“The Accident at Fukushima: What Happened?”

February 27, 2012

Takao Fujie
President and Chief Executive Officer
Japan Nuclear Technology Institute (JANTI)

“The Accident at Fukushima: What Happened?”

Foreword

Thank you for the kind introduction. My name is Takao Fujie, and I am the President and CEO of the Japan Nuclear Technology Institute. I would like to thank you for inviting me to WM 2012. I am greatly honored to have the opportunity to speak to all of you who have traveled from around the world in order to be here.

First of all, I would like to express my gratitude for the generous support we have received from countries globally in the wake of the Great East Japan Earthquake on March 11 last year.

At 2:46 PM, on the coast of the Pacific Ocean in eastern Japan, people were spending an ordinary afternoon: children at nurseries and schools, parents at work, and elders safe at home. Though they were to be horrified by the sudden long, violent shaking, there were very few injured or dead at this point, and people began making sure they and their loved ones were safe. However, just as they thought everything was fine, a tsunami warning was issued and they had to evacuate to higher areas. The tsunami that crashed down 30-40 minutes later was enormous in size. It easily cleared the high levees, washing away cars and houses and swallowing buildings of up to three stories in height. It was due to this tsunami that the disaster became one of a not imaginable scale, which saw the number of dead or missing reach about 20,000 persons.

I will show you a short video of the tsunami, hitting Kesennuma City of the Tohoku district in Japan. This video was provided by Japan Coast Guard.

The enormous tsunami headed for 15 nuclear power plants on the Pacific coast, but 11 power plants withstood the tsunami and attained cold shutdown. But the cores of three reactors at the Fukushima Daiichi Nuclear Power Plant suffered meltdown. As a result, more than 160,000 residents were forced to evacuate, and are still living in temporary accommodation.

Today, my main focus will be on what happened at the Fukushima Daiichi, and how station personnel responded to the accident, with considerable international support.

(1) Overview of the Great Eastern Japan Earthquake and Tsunami

The epicenter of the earthquake is indicated by an X on this map. The earthquake had a magnitude of 9.0, the fourth largest ever recorded in the world. A very large number of aftershocks were felt after the initial earthquake. More than 100 of them had a magnitude of over 6.0.

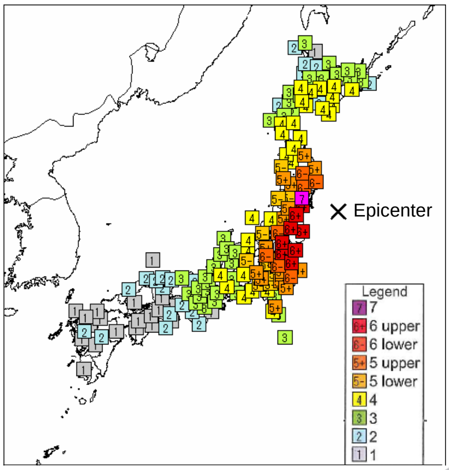
The large earthquake caused by this enormous crustal deformation spawned a rare and enormous tsunami. The largest tsunami reading taken from all regions was 40 meters in height. This tsunami reached the West Coast of the United States and the Pacific coast of South America, with wave heights of over two meters.

The flood height of the tsunami that struck each power station ranged to a maximum of 15 meters. The Fukushima Daiichi Nuclear Power Plant Units experienced the largest.

1

The 2011 Earthquake off the Pacific Coast of Tohoku

1. Date : March 11, 2011
2. Epicenter : ~130 km offshore
3. Depth : ~ 24 km
4. Magnitude : Mw 9.0
5. Seismic Intensity : 7 (Miyagi Pref.)
   6 upper (Fukushima Pref.)

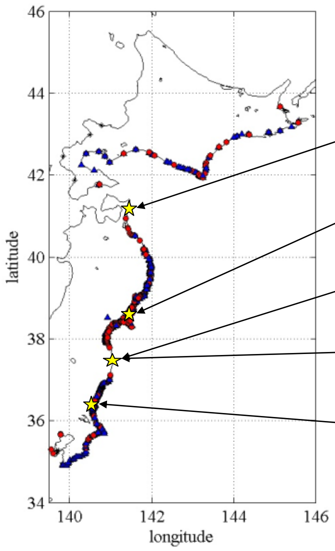


Source: Website of Japan Meteorological Agency

～ Toward the further Nuclear Safety ～ Japan Nuclear Technology Institute

2

Tsunami Height Observed at Nuclear Power Stations on Pacific Coast of Japan



Name of NPS	Operating	Outage
Higashidori	–	1
< 4m		
Onagawa	3	–
13m		
Fukushima Daiichi	3	3
14~15m		
Fukushima Daini	4	–
6.5~7m, Locally >14m		
Tokai Daini	1	–
5.4m		

:Tsunami Observation Points

～ Toward the further Nuclear Safety ～ Japan Nuclear Technology Institute

(2) Overview of Accident at Fukushima Daiichi Nuclear Power Station

The Fukushima Daiichi Nuclear Power Station is made up of six BWRs. Units 1~3, seen here on the left from the center, experienced meltdown. All of these Units were constructed in the 1970s. Units 1 through 3 were operating at rated power and Units 4 through 6 were shut down for refueling.

Although the seismic motion recorded at the power station exceeded the design basis in some areas, the integrity of the power station facility structures was maintained and the automatic scram of the reactors activated as designed. However, damage to substation equipment and switchyard equipment at the power station caused all of Units 1 through 6 to lose off-site power. For example, this 275 kV circuit breaker at the substation connected to the Fukushima Daiichi was damaged. A circuit breaker for the Unit 1 power transmission lines at the power station was also damaged.

The emergency diesel generator started up automatically, as it should, at each unit, and safety systems then functioned normally to start reactor cooling.

3

Fukushima Daiichi Nuclear Power Station
(Before Accident)

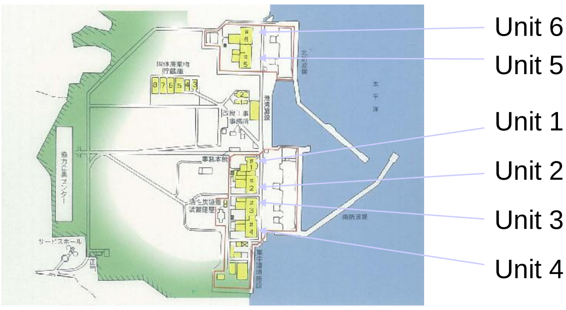
Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

4

Major Specifications of Fukushima Daiichi NPS



Location	Unit	In operation since	Plant type	Power Output (MW)	Main Contractor	Pre-earthquake status
Ohkuma	1	1971.3	BWR-3	460	GE	Operating
	2	1974.7	BWR-4	784	GE/Toshiba	Operating
	3	1976.3	BWR-4	784	Toshiba	Operating
	4	1978.10	BWR-4	784	Hitachi	Shutdown for maintenance
Futaba	5	1978.4	BWR-4	784	Toshiba	Shutdown for maintenance
	6	1979.10	BWR-5	1100	GE/Toshiba	Shutdown for maintenance

Source: Website of Tokyo Electric Power Company

5

Example of Damage by Earthquake

275kV Circuit Breaker of Substation

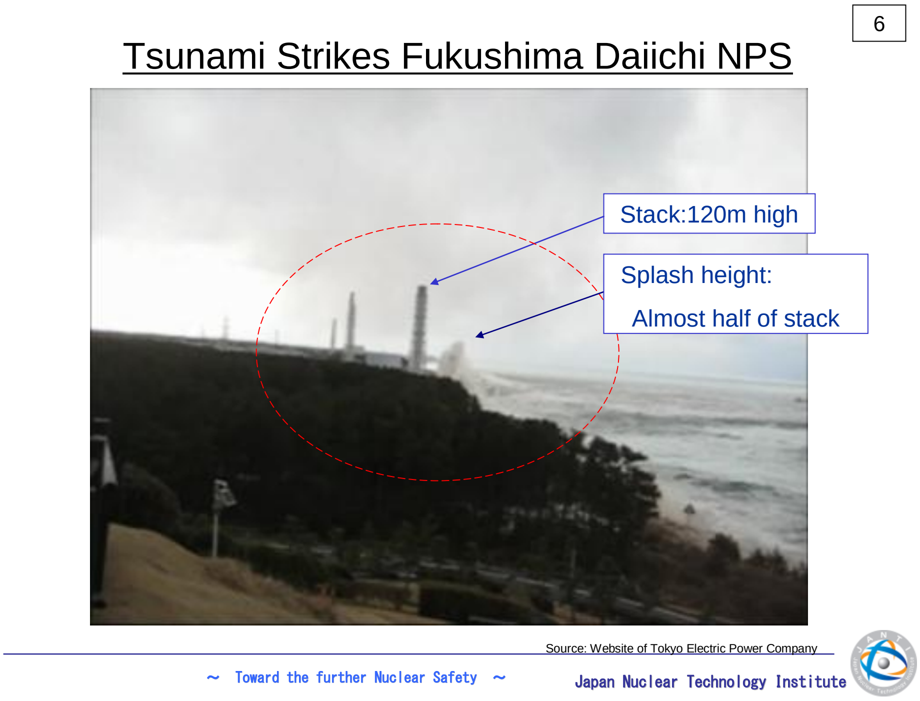
Circuit Breaker of Fukushima Daiichi NPS

Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

Within about 50 minutes of the earthquake striking, the enormous tsunami engulfed the power station. This photograph taken from the observation deck shows a wave that has crashed into the breakwater and reached a height half of the 120-meter tall stack.



I will show you a series of photographs of the tsunami striking the north breakwater. This wave rode over the 10-meter high breakwater and covered two-thirds of the 15-meter tall surge tank.

The next series of photographs show submerged oil tanks in the area surrounding the radioactive waste treatment facility, the ground level of which is 10 meters above sea. The 5.5 meter tank has been completely submerged. This indicates that the flood height has reached more than 15 meters.

7

Tsunami Striking North Breakwater

Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

8

Flooding by Tsunami around R/W Treatment Facility

Source: Website of Tokyo Electric Power Company

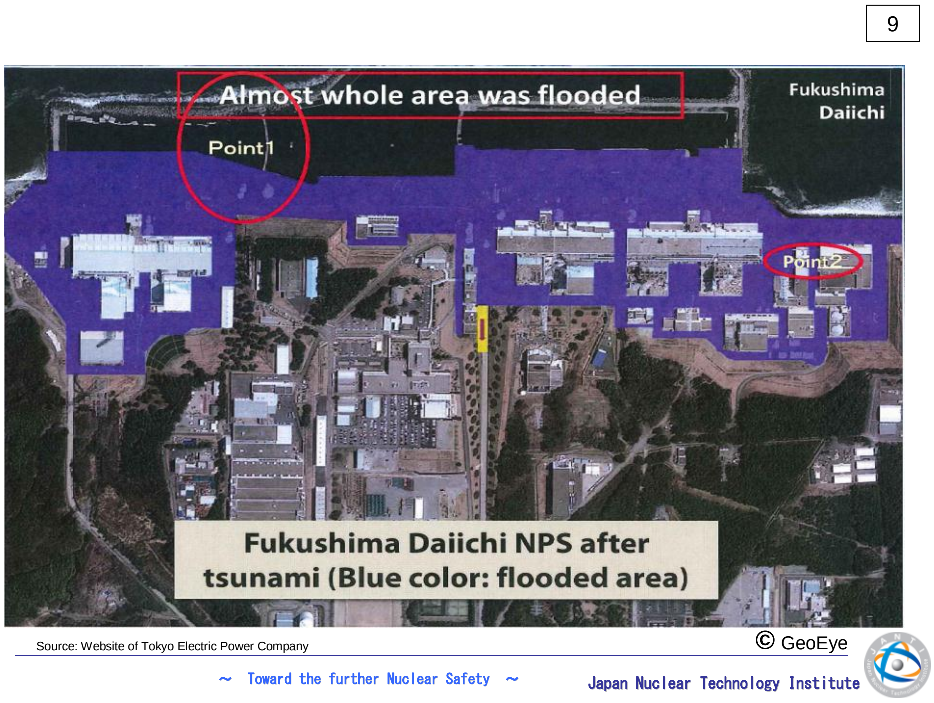
～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

From an aerial photograph of the Fukushima Daiichi Power Station, the flooded areas can be seen in blue. In addition to the seaside area, the area around the reactor buildings and turbine buildings of all units has flooded. The devastation after the tsunami withdrew is apparent.

One of the oil tanks that had been on the seaside of Unit 1 was pushed 180 meters inland by the tsunami. The tank was carried to the Unit 1 turbine building and blocked the road. This road was a main access route to other Units. Because it was now blocked, a huge obstacle was created for accident response.

Because of the power of the tsunami, equipment in the yard has been destroyed and all that remains is a pile of rubble. Seawater pumps were also damaged.



10

Example of Damage by Tsunami - Oil Tank

Source: Website of Tokyo Electric Power Company

~ Toward the further Nuclear Safety ~

Japan Nuclear Technology Institute

11

Example of Damage by Tsunami - Seawater Facility

Source: Website of Tokyo Electric Power Company

~ Toward the further Nuclear Safety ~

Japan Nuclear Technology Institute

The ground level of the main buildings are 10 meters above sea , but the flood height by the tsunami was 15 meters and it left the surrounding area submerged under 5 meters of water. As a result, water entered the turbine buildings through the entrance and “openings” such as the air supply louver. Equipment in the basement of the turbine building, including the emergency diesel generator, power supply panels, and batteries, was damaged by the water, or flooded.

As a result, the emergency diesel generator stopped, and a station blackout occurred at Units 1 through 4. Moreover, with the exception of Unit 3, DC power, such as batteries, were simultaneously rendered inoperable, which caused instruments monitored in the main control room to stop working. It became impossible to observe the status of the plant. All functions of the primary cooling system were lost, with the exception of some equipment which remained partially functional.

I would like to use Unit 1 as an example in order to explain how the accident unfolded.

After station blackout, fire engines were used to inject water into the reactor as an emergency cooling method, while attempts were made to operate the vents to release the internal pressure of the containment vessel through dedicated pipes into the atmosphere.

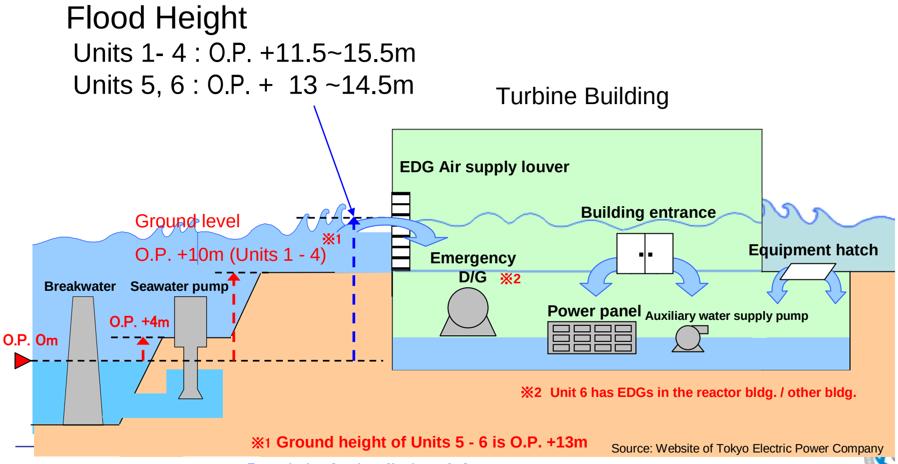
I will show you the conditions on site.

Please try to imagine yourself in the situation I am about to describe. First, think that you are in the main control room.

The earthquake has struck, you are using emergency power to perform post-scram work, suddenly the power goes out, all light vanishes, and you are left in complete darkness. The alarms that have been ringing are now silent and the main control room is plunged into silence. Operators are in a state of disbelief.

12

Flood Pathways into Turbine Building



～ Toward the further Nuclear Safety ～ Japan Nuclear Technology Institute

13

Chronology of Accident at Unit 1

March 11 14:46 Great East Japan Earthquake occurred

Reactor automatically scrammed

【SHUTDOWN】

↓

15:37 Station black-out due to Tsunami strike

(Sea water systems also lost)

Water injection 【COOLING】 | **Venting 【CONTAINMENT】**

March 12 15:36 Hydrogen Explosion Occurred

March 12 19:04 Injection of sea water started

～ Toward the further Nuclear Safety ～ Japan Nuclear Technology Institute

Since instrument power in the main control room had been lost, it was impossible to monitor the status of the reactor. Station personnel now carry heavy batteries from within the power station into the main control room as power supplies for important instruments, such as the reactor water level gauge.

An operator uses a flashlight to read one of the instruments that was brought to life, using the temporary batteries. Normal communication systems have been rendered inoperable and only the emergency hotline between the main control room and the emergency response center could be used, which greatly impaired accident response efforts.

The deputy shift supervisor is in the Unit 1 main control room at the time, faced with a situation he had never dreamt of. Since the lights had gone out and it was pitch black, a portable generator was brought in for temporary lighting in order to engage in emergency response work.

During this time, the core of Unit 1 had begun to melt. As well as in the reactor building, radiation levels inside the main control room started to rise. Operators were therefore wearing full face masks and protective clothing.

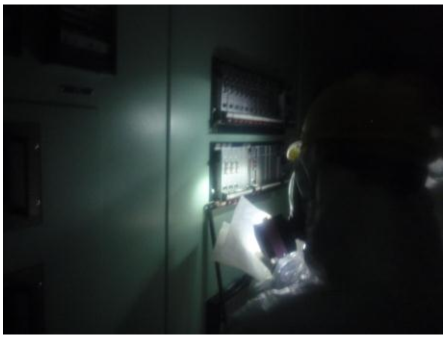
As a result of not being able to inject water into the reactor, a large amount of hydrogen was produced. It is theorized that the water level continued to decrease, the fuel melted and it fell to the bottom of the pressure vessel, consequently damaging it.

Because the pressure inside the containment vessel continued to rise, attempts were made to vent containment vessel pressure for fear of damage. However, since surrounding radiation levels were extremely high and there was neither power nor air to activate the drive mechanisms, it became extremely difficult to open the valves in the vent line.

14

Major Activities at Unit 1

Temporary Batteries



Operator

Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

15

Major Activities at Unit 1

Deputy Shift Supervisor

Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

It wasn't until 2:30 PM on March 12, that the operators were able to connect an air compressor and open the valve. Here we see steam being discharged from the exhaust stack.

Meanwhile, as traffic conditions worsened due to the earthquake, the arrival of power supply vehicles was delayed. Since most of the power supply panels in the turbine building were rendered inoperable by the tsunami, it took a great deal of time to restore power. However, temporary cables had finally been connected from the power supply vehicle to power supply panels that had not been flooded, and the high-pressure pumps were near to being activated.

It was then at 3:36 PM on March 12, that a hydrogen explosion occurred in the reactor building.

This explosion blew off the roof and the wall panels of the top floor, leaving its metal frame exposed. In the Unit 1 main control room, the explosion caused the ceiling light molding to fall to the floor. The explosion also caused debris to fall on the road next to Unit 1 and blew out the windows of the office building.

16

Major Activities at Unit 1 - PCV Venting

Before PCV Venting

After PCV Venting

Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

17

Hydrogen Explosion at Unit 1

March 12 15:36 Hydrogen Explosion Occurred at R/B.

Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

18

Damage by Hydrogen Explosion

Main Control Room

Adjoining Building

Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

It damaged the temporary power cables and power supply vehicle, and the high-pressure pumps could not be activated. Furthermore, the seawater injection hoses that were being prepared to use a fire engine as a water source were damaged, thereby delaying the injection of seawater into the reactor.

In the scattered debris, work to inject seawater into the reactor using a fire engine began at around 7:00 PM on March 12. What I have just described is how the accident at Unit 1 unfolded.

At Units 2 and 3, station blackouts occurred and the only turbine-driven pump that was still operating stopped to function after the batteries became discharged, which led to meltdown. Also, at Unit 4, where all the fuel had been removed from the core to the spent fuel pool, hydrogen released from the venting the containment vessel of Unit 3 flowed into the Unit 4 reactor building through the merging exhaust pipe and is thought to have resulted in the hydrogen explosion.

This was taken on March 15, four days after the accident, and shows the condition of the reactor buildings of Units 1 through 4. With the exception of Unit 2, other reactor buildings all show extensive damage due to the hydrogen explosions.

It was in this environment of scattered debris from the hydrogen explosions and tsunami, very high radiation levels, frequent large earthquake aftershocks, and continuous tsunami alarms, that work to restore power and inject seawater to cool the fuel were continued.

I think we can agree that it was to a great extent the bravery of the Power Station, Fire and Self-Defense Force personnel who devoted themselves to the task at hand that prevented the accident from worsening.

19

Major Activities at Unit 1 - Seawater Injection

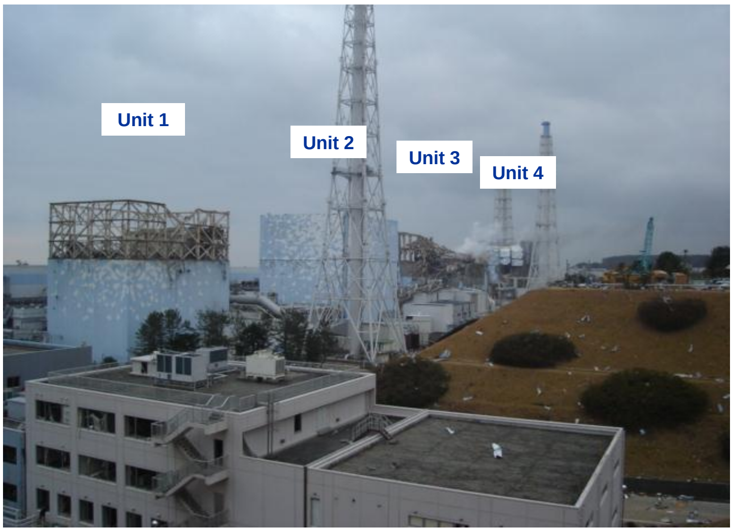
Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

20

Units1 - 4 after Hydrogen Explosions

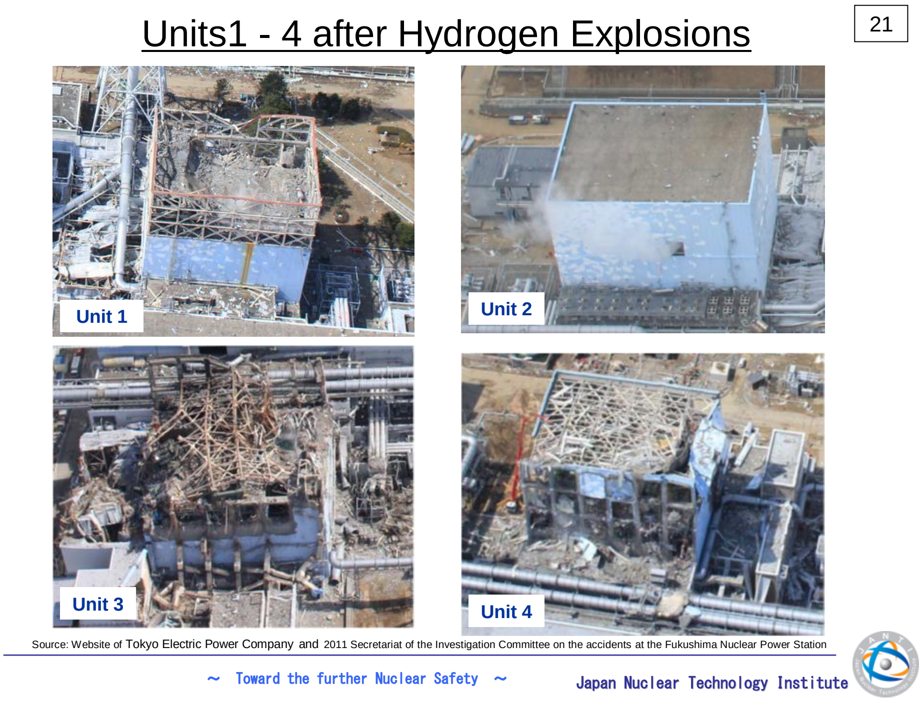


Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

I will next show you some aerial photographs of the reactor buildings for each unit.

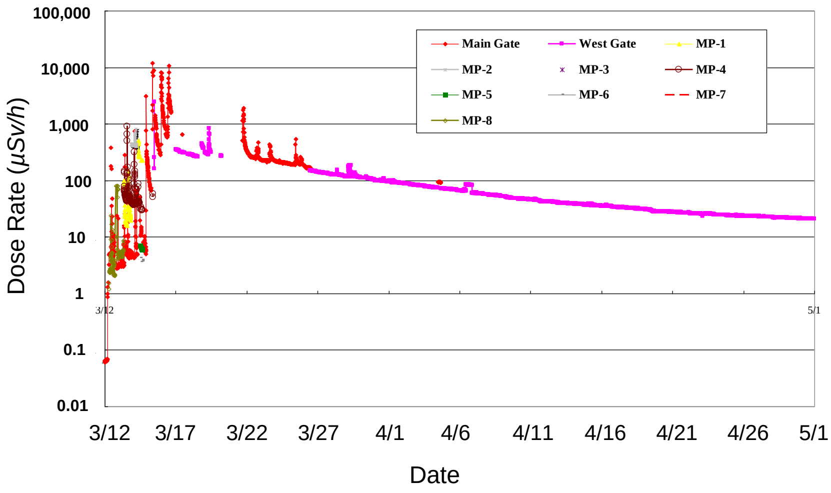


For the dose rate trend at the site boundary after the accident, peak values exceeded 10mSv/h, but that radiation level gradually started to decrease after the end of March.

The results of an analysis of core damage by TEPCO show that at Unit 1, where core meltdown occurred the quickest, almost all of the fuel melted and fell from the pressure vessel onto the concrete of the containment vessel. However, even though the accuracy of this analysis remains unclear, it is believed that the containment vessel prevented fuel debris from penetrating the concrete. Furthermore, at Units 2 and 3, a large amount of fuel accumulated within the pressure vessel due to the water injection into the reactor that continued for some time after the accident, and it is predicted that only some of the fuel that fell dropped into the containment vessel.

22

Dose Rate Trend at Site Boundary

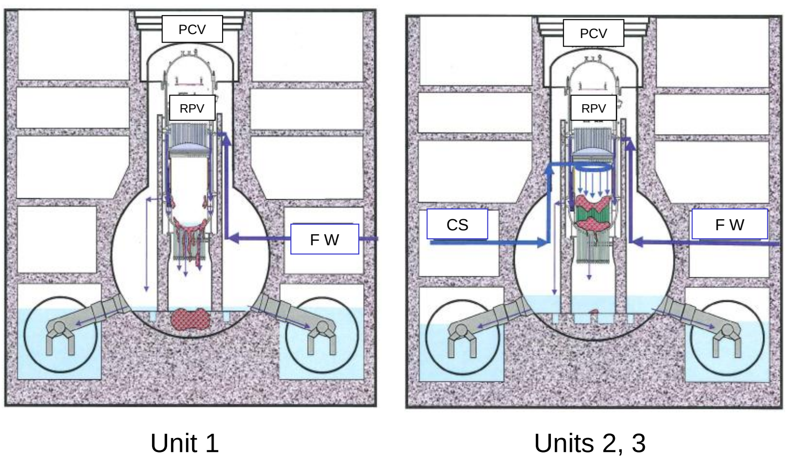


Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～ Japan Nuclear Technology Institute

23

Estimated Damage of Reactor Core



Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～ Japan Nuclear Technology Institute

(3) Impact on Environment Surrounding Nuclear Power Station

As a result of the meltdowns at Units 1, 2, and 3, a large amount of radioactive material was discharged into the environment surrounding the power station. Radiation levels were measured from the air using helicopters and the result of a survey of cesium contamination density showed that, as seen in this diagram, highly concentrated contamination, marked in red, spread to the northwest of the power station, with some of the contamination extending beyond a 30 km radius.

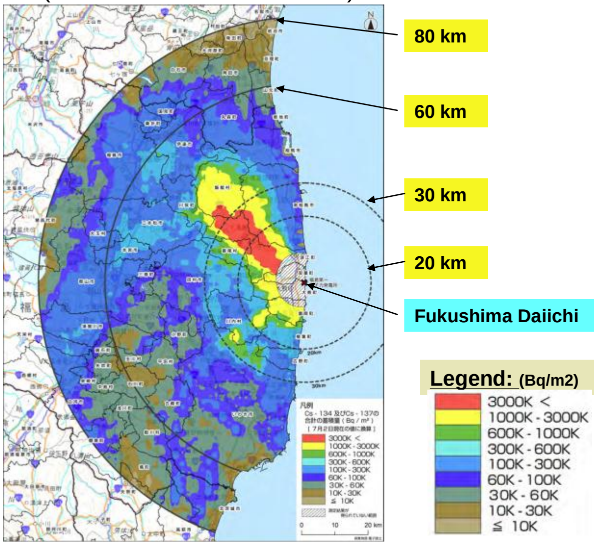
Radionuclide migration was due to the direction of the wind at the time of discharge of the radioactive material, as well as rainfall which caused the contamination to drop to ground level. Residents living within a 20 km radius of the power station, and also those in the northwest where contamination levels were high, were evacuated. There are also many residents who evacuated voluntarily.

If we compare the dispersion of contamination with that of the Chernobyl accident, we see that the range of contamination from the Fukushima accident is relatively small, especially when we consider that the cores of three reactors actually underwent melt-down.

24

Land Contamination around Site

(Cesium134 and Cesium137)

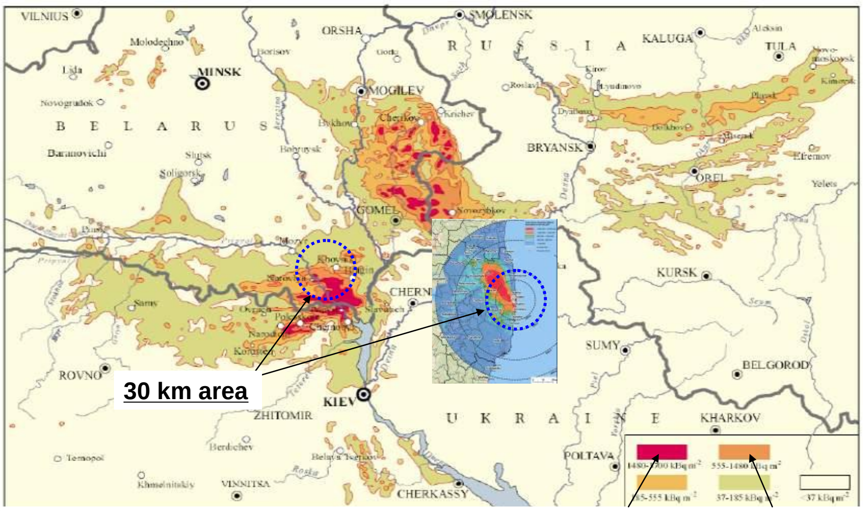


Source: Website of Ministry of Education,Culture,Sports,Science & Technology in Japan

~ Toward the further Nuclear Safety ~ Japan Nuclear Technology Institute

25

Comparison with Spread of Contamination from Chernobyl Accident



Source :IAEA Pub-1239 "Environmental Consequences of the Chernobyl Accident and their Remediation :Twenty Years of Experience " (April 2006)

Confiscated/Closed Zone: Cs-137:1480-3700kBq/m2

Permanent Control Zone: Cs-137: 555-1480kBq/m2

~ Toward the further Nuclear Safety ~ Japan Nuclear Technology Institute ⑩

(4) Actions to Bring the Accident at Fukushima Daiichi Nuclear Power Station Under Control

Since April of last year, TEPCO has been enormously engaged in activities fully aimed at stabilizing the power station and has set goals aimed at creating a situation where the power station and spent fuel pools are cooled in a stable manner and radioactive material discharge is suppressed.

This work is largely conducted by a “circulating water cooling system” which contains the large amount of accumulated water, contaminated by radioactive material, while at the same time processing, storing it or recycling it to cool the fuel in the reactor. TEPCO has also implemented “radioactive material suppression countermeasures”.

This schematic shows the flow of the circulating water cooling system. Highly contaminated water that has flowed into the turbine building is processed using a decontamination and desalination system, and processed water is returned to the reactor for cooling the fuel. The contaminated water is processed by a combination of several technologies, including cesium adsorption and desalination using reverse osmosis.

For a period of several months following the accident, the critical situation faced was that a huge amount of highly contaminated water, around 100,000 tons, had accumulated inside the reactor and turbine buildings of the Fukushima Daiichi Nuclear Power Station. In order to prevent contaminated water from overflowing from the buildings into the ocean, one of the most urgent and highest priority issues was to establish such circulating water cooling system.

26

Roadmap towards Stabilization

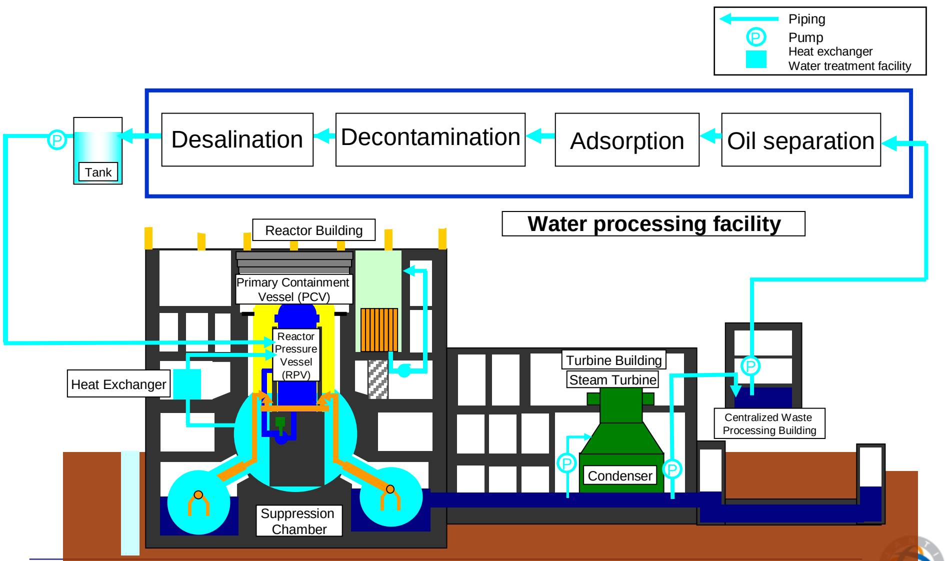
	April '11 – Step 1 – July '11	Step 2 – Dec. '11	Mid-term issues
Reactors	**Stable cooling** **Injection of water**	**Cold shutdown condition** **Circulating injection cooling**	**Protection against corrosion cracking of structural materials**
Spent Fuel Pools	**Stable cooling**	**More stable cooling**	**Start of fuel removal work**
Accumulated Contaminated Water	**Secure storage location**	**Reduction of total amount of contaminated water**	**Installation of full-fledged water processing facilities**

Source: Website of Tokyo Electric Power Company

~ Toward the further Nuclear Safety ~ Japan Nuclear Technology Institute

27

Circulating Water Cooling System



Source: Website of Tokyo Electric Power Company

~ Toward the further Nuclear Safety ~ Japan Nuclear Technology Institute

The equipment was installed at a fevered pitch, on the most compressed schedule possible. I thought that special mention should be made of the fact that we are able to process contaminated water. I would also mention that this work has been successfully achieved by adopting not only Japanese, but also French and US technologies. TEPCO has also continued to install and enhance holding tanks for the emergency storage of high-level accumulated water, as well as for processed water.

One of the countermeasures for suppressing the discharge of radioactive material into the environment is to provide the damaged Unit 1 reactor building with a “building cover”, and this work was completed at the end of last year. Taking high radiation dose rate into consideration, the structure for the cover was designed for assembly at site with neither welding nor bolting, but rather by adopting Japanese traditional installation and fitting techniques.

Work to restore the site, such as removing reactor building debris that was scattered by the hydrogen explosions, continues. Because the radiation level of the debris is so high, remote control equipment is applied to all work on site.

29

Reactor Building Cover - Unit 1

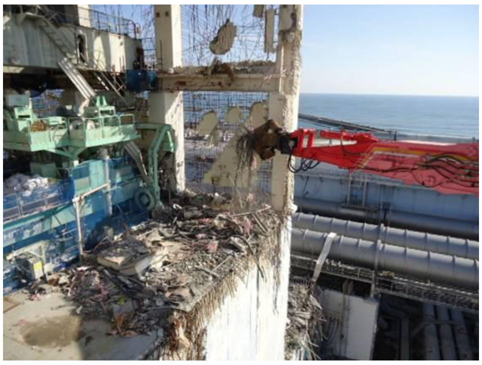
Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

30

Removal of Debris from Reactor Building



Source: Website of Tokyo Electric Power Company

～ Toward the further Nuclear Safety ～

Japan Nuclear Technology Institute

In order to prevent underground water from leaking into the ocean and further spreading contamination, steel plates have been sunk into the ground along the coast at the wharf, starting the work to build a water shielding wall that will cut off underground water from the sea.

The temperature of the bottom of the pressure vessel and within the containment vessel has decreased to under 100° C, and the amount of radioactive material being discharged into the atmosphere has been reduced. As a result, Step Two was achieved in December of last year and the government announced that cold shutdown state had been achieved.
With the completion of Step Two, power station activities have now entered a new phase which includes the long-term goal of decommissioning the reactor, within approximately 30 to 40 years.

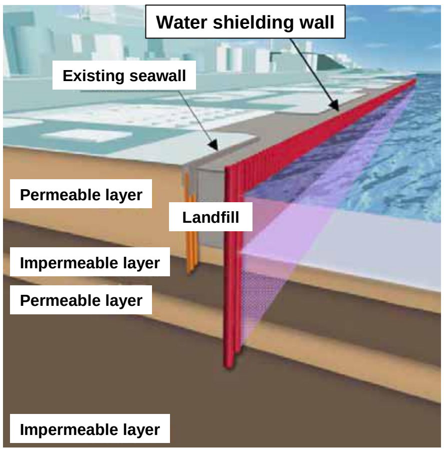
According to the mid to long-term roadmap decided on by the government and Tokyo Electric Power Company, the plan of activities to bring the accident under control, as well as the related research and development, consists of three phases.

In order to proceed with this mid to long-term roadmap, water injection needs to continue, and cold shutdown state needs to be stably maintained. At the same time, the development of various technologies is required in order to remove fuel debris. I hope that the collective wisdom of the global community will aid in solving this difficult issue.

31

Water Shielding Wall

Overview



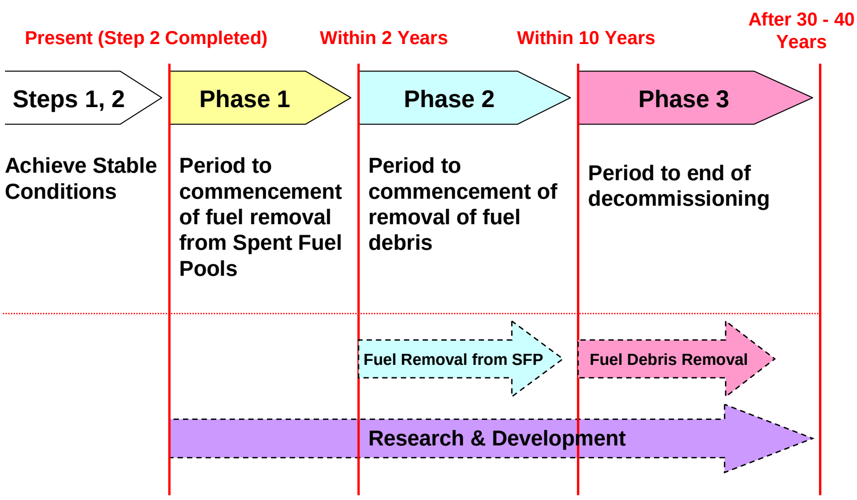
Cross-section

Source: Website of Tokyo Electric Power Company

~ Toward the further Nuclear Safety ~ Japan Nuclear Technology Institute

32

Mid- and Long-Term Roadmap



Source: Website of Tokyo Electric Power Company

~ Toward the further Nuclear Safety ~ Japan Nuclear Technology Institute

(5) Conclusion

March 11, just two weeks away, is the one-year anniversary of the 2011 Great East Japan Earthquake and Tsunami.

In conclusion, I would like to say three things to you.
Firstly, we will leverage the lessons we have learned from the Fukushima Daiichi accident to further improve the safety of nuclear power facilities and regain the trust of society.

In this connection, not only international organizations, including IAEA, and WANO, but also governmental organizations and nuclear industry representatives from various countries, have been evaluating what happened at Fukushima Daiichi.

Secondly, I want to mention that support from many countries has contributed to successfully stabilizing the Fukushima Daiichi Nuclear Power Station. International cooperation is required as we start along the long road to decommissioning the reactors. I expect that such cooperation with the international community will achieve the decommissioning of the damaged reactors.

Thirdly and finally, recovery plans by the Japanese government to decontaminate surrounding regions have been started in order to get residents back to their homes as early as possible. I pray for their speedy return.

Looking at the world's nuclear power industry, there are currently approximately 440 reactors in operation and 60 under construction. I believe the importance of nuclear power generation will not change in the years to come.

Newly accumulated knowledge and capabilities must be passed on to the next generation. This is the duty put upon us and which is one that we must embrace.

Thank you very much indeed for your attention.

END

Japan Nuclear Technology Institute (JANTI)