Report on the Measures to Continue Water Injection into Reactors of Unit 1, Unit 2, and Unit 3 at Fukushima Daiichi Nuclear Power Station

August, 2011

Tokyo Electric Power Company

Report on the Measures to Continue Water Injection into Reactors of Unit 1, Unit 2, and Unit 3 at Fukushima Daiichi Nuclear Power Station Table of Contents

Report on the Measures to Continue Water Injection into Reactors of Unit 1, Unit 2, and Unit 3 at Fukushima Daiichi Nuclear Power Station

1. Status of installation of reactor water injection systems

(1) Background

Reactors of Units 1 to 3 in Fukushima Daiichi Nuclear Power Station (hereafter, "Units 1 to 3") were shut down by inserting control rods after Tohoku-Chihou-Taiheiyo-Oki Earthquake, however, the offsite power and the emergency power were both lost by the tsunami, therefore the function of emergency core cooling facilities to remove decay heat after the shut down of reactors was lost.

In order to cool down the cores, we need to restore the function of emergency core cooling facilities, and inject water to the cores or establish circulating cooling using heat exchanger. However, high radioactive dose inside the reactor buildings prevents us from approaching the facilities, so we haven't restored it yet. Thus, right after the accident we sprayed water by fire engines to secure the function to inject water into the reactors.

On the other hand, water spray by fire engines causes radiation exposure issues in operation including at the time of fueling. Therefore, in line with the progress of restoring fresh water supplying systems, power supply, etc., we installed reactor water injection pumps etc. Now we inject water by reactor water injection systems, the details of which are stated below.

(2) Overview of the facilities of reactor water injection systems

a. Design conditions

The followings are the basic parameters related to the design of reactor water injection systems for Units 1 to 3.

① Decay heat (as of April 12, 2011*)

Unit 1 ：1.9 MW
Unit 2 ：2.9 MW
Unit 3 ：3.0 MW

② Volume of injected water equivalent to decay heat (as of April 12, 2011*)

Unit 1 ：2.6 m^3/h
Unit 2 ：4.0 m^3/h
Unit 3 ：4.1 m^3/h

(Attachment - 1)

* In response to the fact that we were unable to approach pumps beside the pure water tank due to the tsunami warning issued after the earthquake on April 11, 2011, we started considering installation of reactor water injection pumps on the hill. Therefore, the data about decay heat at that time were adopted as the design conditions.

b. Design principle

The facilities should satisfy following functions so that they can satisfy design conditions of reactor water injection systems for Units 1 to 3.

① To secure water injection rate necessary to remove decay heat from fuel in reactor pressure vessels.

② To configure facilities so that the function can be recovered quickly even if the function is lost due to events such as breakdown of pumps, blackouts, etc.

Please note that although "JSME S NC-1 (Standards of nuclear facilities for generation, standards for design and construction)" and "guidelines in earthquake-proof design evaluation regarding reactor facilities for generation" should be applied, we applied emergency measures based on Article 64 of Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors because reactor water injection systems needed to be installed promptly.

c. Configuration of the system

Reactor water injection systems inject water to reactors using the filtrate water or the water made by degreasing, desalting, and decontaminating the contaminated water (hereafter, "treated water"). The systems consist of facilities including injection pumps and injection lines. Each facility is multiplexed to prevent loss of the function due to breakdown of machinery. The detailed configuration of each facility is stated below.

(a) Pump

Reactor water injection pumps consist of 9 pumps, 6 reactor water injection pumps on the hill which are installed at the parking lot on the seashore side of the Administration Office Building, and 3 reactor water injection pumps on the side of pure water tank which are installed beside the pure water tank. (Refer to "d. Specification of major equipments")

Reactor water injection pumps on the hill consist of 3 regular pumps, with power supplied from in-station power source, and 3 emergency pumps, with power supplied from dedicated diesel generator (hereinafter, D/G) and isolated from in-station power source. 3 reactor water injection pumps on the side of pure water tank can be supplied power both from in-station power source and from dedicated D/G. Power source of reactor water injection system is supplied from Ohkuma Line No.2, and it can be switched to the supply from Ohkuma Line No.3, Touden Genshiryoku Line of Tohoku EPCO, and Yonomori Line No.1, in case of outage of Ohkuma Line No.2. In addition, if all these lines go outage, it can be switched to the supply from emergency D/G of Unit 5 and 6, and from power source vehicle. (Refer to "f. Others")

Water supply capabilities of the pumps are 20 m3/h/unit for the reactor water injection pumps on the hill and 37 m3/h/unit* for the reactor water injection pumps on the side of pure water tank, to secure the necessary water flow amount against the decay heat, Moreover, tie-line is equipped at the outlet line of the pump to change the number of pumps in operation, so as to maintain the water flow amount in case that the necessary water flow amount is decreased.

* Reactor water injection pumps on the side of pure water tank have different water supply capability, since they were used before this investigation. Currently they are installed as the backup of the reactor water injection pumps on the hill.

(b) Tank

Water source of the reactor water injection system consists of the treated water buffer tank, the filtrate water tank, and the pure water tank (Refer to "d. Specification of major equipments"). Since the treated water is mainly used as the water source, the treated water buffer tank is mainly used. The treated water buffer tank has the capacity (1000m3) of the water injection amount equivalent to decay heat in the design condition (approx. 11m3/h, total of Unit 1 to 3), including margin, and the treated water is supplied as needed, so as not to lose water source. In addition, it is composed that the filtrate water tank can also supply water, in the case that the treated water supply is stopped due to such troubles as of the treatment equipment.

Regarding the reactor water injection pumps on the side of pure water tank, its water source is the pure water tank.

(c) Reactor Water Injection Line

Reactor water injection systems consist of the water injection line from the reactor water injection pumps on the hill and the water injection line from the reactor water injection pumps on the side of pure water tank. The water injection lines are separated from each other considering fracture of the line. The water injection line is configured so that the significant pressure drop or fluid vibration is not occurred when the water is injected at the rated flow rate of the pump (Refer to e. Specification of main plumbing).

(d) Others

Fire engines are equipped to maintain the water injection into reactors, in case that there occur damages in multiple facilities. For the water source, in addition to the above mentioned water sources, the basement pure water tank is to be made available.

Even if water can not be injected by above measures, water injection by the fire engines with seawater as the water source is also possible (Refer to f. Others).

(Attachment-2)

(Attachment-3)

d. Specification of major equipments

Name		Specification	
Pump	Regular reactor water injection pump on the hill (Offsite power)	No. of unit Flow rate Pump head Output	3 $20m^3$ / h / unit 113m 11kW
	Emergency reactor water injection pump on the hill (D/G power)	No. of unit Flow rate Pump head Output	3 $20m^3$ / h / unit 113m 11kW
	Reactor water injection pump on the side of pure water tank (Offsite or D/G power)	No. of unit Flow rate Pump head Output	3 37 m^3 / h / unit 93m 18.5kW
Diesel Generator	D/G for emergency reactor water injection pump on the hill	No. of unit Capacity	1 125kVA
	D/G for reactor water injection pump on the side of pure water tank	No. of unit Capacity	1 125kVA
Tank	Treated water buffer tank	No. of unit Capacity	1 1000 m^3 / unit
	Filtrate water tank	No. of unit Capacity	2 8000 m^3 / unit
	Pure water tank	No. of unit Capacity	2 2000 m^3 / unit

e. Specification of major plumbing

Name	Specification	
Reactor water injection pump unit on the hill (steel pipe)	Outer diameter/nominal thickness Material Maximum operating pressure Maximum operating temperature	60.5mm/3.5mm(50A) 76.3mm/3.5mm(65A) 89.1mm/4.0mm(80A) SUS304TP 1.4MPa 50℃
Reactor water injection pump unit on the hill tie line (flexible tube)	Inner diameter Outer diameter Material Maximum operating pressure Maximum operating temperature	63.5mm 76.0mm SUS304 1.4MPa 50℃
From reactor water injection pump unit on the hill to the side of pure water tank (pressure tight hose)	Inner diameter Outer diameter Material Maximum operating pressure Maximum operating temperature	76.2mm 99.0mm polyvinyl chloride 0.98MPa 50℃
From the side of pure water tank to Unit 1-3 Turbine Building entrance (polyethylene pipe)	Inner diameter Outer diameter Material Maximum operating pressure Maximum operating temperature	72.6mm 90mm polyethylene 1.0 MPa 40℃
From Unit 1 Turbine Building entrance to injection point (line from reactor water injection pump on the hill) (pressure tight hose)	Inner diameter Outer diameter Material Maximum operating pressure Maximum operating temperature	76.2mm 99.0mm polyvinyl chloride 0.98MPa 50℃
From Unit 2,3 Turbine Building entrance to injection point (line from reactor water injection pump on the hill) (pressure tight hose)	Inner diameter Outer diameter Material Maximum operating pressure Maximum operating temperature	50.8mm 68.5mm polyvinyl chloride 0.98MPa 50℃
Reactor water injection pump unit on the side of pure water tank (steel pipe)	Outer diameter/nominal thickness Material Maximum operating pressure Maximum operating temperature	89.1mm/5.5mm(80A) 60.5mm/3.5mm(50A) 76.3mm/3.5mm(65A) SUS304TP 1.4MPa 50℃
From reactor water injection pump unit on the side of pure water tank to Unit 1 Turbine Building entrance (pressure tight hose)	Inner diameter Outer diameter Material Maximum operating pressure Maximum operating temperature	76.2mm 99.0mm polyvinyl chloride 0.98MPa 50℃
From Unit 1 Turbine Building entrance to Unit 1-3 injection point (line from reactor water injection pump on the side of pure water tank) (fire hose)	Inner diameter Material Maximum operating pressure	63.5～66.5mm polyester 1.6MPa

f. Others

Name	Specification	
Fire engine（A-1 class）	Number of Vehicles Standardized Discharge Pressure Discharge Capability Water Cannon Pressure Discharge Capability	1（2 for backup） 0.85MPa more than 168m^3/h 1.4 MPa more than 120m^3/h
Fire engine （ A-2 class）	Number of Vehicles Standardized Discharge Pressure Discharge Capability Water Cannon Pressure Discharge Capability	8（4 for backup） 0.85MPa more than 120m^3/h 1.4 MPa more than 84m^3/h
Power Source Car for Site Power	Number of Vehicles Capacity	1 750 kVA
Raw Water Underground Tank	Number of Tanks Capacity	1 970 m^3

2. Principle of ensuring security

Water injection into the reactors is a highly prioritized task for the restoration work. It should be conducted safely, steadily and quickly. However, considering its emergency and work circumstances, it was difficult to design and construct it as it was. Due to these reasons, the following points are checked in terms of safety. Details are described in the next section.

(1) Structural strength and anti-earthquake safety of facilities for reactor water injection systems

(2) Cooling capacity of reactor water injection systems

(3) Operation and maintenance management of reactor water injection systems

(4) Countermeasures against loss of functions of reactor water injection systems

(5) Other necessary items regarding safety evaluation of reactor water injection systems

3. Concrete measures to ensure security

(1) Structural strength and anti-earthquake safety of facilities for reactor water injection systems

The structural strength of the reactor water injection systems is categorized into Class 2 equipment, which is equivalent to that of Emergency Core Cooling System, in terms of technical standards. However, since the design, procurement, and installation work must be conducted in a short period, the strength does not satisfy the requirement of Class 2 equipment defined in “JSME NC-1 Design and Construction Standards, Standards of Nuclear Power Facilities”.

However, “JEAG 4612 Guideline of Importance Category for Electric and Mechanical Equipment with Safety Functions” describes “secure the highest safety reliability that can be reasonably achieved, and maintain the reliability”. Reactor water injection systems use general industrial products such as JIS standard products, considering the emergency and the current work circumstances in the power station. At this moment, it satisfies reasonably achievable strength.

In terms of anti-earthquake design, systems relating water injection into reactors are categorized into S class. Because design, procurement, and installation must be conducted in a short period, it has not satisfied the requirements.

However, in order to protect facilities from earthquake that might continuously occur in the near future and maintain smooth operation and sound functions, reasonably achievable countermeasures are to be taken. The following concrete measures have been taken.

・ Seismic capacity of water injection pump unit (injection pump, power source, main pipeline (steel pipe and flexible tube)) is improved by loading the unit on a truck which has a damper. To prevent a fall, the unit is fixed on the truck with bolts.

- Polyethylene pipeline, pressure-resistant hose and fire hose have flexibility, which should avoid significant stress caused by earthquake displacement. In addition, polyethylene pipeline and pressure-resistant hose are connected by welding and clamping respectively. Both measures meet the specification of hoses, confirmed in tests, etc.

(Attachment-4)

(2) Cooling capacity of reactor water injection systems

Regarding reactor water injection systems, the amount of water to be injected is controlled in accordance with decay of decay heat, transition of temperature of parts of reactor pressure vessels, etc. In addition, taking the possibility of leakage from pipe arrangement, valves, and etc. into consideration, water above the amount equivalent to decay heat has been injected continuously. As of August 1, approximately 16 m^3/h (Unit 1-3 total) of water has been injected in spite of the amount of water equivalent to decay heat, which is 4.5 m^3/h（Unit 1-3 total）.

The temperature at the bottom of the reactors in the past one month remains stably under 140^{o}C without any continuous behavior of increase in temperature, and reactor water injection systems keep cooling the reactors sufficiently.

(Appendix-5)

(3) Operation and maintenance management of reactor water injection systems

a. Operation management

- Parameters (volume of water injection, pressure of water injection, and water level of buffer tanks) related to performance of reactor water injection systems are observed by the monitors set in the main anti-earthquake building. If any sign of abnormality of equipment is detected in the parameters, countermeasures will be taken immediately.
- Countermeasures to abnormalities such as alarms (trip of pumps, decline in water flow) occurred at regular reactor water injection pumps on the hill (please see (4)), are prepared in the manuals. In addition, with regard to countermeasures to abnormalities, trainings are implemented sequentially.

b. Maintenance management

- Regarding water injection pump units（water injection pumps, batteries, main pipe arrangements (steel pipes and flexible tubes)）, expendable parts such as gasket packing will be replaced as necessary, and maintenance will be conducted if damages of the units are identified.

・ Polyethylene pipes, pressure hoses and fire hoses will be replaced if damages are identified.

・ In addition, to conduct the maintenance immediately at anomalous occurrence, expendable parts are being secured.

(4) Countermeasures against loss of functions of reactor water injection systems

Assuming the case in which the reactor water injection systems lose their functions, power source, water source, and water injection line are multiplexed. It is possible to restart water injection within about one hour after the loss of functions. The concrete abnormal conditions assumed are as follows. In case water injection cannot restart, countermeasures such as fire trucks etc. are prepared.

a. Pump failure

If failures in the water injection pump on the hill are detected, workers will promptly move to the parking lot located at ocean side of administrative main building and activate alternative pump or emergency water injection pump on the hill to restart water injection to the reactor (Time necessary for restarting water injection：Approx. 30 min.).

（Attachment-6）

b. Loss of power

The power source for the regular water injection pump on the hill is multiplexed by a number of busses. However, since it takes time to switch the power sources, workers will promptly move to parking lot located at ocean side of administrative main building in case of power loss of the regular reactor water injection pump on the hill and conduct water injection into the reactor through emergency reactor water injection pump on the hill (organizing the system and activate emergency reactor water injection pump on the hill) and fire engines standing by (organizing the system and activate fire engines). (Time necessary for resuming water injection：Approx. 30 min.)

As soon as water injection to the reactor through an emergency reactor water injection pump on the hill is initiated, water injection by fire engines will be stopped. Then, the power will be restored by switching the power source.

（Attachment-7）

c. Loss of water source

A water source for the reactor water injection pump on the hill is normally a buffer tank. However, when there is some sort of problem in the tank such as damages followed by leakage etc, workers will move to the parking lot located at ocean side of administrative main building and open the main valve for supplying filtrate water and switch the water source to filtrate water tank (Time necessary for resuming water injection：Approx. 30 min.).

If both the buffer tank and the filtrate water tank lose their functions, since there would be no filtrate water supplied to pure water tank, raw water tank at the basement will be utilized as an alternate water source and water will be injected through fire engines standing by. In concrete terms, workers will move to the side of the filtrate water tank as well as the parking lot located at ocean side of administrative main building and conduct water injection into the reactor (organizing the system, activating 2 fire engines deployed beside the filtrate water tank and at the parking lot located at ocean side of administrative main building) by fire engines using water from raw water tank at the basement (Time necessary for resuming water injection：Approx. 60 min.).

（Attachment-8）

d. Damages to reactor water injection systems

If there are damages to the water injection line through the reactor water injection pump on the hill, workers will promptly move to the side of the pure water tank and inject water into the reactor (organizing the system and activating pumps installed beside the pure water tank) through water injection pump installed beside the pure water tank (Target time for resuming water injection： Approx. 30 min.).

（Attachment-9）

e. The treatment in case that multiple facilities of reactor water injection systems have lost function and others

Reactor water injection systems are set up in order to prevent function loss due to equipment’s failure and other reasons. If multiple facilities should lose function at a time, the system restore injection by dispatching fire engines and laying coolant injection lines again, depending on the damage to the water reservoir and other circumstances. The time to restore the water injection is estimated approximately 3 hours from the start of the work taking into account the length of the hose and the time necessary to lay the hose, while the time could change depending on the circumstances

If the interruption of water injection to reactors could be assumed to happen for several hours, the amount of maximally-available water injection would be increased within the range of fire engines' capacity, because the temperature of fuel could increase to the level where product by nuclear fission could be emitted again or chemical reaction between water and Zirconium could start.

If the interruption period of water injection is assumed to be more than 12 hours, it would be necessary to increase the amount of water injection in order to remove not only decay heat but also heat caused by the reaction because rapid chemical reaction between water and Zirconium might have occurred. In this case, 2 fire engines will be laid in series for each reactor, setting up 2 coolant injection lines. If water injection would be started again with increased amount of coolant, it would be confirmed that the injection of nitrogen gas is implemented. Further more, the amount of water injection would be adjusted monitoring parameters such as temperature, pressure, and others.

(Attachment-10)

(Attachment-11)

(5) The other necessary matters in the safety assessment of the installment of reactor water injection systems

As mentioned above, for the reactor water injection systems, it is possible to restore the water injection approximately in an hour using its backup facilities even if the injection pump located on a hill is halted due to failure of power supply and other reasons. Because the temperature of fuel is evaluated to increase up to approximately 70 degree Celsius in approximately one hour, it is concluded that any significant problem would be seen in terms of the emission of product by nuclear fission or of chemical reaction between water and Zirconium.

(Attachment-12)

End

Report on Installation of Reactor Water Injection System
Attachment　Table of Contents

Decay heat and the amount of water injected equivalent to decay heat

As of April 12, 2011, the estimated value is shown below regarding the decay heat and the amount of water injected equivalent to decay heat:

	Decay heat	Amount of water injected equivalent to decay heat
Unit 1	1.9 MW	2.6 m^3/h
Unit 2	2.9 MW	4.0 m^3/h
Unit 3	3.0 MW	4.1 m^3/h

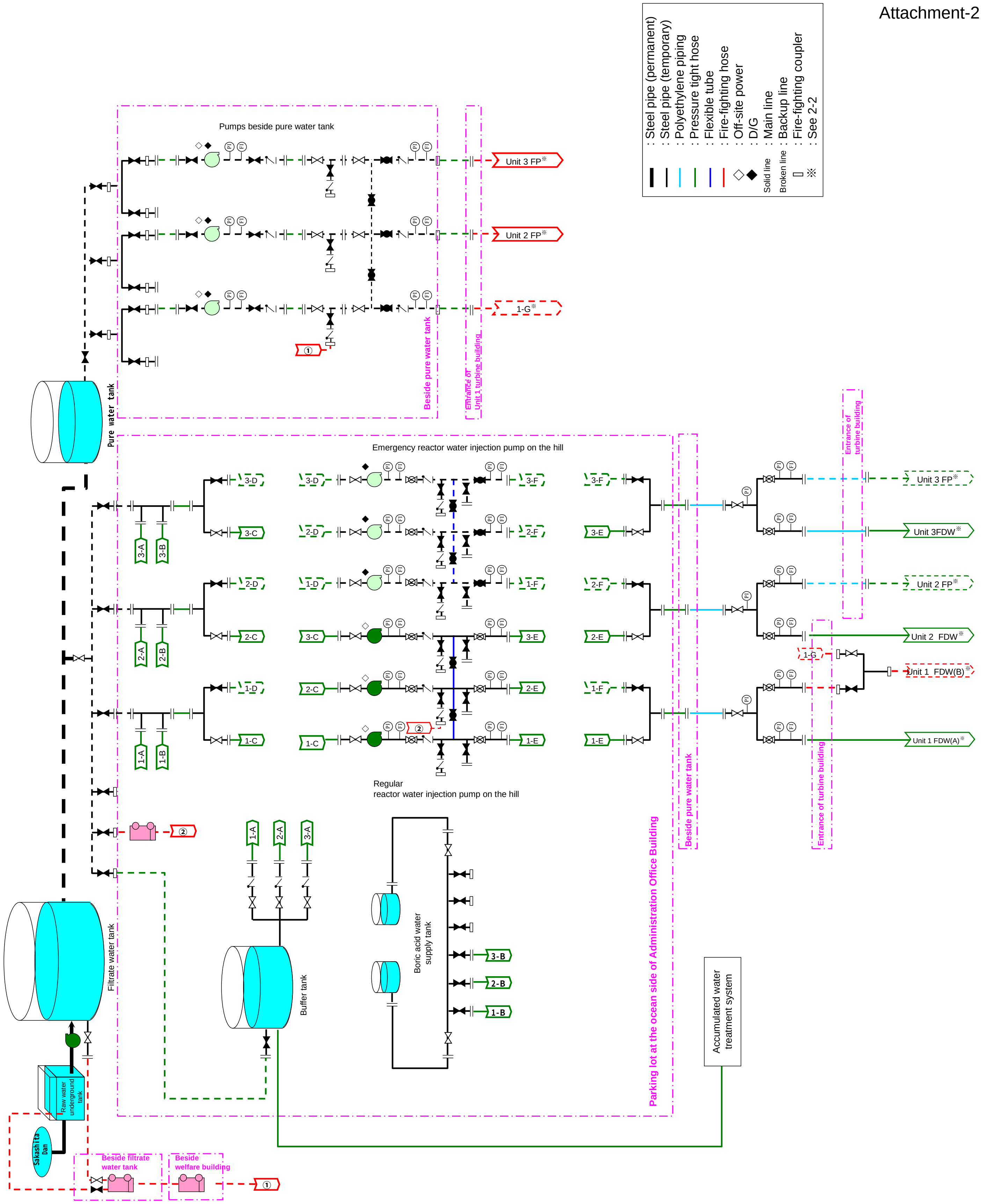
The decay heat was estimated by using a calculation code named "ORIGIN" that calculates generation and decay of the nuclide. The amount of water injected equivalent to decay heat is calculated as follows, which we think is the minimum required to cool down the decay heat of nuclear reactor:

$$W = Q \times \rho \times 1000 \times 3600 / (hv - hw)$$

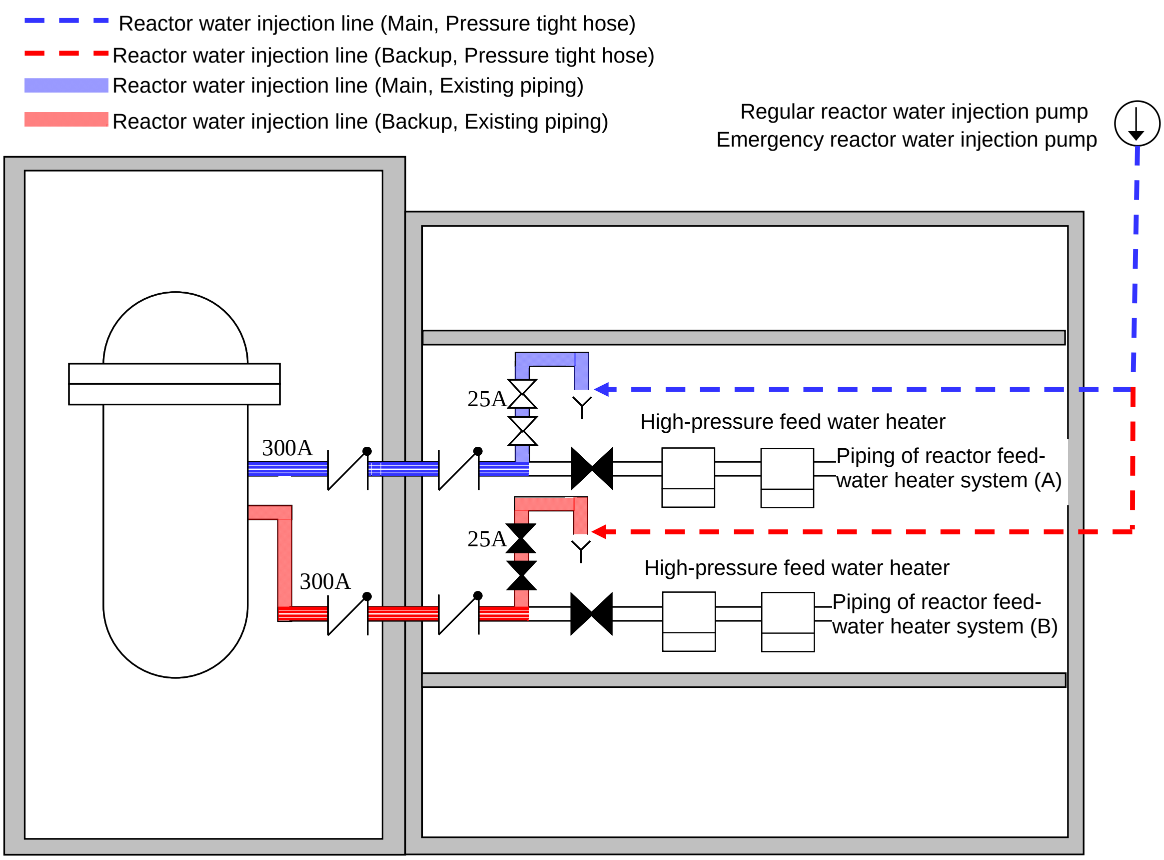
W：Amount of water injected equivalent to decay heat（m^3/h）
Q：Decay heat (MW)
hv：Steam (100℃) Enthalpy (kJ/kg）
hw：Water injection (20℃) enthalpy (kJ/kg)
ρ：Water injection specific volume (m^3/kg)

End

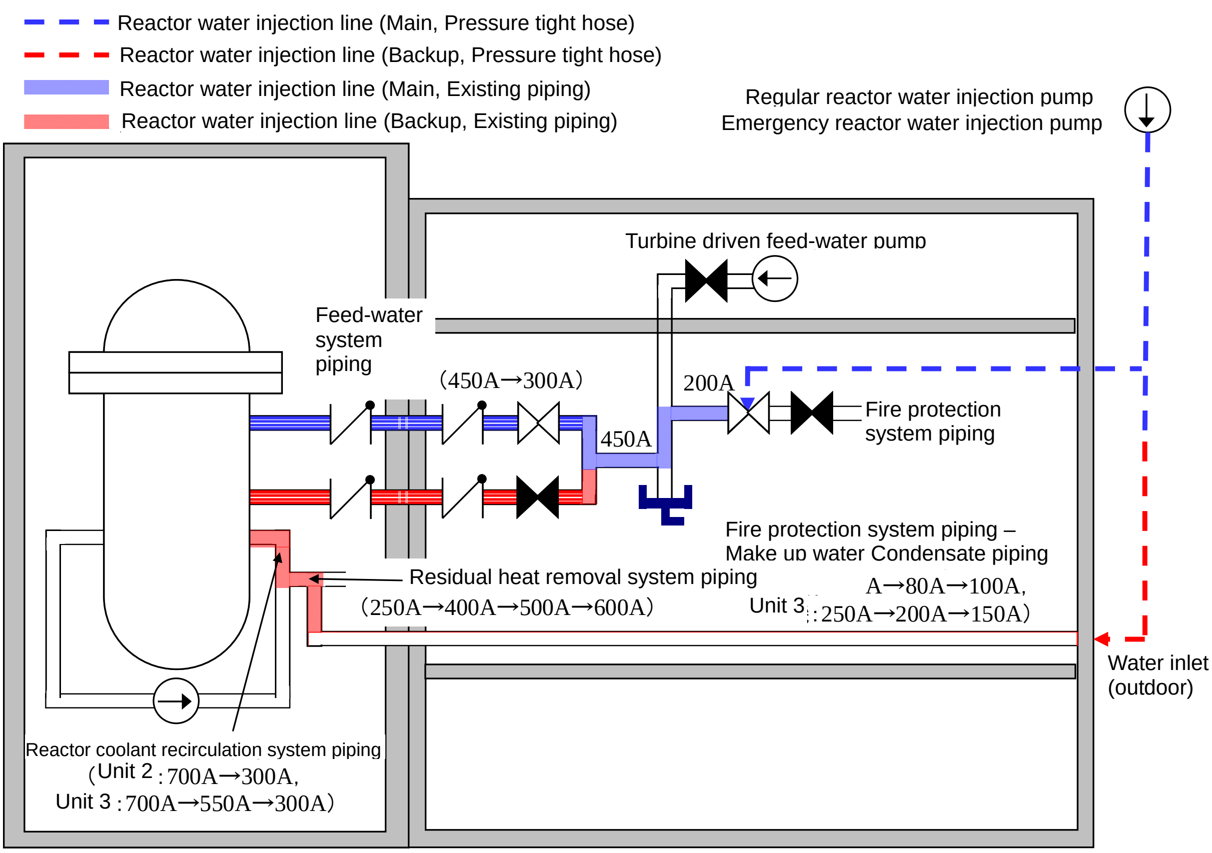
Attachment-2



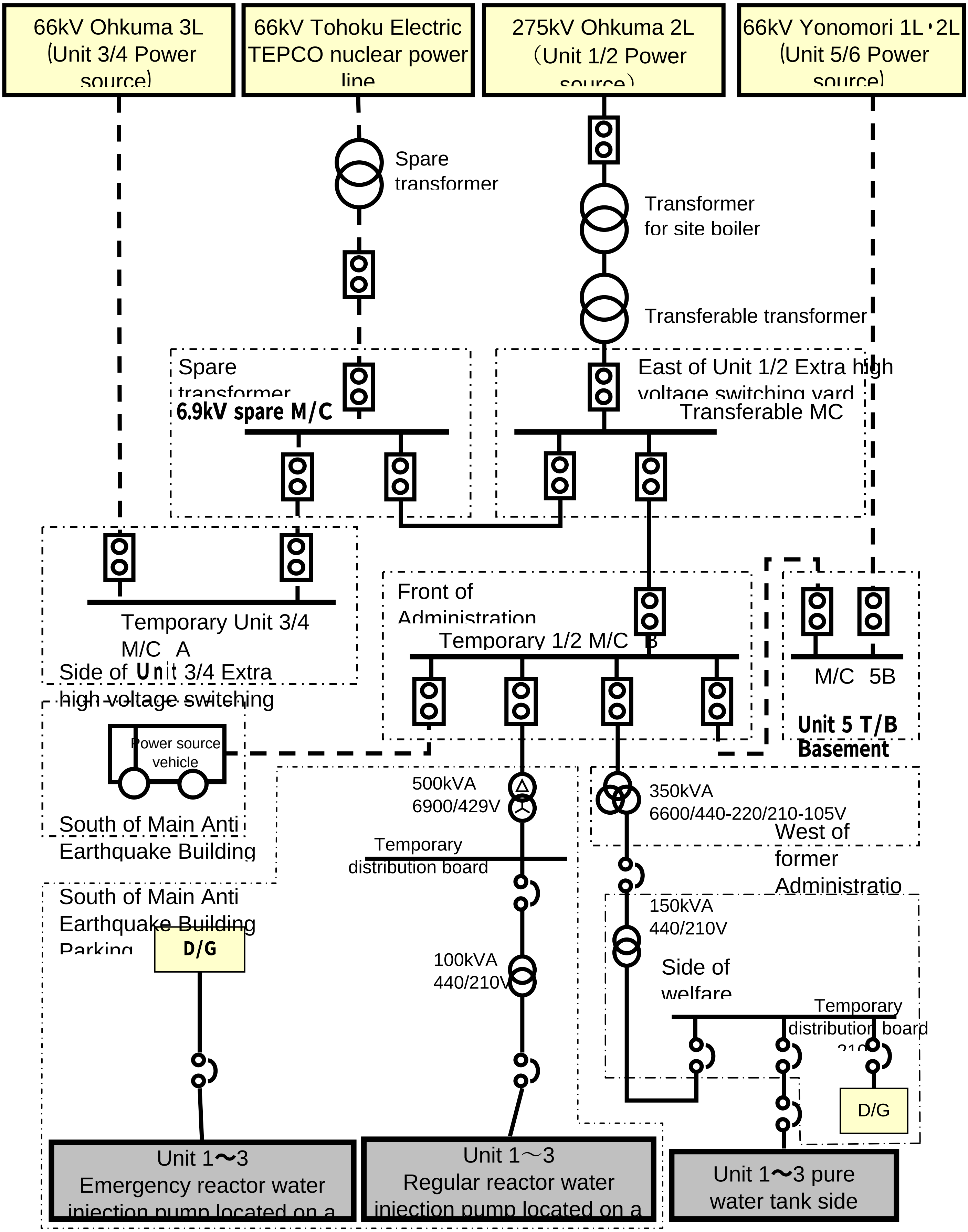
Overview of Regular reactor water injection system genealogy



Overview of regular water injection system genealogy (Unit 1)



Overview of regular water injection system genealogy (Unit 2/3)



Power source diagram of reactor water injection system

Attachment -4

Importance degree classification regarding design and installation of reactor water injection system

(1) Safety importance degree classification

As reactor water injection system is considered equivalent to emergency core cooling system under “Audit Guideline for safety function importance degree classification of light water reactor facility for power generation” and “Guideline of importance degree function of electrical / mechanical instrument possessing safety function（JEAG4612）”, it is classified as follows;

① Reactor water injection system：MS-1

Although emergency core cooling system is a class 2 facility under technical standard, and its strength is supposed to be evaluated under the Design / Construction Standard（JSME S NC1-2005）, as stable water injection to reactor core is important in restoration of the accident, strict strength evaluation as required in the Design / Construction Standard will not be implemented, as an emergency measure.

However, under JEAG4612, as basic target of design of MS-1 (Class 1) facility is set as “to achieve and maintain reasonably achievable highest credibility”, it is designed based on JIS etc.

(2) Classification of quake resistance importance degree

As reactor water injection system is considered equivalent to emergency core cooling system under “Audit guideline for quake resistance design regarding nuclear reactor facility for power generation” and “Technical guideline of nuclear power station quake resistance design (JEAG4601)” it is classified as follows;

① Reactor water injection system：S Class

Although reactor water injection system installed this time is classified at S as above, under the current condition where there are damages by earthquake and tsunami, it is not possible to design and install based on strictly required S class quake resistance safety evaluation.

On the other hand, as stable water injection to reactor core is important in restoration of the accident, and safe, certain and quick action is necessary, design and implementation is carried out within reasonably achievable range as emergency measures, taking in account of design and installation period, workers’ exposure, etc.

End

Decay heat equivalent water injection amount and actual water injection amount

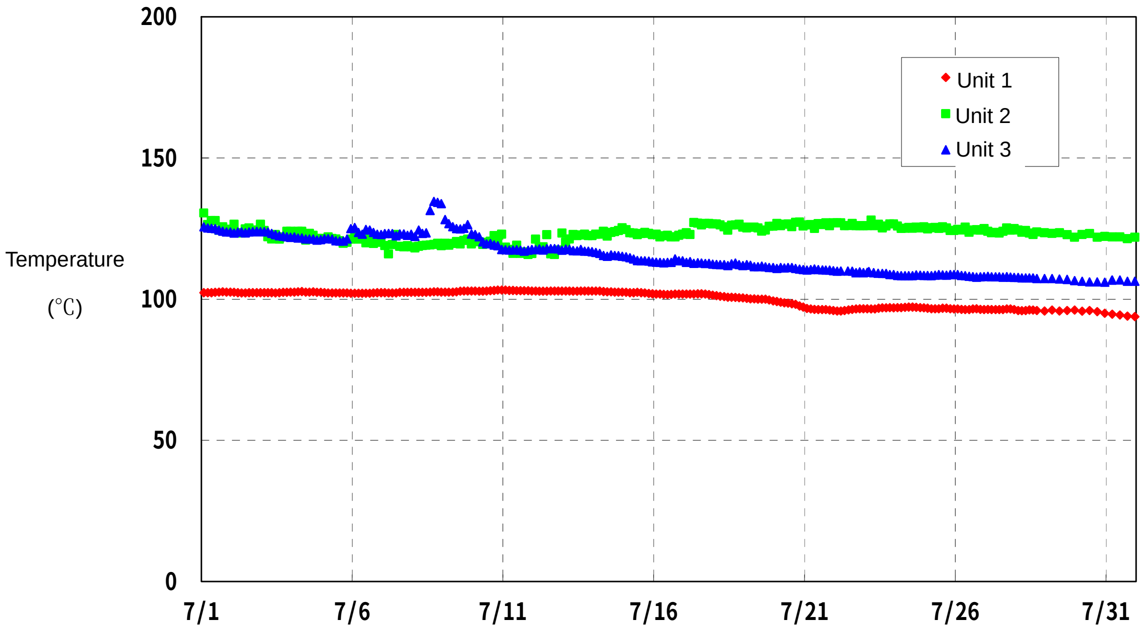
Reactor decay heat, evaluated amount of decay heat equivalent water injection amount, and actual injection amount at Unit 1～3, as of August 1, 2011 is shown in the chart below.（Refer to Attachment 1 for evaluation method of decay heat, and evaluated amount of decay heat equivalent water injection amount）

	Decay heat	Decay heat equivalent water injection amount	Actual injection amount
Unit 1	0.82 MW	1.1 m^3/h	Approx. 3.5 m^3/h
Unit 2	1.2 MW	1.7 m^3/h	Approx.3.5 m^3/h
Unit 3	1.2 MW	1.7 m^3/h	Approx.9.0 m^3/h

（Rated flow of Reactor water injection pump located on a hill, and pure water tank side reactor water injection pump inject at $20m^3/h$ and $37m^3/h$ respectively, and it is capable to supply water necessary for cooling）

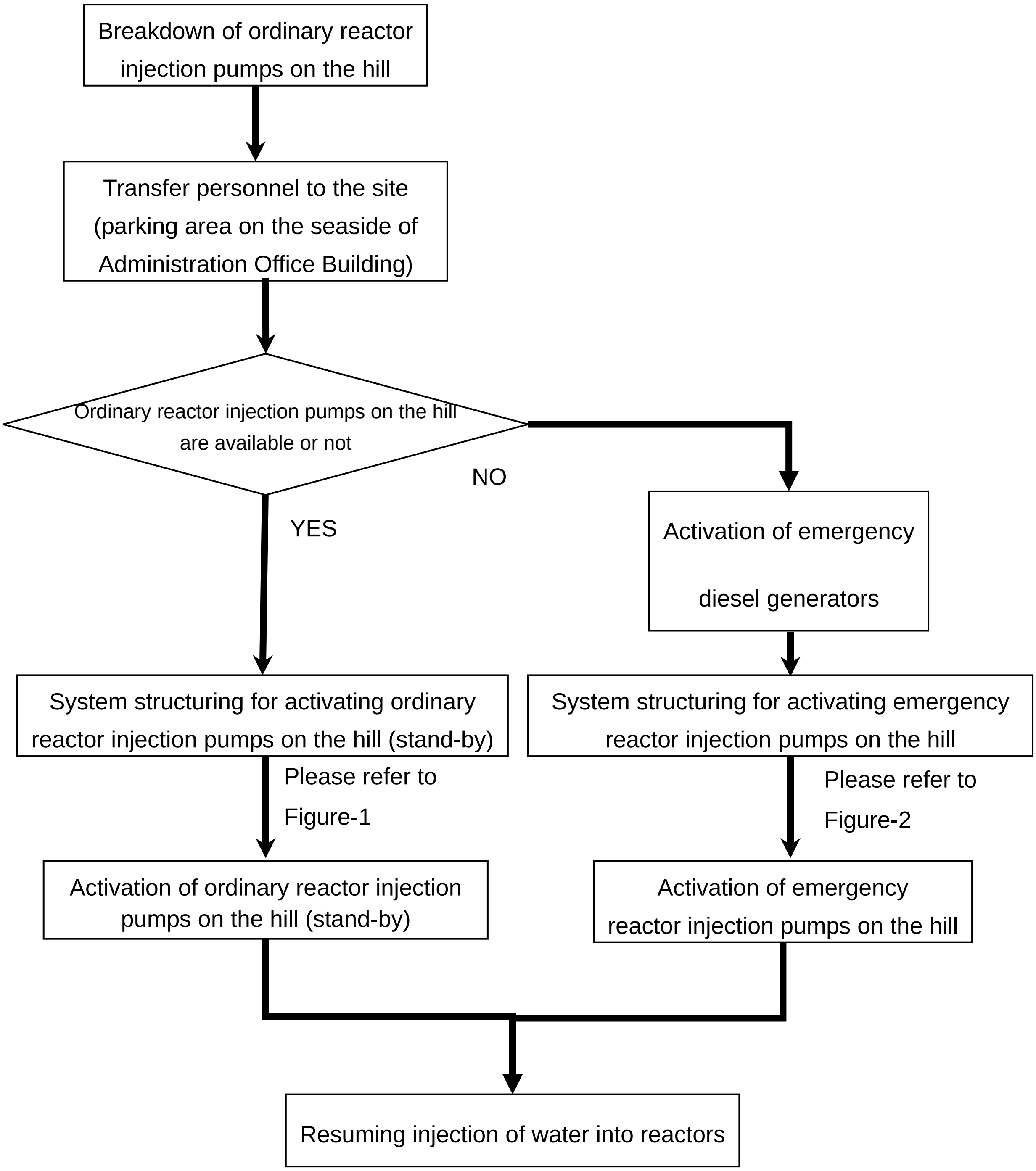
Actual injection amount exceeds the amount of decay heat equivalent water injection amount. As there are possibilities of leakage from water injection pipes and valves, it is considered that not all injected water is contributing to cooling. Therefore amount of actual water injection exceeds decay heat equivalent water injection amount. The graph below shows the transition of temperature of the bottom of RPV. It shows that the current injection amount adequately keeps it cooled.

Transition of temperature of the bottom of RPV (July 1～August 1)

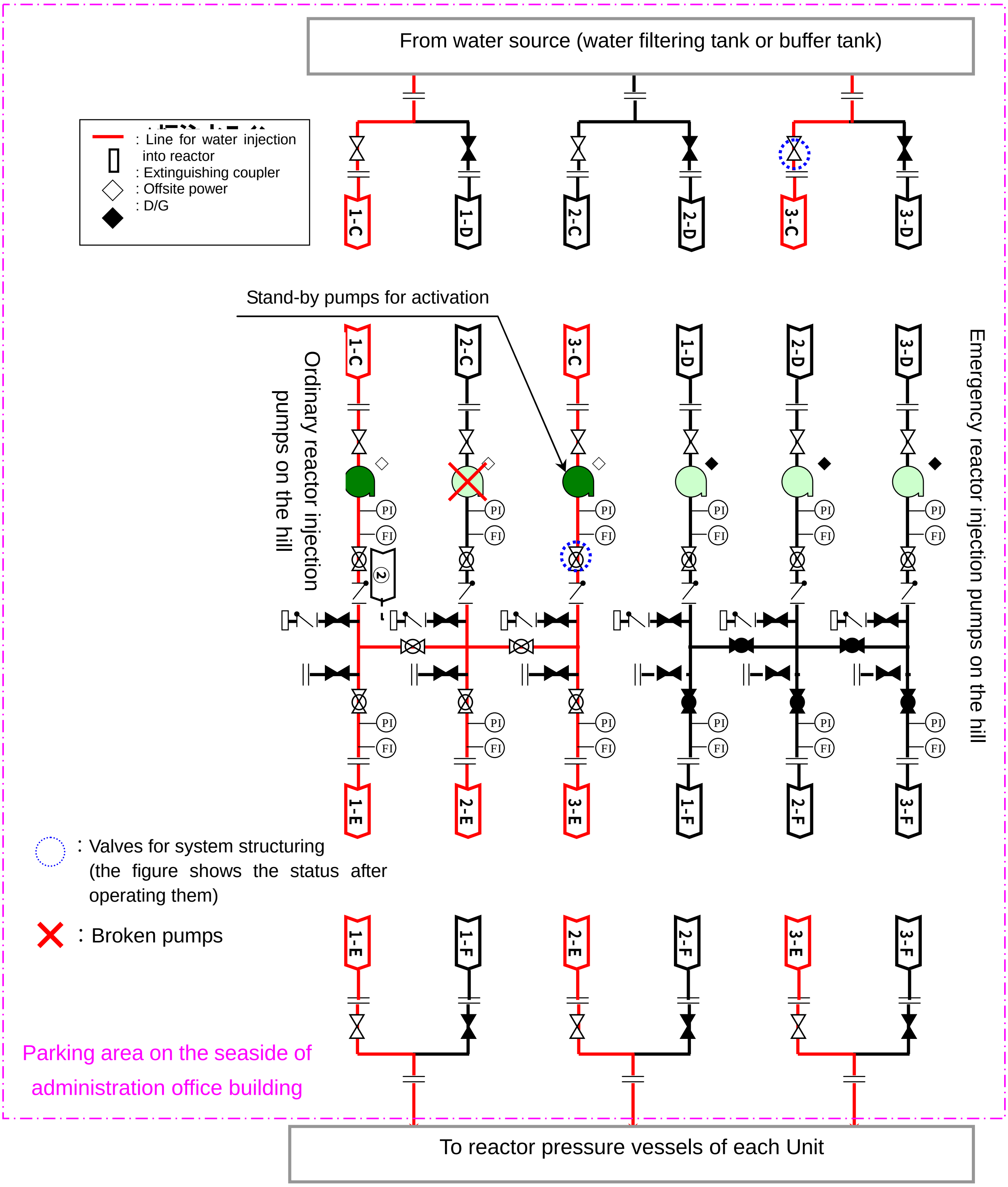


End

Flowchart for the response to and simple system diagram for breakdown of pumps



Flowchart for the response to the breakdown of pumps

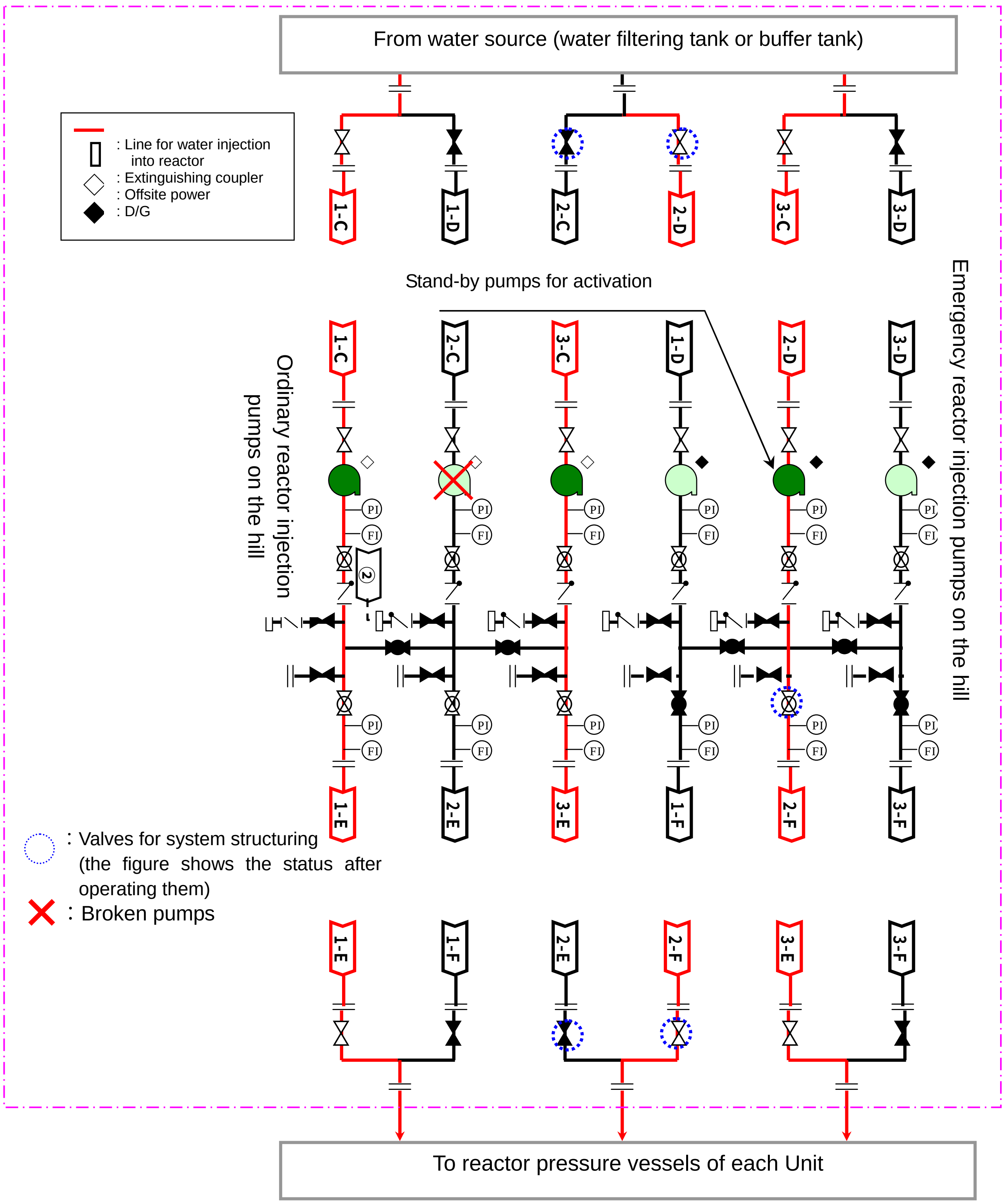


*Example: Breakdown of pumps for Unit 2

Figure-1 Simple system diagram of water injection

into reactors for the breakdown of pumps*

(Water injection into the reactor by activating stand-by units)

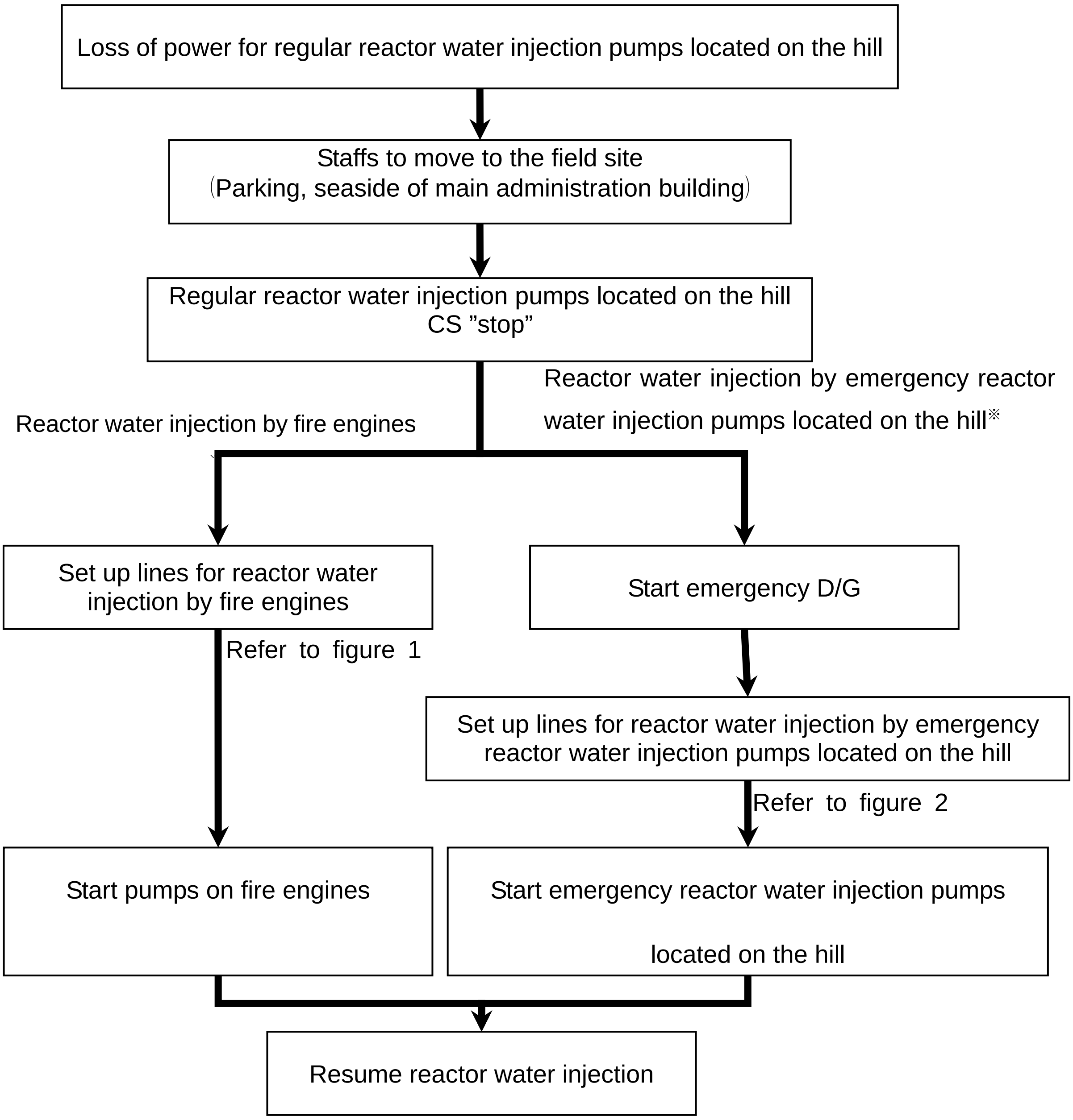


*Example: Breakdown of pumps for Unit 2

Figure-2 Simple system diagram of water injection into reactors for the breakdown of pumps*

(Water injection by activating emergency reactor injection pumps on the hill)

Response flowchart in the event of loss of power and conceptual system diagrams



※ To execute reactor water injection by fire engines and by emergency reactor water injection pumps located on the hill at the same time.
As soon as the reactor water injection by emergency reactor water injection pumps located on the hill commences, to stop fire engines.

Response flowchart in the event of loss of power

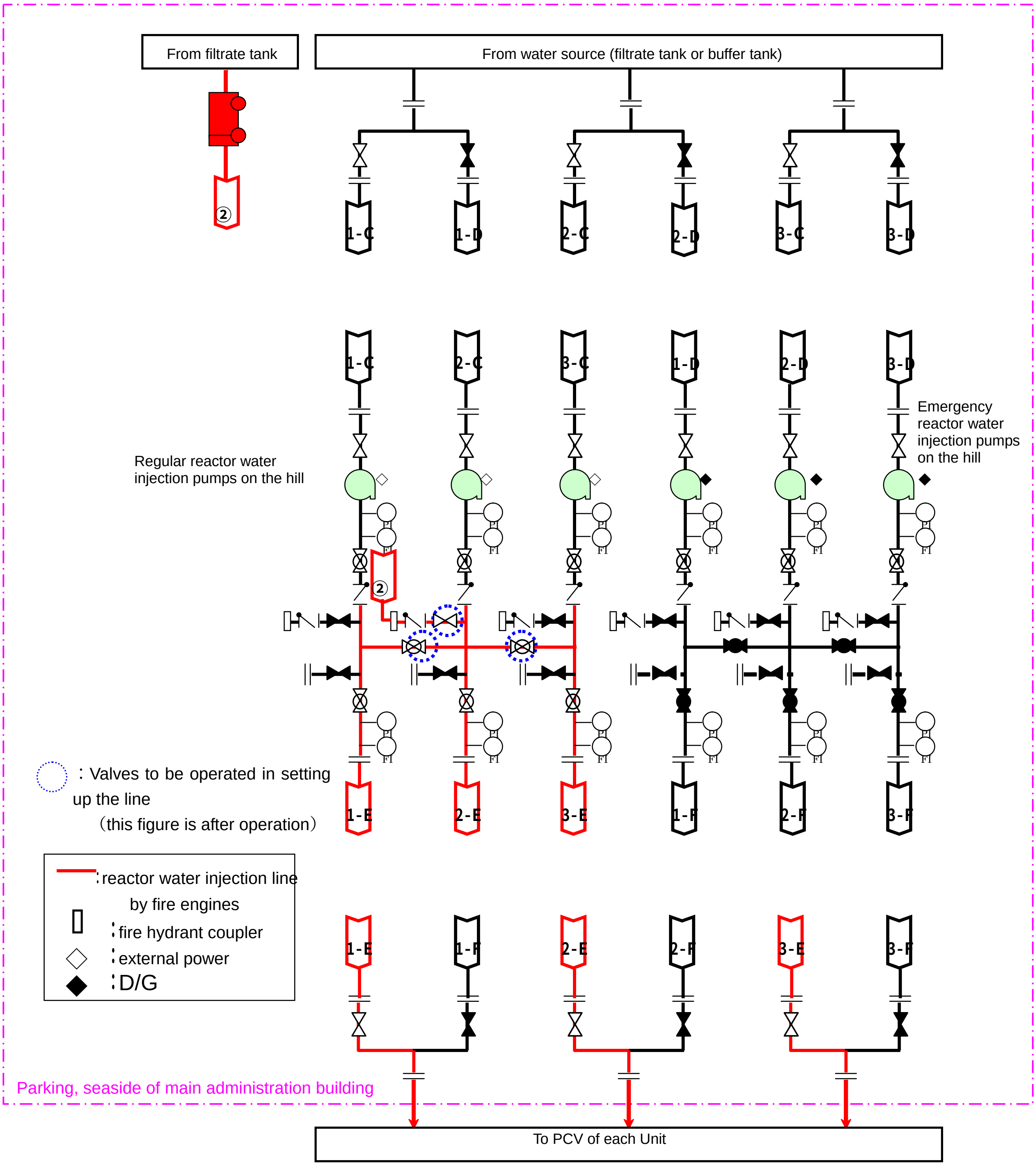
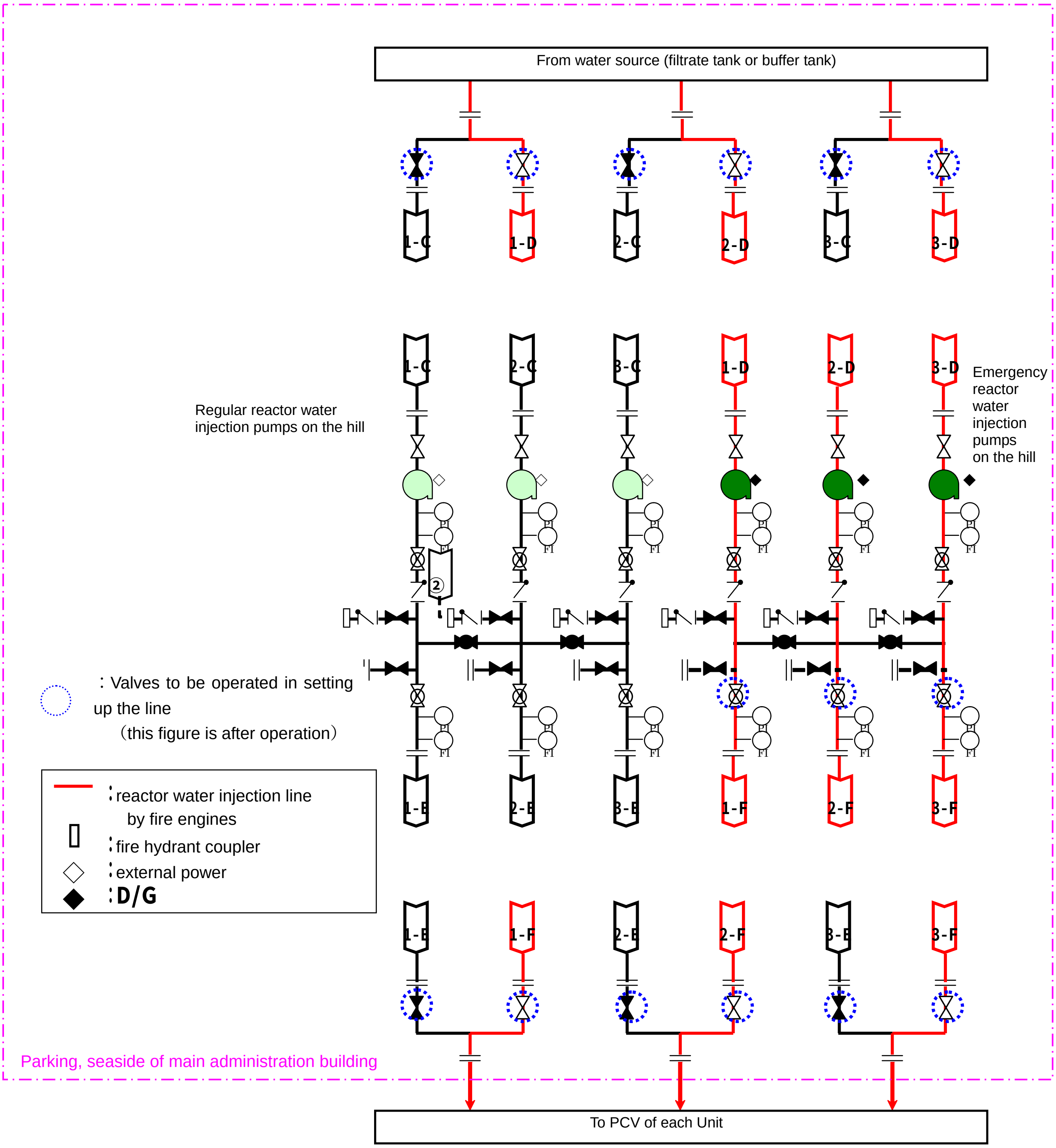


Figure 1: a conceptual system diagram for reactor water injection in the event of loss of power

（reactor water injection by fire engines）

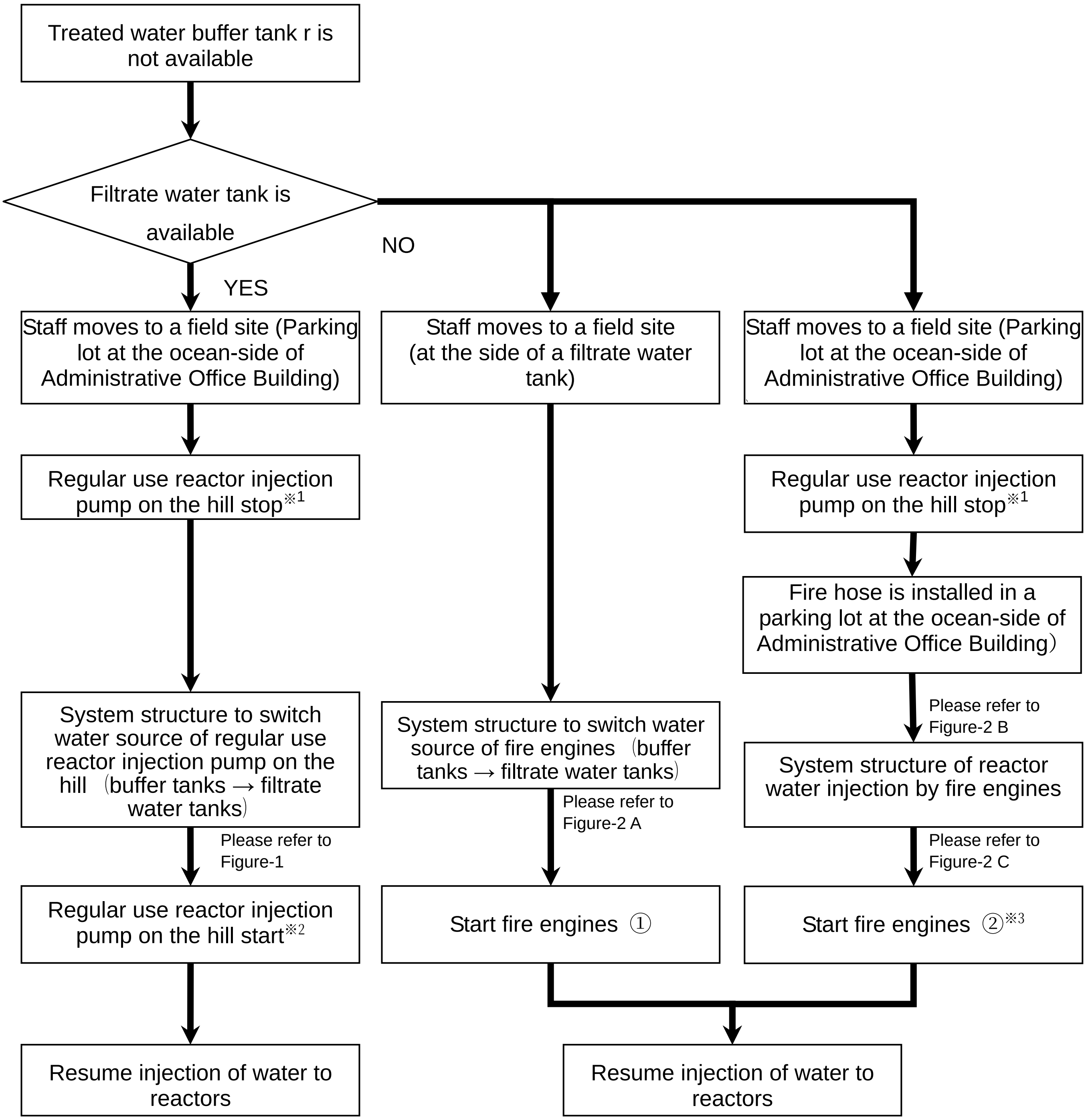


※ This example is when the tie-line is not used

Figure 2: a conceptual system diagram for reactor water injection in the event of loss of power※

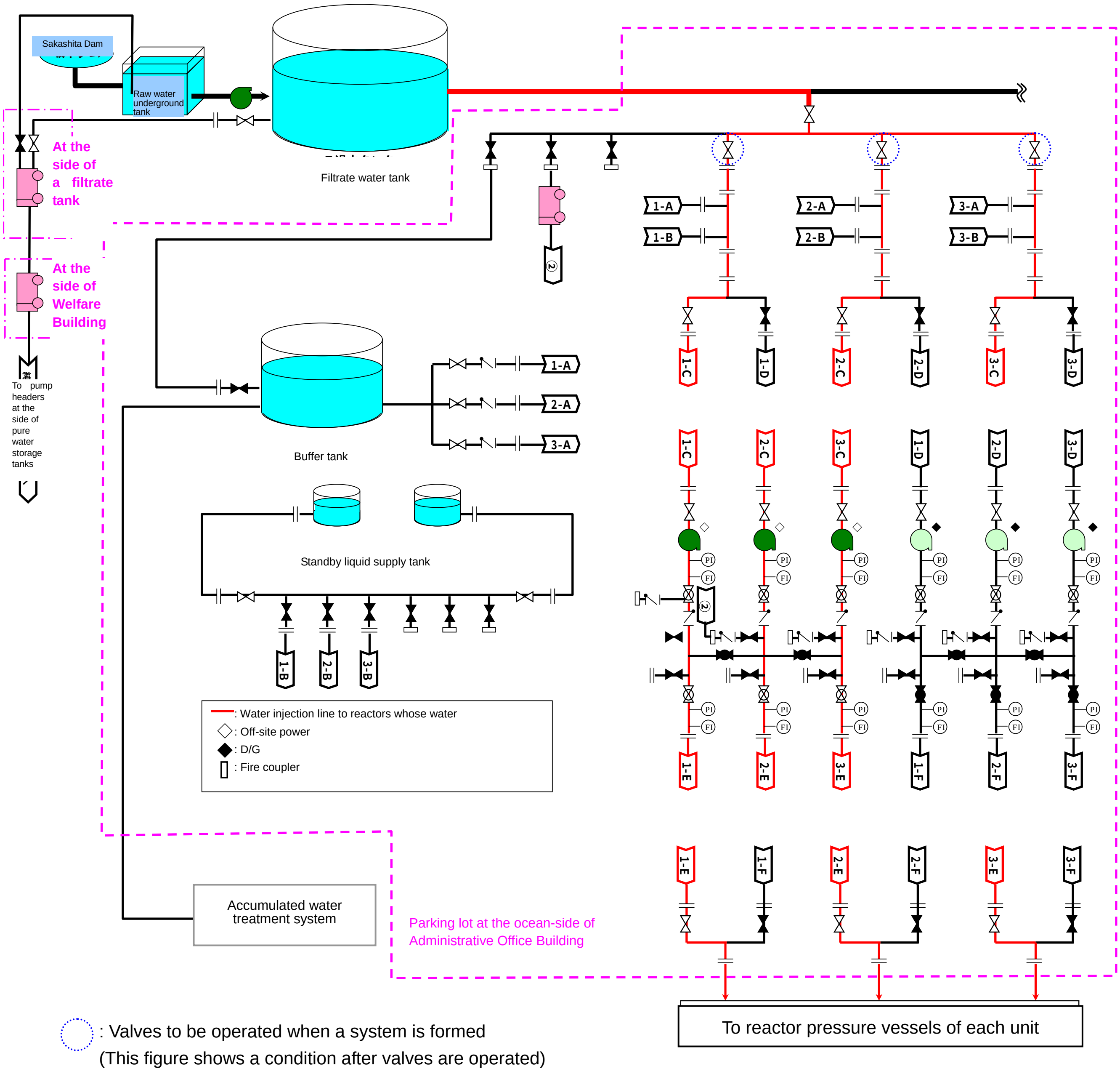
(reactor water injection by emergency reactor water injection pumps located on the hill)

Flow of countermeasures and simplified system diagram in case of failure of power source



※1 In case a water level in a buffer tank is too low to operate it
※2 In case pumps on a hill to inject water to reactors stop
※3 In case pumps on a hill to inject water to reactors are in operation, they are shut down

Flow of countermeasures in case of failure of power source



※ Example in a case a tie-line is not used

Figure-1 Simplified system diagram※ of injection of water to reactors in case of failure of power source (Injection of water to reactors whose water source is a filtrate water tank)

Fire hoses are regularly connected between fine engines at the side of a filtrate water tank and those at the side of Welfare Building. However, in case we inject water to reactors whose water source is a raw water underground tank, we change the destination of the connection from those at the side of a filtrate water tank. The destination is change to those at the ocean-side of Administrative Office Building from those at the side of Welfare Building.

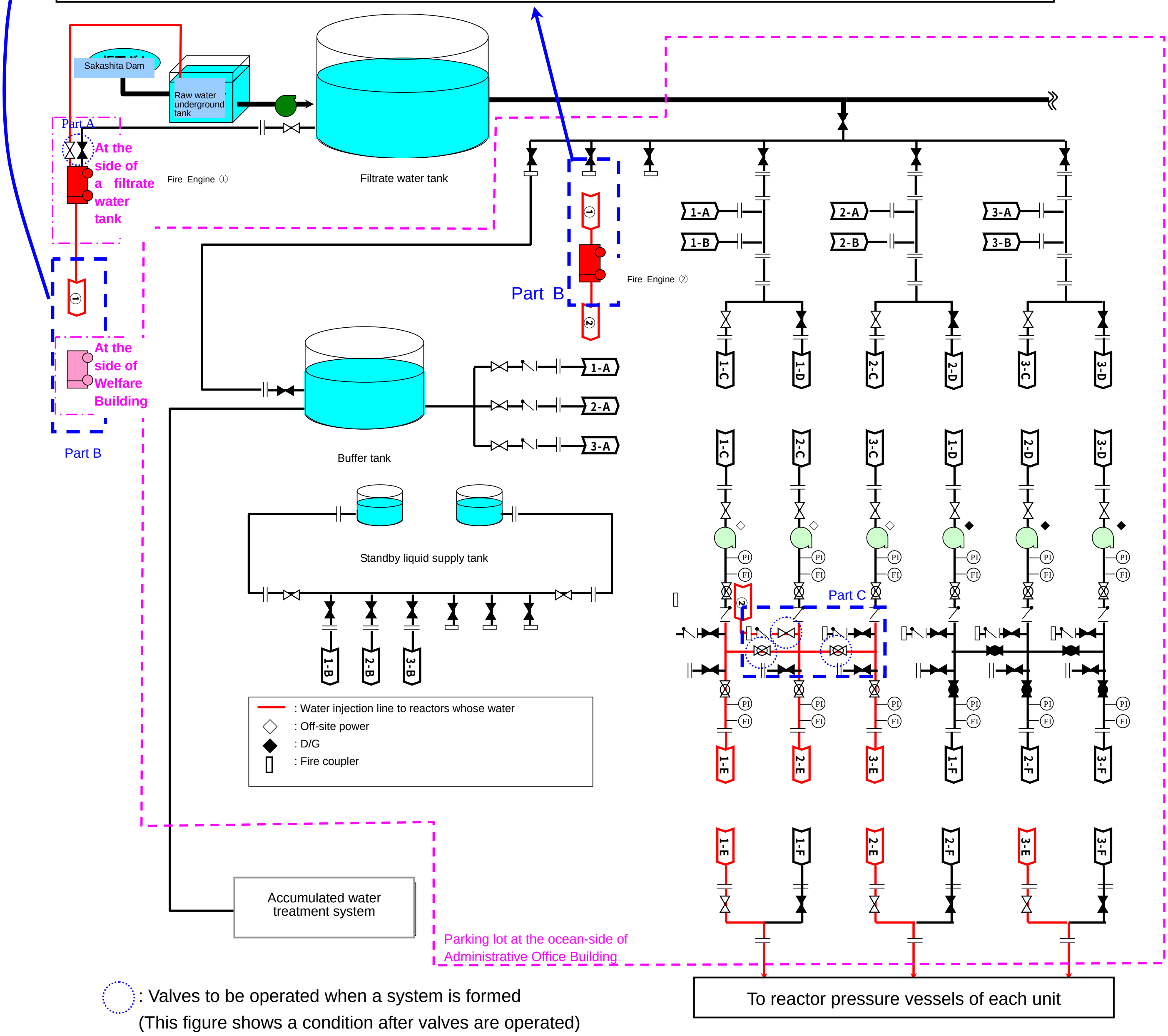
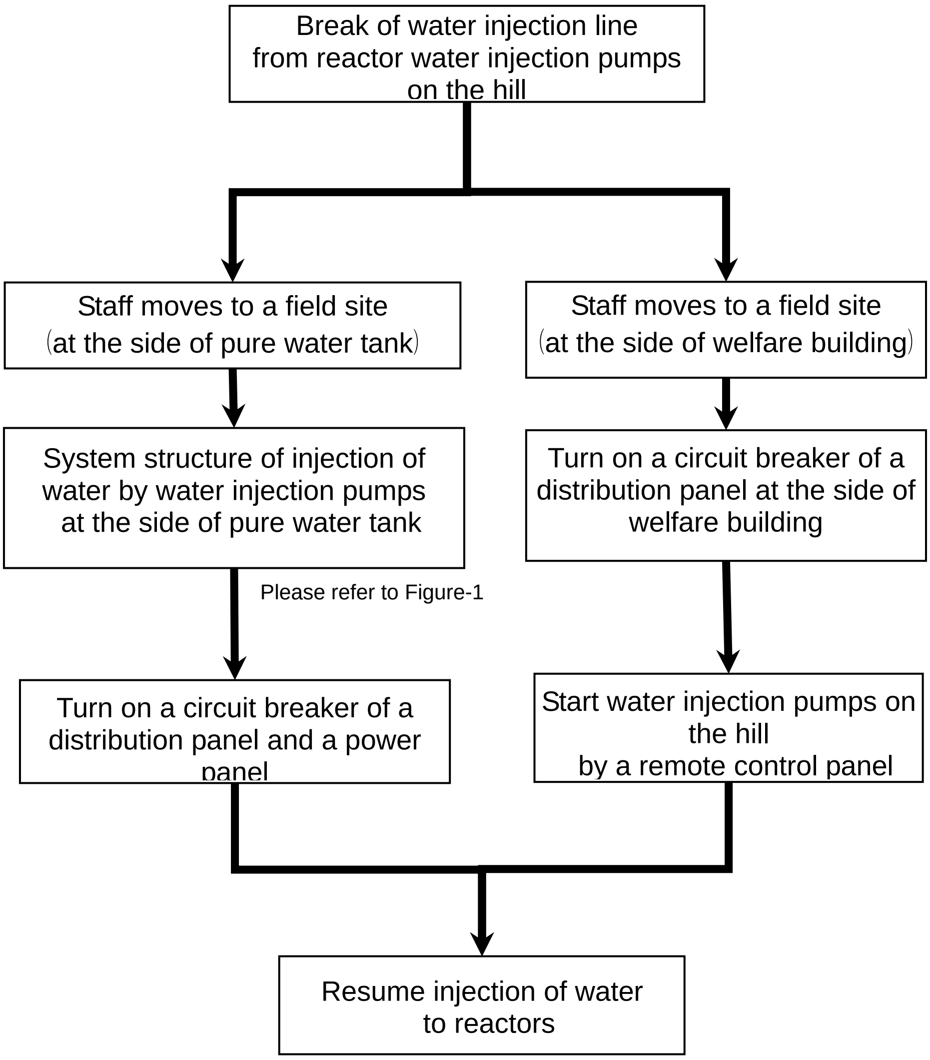
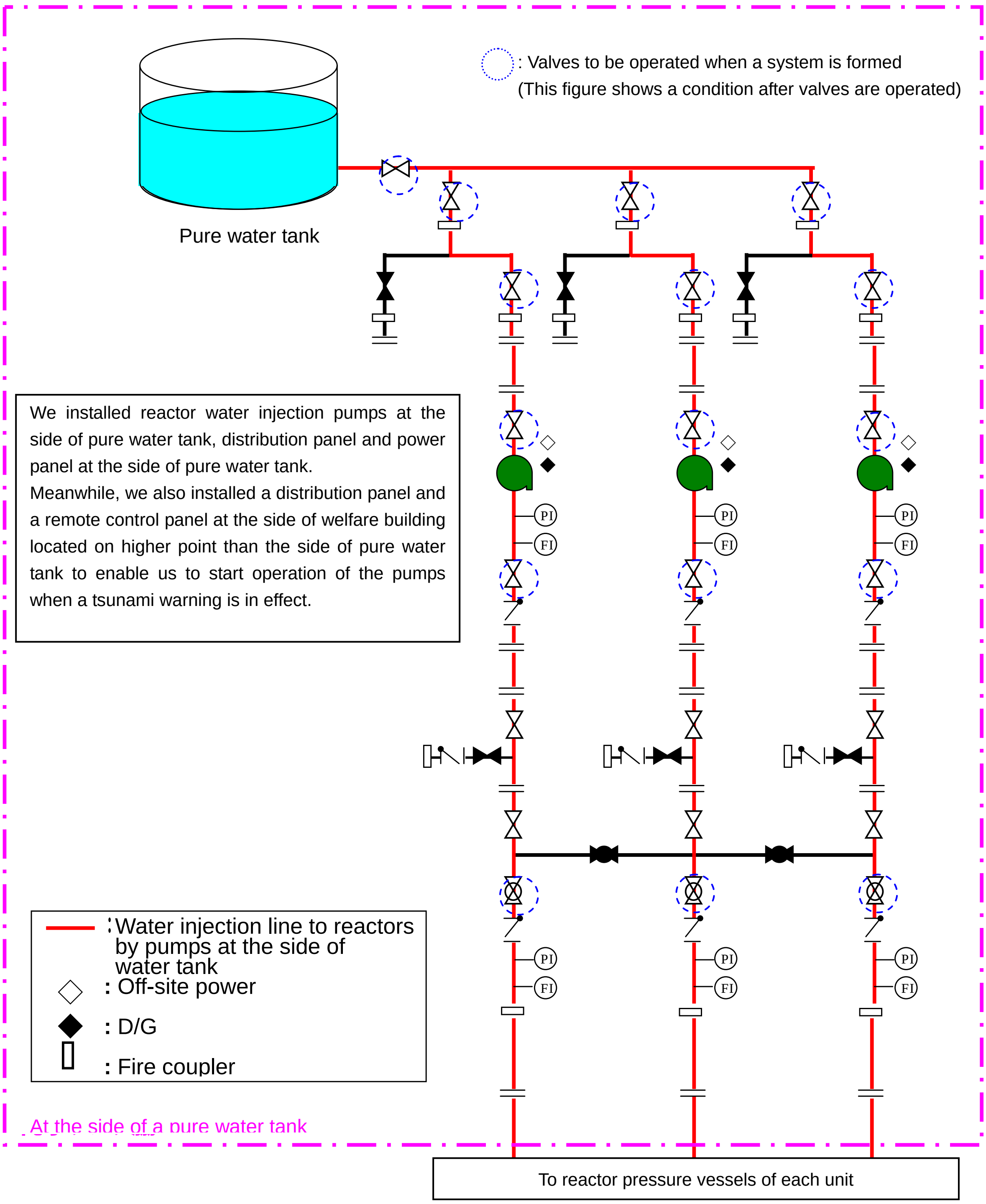


Figure-2 Simplified system diagram of injection of water to reactors in case of failure of power source (Injection of water to reactors whose water source is a raw water tank at the basement)

Flowchart of countermeasures and simplified system diagram in case of break of water injection line to reactors



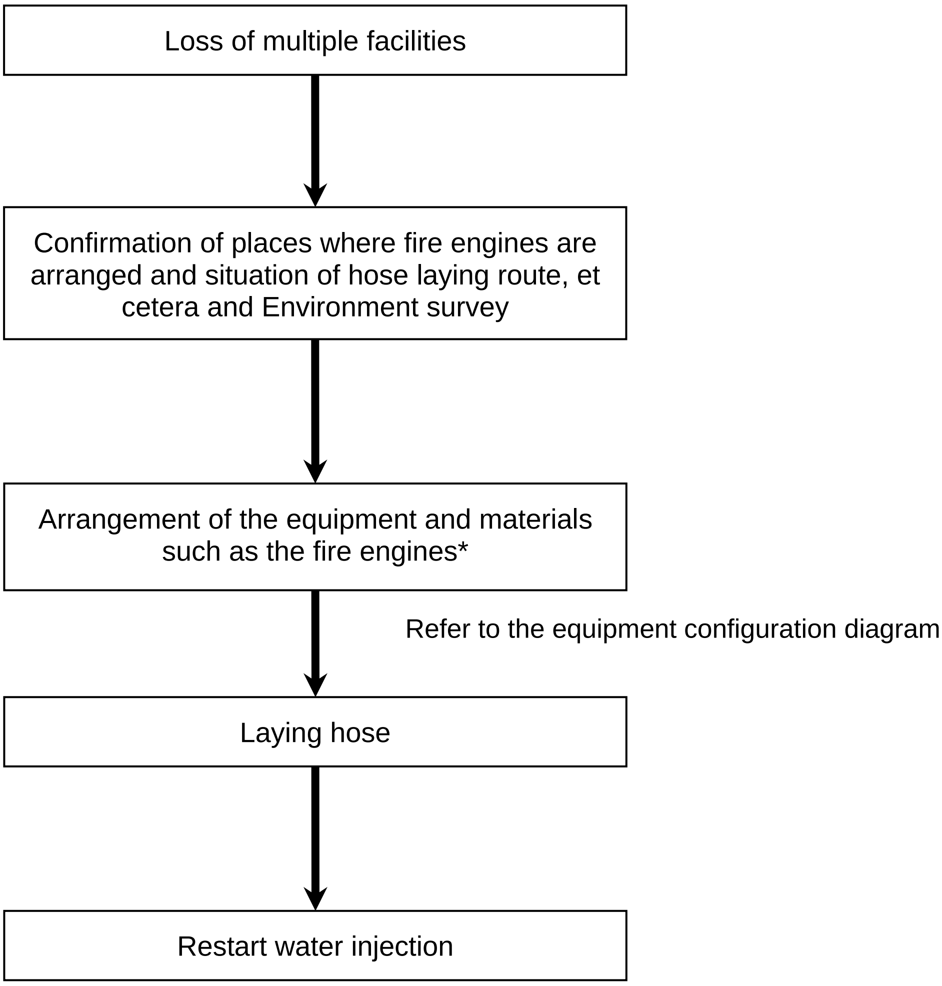
Flow of countermeasures in case of break of water injection line to reactors



※ Example in a case a tie-line is not used

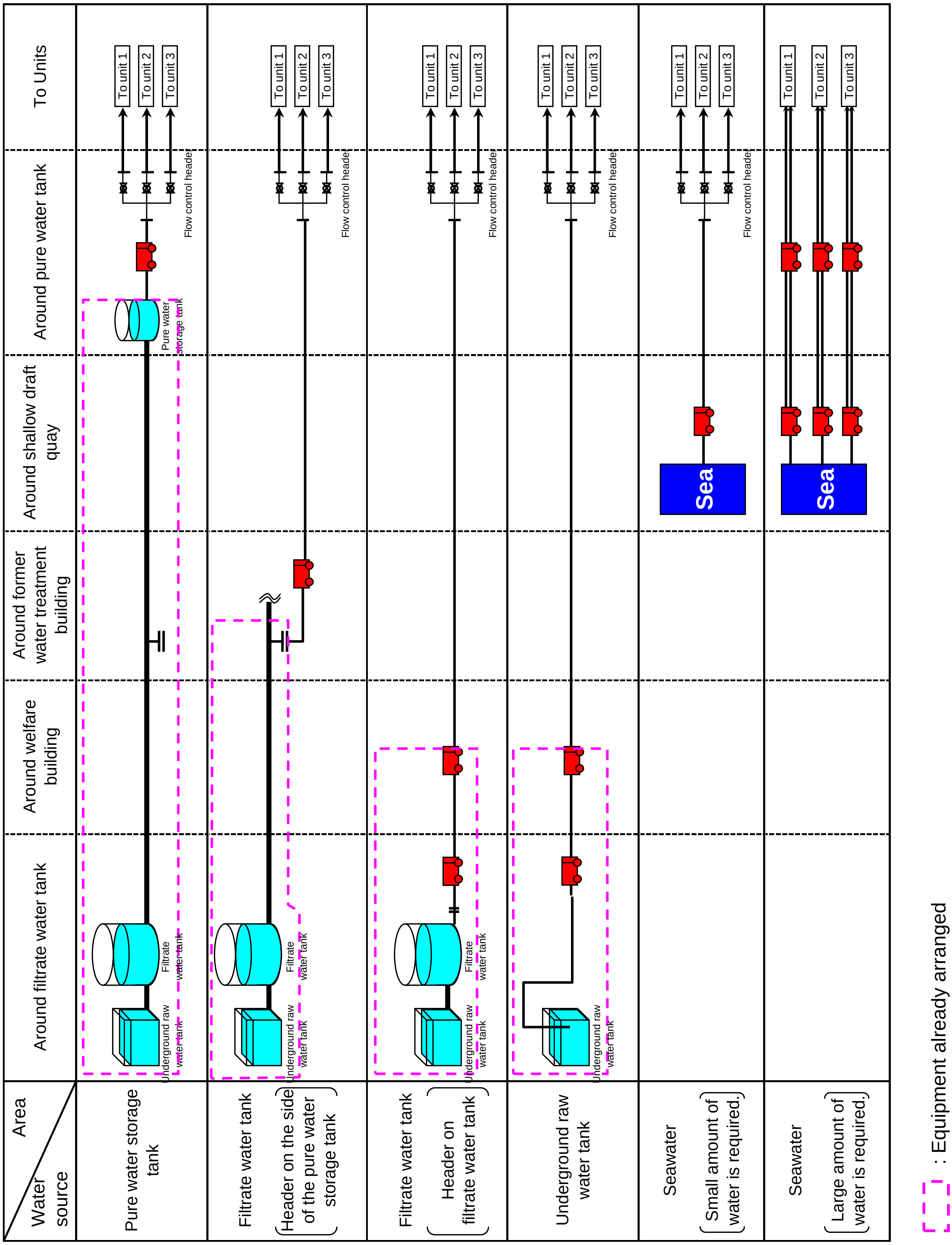
Figure-1 Simplified system diagram※ of injection of water to reactors in case of break of water injection line

Flowchart of countermeasures and equipment configuration diagram in loss of multiple facilities



* They are arranged considering water sources, amount of water injection and situations.
Candidates of the water source: Pure water storage tank and filtrate water tank (header on the side of the pure water storage tank and header in the former water treatment building), underground raw water tank, and seawater (if huge amount of water is necessary.)

Flow of countermeasures in loss of multiple facilities



Equipment configuration diagram in loss of multiple facilities

Attachment-11

The time required for increasing water-injection to prevent a sudden temperature rise

In order to prevent a sudden temperature rise caused by rapid chemical reactions between H^2O and zirconium, we have estimated how much time it will take to increase the amount of water injection. As the result below that took 13 to 15 hours (as of August 1) shows, we decided it will require 12 hours from a conservative viewpoint.

A target amount of water injection this time will be $30m^3/h$ (1u) and 55 m^3/h (2u & 3u) seen from a conservative viewpoint. According to the "Operation guideline 1: Water injection to the damaged core", one of the sections of the Accident Management Guideline, these amounts are supposed to be enough to remove the reaction heat between decay heat and un-oxidized metal as well as the decay heat from fuel after a severe accident.

We can say that we will secure these amounts by connecting in series two fire engines so that we can have two lines for water injection. However, the record right after the accident shows it required some large amounts like 60 m^3/h, 78 m^3/h and so on.

【Evaluation: Temperature rise in fuel when halting water injection】

1. Assumption

As for the state of heat insulation by seeing from a conservative viewpoint, we assume that the entire decay heat will contribute to the heating up of nuclear fuels.

2. Condition

- Decay heat：0.82 MW（1u）, 1.19 MW（2u）, 1.22 MW（3u）, As of August 1, evaluated by using ORIGEN
- The entire amount of nuclear fuel: 120t (1u), 164t (2u & 3u)
- Fuel comparison heat: 0.4kJ/kg・℃
- Water amount in RPV: 0m3
- The temperature at which a H^2O-zirconium reaction progresses rapidly: 1200℃
- Fuel temperature: 300℃

3. Formula

Time for temperature increase [h] =

Entire fuel amount[t]×10^3×Fuel comparison heat[kJ/kg・℃]／
Decay heat[MW]×10^3×3,600[sec/h]×
(1,200-300) [℃]

4. Result

Times required for temperature increase up to 1,200℃ are as follows:

	1u	2u	3u
Time required up to 1,200℃	15 hours	14 hours	13 hours

End

Fuel temperature increase when water injection into reactors stopped

1. Assumptions of evaluation

Assuming conservative adiabatic condition, it was supposed that the heat up of fuel was attributed to all decay heat.

2. Condition of evaluation

- decay heat: 0.82MW (Unit 1), 1.19MW (Unit 2) and 1.22MW (Unit 3) evaluated by using multipurpose calculation code, "ORIGEN" as of Aug. 1 2011.
- total fuel amount: 120 t (Unit 1) and 164 t (Unit3, Unit3)
- fuel specific heat: 0.4kJ/kg・℃
- quantity of water inside Reactor Pressure Vessel: 0m3

3. Evaluation calculation formula

$$\text{Temperature increase } [^\circ C] = \frac{\textit{Decay heat}\,[MW]\times 10^3 \times 3600\,[\mathrm{sec}/h]}{\textit{Total fuel amount}\,[t]\times 10^3 \times \textit{fuel specific heat}\,[\mathrm{kJ/kg}\cdot{}^\circ C]}\times 1[h]$$

4. Evaluation result

Fuel temperature increase without water injection (1 hour) is shown in following table.

	Unit 1	Unit 2	Unit 3
temperature increase per hour w/o water injection	approx. 62℃	approx. 65℃	approx. 67℃

End