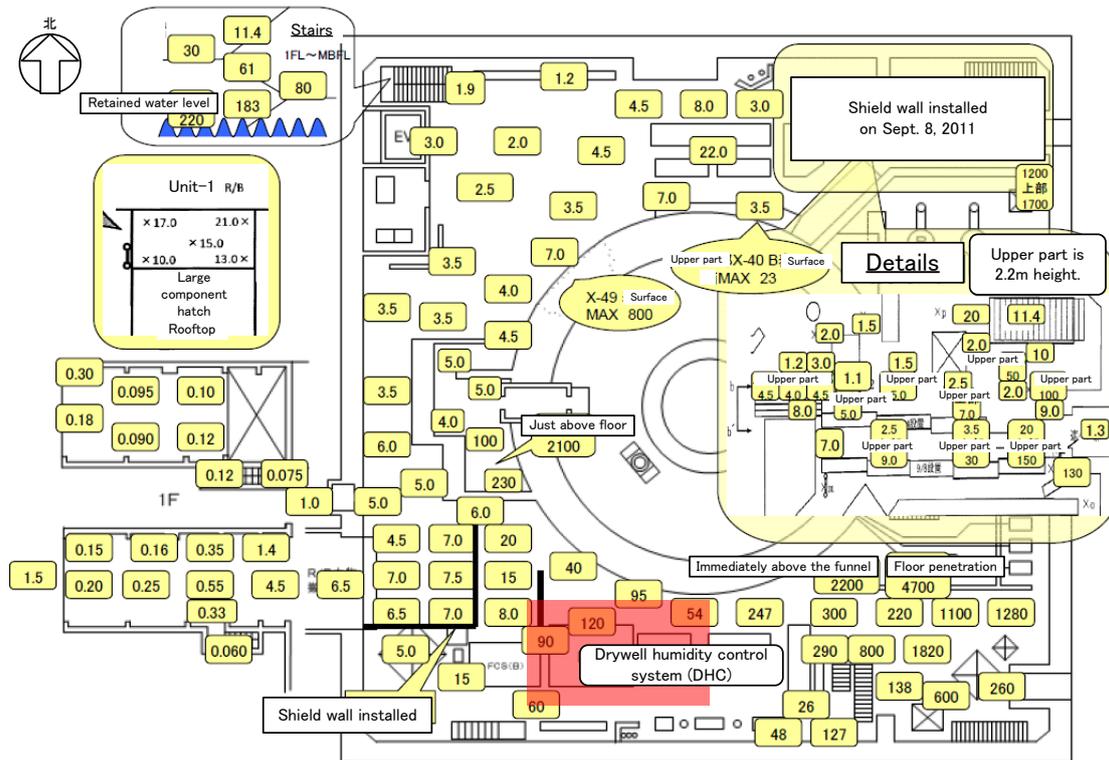


Figure 2 Air dose rates measured on Floor 1 of Unit-1 R/B (mSv/h) [1]

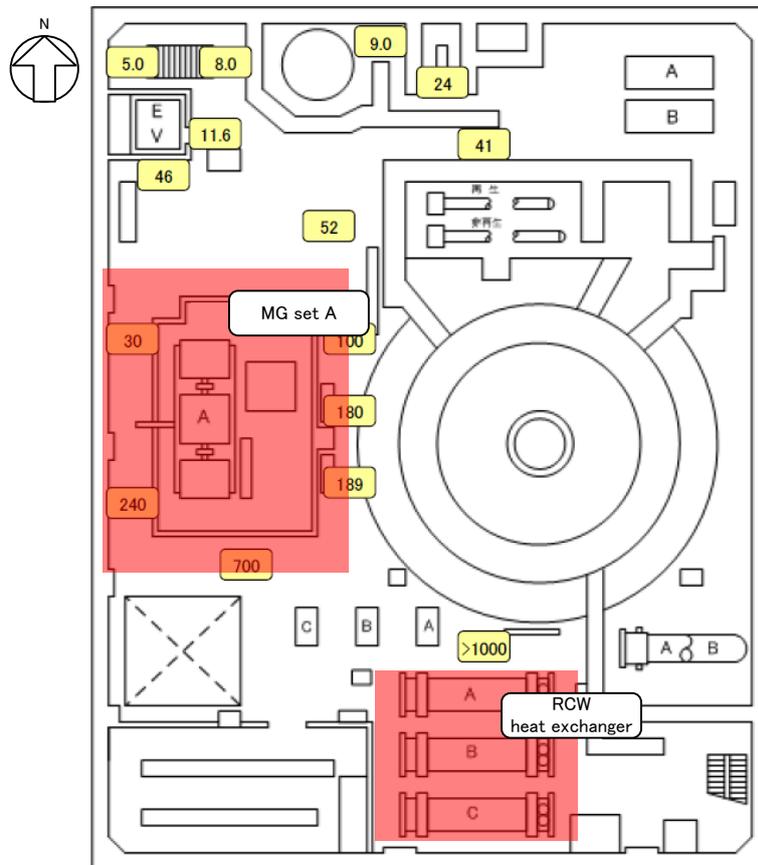


Figure 3 Air dose rates measured on Floor 2 of Unit-1 R/B (mSv/h) [1]

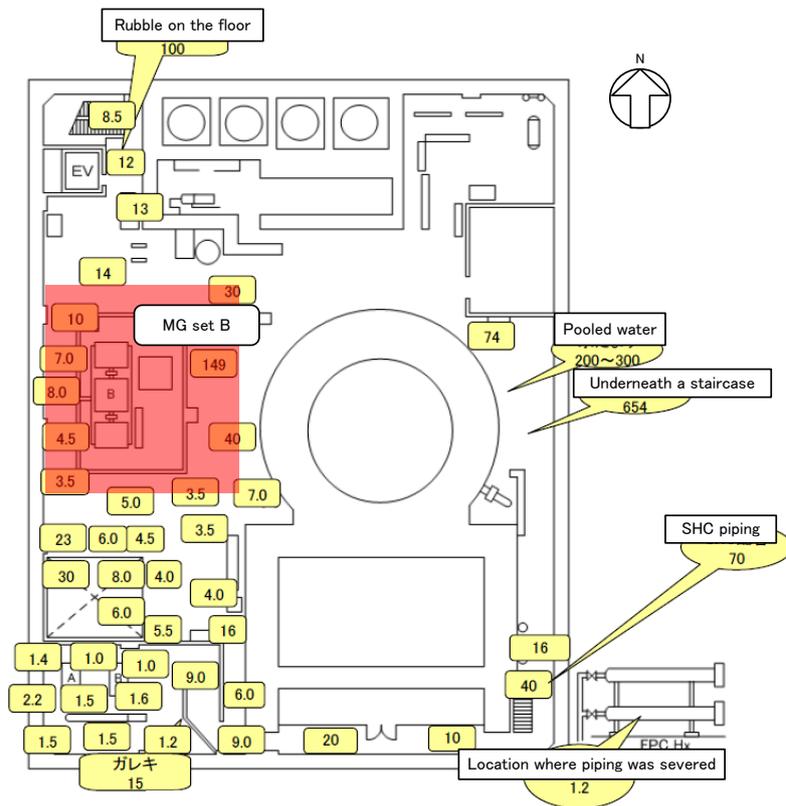


Figure 4 Air dose rates measured on Floor 3 of Unit-1 R/B (mSv/h) [1]

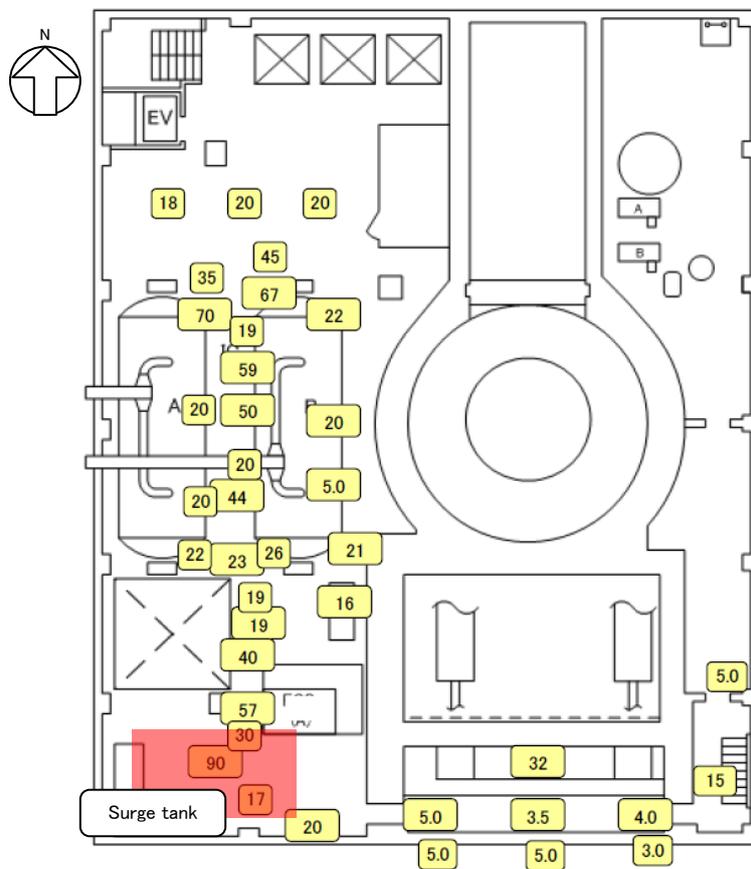


Figure 5 Air dose rates measured on Floor 4 of Unit-1 R/B (mSv/h) [1]

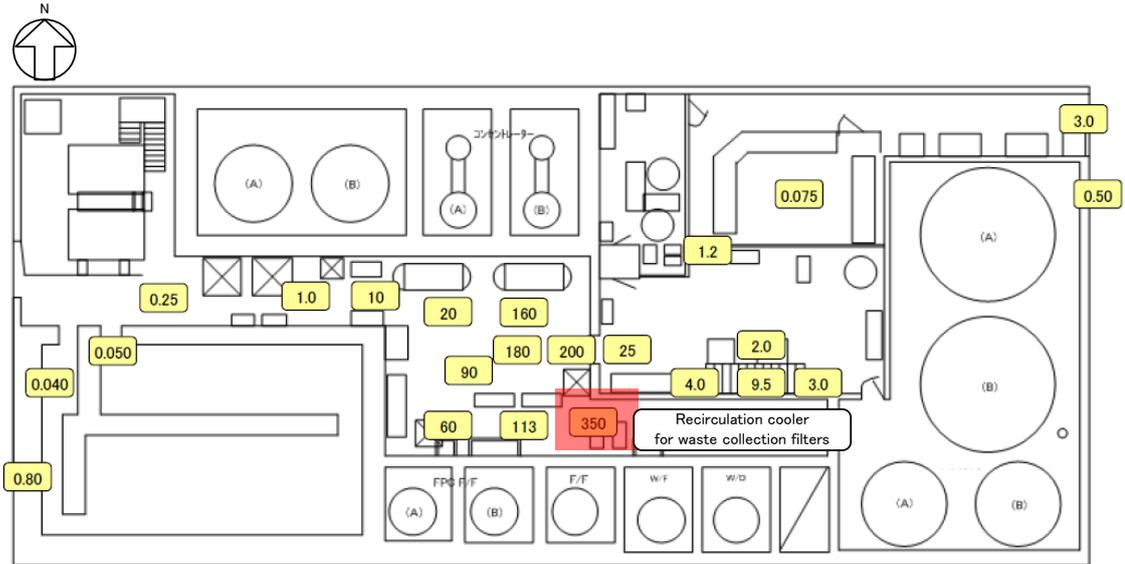


Figure 6 Air dose rates measured on Floor 1 of Unit-1 R/B (mSv/h) [1]

4. Examination of contamination paths of RCW piping

Migration paths of radioactive materials were checked based on an assumption in which the molten fuel of Unit-1, when it had relocated to the PCV pedestal, had damaged the RCW piping in the PCV pedestal for cooling the equipment drain sump.

The RCW system discharged its surge tank vent exhaust directly to the air in the R/B (Figure 7). Therefore, the pressure distribution in the RCW lines is considered to have been in a distribution with the pressure at the surge tank at 1 atmospheric pressure (about 0.1MPa[abs]). On the other hand, it has been confirmed that the PCV pressures of Unit-1 in the accident progression were kept high after the DW pressure of 0.6MPa[abs] had been measured at about 23:50 on March 11th until the PCV wet well venting (W/W venting) was successfully carried out, and then decreased over the period from 14:30 to 14:50 on March 12th when the W/W venting was implemented. Since it is probable that the migration behavior of radioactive materials in the RCW piping depended on the PCV pressures, investigation was made in Sections 4.1 and 4.2 concerning the destination of radioactive materials in the respective cases of high PCV pressures and low PCV pressures.

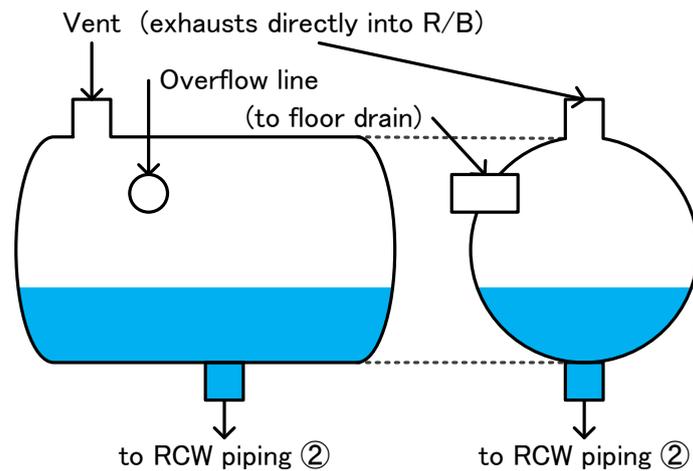


Figure 7 Structure of RCW surge tank (image)

4.1. Examination of migration of radioactive materials while the PCV pressures were high

Radioactive materials migrate from the PCV to the RCW piping, since the PCV pressure at the location of damage (of the RCW piping) is higher than the pressure at the surge tank with the elevation difference and other factors being taken into account. Figure 8 shows the evaluation results of radioactive material migration in the RCW piping for the high PCV pressure situation, based on the RCW piping routes shown in Section 2 (Figure 1). When the RCW piping in the PCV pedestal is damaged, radioactive materials migrate into the RCW piping ① in Figure 8. The other side of the piping (upstream) was excluded in the evaluation, because it has a check valve near the inlet to the PCV and therefore the radioactive migration was considered to be insignificant. The RCW piping ① has three branch lines: the junction to the R/B is located closer to the PCV; the line goes to the CRD pumps and other auxiliary equipment in the Basement Floor 1; and the last line, the RCW main piping ② has a surge tank downstream. None of these three lines would have presented particular difficulties for radioactive materials to migrate through, although it is difficult to show this quantitatively. It should be noted that the high dose rates observed on the R/B Floor 1 could be due to the radioactive materials migrating to the R/B. The situation in the R/B Basement Floor 1 has not yet been investigated; it is the installed location of CRD pumps and other auxiliary equipment.

The RCW piping ② has four branch lines. The line to the surge tank is likely to be at about atmospheric pressure at its end and therefore the radioactive materials could have tended to migrate in the direction of the surge tank. This is consistent with the high dose rates observed

around the surge tank on the R/B Floor 4 (Figure 5). Migration to other lines depends on the distance and paths to the destination equipment or on the elevational relations with the surge tank, which is an easier destination for migration. But all downstream lines return to the heat exchanger outlet line in a closed circuit. Therefore, the line pressures are considered close to the RCW pressures and it can be considered to have been hard for radioactive materials to migrate to these lines. It should be noted that the relatively high dose rates observed in the vicinity of the MG set (A) could have been affected by the RCW heat exchanger, as mentioned in Section 2, and they could have been caused not only by the contamination in the piping.

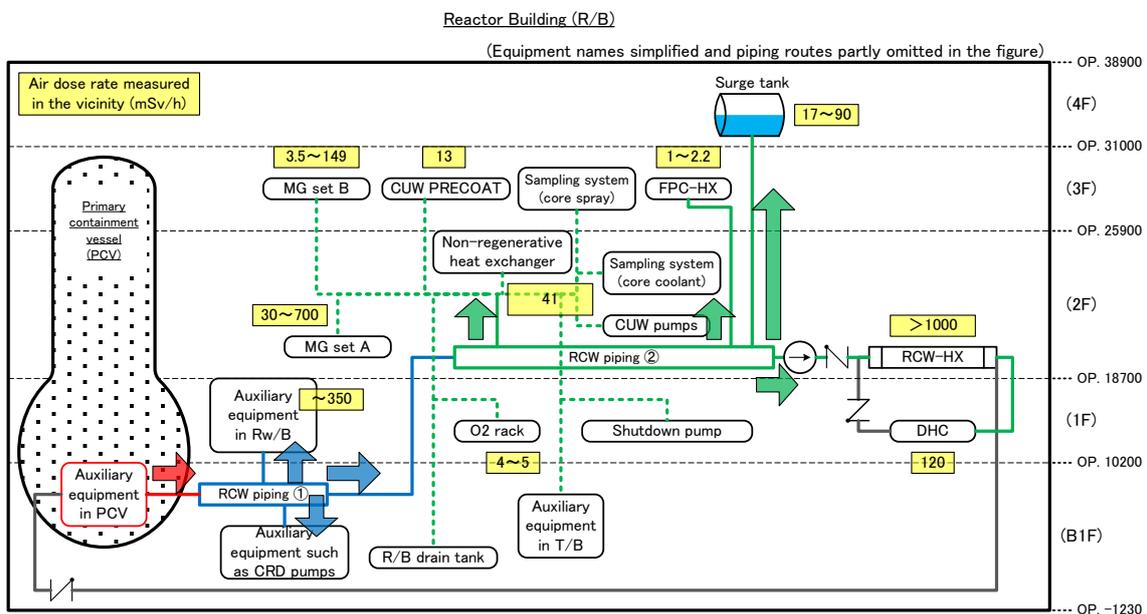


Figure 8 Migration of radioactive materials in the case of high PCV pressures

4.2. Examination of radioactive materials migration after the PCV pressures decreased

At Unit-1, the PCV pressures decreased from 14:30 to 14:50 on March 12th on the occasion of W/W venting. The radioactive materials which migrated to the surge tank when the PCV pressures were high would come down to the level where the pressures balanced with the PCV pressures. Figure 9 shows feasible migration paths for the radioactive materials accumulated in the surge tank.

When the radioactive materials being accumulated in the surge tank migrated to the RCW piping ②, they would proceed to the RCW piping ① (to the left in Figure 9) or the RCW heat exchanger (to the right). The heat exchanger had a large surface area and a large amount of

radioactive materials could be deposited therein. This estimation is consistent with the high dose rates observed around the RCW heat exchanger on R/B Floor 2 (Figure 3). It is also consistent with the high dose rates near DHC on R/B Floor 1 (Figure 2).

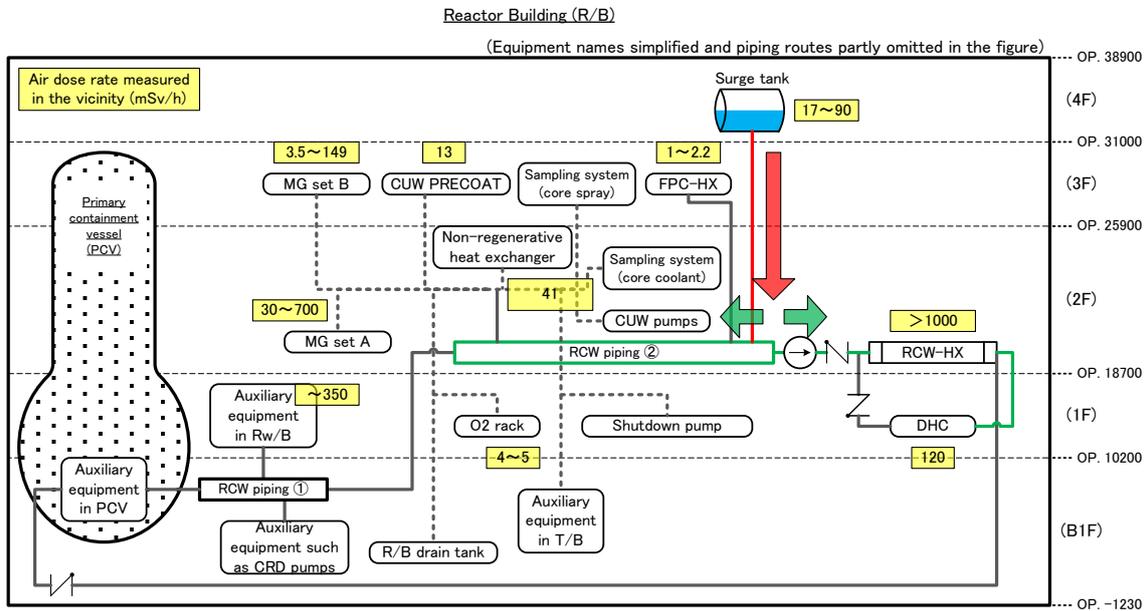


Figure 9 Migration of radioactive materials in the case of low PCV pressures

4.3. Summary of examinations

Migration paths of radioactive materials were reviewed when the RCW piping for cooling the equipment drain sump housed in the PCV pedestal was damaged. RCW piping routes were reviewed, and the correlation with the Unit-1 PCV pressure changes in the process of accident progression was reviewed. The review results were found consistent with the following features noticed in the air dose rate measurements at Unit-1.

- High dose rates near the dry-well humidity control system (DHC) in the southwest area on R/B Floor 1 (the high dose rate in the southeast area was excluded from evaluation, because it came probably from other reasons)
- High dose rates near the RCW heat exchanger in the south area on R/B Floor 2
- High dose rates near the surge tank in the southwest area on R/B Floor 4

From the evaluation above, the cause of high dose rates around the RCW piping noticed in the air dose rate surveys of the Unit-1 R/B has been confirmed as likely to be the earlier estimation of “the RCW piping in the PCV pedestal being damaged by the fallen molten fuel and

the radioactive materials being transferred therein.” Consequently, the likelihood of the molten fuel of Unit-1 having relocated from the reactor pressure vessel to the PCV pedestal as mentioned to date has been endorsed by the current evaluation, too. There remains one item, however, which is not rationally explanatory to date, that is, the information that water was present in the surge tank at the time of a survey done around May 2011. If new information were obtained by a field survey or other means, further examination would become possible.

5. Relationship with measures

At the Kashiwazaki-Kariwa NPS, the RCW system piping that penetrates the PCV has PCV isolation valves (or check valves) installed both inside and outside the PCV at locations close to the PCV penetration (Figure 10). These valves are designed to detect a water level decrease or an increase in D/W pressure and automatically isolate before the RPV is damaged and the molten fuel migrates to the lower D/W (the check valves prevent backflow from inside the PCV to the outside), thereby preventing the spread of contamination to the piping outside the PCV. The isolation valves are powered by a gas turbine generator, an inter-unit power supply, and a power supply truck to improve the reliability of the isolation operation. The D/W sump has a line to transfer sump water outside the PCV, and similar to the RCW system, this line is equipped with isolation valves with automatic isolation functions both inside and outside the PCV penetration. In addition, a corium shield is installed in the lower D/W to prevent molten fuel from entering the sump (Figure 11).

In addition to the above equipment measures, the operational procedure to cool molten fuel dropped into the lower D/W by filling the lower D/W with water and maintaining the water level before the RPV is damaged was in place from before the Fukushima Daiichi NPS accident. In addition to the MUWC system that has been in place at Kashiwazaki-Kariwa NPS Units 6 and 7, a water injection method using fire trucks has been implemented as a means of water injection into the lower D/W to improve the reliability of the lower D/W water injection and reduce the risk of piping damage that could lead to an enlarged contamination pathway.

Therefore, it is considered possible to prevent the spread of contamination within the relevant system due to damage to the equipment used to cool the sump, which is thought to have occurred at Fukushima Daiichi Unit 1.

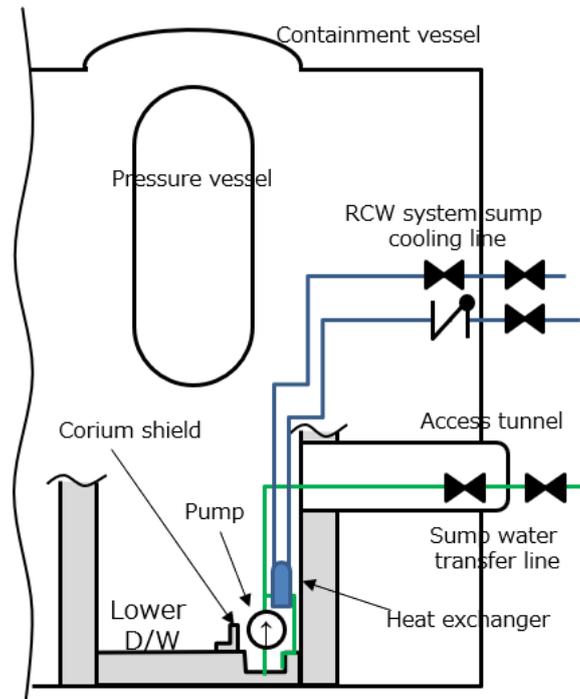


Figure 10 Isolation valves in RCW system and sump water transfer line

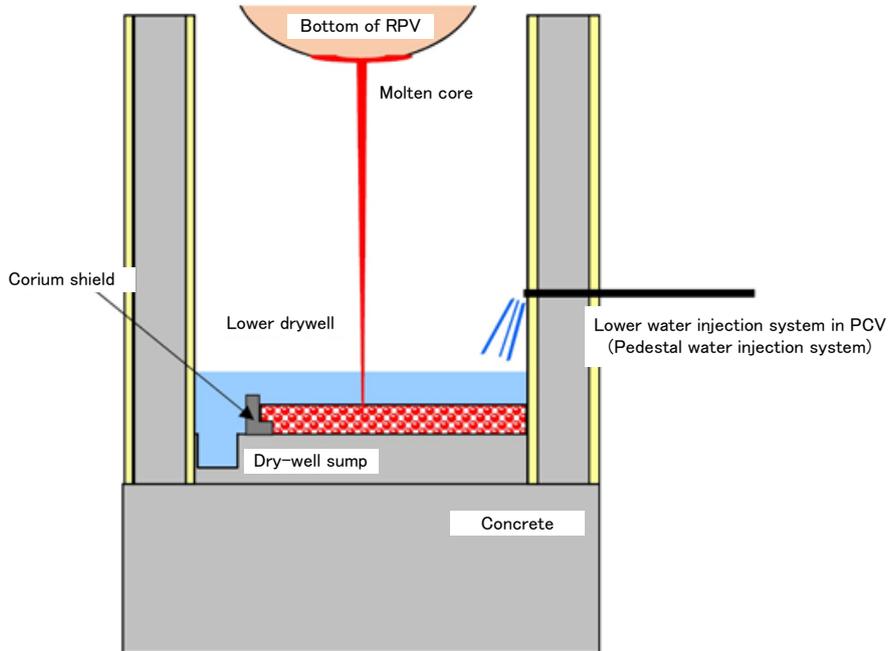


Figure 11 Schematic drawing of the structure to prevent molten fuel from flowing into the dry-well sump

6. Conclusion

Migration of radioactive materials was investigated for the case of damage to the RCW piping in the PCV. The results confirmed the likely causes of high dose rates around the RCW piping, which had been noticed in the air dose rate survey, were due to molten fuel that relocated on the PCV pedestal and damaged the RCW piping, and migration of the radioactive materials in the RCW piping. The results also confirmed it was highly possible that the molten fuel had relocated from the RPV to the PCV.

References

[1] TEPCO, Air dose rates in buildings, <http://www.tepco.co.jp/nu/fukushima-np/f1/surveymap/index-j.html>, March 27th, 2014

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[2] TEPCO, Results of investigation of contamination situations in the south area on the first floor of reactor building of Unit-1, Development of remote decontamination technologies for reactor buildings, National Project, http://www.tepco.co.jp/nu/fukushima-np/handouts/2014/images/handouts_140124_08-j.pdf, January 17th, 2014 (in Japanese)