October 1, 2011
Tokyo Electric Power

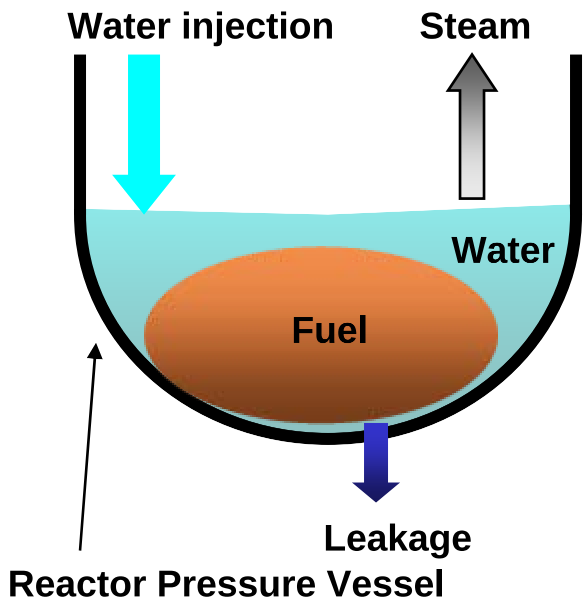
Reactor and Fuel Status in Case of a Reactor Water Injection System Malfunction

［Outline］

- In order to achieve a cold shutdown of Units 1 to 3 at Fukushima Daiichi Nuclear Power Station, we will continue to make efforts to cool the reactors.
- The reactor water injection system, the system that cools the reactor, is designed to reduce potential failure (water injection disruption) by increasing its reliability through multiplexing equipment, etc. Its system is also designed to immediately resume water injection in the event of a malfunction.
- Here, we will explain the status of the reactor and fuel in the event of malfunction regardless of cause of the reactor water injection system.

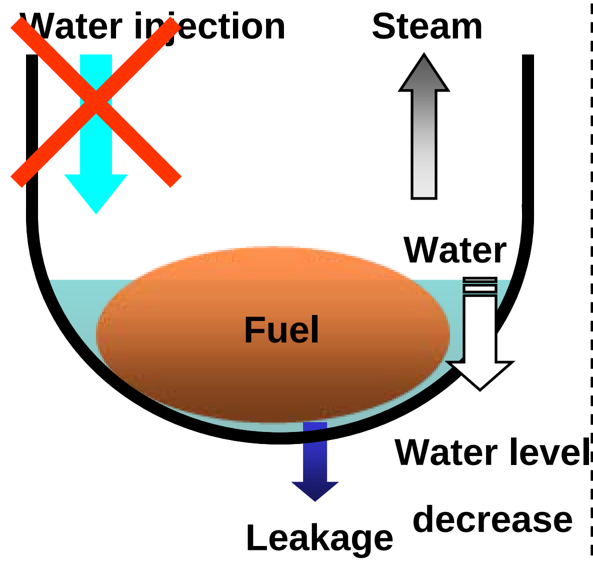
Status of malfunction in the reactor water injection system （Image）

Normal



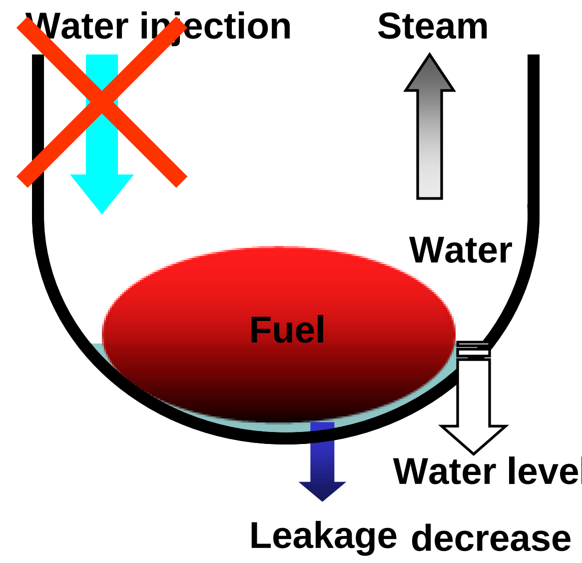
- Amount of injected water and steam/leakage are balanced, maintaining a steady water level.
- Fuel is stably-cooled.

Injection disrupted



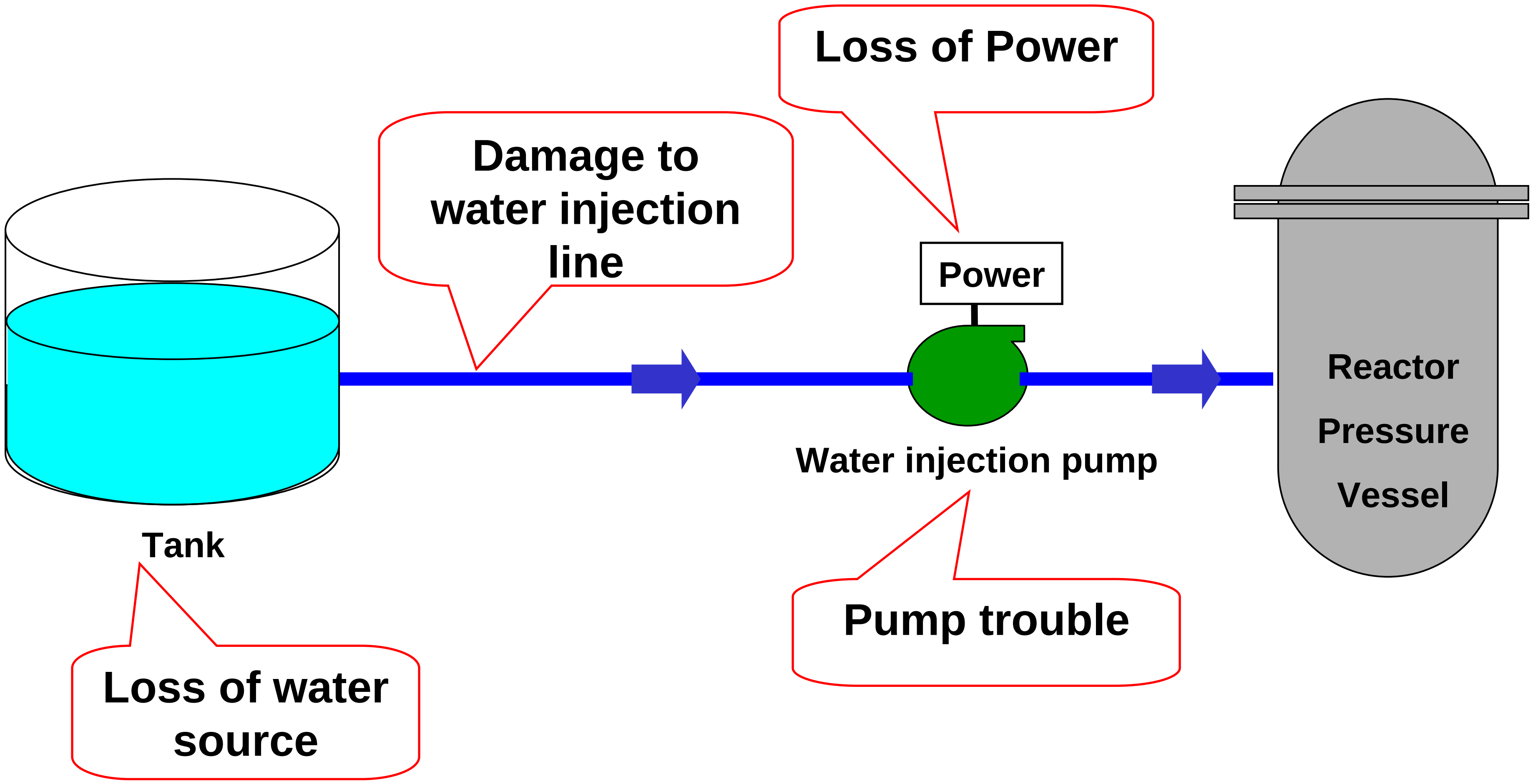
- Imbalance of outflow (steam and leakage) and water injection causes decrease in water level.
- Increase in exposure of fuel and its temperature.

Injection disrupted over extended time period



- Water level significantly decreases by water injection disruption over extended time period.
- Further increase in exposure of fuel
- Fuel temperature increase

Assumed malfunctions in reactor water injection system



Procedures in case of a malfunction

Category	Status	Procedure	Time needed to resume water injection
Pump failure	Pump operation failure	Resuming water injection by activating stand-by unit or emergency reactor injection pump on the hill.	Approx. 30min.
Power loss	Power loss in operating pump	Resuming water injection via emergency reactor injection pump on the hill and fire truck.	Approx. 30min.
Water source loss	Loss of function in buffer tank（Leakage from damaged tank, etc.）	Resuming water injection via switching to filtrate tank.	Approx. 30min.
Damage to water injection line	Damage to water injection line from operating pump	Resuming water injection using a different line that is from a pump besides a pure water tank.	Approx. 30min.

Even if either equipment malfunctions, it is possible to resume water injection to the reactor in approx. 30min.

Evaluation of fuel temperature increase in case of a 1 hour disruption of injection to the reactor

■Evaluation conditions

- From a conservative perspective, it is assumed that all decay heat contributes to fuel temperature increase. (Heat radiation affecting construction material is not considered.)
- From a conservative perspective, the water inside the Reactor Pressure Vessel at the disruption is assumed to be zero. (Assuming that the full exposure of fuel and disruption occurs simultaneously.)
- Decay heat of the fuel
  Unit1 0.64MW, Unit2 0.91MW, Unit3 0.93MW
  (Evaluation value as of October 1)
- Specific heat of fuel 0.4kJ/kg℃
- Weight of fuel
  Unit1120ton, Unit2 164ton , Unit3 164ton

■Result of evaluation

- Fuel temperature increase in case of a 1 hour disruption was estimated approx. 50 ℃ in the conservative assumption above.
  Unit1 Approx.48℃, Unit2 Approx.50℃, Unit3 Approx.51℃

Procedures for reactor water injection disruption over an extended time period. （simultaneous malfunction , etc.)

■Simultaneous loss of equipment functions for the reactor water injection system.
Resuming water injection according to the damage to the water source as well as the condition of the site after re-deploying the fire truck and re-laying the injection line. Factoring in the distance of the hose laying etc. we assume it will take about 3 hours from inception to resume injection. However, time varies according to site conditions.

Loss of equipment function

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Confirming fire truck deployment, hose laying location, etc. Environment survey

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Deployment of equipment such as fire trucks
（Deployment based on water sources, amount of water injection and the environment）

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Hose laying

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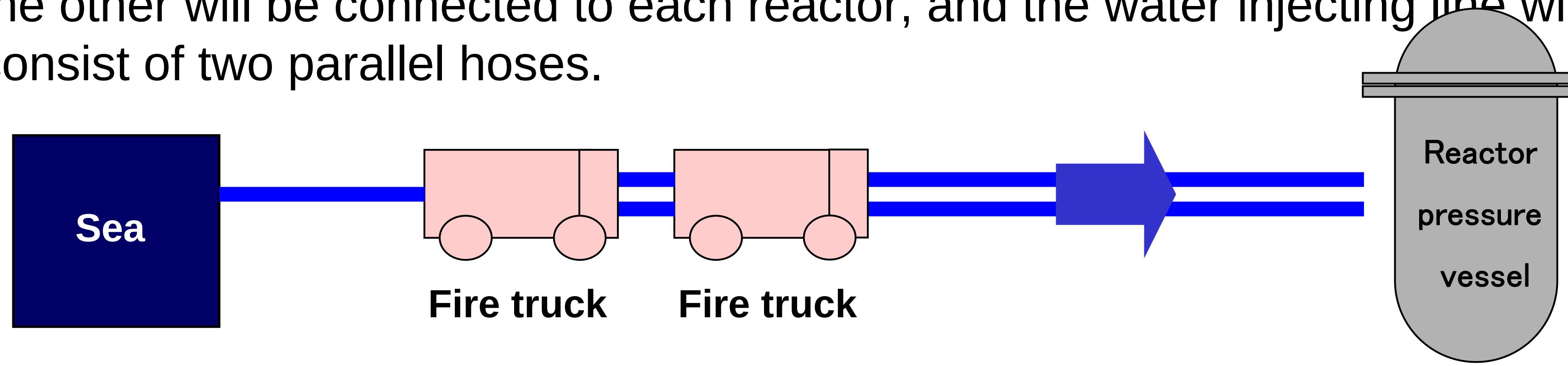
Resuming reactor water injection

Evaluation and procedures for reactor water injection disruption over an extended time period.

- If the disruption continued over an extended time period, there may be a case of rapid water-zirconium reaction when injection is resumed. Therefore, increasing the amount of injection is required to remove decay heat as well as reaction heat. For implementation, two trucks positioned one in front of the other will be connected to each reactor, and the water injecting line will consist of two parallel hoses.



- Time required from disruption to rapid water-zirconium reaction.
  - Evaluation condition：Evaluation for decay heat, etc. are as same as the case of a 1 hour disruption.

    Initial fuel temperature　300℃

    Rapid water-zirconium reaction temperature　1200℃
  - Evaluation result：Time required for the temperature to reach 1200℃ is as follows.

    Unit１ Approx.19 h. Unit２ Approx.18h. Unit３ Approx.18h

    【Reference】 Longest disruption time for each unit at the occurrence of the accident.

    Unit１ Approx.14h. Unit２ Approx. 6h. Unit３ Approx. 7h.

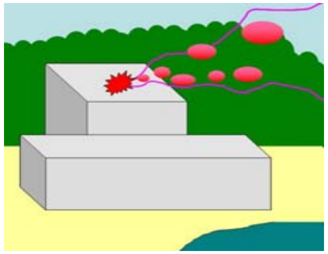
What if the disruption time is longer than expected?

- Assuming that the disruption time of water injection to the reactor is longer than expected.

- **Fuel melting** and the fall of melted fuel on the Primary Containment Vessel under the conservative conditions indicated above (Approx.50℃/h of temperature increase),
  - Reaching melting point (Approx.2200℃) of eutectic （U-Zr-O） in approx. 38-hour disruption of water injection.
  - Reaching melting point (Approx.2800℃) of Uranium dioxide in approx. 50-hour disruption of water injection.

  - Temperature increase slows down under high temperatures due to the radiation effects etc. and actual time required for fuel melting tends to be longer. (Details to be evaluated)

- Release of a large amount of fission product to the environment
  - Radioactive dose is expected to exceed the evacuation level(10mSv) at the boundary of the power station when a large amount of fission product is released into the environment.



Summary

- Reliability for the reactor water injection system for cooling is increased by multiplexing equipments, etc. The assumed disruption time for each equipment is approx. 30min.
- Fuel temperature increase in case of a 1 hour injection disruption is approx. 50℃ based on a conservative assumption.
  Also, it will take approx. 18～19 hours to reach temperatures where the water-zirconium reaction becomes rapid following injection disruption.
- If the injection was disrupted for long time, the reoccurrence of melted fuel, the release of fission products to the environment etc. are assumed.
- The reactor water injection system is the most important system for reactor cooling. Therefore, we will continue our efforts to increase its reliability.