INTRODUCTION IN FUKUSHIMA WATER LEAK PROBLEM

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The purpose of the paper is to present the water leak problem from Fukushima Daiichi Reactors. A short review of the existing condition which represent interest for developing a water stopper technology is presented. In the end it is recommended to use sealing technology which will use liquid metal.

Keywords: wood’s metal; liquid metal; injection; Fukushima water leak; decommissioning

ACRONYM LIST

TEPCO – Tokyo Electric Power Company;
R&D – Research and Development;
PCV – Primary Containment Vessel;
TMI-2 – Three Mile Island Unit 2;
FY2014 – Fiscal Year 2014;
SFP – Spent Fuel Pool;
RPV – Reactor Pressure Vessel;

1. Introduction

After the accident from Fukushima Daiichi Nuclear Power Plant, the government and TEPCO prepared the “Mid and Long term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station Units 1-4.

The first step of the roadmap, the “steady downward trend in radiation levels” [1] was achieved in July 2011, and in December 2011 the objective of Step 2, “Release of radioactive materials is under control and radiation doses are being significantly held down” was achieved.

After finishing the second step, the actions were drifted from efforts to have a stable reactor to efforts for maintaining the stable state.

The Expert Group for Mid-and-long-Term Action at TEPCO Fukushima Daiichi Nuclear Power Station, which was established by the Japan Atomic Energy Commission, had examined technical challenges and research and development points. The conclusion was that “It will take no more than ten years

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before removal of fuel debris starts. It is estimated that the completion of decommissioning will take at least 30 years” [1].

The Mid and Long term Roadmap [1] is divided in 3 Phases. Below each Phase is briefly explained:

Phase 1: This phase started after the completion of Step 2 and ended with the commencement of the removal of fuel from the spent fuel pool for the Reactor 4 in 18 November 2013. The phase was for intensive preparation for the decommissioning containing preparations for the commencement of fuel removal from the spent fuel pools, research and development activities for fuel debris removal, on-site investigations.

Phase 2: The phase started after the completion of Phase 1 and ends with the start of fuel debris removal for the first unit. The time schedule for Phase 2 is 10 years after completion of Step 2. In this phase many R&D activities and PCV repair operations towards the fuel removal will start.

Phase 3: Will start from the completion of Phase 2 and will end with the completion of decommissioning. The time schedule is 30 – 40 years after the completion of Step 2. In this phase fuel debris removal and other activities up to the completion of decommissioning will be carried out.

One of the biggest problems in the decommissioning of the reactors is the removal of fuel debris. The location and properties of the fuel debris, the location of the damaged parts of the PCVs and pressure vessels and other details are not known, but it is considered that, like Three Mile Island Unit 2 (TMI-2) the safest approach is the removing of fuel debris submerged in water.

In order to remove the debris underwater, it is necessary to stop the water leakage under a severe environment with high doses and limited space towards filling the PCV with water. To this end, it is required to quickly develop technologies/methods of examinations and repair (stopping the water leak) towards stopping the water inside the PCV.

This paper will focus on the water leak problem and will present a possible solution it. In order to investigate and find a suitable solution for the water leak problem, the investigation of the PCV is necessary. The first unit to be investigated was chose to be Unit 2 and the scheduled operations are [1]:

- First half of FY2014: Completion of decontamination to allow the lower part of the PCV of Unit 2 to be investigated;
- First half of FY2015: Completion of decontamination to allow the upper part of PCV to be investigated;
- Second half of FY2019: Completion of the operations to lower the dose levels inside the reactor building.

After the above stages will be completed, it will be possible to have exact information about the water leak and to consider the best solution to stop it.

Nevertheless, the research regarding the stop of water leak should begin before the end of investigations, based on the current known leak points.

2. Main water leak problems

The main water leak problems in Fukushima Reactor are at Drywell, Suppression chamber and Torus room. In order to resolve the problems in these designated areas, special equipment and technique must be developed. In every situation, besides the robot which will do the work, a special technology, to stop the leakage of water from objects of complex shapes, to make water sealing with a durability of 20 years under high dose and to be operated by remote control, must be also developed.

2.1. Drywell

2.1.1. Electrical penetration:

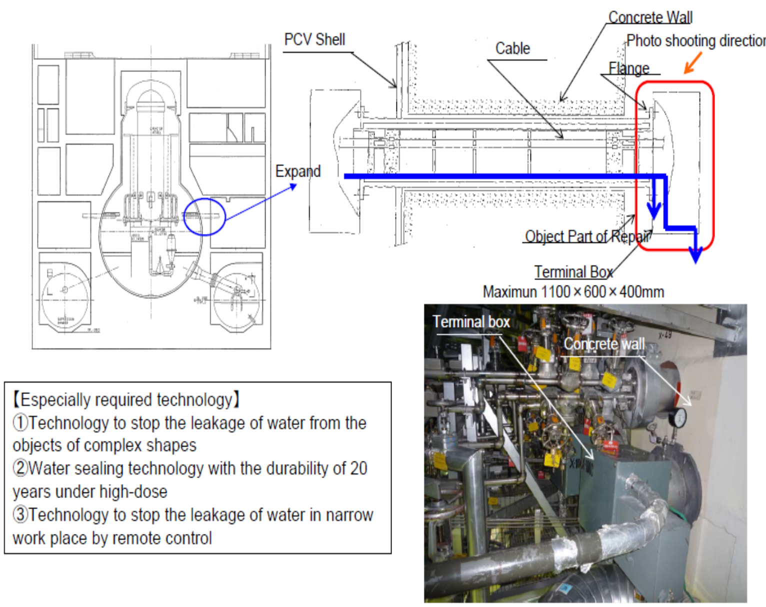


Fig. 1 – Electrical penetration problem [2]

One of the Drywell problems is the electrical penetration. In Fig. 1 it can be observed that water can leak through the terminal box and a solution to seal it must be found before starting to flood the PCV.

2.1.2. Equipment hatch:

The second drywell problem is the equipment hatch. The water leak present there is hard to seal because of the large dimensions of the parts which needs repairs. The Equipment hatch problem is presented in Fig. 2.

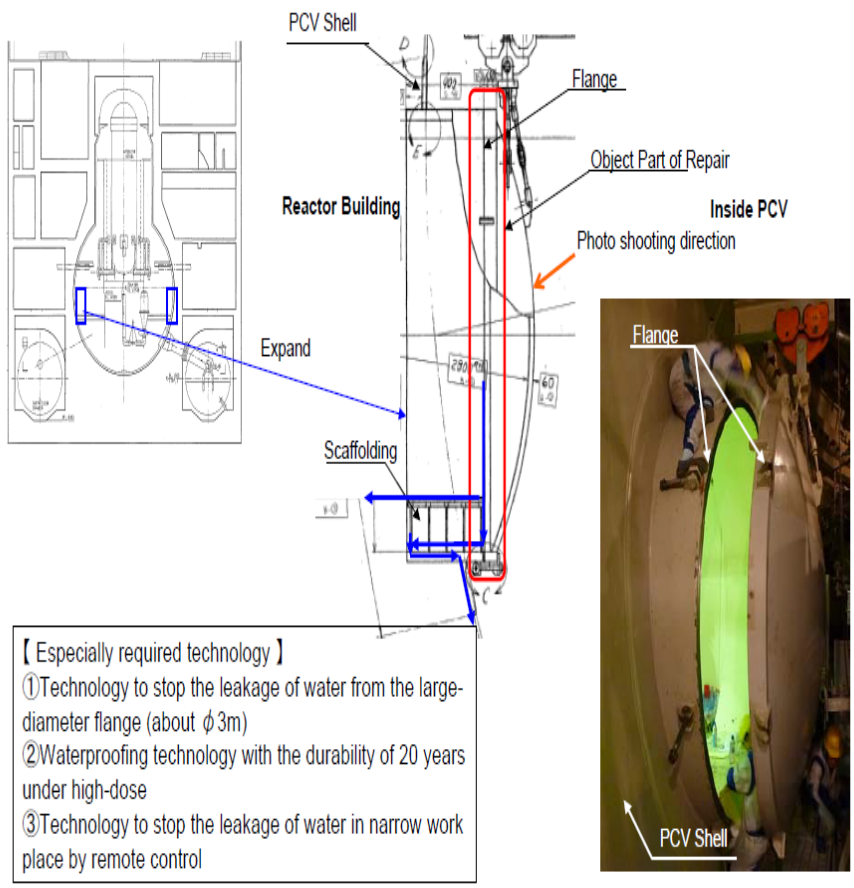
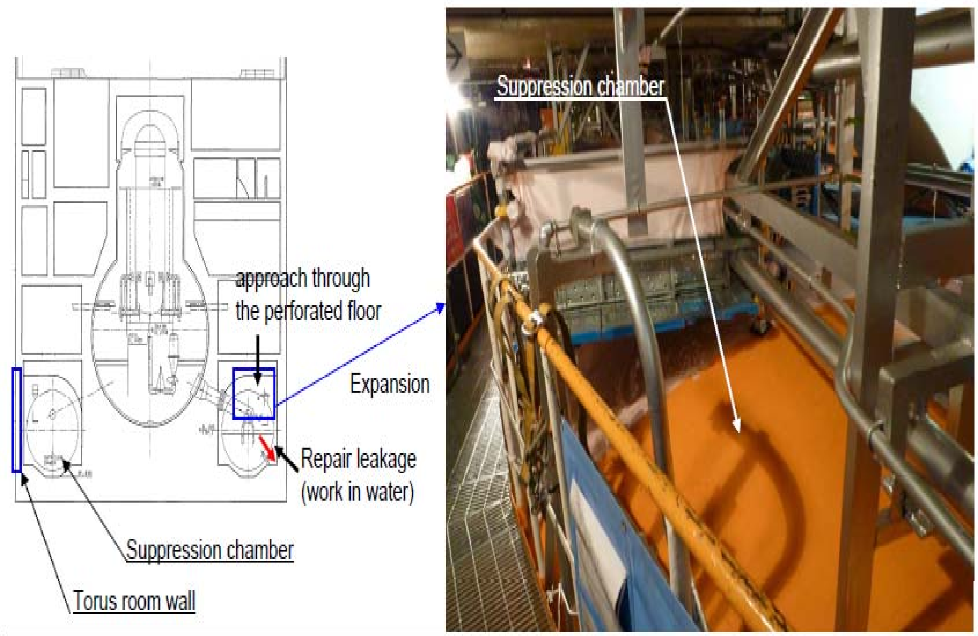


Fig. 2 – Equipment hatch [2]

2.2. Suppression chamber and torus room

A water leak also exists in this part of the reactor. The high radiation dose will make the repairing process very difficult. In order to seal the water leak from this part a special robot must be built. The robot should perforate a concrete wall and a steel plate. After these operations, it must seal the water leak. All the activities must be done in remote control. A schematic of the works that must be performed here is presented below in Fig. 3.



【Especially required technology】
①Technology to perforate the steel plate (20mm thick) and concrete floor (500mm thick) in the remote
②Technology to perforate exactly by remote control in the space where many pipes, frames are exist

【 Especially required technology 】
①Technology to stop the leakage of water in turbid water by remote control
②Water sealing technology with the durability of 20 years under high-dose

Fig. 3 – Suppression chamber and torus room [2]

3. Reactors known status

Another important factor for the water stopping equipment is the status of the 4 reactors. Above a short description of the known position of the corium, the water level, injection water temperature and water temperature inside the reactor is shown. These factors are very important because they can influence the method of water stopping. The water level will indicate if the repair operations will be made under water or not, the temperature of injection water and temperature of water inside the reactor can indicate the minimum – maximum temperature change at which the materials used for reparation should resist.

The main steps toward decommissioning [3] are shown in Fig. no. 4, below. The fuel removal from Reactor 4 were finished at the end of 2014 and preparatory works for removing the fuel from SFP (spent fuel pool) and fuel debris from reactors 1-3 are ongoing.

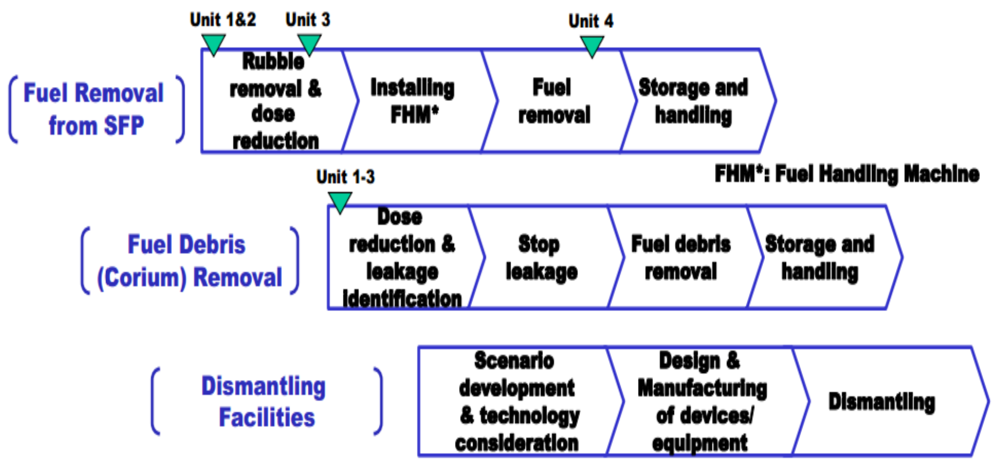


Fig. 4 – Main works and steps toward decommissioning [3]

From Fig. 4 it can be seen that the main work for Units 1-3 is still the dose reduction. This is necessary in order to go to the next steps such as installing the fuel handling machine and start of the fuel removal. In case of Unit no. 4, the fuel removal operations were stopped for two months in order to inspect the crane. The operations were restarted at the beginning of September 2014 and were finished at the end of 2014.

In Fig. 5 the status of the 4 units is briefly shown. The figures present the believed status of the 4 reactors.

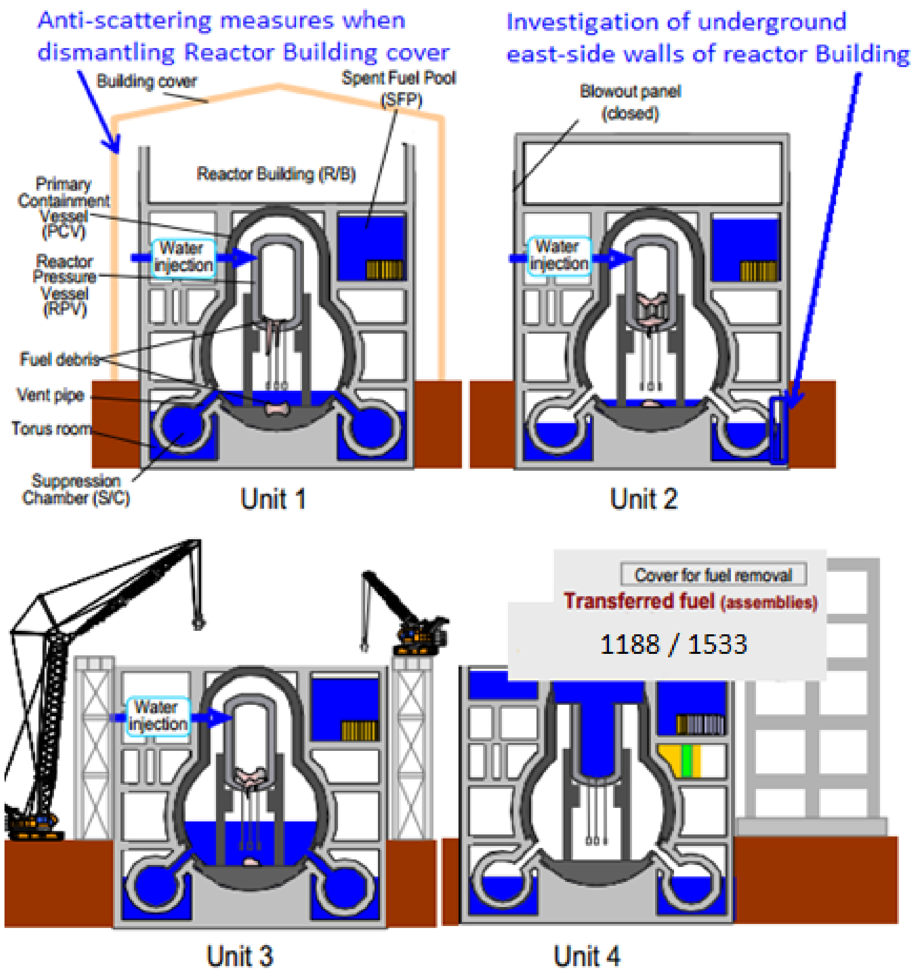


Fig. 5 – Believed status of the reactors [3]

It can be seen that the first 3 reactors are the most damaged ones and the reactor core has melted and also escaped the reactor vessel. The most severe problem is believed to be at Reactor 1 where the core of the reactor has totally escaped the reactor vessel. In the first 3 units there is a continuous water injection to cool down the corium. The water temperature inside the reactor is measured by thermocouples in multiple locations. For water stopping reparations, the water temperature, the temperature of the RPV bottom and also the temperature of gaseous phase inside the Reactor Containment Vessel is very important and can be seen in Fig. 6.

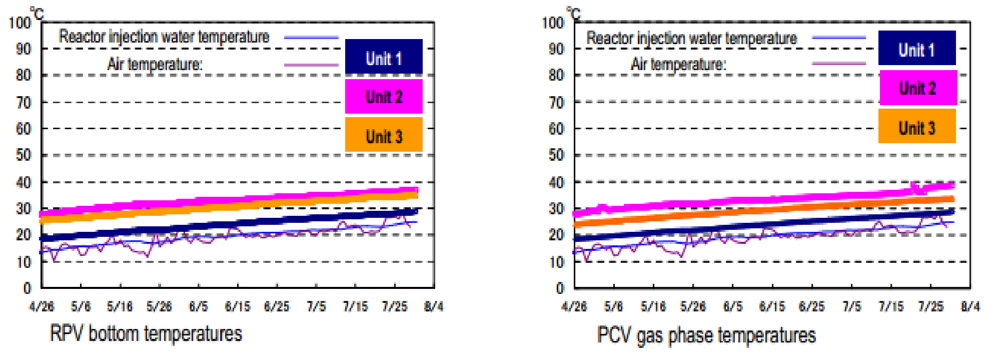


Fig. 6 – Temperatures inside the reactors [3]

From the graph it can be seen a very low temperature compared with the others at the RPV bottom temperature of Unit 1. Unit 2 and 3 are mainly at the same temperature with a small increase at Unit 2. Based on these temperature report and temperature difference between the 3 Units, it is believed that for Unit 1 the entire core was melted and escaped from Reactor Vessel and now is covered with water at the bottom of PCV. Also based on the temperature difference it is believed that more melted fuel escaped from Unit 2 reactor vessel than Unit 3.

The temperature graph presented in Fig. 6 was made with temperature data from the end of April (26^{th}) 2014 to the beginning of August (4^{th}) 2014. As the graph shows, the environment temperature (air temperature) had a great impact on the temperature increase. As the air temperature increased with the summer season, the injection water temperature increased (almost the same temperature with the air temperature) and also the temperature at the bottom of RPV and the temperature of gas phase in PC.

Based on all the above information, a very good method for stopping the water leak can be the liquid metal method.

This method that I propose will use liquid metal as a water stopper. For using this kind of method there are some advantages like ease of use, possibility to control the freezing, possibility to be remote controlled, durability.

The freezing control is very important because it will allow using an optimum quantity of water stopper material (liquid metal). Another advantage is the radiation shield. The liquid metal can also be used to cover the debris and melted fuel. This layer will also act as a radiation shield. The proposed candidate for the liquid metal is Wood's metal.

Wood's metal is a eutectic alloy of 50% bismuth, 26.7% lead, 13.3% tin and 10% cadmium. The low melting point (71 ^{o}C) makes it the perfect candidate for water stopping material. Also, because of its composition of led bismuth and cadmium is good for radiation shielding.

Very important for this method of water stopping will be the flow and solidifying characteristics of the liquid metal. An installation was made and initial test with Gallium were conducted. For the initial test Gallium was chosen because of its even lower melting point of 29.76 ^{o}C which could permit a very simple installation just to verify if it's possible to stop a water leak by liquid metal and if it's possible to control well the freezing of it.

The initial test [4][5] demonstrated that it was possible to use liquid metal as a water stopper and by modifying the water temperature or the liquid metal injection temperature the freezing could be controlled with ease.

For the continuation of this work, a new installation was already build and experiments were conducted with Wood's Metal.

4. Conclusions

This paper was made to gather all the important known information about Fukushima Daiichi Reactors condition for the water sealing technology. A key role is played by the temperatures inside the reactors such as bottom RPV temperature and gas temperature inside PCV.

Another key factor for the water stopping technique is the place from where water is leaking. Also, the technology must be durable and it is a must to be remote controlled.

The proposed method to stop the water leak is the use of liquid metal. The chosen candidate was Wood's metal which has also the capability to act as a radiation shield. The preliminary tests showed that it is easy to control the temperature of liquid metal. In this case a simple injection installation can be made.

Experiments must be done in order to validate the use of Wood's metal and also to demonstrate that the technology can work. These results will be published in a future paper.

Acknowledgement

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R E F E R E N C E S

[1]. *Nuclear Emergency Response Headquarters; Council for the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station,* Mid-and-long-Term Roadmap towards the Decommissioning of Fukushima Daiichi Nuclear Power Station Units 1-4,

[2]. *Hitachi GE-Nuclear Energy Co., Ltd. Toshiba Corporation, Mitsubishi Heavy Industries, Ltd.*, Development of remote-control operated machine and measuring equipment related to Containment Vessels.
[3]. *Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment*, Progress Status and Future Challenges of the Mid-and-Long-Term Roadmap toward the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4, July 31, 2014.
[4]. *M. Mihalache, R. Secareanu, M. Takahashi*, Fundamental Study on Heavy Metal Freezing Behavior for Stopping Water Leakage from LWR Containment Vessel, ICONE 22 presentation.
[5]. *M. Takahashi*, *R. Secareanu*, *M. Mihalache, A. Chapelat*, Fundamental study on heavy metal freezing behavior for stop of water leakage from LWR containment vessel, Progress in Nuclear Energy, accepted, to be published.