How Onagawa Responded at the Time?

The Nuclear Power Station That Withstood the Great East Japan Earthquake

A Report from the Scene by

Science Journalist

Wako Tojima

Contents

Cover images
The Samenoura community of Ishinomaki City, near the Onagawa Nuclear Power Station, right after the disaster hit.
Before the disaster, many people in this community were engaged in fishing and living out their daily lives, but they suffered enormous damage from the tsunami.
With nearly all the homes and other buildings having been washed away, more than 100 residents took refuge at the Onagawa NPS. (March 2011)

*This pamphlet is a translation of the revised version of an article published in the monthly magazine *Hiroba* (No.431) issued by the Tohoku Energy Conference.

Lessons to take us to the future

With three years having passed since the accident at the Tokyo Electric Power Company (TEPCO) Fukushima Daiichi Nuclear Power Station resulting from the Great East Japan Earthquake, efforts continue on raising the safety level of nuclear power plants throughout Japan. The importance of learning the lessons from this accident in upgrading safety goes without saying, but at the same time there is much of value to be learned from the examples of the nuclear power plants that withstood the earthquake and tsunami.

For a case study, science journalist Wako Tojima visited the Onagawa Nuclear Power Station owned and operated by Tohoku Electric Power Co., Inc. and filed this report from the scene.

Wako Tojima listens to Superintendent Shun Tsubata at the Onagawa Nuclear Power Station (Onagawa-cho, Oshika-gun and Ishinomaki City, Miyagi Prefecture), where work proceeds on raising the flood wall height

The untiring steps toward greater safety to be learned from the nuclear power plant that withstood the disaster

Where is the boundary between success and failure?

Since the Great East Japan Earthquake of March 11, 2011, I have walked in the disaster sites and have seen the aftermath up close.

The Fukushima Daiichi Nuclear Power Station owned by Tokyo Electric Power Co., Inc. had the misfortunate of suffering a major accident. The Fukushima Daini and Onagawa Nuclear Power Stations, meanwhile, were able to shutdown safely even though Fukushima Daini was situated geographically close to Fukushima Daiichi and Onagawa experienced the same or greater levels of shaking and tsunami waves as Fukushima Daiichi. What's more, as the surrounding communities were devastated by the disaster, the Onagawa site actually served as a shelter for evacuees.

What was it that decided the very different fates of these facilities?

I wanted to walk around seeing as many cases as possible, listening to the stories of those who experienced it firsthand, and confirming with my own eyes the "boundary between success and failure."

In the course of documenting this story, I became convinced that, in addition to learning from failure, there is much to be learned from success that can help take us to the future.

Fukushima Daiichi Nuclear Power Station following hydrogen-air explosions

Fukushima Daiichi Nuclear Power Station
when the tsunami arrived

Fukushima Daini Nuclear Power Station when the tsunami arrived
Photos: Tokyo Electric Power Co.

The success of Onagawa was not a "miracle"

In November 2013 I had the opportunity to give a talk in Taipei. After the Fukushima Daiichi accident, there was growing concern in Taiwan about the safety of nuclear power generation, and I was invited to speak because of a desire to learn more about the situation in Japan.

My presentation, aided by photograph slides, showed the situation when I visited nuclear power plants throughout Japan after the disaster.

I was surprised to discover that in Taiwan, it was not widely known that nuclear power plants had survived the Magnitude 9.0 earthquake and tsunami.

After my talk, reporters from various media pressed me for details about the reasons for the "success" of the Onagawa Nuclear Power Station.

Speaking with confidence and pride, I stated repeatedly that, "While there are those who see the success of Onagawa as a 'miracle,' I don't agree. Having visited the site, I believe it was because of the readiness in place at the time that the reactors were shut down safely."

What I would like to talk about here is why I feel that way.

The Great East Japan Earthquake and its unprecedented devastation

At 14:46 on March 11, 2011, an earthquake struck approximately 130 km off the Sanriku coast, on the ocean floor at a depth of around 24 km. The magnitude was 9.0. Nearly 20,000 people lost their lives to this, one of the largest quakes ever to strike Japan.

The intensity of shaking in Japanese scale was Shindo 6+ at the Fukushima Daiichi Nuclear Power Station, while Shindo 6- was recorded in Onagawa-cho, Miyagi Prefecture, the site of the Onagawa Nuclear Power Station. Peak ground acceleration of 567.5 Gal, an unprecedented level, was measured in the second basement floor of the Onagawa Unit 1 reactor building.

Then a tsunami exceeding 18 meters, "as if the entire sea had risen up," swallowed the town of Onagawa-cho. Eight percent of the approximately 10,000 residents died, and some 4,411 homes were totally or partially destroyed.

Most reactors safely achieved cold shutdown

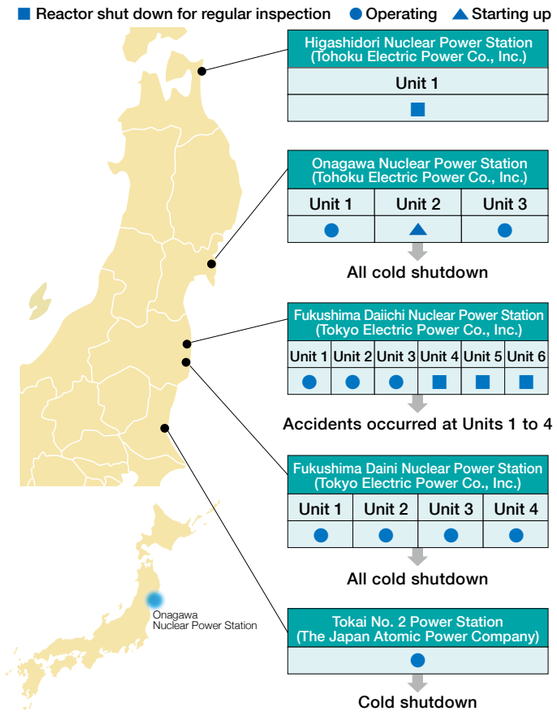
Of the 54 nuclear power plants in Japan, those directly affected by this Great East Japan Earthquake were the nuclear power-related facilities along the Pacific coast of eastern Japan.

From the north, these were the Higashidori Nuclear Power Station owned by Tohoku Electric Power and the reprocessing plant owned by the Japan Nuclear Fuel Limited in Aomori Prefecture, the Onagawa plant in Miyagi Prefecture, the Fukushima Daiichi and Daini Nuclear Power Stations both owned by TEPCO in Fukushima Prefecture, and the Tokai No. 2 Power Station owned by the Japan Atomic Power Company in Ibaraki Prefecture.

While Units 1 to 4 of Fukushima Daiichi unfortunately incurred accidents, Units 5 and 6 on the same site, Fukushima Daini Units 1 to 4 located 10 km away, Onagawa Units 1 to 3 located closer to the epicenter, and all the other facilities were free of major safety problems.

The status of each individual reactor was varied, such as being stopped for regular inspection, on the point of being started up, or operating normally; but looking at the results, most of the plants were able to achieve cold shutdown of their reactors (Fig.1).

Fig.1 Situation at nuclear power stations at time of Great East Japan Earthquake and after



Fukushima Daini, where 200 persons hooked up cables totaling 9 kilometers in length

What was the reason for the very different fates of Fukushima Daiichi and the other power plants?

At the time of the earthquake, Units 5 and 6 of Fukushima Daiichi were undergoing regular inspection. Units 1 to 4 of Daini were all in operation.

Comparing tsunami wave heights, at Daiichi Units 1 to 4 they varied from 11.5 to 15.5 meters. At Units 5 and 6 the waves were 13 to 14.5 meters high. Whereas Units 1 to 4 are situated at a height of 10 meters, Units 5 and 6 are at 13 meters.

For this reason, Units 1 to 4 lost their external power supply, followed by loss of the emergency diesel generators and power panel functioning as well as DC power supply due to the tsunami, on top of that, loss of heat removal functioning by seawater pumps (Fig. 2).

One of the emergency diesel generators for Unit 6, on the other hand, was still "alive" and managed somehow to be started up. Fortunately it was possible to connect this power also to the adjacent Unit 5, enabling a heat removal route to be obtained by means of this temporary power supply and seawater pump.

Meanwhile, there was Fukushima Daini located 10 km from Daiichi. The inundation height here was around 7 meters and the site is located at a height of 12 meters. The effects of the tsunami were accordingly less severe than at Daiichi. Even so, the tsunami came in with considerable force toward the mountain side, causing water to flow into the buildings.

As a result, the emergency power for Unit 1 was flooded. All the seawater pumps were also knocked out, with the exception of Unit 3.

"Because Unit 3 had survived, 500 people put in an exhaustive effort to restore power, such as by replacing the motor and cable."

Naohiro Masuda, the Fukushima Daini Site Superintendent, conveyed his vivid recollections of the situation that day.

Late on the night of March 11, while the tsunami warning was continuing the staff at the Fukushima Daini Power Station walked inside the facilities to confirm the extent of damage to equipment. With many of the instruments having suffered damage from the water, they worked at a fever pitch in attempting to restore the residual heat removal system (RHR).

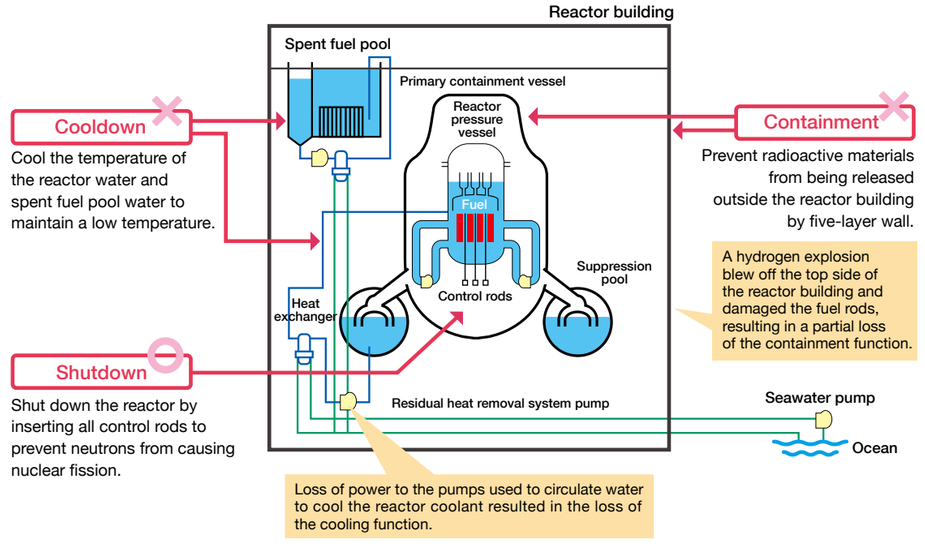
By the following day (March 12) they had somehow managed to obtain replacement electric motors, power cable, a power supply truck, and mobile transformer. One electric motor was air-lifted from a Toshiba plant. Another was transported by truck from the Kashiwazaki-Kariwa Nuclear Power Station (TEPCO) in Niigata Prefecture.

Power generation staff inspected the component cooling water system (CCWS) pump, which is part of the residual heat removal system, and replaced its electric motor.

It then took only a day to hook up a cable from the power panel in the waste processing building, which had survived the disaster. Most of the temporary cable, with a total length of 9 km, was carried on the shoulders and backs of approximately 200 workers, all cooperating to deploy the cable.

Thanks to their effort, the residual heat removal system pump was started up. By the morning of the 15th, cold shutdown of all units had been confirmed.

Fig.2 Outline of the Accident at the Fukushima Daiichi Nuclear Power Station



At the time I visited in July 2012, while clear traces of the tsunami were still visible here and there, the recovery work was proceeding steadily.

I was able to spend time walking throughout the plant, and was permitted to visit every nook and corner, including the reactor containment vessel. The impression I got was of calm, quiet and orderly procedures taking place, much like a regular inspection.

According to Site Superintendent Masuda, "The equipment vital to safety was not damaged by the earthquake. The plant is stabilized, so we carry out repeated training in maintenance and security, making sure our workers master a wide range of techniques."

The power supply trucks, fire trucks and heavy equipment needed in an emergency are kept on high ground, and each day is filled with training in connecting power cables, operating heavy equipment, supplying water and so on.

I also learned that the maintenance workers are making efforts to obtain qualifications, including a license to operate heavy equipment, so that they will be capable of making an emergency response on their own if that becomes necessary.

The policy is to have front-line workers build up the capability to handle any kind of situation, and believing in that capability, to entrust things to them. The "keys to success" that I observed at Fukushima Daini were confirmed for me even further at Onagawa.

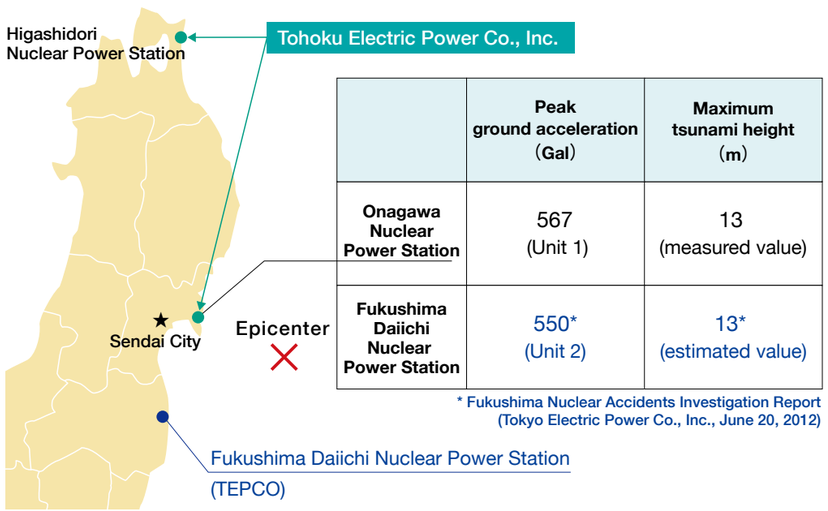
Achievement of Stopping, Cooling, and Containing

The Onagawa Nuclear Power Station is located at the center of the Oshika Peninsula at the southern tip of the Sanriku Coast, in Onagawa-cho, Oshika-gun and Ishinomaki City, Miyagi Prefecture. The distance from the earthquake epicenter is approximately 123 km, which is closer than Fukushima Daiichi.

Peak ground acceleration of 567.5 Gal, an unprecedented level, was measured in the second basement floor of the Onagawa Unit 1 reactor building. This was greater than the 550 Gal recorded at Unit 2 of Fukushima Daiichi (Fig. 3).

The maximum tsunami height at both Fukushima Daiichi and Onagawa was around 13 meters.

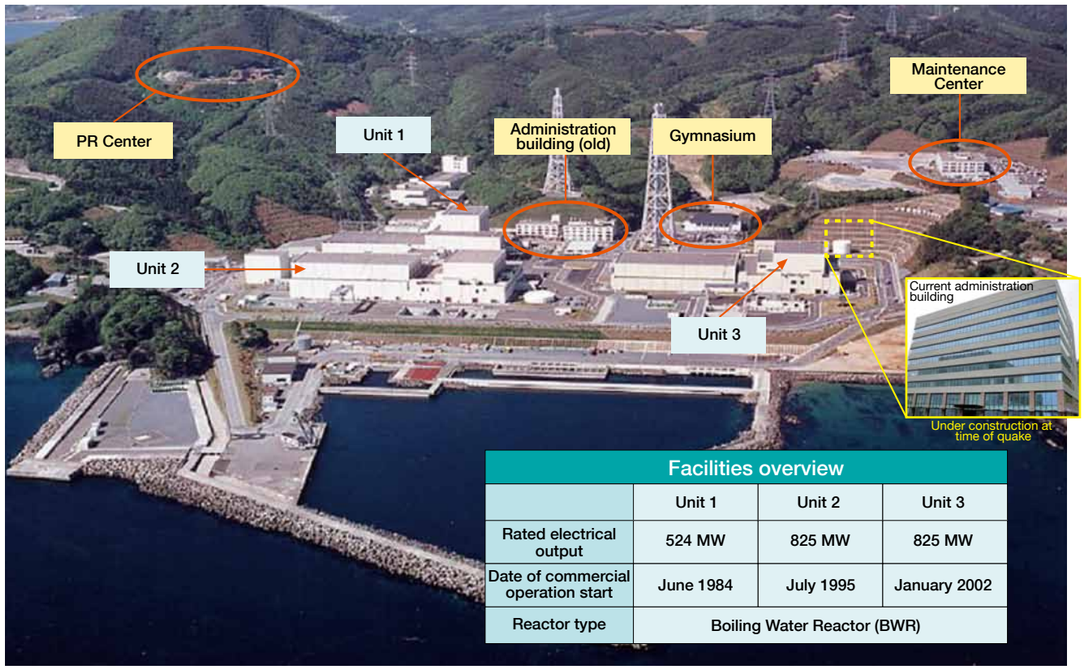
Fig. 3 Scale of earthquake and tsunami at Onagawa Nuclear Power Station and Fukushima Daiichi Nuclear Power Station



	Peak ground acceleration (Gal)	Maximum tsunami height (m)
Onagawa Nuclear Power Station	567 (Unit 1)	13 (measured value)
Fukushima Daiichi Nuclear Power Station	550* (Unit 2)	13* (estimated value)

* Fukushima Nuclear Accidents Investigation Report (Tokyo Electric Power Co., Inc., June 20, 2012)

Fig. 4 Overview of Onagawa Nuclear Power Station



Onagawa Units 1 to 3 are BWR (Boiling Water Reactors), the same as at the Fukushima plants. Unit 1 (524 MW) started commercial operation in June 1984. Unit 2 (825 MW) went into operation in July 1995 and Unit 3 (same output) in January 2002 (Fig. 4).

At the time the quake hit, Units 1 and 3 were operating normally at full output. The reactor of Unit 2 had just begun its startup procedure at 14:00.

When the heavy shaking from the earthquake was detected, all three units went into automatic shutdown mode as they were designed to. Then the emergency diesel generators (DG) were automatically started. Next the reactor core isolation cooling system (RCIC) in Units 1 and 3 was manually started.

At 15:29, 43 minutes after the quake, the largest tsunami wave arrived. Seawater flowed into a building attached to the Unit 2 reactor building as a result, shutting down the reactor component cooling water system train B and the high-pressure core spray component cooling water system.

Toppled heavy oil storage tank
(Stored amount when toppled: approx. 600kl)

Fortunately, train A was unaffected; moreover, power could be shared between each of the units. Reactor cooling by pump was therefore started for all units.

In just over 10 hours, the reactor temperature at all units dropped below 100°C, achieving cold shutdown.

The exhaust pipe monitors and radiation monitors in each zone showed no abnormal readings.

The three steps of Stopping, Cooling, and Containing had safely been completed (Fig. 5).

The main damage from the earthquake was fire damage to the non-safety related High Voltage Metal Clad Switchgear (A), housed inside the power panel of Unit 1. There were no problems with the non-safety High Voltage Metal Clad Switchgear (B) and emergency power supplies.

The main damage from the tsunami was flooding of buildings adjacent to the Unit 2 reactor building and toppling of a heavy oil storage tank near the bay. None of this damage had any effect on cold shutdown of the reactors.

Fig. 5 Plant status after earthquake struck (main timelines of Units 1 to 3)

Unit 1 (operating at rated thermal output)	Unit 2 (beginning startup sequence after 11th regular inspection)	Unit 3 (operating at rated thermal output)
◆ March 11 (Fri.)	◆ March 11 (Fri.)	◆ March 11 (Fri.)
14:46 Reactor automatically shut down	14:46 Reactor automatically shut down*	14:46 Reactor automatically shut down
Main turbine automatically shut down		
14:47 Emergency diesel generators (DG) (A) (B) automatically started	14:47 DG (A) (B) (H) automatically started	14:47 Main turbine automatically shut down
14:57 Fire alarm announcement	14:49 Cold shutdown confirmed	14:57 Reactor sub-criticality confirmed
14:59 Reactor core isolation cooling system (RCIC) manually started		
15:05 Reactor sub-criticality confirmed		15:26 RCIC manually started
15:29 Highest tsunami wave arrived		
	15:35 DG (B) automatically stopped (because CCWS stopped due to flooding from tsunami)	
	15:42 DG (H) automatically stopped (because CCWS stopped due to flooding from tsunami)	
22:55 Fire declared to be extinguished		
23:46 Reactor cooling begun by means of residual heat removal system (RHR) pump (A)		23:51 Reactor cooling begun by means of RHR pump (A)
◆ March 12 (Sat.)	◆ March 12 (Sat.)	◆ March 12 (Sat.)
0:58 Cold shutdown confirmed	12:12 Reactor cooling begun by means of RHR pump (A)	1:17 Cold shutdown confirmed
	*Reactor was sub-critical because startup had just begun (at room temperature and normal pressure)	

Fig. 6 Securing of power supply immediately following earthquake

1. Emergency power supply was secured	Emergency diesel generators (DG) were all normal **(in standby mode)***
2. External power supply was also secured	(1) Matsushima main lines (275 kV): 1 line normal, 1 line stopped (restored Mar. 17, 2011) (2) Oshika main lines (275 kV) : 2 lines stopped (restored Mar. 12, 2011) (3) Tsukahama branch line (66 kV) : 1 line stopped (restored Mar. 26, 2011)

*The Unit 2 train B DG and train H DG (high-pressure core spray) became unavailable due to tsunami flooding. (The train A DG was available and power interconnection between all units was possible.)

The many layers of readiness at Onagawa

The biggest difference that emerges between Onagawa and Fukushima Daiichi is the safety margin for earthquakes and tsunamis. From the hard (equipment) standpoint, first of all, I would like to note the following three points.

The first is that a power supply could be obtained immediately following the earthquake and also after the tsunami arrived (Fig. 6).

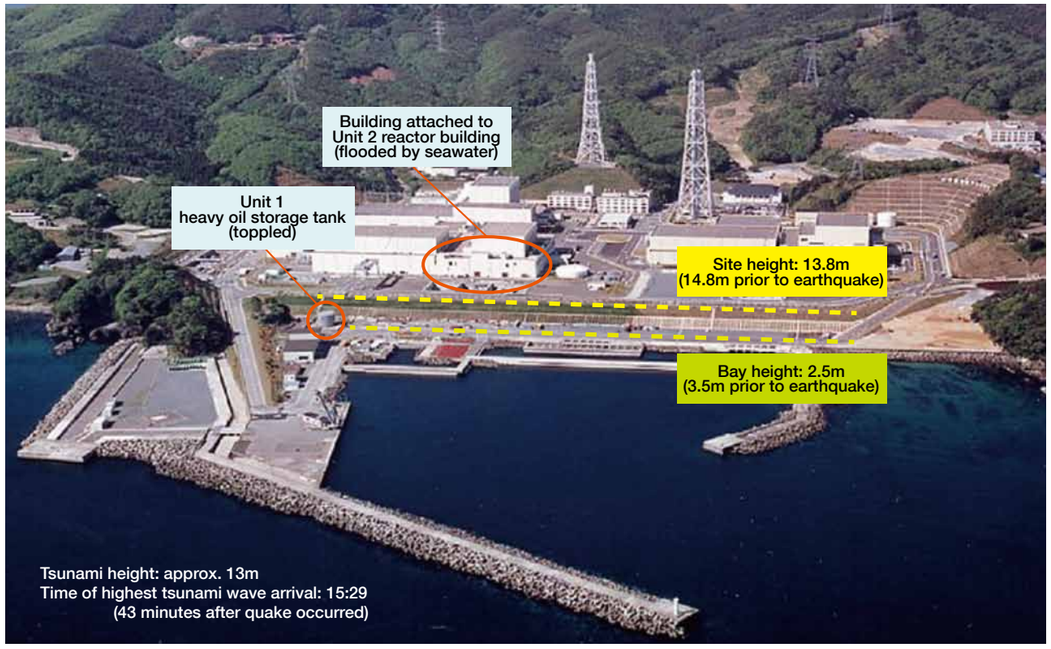
At Fukushima Daiichi Units 1 to 4, external power supplies were lost, and emergency power supplies were also all stopped due to the tsunami. By contrast, Onagawa still had one of five external power lines connected to the power station, and was able to use six of the eight emergency diesel generators. It was also possible to share the emergency generators among all units.

The second is the height of the site (Fig. 7).

The maximum tsunami height initially assumed at both Fukushima Daiichi and Onagawa was around 3 meters. Fukushima Daiichi was therefore built at a height of around 10 meters, whereas Onagawa was built at a height of approximately 14.8 meters.

As noted earlier, the maximum tsunami height on March 11 was around 13 meters at both locations. Thanks to this extra margin at Onagawa, even though the whole peninsula dropped one meter lower due to land subsidence in the quake, the facility was protected by the 13.8 meter height of its location and it was not washed over by the tsunami.

Fig. 7 Tsunami situation



When I visited the Onagawa Nuclear Power Station one year after the disaster, Toshiaki Yashima, Chairman Emeritus of Tohoku Electric who had been involved in the plant even before it was built, repeatedly expressed deep appreciation for the "predecessors."

According to Mr. Yashima, Tohoku Electric formed an internal committee of experts to study past tsunamis around 1968. They decided to locate the plant at a height of 14.8 meters, citing historical evidence of large tsunamis in the past, including the Sanriku tsunamis of 1896 (Great Meiji Tsunami) and 1933 (Showa Sanriku Tsunami) as well as the Jogan Tsunami of 869 and Keicho Sanriku Tsunami of 1611.

Then in 1987 when applying for approval to build Unit 2, the estimated tsunami height was revised upward to approximately 9 meters after studying the effects of the Jogan Tsunami (geological survey). On this basis it was decided to perform additional reinforcement on the flood wall to protect the embankment with concrete blocks, up to a height of 9.7 meters from the base (Fig. 8).

In addition the seawater pump room in each Unit had been built in a pit surrounded by walls at the time of construction, and work had been carried out since then to deepen the intake channel for obtaining emergency cooling seawater during low tide.

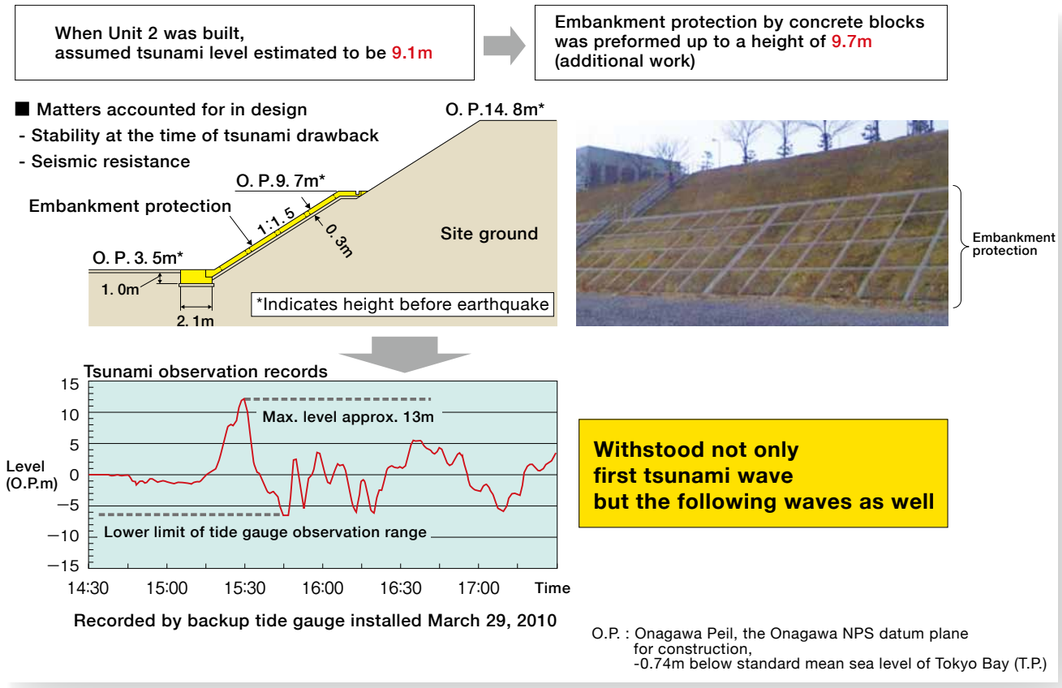
Thanks to these various countermeasures carried out over time, the facility "withstood not only the first tsunami wave but the following waves as well."

Third was the seismic margin.

By June 2010, work had been completed for upgrading the earthquake safety at Onagawa, including the addition of supports for equipment and pipes. This was done at a total of around 6,600 places for the three units.

The towers supporting the exhaust ducts were also reinforced with steel, and the towers and ducts were connected by seismic dampers, in order to increase the seismic margin further.

Fig. 8 Strengthening of flood wall (embankment protection)

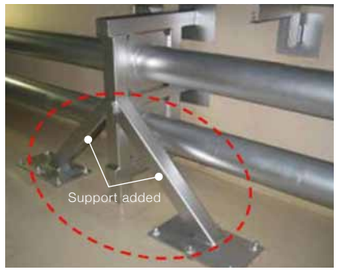


O.P. : Onagawa Peil, the Onagawa NPS datum plane for construction, -0.74m below standard mean sea level of Tokyo Bay (T.P.)

Seawater pump room pit

Based on what was learned from the Niigata Chuetsu-oki earthquake of 2007, major seismic reinforcement by means of braces had also been completed by 2010 in the administration building, including the emergency response room and computer room.

The new administration building currently in use with its seismic isolation structure had been under construction since 2009, but seismic reinforcement of the old building in use at the time of the earthquake was carried out at the same time.



Pipe with support added

These extra layers of readiness proved their worth at the time of the disaster. As I will talk about later below, not only did the old administration building serve as an emergency response room, but it also provided temporary shelter for residents fleeing the disaster in the nearby communities, as the seismic upgrades were of great benefit.

Old administration building that had been reinforced with braces for improved seismic resistance

A sterling example winning worldwide praise

In July 2012, around the same time as my visit to the Onagawa Nuclear Power Station, the plant was visited also by a mission of 20 international experts, led by Sujit Kumar Samaddar, Head of the International Seismic Safety Centre of the IAEA (International Atomic Energy Agency), and including regulatory agency staff from the French IRSN (Institute for Radiological Protection and Nuclear Safety) and U.S. NRC (Nuclear Regulatory Commission) as well as civilian experts. Their purpose was to share data from Onagawa with IAEA member countries.

After spending 11 days walking throughout the facility and conducting thoroughgoing investigations, the mission members were surprised to discover "no significant damage" that would affect structural performance.

IAEA mission to Onagawa Nuclear Power Station to examine the performance of systems, structures and components following the Great East Japan Earthquake and Tsunami

The report states that "Despite prolonged ground shaking and a significant level of seismic energy input to NPS facilities the structures, systems and components of the Onagawa NPS performed its intended functions without any significant damage. The lack of any serious damage to all classes of seismically designed facilities attests to the robustness of these facilities under severe seismic ground shaking. It was concluded that the facilities of the Onagawa NPS remain "remarkably undamaged" given the magnitude, distance and duration of ground shaking. "

When I returned to the Onagawa Nuclear Power Station once again in October 2013, I heard another piece of good news.

WANO (the World Association of Nuclear Operators) had decided to present a Nuclear Excellence Award to Tohoku Electric Senior Executive Officer Takao Watanabe (currently Managing Director and General Manager of the Nuclear Power Department), who at the time of the earthquake was Superintendent of the Onagawa Nuclear Power Station. The award was for promotion of excellence in the safe operation of commercial nuclear power.

WANO cited the following three reasons for the award.

1. For his superb leadership in preparing the Onagawa nuclear plant and staff to be ready for emergencies.

2. For his inspirational leadership enabling the safe shutdown of three reactors during the largest earthquake and tsunami encountered by any nuclear plant in the world.

3. For providing for the safety of many residents of the local community following the earthquake and tsunami.

Members whose combined efforts earned them a WANO Nuclear Excellence Award

What impressed me in particular about this award was that it acknowledged the "people" (soft) aspect of the successful outcome. In any case, the actions could not have been accomplished without the tireless efforts of the Superintendent and entire staff.

Attending the awards ceremony in Moscow, Mr. Watanabe said that what made him happy more than anything was being told by the WANO Chairman, "This award is for you and for your staff."

"Then when I was leaving the ceremony, one of the attendees, whom I had never met, said to me, 'We are very proud of you.' It was an emotional moment for me."

WANO awards ceremony in Moscow
Photo: The Electric Daily News (The Denki Shimbun)

How did the plant staff respond at the time?

Just what kinds of feats, recognized also by nuclear plant operators around the world, did the Onagawa NPS staff pull off?

How did each of the people on the scene go into action?

I will try to piece together the story, based on talking with then Superintendent Watanabe, the people working in the plant at the time, and people from the nearby community. (The positions of people mentioned are as of that time.)

March 11, 2011. At the Onagawa Nuclear Power Station, Units 1 and 3 continued to generate power stably.

Unit 2 was at the end of a regular inspection, and Kazuo Sakuma, Shift Supervisor and head of Team A, responsible for Units 1 and 2, had been busy since morning making final checks for restarting the reactor.

Team A consisted of 12 members working under Mr. Sakuma. That morning, following a day off, the daytime shift started from 8:40 in the main control room.

14:00. Right on schedule, they began pulling control rods from Unit 2 and the startup process was proceeding normally.

"We'll be able to start generating power shortly."

Along with a feeling of accomplishment after completing the regular inspection process, there was an air of excitement as the reactor was being put back into service.

14:46. Before long the reactor would reach criticality.

"Things are looking pretty good."

Mr. Sakuma sat down in his chair with a sense of relief. Right at that moment he could hear and feel the shaking. Then the main control room began swaying violently.

He instinctively stood up and moved to the center of the room, where he hung on to a pillar, while looking at the display panel to check the plant status. The operators held onto hand rails on the control panel and likewise carefully watched the display.

The generator output meter could be seen dropping rapidly, from 100% to 0%. They knew the Unit 1 reactor had shut down automatically.

Meanwhile, in his office on the second floor of the administration building, Superintendent Takao Watanabe, who was waiting for notification that Unit 2 had reached criticality, felt the sudden shaking and ducked under his desk.

Looking at the generator output meters in the Superintendent's office, he could see them dropping rapidly for Units 1 and 3. Struggling to stand as the room continued to sway, he shouted to the others, "Units 1 and 3 have stopped! We need to hold an emergency session!"

Before long dozens of people, including the Superintendent, Deputy Superintendent, and supervisors/section managers, had assembled in the emergency response room on the third floor of the administration building.

"The first thing we need to do is gather accurate information and communicate it!"

Mr. Watanabe set up contact lines for each reactor unit so that the plant situation could be conveyed from the main control room of each unit to the emergency response room. While gathering information and trying to determine the situation, he kept the Head Office, located in Sendai City, informed about the plant status.

Managing Director Takao Watanabe, who was Superintendent of the Onagawa Nuclear Power Station at the time of the Great East Japan Earthquake

Talking with Managing Director Watanabe about the situation and response at the plant when the Great East Japan Earthquake struck, while looking at pictures from that time

Narrowing down of contact routes and concentrating on the situation at hand

"The Head Office played the role of exchanging information outside the company, so we were able to concentrate on the situation facing us," said Mr. Watanabe, as he recalled the situation on that day.

"For contacts we used double routes. There were two routes between the emergency response room and the main control rooms of Units 1 and 2, where they were faced with the serious situations of a power panel fire and inflow of seawater into the building. One was a route between the Shift Supervisor and the Engineering Supervisor in the emergency response room, and the other route was between me and the Deputy Superintendent on the scene.

Similarly, for keeping the Head Office informed, the Engineering Supervisor of the plant contacted a section manager in the Head Office Nuclear Power Department. To supplement this, we also set up the second route between me and the General Manager of the Nuclear Power Department. Because he used to be the Superintendent of a nuclear power plant, he had a good handle on the information."

"Just doing video conferencing all day would be like doing a play-by-play of a fire scene. It's definitely not a good thing. During that time the fire will keep spreading."

When the plant decided to take in local residents who were fleeing from the disaster, for example, the conversation with the Head Office was typically short and to the point.

"We're going to offer shelter to evacuees."

"OK, how many?"

"We'll let you know when we figure that out."

Keeping reports to the necessary minimum, they devoted their attention to dealing with the situation at the plant. Assignment of personnel was left up to the Superintendent, who could make decisions and act on them immediately. The Head Office had people who were well familiar with the plant, and they devoted their efforts to providing logistical support.

Their trust of the people on the scene paved the way to a successful outcome.

Talking with Superintendent Shun Tsubata,
Assistant Staff Manager Kazuo Sakuma,
and Assistant Manager Yasuhiro Utsumi about the situation
and response at the plant at the time of
the Great East Japan Earthquake

Ten persons donned fire suits and went to scene of fire

14:49. Cold shutdown of Unit 2, which had just started up moments earlier, was confirmed. The operators in the main control rooms, while continuing to be rocked by aftershocks, carried out operations toward cold shutdown of the remaining Units 1 and 3, with no time to sit down.

They were well prepared for such a situation, having conducted regular drills premised on various accidents and disasters, using a simulator identical to an actual main control room. Therefore Mr. Sakuma was confident they would be able to take the reactors safely to cold shutdown.

Even so, the shaking this time was unlike anything they had experienced. And then there were the reports of a huge tsunami approaching. No doubt they were fighting to maintain their composure. By then the floor was scattered with debris from ceiling panels and fluorescent lights that had fallen, which crashed and cracked under the feet of the workers. As they endeavored to recall their training, they kept on encouraging each other.

Meanwhile, fire alarms had been sounding since right after the quake.

Workers heading to the scene reported thick black smoke rising.

Yasuhiro Utsumi, Specialty Leader for Turbine Facilities in the Mechanical Maintenance Section, was in the administration building when he felt the initial shaking. When he learned of a tsunami warning and evacuation order, he headed on foot to the gymnasium parking lot.

"Take refuge! Everyone evacuate!"

Learning of the Superintendent's instructions, the plant staff assembled in the parking lot. At the same time, said Mr. Utsumi, "We also had heard about a fire breaking out, and were ready to go out and fight it."

"We need ten people from Turbine Facilities to go to the scene of the fire."

When that instruction went out, Mr. Utsumi, who was familiar with the location, was first to decide.

When he asked, "Who else is going?" nine people quickly raised their hands at the same time.

"Wow, these people are all volunteering?"

He was moved almost to tears. As they put on their fire suits in the gymnasium, Mr. Utsumi was racking his brain, trying to decide the best route for finding their way to the fire while keeping them all safe.

Assistant Staff Manager Kazuo Sakuma
(Shift Supervisor at the time)

Yasuhiro Utsumi,
Assistant Manager of Turbine Facilities
in the Maintenance Department
(Specialty Leader at the time)

All they knew was that the fire was in the Unit 1 turbine building; they did not know what was burning or the exact location. Entering the turbine building, they first gathered up any fire extinguishers they happened upon. Hoping to use the stairway nearest to the fire, they opened the door, but were immediately engulfed in thick black smoke, obscuring their vision.

"We can't go down this way."

While keeping in touch with the Mechanical Maintenance Manager by phones, they tried to find another route they could use.

Mr. Utsumi and the deputy leader of the fire-fighter group strapped on oxygen masks, and walked carefully a step at a time inside the stairwell, darkened from the billowing smoke.

"If it's burning, we ought to see flames," he thought. But no flames were to be seen anywhere. Inside the high-voltage power panel, sparks from a breaker had melted cable insulation. That was the cause of the smoke.

Since their oxygen supply was nearly exhausted, they returned for the time being. Just in the nick of time. The moment they returned to the stairs and opened the door, an alarm started beeping. Only a small amount of oxygen remained.

After repeated trips back and forth, they were finally able to put out the fire using a dry chemical fire extinguisher. By that time it was 22:55.

"We prepared extra sandbags just in case"

While the fire alarm was echoing in their ears, they learned that a building attached to the Unit 2 reactor building was becoming flooded.

The Unit 2 reactor, as noted above, had stopped during its startup process and cold shutdown had been confirmed a few minutes later. Right after the earthquake struck, three emergency diesel generators had started up and were ready to supply electricity at any time.

At 15:29, the largest tsunami wave arrived. This was followed by the successive stoppage of two diesel generators, at 15:35 and 15:42. Alarms sounded in the main control room.

An operator immediately ran to the scene, and reported that "Water is filling up the component cooling water heat exchanger room in the third basement floor of the reactor building!"

Where was the water coming from? That was still unclear. Superintendent Watanabe asked the Radiation Safety Section to analyze the water.

Once it was clear that it was seawater, 25 people from Reactor Facilities in the Mechanical Maintenance Section, using eight emergency pumps, began pumping out the water. They could not pump it to ground level from the third basement level all at once. Some quick-thinking worker found a large plastic container.

They put the container on a landing in the stairwell, pumped water into it, and then pumped that water up to a higher level. Since the elevator was stopped, they had to carry equipment up and down the stairs. Mustering all hands available, they continued this bucket brigade process through the night.

Of the three emergency generators, the one that was working had to be protected by all means.

"Just in case, prepare a hundred sandbags!"

Upon receiving this instruction from Jiro Masuko, Deputy Superintendent, everyone pitched in to carry sandbags down to the third basement level.

Hearing that more water might be coming, Mr. Masuko asked for more sandbags. "We made some extra ones. How many are needed?"

"How many did you make?"

"We've made 300 so far."

Without waiting around to be told what to do next, people given one instruction were taking action in advance by thinking ahead. When it came to preparing and hauling sandbags, too, people would take the initiative, announcing, "I will send some people from my group to help!"

Thinking ahead to how they could help out, the plant staff took advance action. Mr. Watanabe was deeply heartened to witness this level of cooperation.

"Let's all take refuge at the power station!"

After the tsunami hit, contacts with the outside world became more difficult; and some 1,500 persons, including workers from partner firms, were stranded in the plant, unable to confirm the safety of their colleagues or families.

Besides those 1,500 persons, on March 11 there were 17 visitors who had come to tour Unit 2, mostly university students from Sendai City.

When the earthquake hit, their tour had just ended and they were returning to the security checkpoint.

"No matter what, we had to keep our guests safe."

That was the first thing in the mind of Nobuo Soekawa, Public Relations Manager at the Onagawa plant PR Center, even as the Center swayed violently in the quake.

After several attempts trying to contact by phones the people from the Sendai Office and PR Center who were showing the visitors around, he finally got through and learned that they were safe, having taken shelter in the administration building.

Before he had time to relish that news, two exhausted-looking men with little more than the clothes on their back opened the glass door of the PR Center. They were Masao Abe, head of the Samenoura district of Ishinomaki City, located south of the Onagawa NPS, and one other person from the district.

"Everything has been washed away. Help the people in our district."

While Mr. Soekawa had heard on the radio about the tsunami warning, he was not aware of the situation in the nearby communities. Seeing the desperate state of his old friend Mr. Abe, he realized how serious things were.

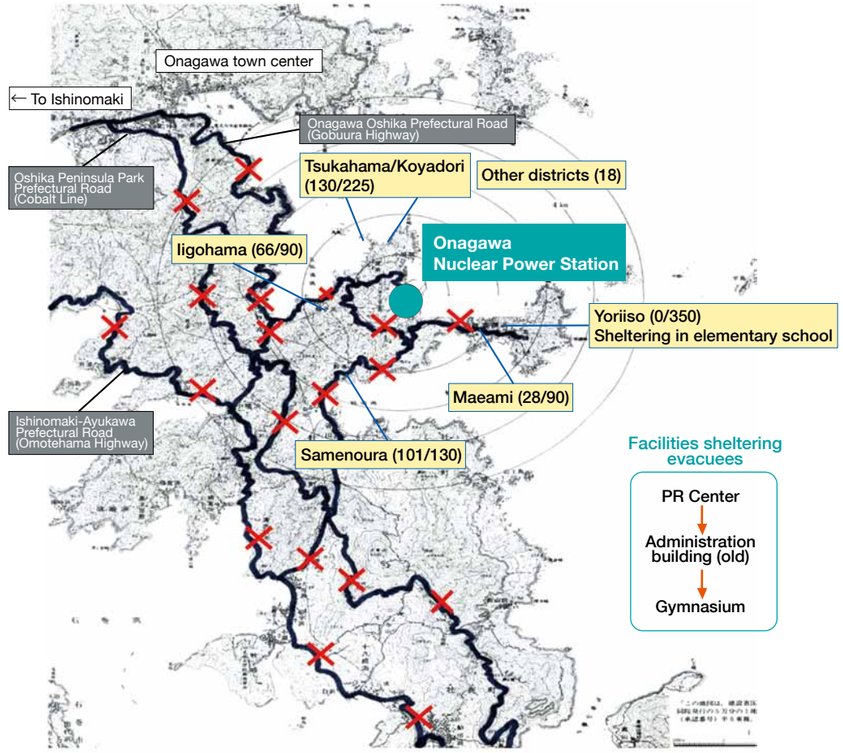


Fig. 9 Sheltering of evacuees at the Onagawa Nuclear Power Station

On that day, Mr. Abe had been filling bags with seaweed in a shed at his home along the coast. While he had managed to escape to higher ground, his home and all his belongings had been washed completely into the ocean.

Only two homes were left in the Samenoura district, the rest having been completely wiped out; and the shelter on high ground was unusable. The residents who had fled to high ground were huddled together outdoors, quaking with fright.

"At this rate the older folks won't make it through the night."

"What are we going to do?"

"How about asking at the power station? Why don't you try the PR Center?"

Someone from the district had raised the idea of going to the power station. District Representative Abe and one other person hitchhiked as far as they could until the road was cut off, then walked the rest of the way until reaching the PR Center, at a height of 120 meters.

Mr. Soekawa quickly opened the large hall and spread out whatever sheets and blankets he could find. It must have been past 16:00. Neither of the men was sure of the exact time, but darkness was beginning to fall and they could feel it becoming increasingly cold.

The number of those taking shelter eventually grew to 50 persons. At the PR Center blankets, work clothes, and disposable hand-warmers were distributed; but there was no heat because the power was out. Before long the darkness of night enveloped the Center.

Superintendent Watanabe made the decision to move the evacuees from the Center to the administration building, making use of two buses that normally carried workers at the plant. There were also some local residents who evacuated directly to the power plant.

The next morning (March 12), two buses were dispatched from the power plant to the Samenoura district to pick up more people. Eventually the number of Samenoura residents taking refuge at the plant reached 101 persons (Fig. 9).

"Why did we think to go to the power plant? We just naturally felt this was one place that would be safe," said Mr. Abe, who was now able to smile calmly as he looked back at that time.

"We knew all about the power plant since before it was built. And having built the weather observation tower, we were aware of the actual plant and radiation levels. The women in our community had also toured inside the plant. At events and festivals we often meet up with people of the plant, and we knew that if something happened, the power plant would be the one place able to stand strong."

The gymnasium of the Onagawa NPS where local residents were given shelter after the Great East Japan Earthquake

Talking with Public Relations Manager Nobuo Soekawa at the Onagawa NPS PR Center about how local residents came to be sheltered at the plant after the Great East Japan Earthquake

"Just load it up with supplies!"

"Can we put up some of the local residents at the plant?"

When he received a phone call from Mr. Soekawa, Superintendent Watanabe had been engaged in a frantic battle to deal with the flooding in the building attached to the reactor building, and putting out the fire.

Still, upon hearing, "There are people soaked to the bone. They are cold and there's no power. What do you want us to do?" without a moment's hesitation he replied, "Let's have them come to the power station."

"There was nothing brave about that decision. We were all victims of this disaster. They were familiar faces, and anyone would have let them in under those circumstances. (During the time they were taking shelter) they wondered if there was anything they could do to help out, and there were offers, including from the tour group, to do things like cleaning, for which we were grateful."

Mr. Watanabe quietly spoke to me about how the residents came to be sheltered at the plant.

Their acceptance required approval of the General Affairs, Public Relations, and Security Sections; but the eyes of these staff members also said, "Let's take them in."

The power plant had around 4,500 emergency meals in stock. With the roads being cut off, the number of employees and members of partner firms "confined" inside the power station grounds exceeded 1,500 people. In other words, there was not enough to feed everyone three meals.

"For now, the only thing we can do is to try and get by on one meal a day."

March 11, evening. That was the assessment of Keiichi Meguro, Assistant Manager of the General Affairs Section. On top of that there were the local residents.

"There's no way we were going to deny food to people who had lost their homes to the tsunami and were soaking wet," said Mr. Meguro.

Because of such sentiments, priority was given to the sheltered residents when distributing emergency food. Uniforms and winter clothing provided for the plant workers were also distributed to them.

"We need food, water, blankets, and oxygen tanks right away," said Mr. Watanabe, speaking to the Head Office by video conference.

The next morning Executive Vice President Takeo Umeda left for the plant in a helicopter loaded up with supplies.

"No one has to come along with me. Just load it up with supplies!" Vice President Umeda then delivered the supplies himself.

On the return trip, the helicopter carried a pregnant woman close to giving birth and a patient requiring oxygen, accompanied by Akemi Kashiwaya from the General Affairs Section, who had registered nurse qualification. The helicopter landed at the Kasuminome Air Field of the Self-Defense Forces, from where they were rushed to a Sendai hospital by ambulance. Ms. Kashiwaya accompanied them to the hospital before turning them over to the care of family members.

The residents who had taken shelter were later transferred to the gymnasium, as their number grew to 364 by March 14.

In late April, people from the Head Office brought over rice balls and tea, and the evacuees were able to walk around enjoying the cherry blossoms on the plant grounds.

In the ocean, evacuation boats that had lost its port set down anchor in the bay of the power station.

For a period of three months in all, up to June 6, the power station continued to protect the local populace.

Living under the same roof, the plant staff and local residents ate together and shared in the joys and tribulations of overcoming the disaster ordeal together. Their bonds became even firmer and stronger than before.

"If the power plant had not taken us in on that day, some people might have frozen to death in Samenoura," said Mr. Abe as he recollected the experience.

"We were not lacking when it came to food and clothing, and people in other shelters were envious because of how good we had it. What made us the happiest was that after moving to the gymnasium, each of us was allowed to make a three-minute phone call. Being unable to use their mobile phones, many of the people didn't know if their family members were safe. We were really, truly grateful for that thoughtfulness."

Even when word of the accident at Fukushima Daiichi reached the gymnasium, "I knew Onagawa would be all right," laughed Mr. Abe.

"It withstood an earthquake and tsunami that powerful, so we believe in the Onagawa NPS. Now we're just hoping it will be restarted soon and go back to producing electricity."

Mr. Soekawa and Mr. Abe, who was head of the Samenoura district of Ishinomaki City at the time

“Handle normal times with emergencies in mind so that you are able to handle emergencies like normal times”

For Onagawa, from the time the earthquake struck, taking command was basically left up to the site, with the Head Office and branches, etc. quickly moving to provide logistical support. The decision to welcome nearby evacuees in the plant was also made by then Superintendent Watanabe.

It would seem that this policy of giving priority to the people on the front lines, who are rooted in the local region, is what led to both the solid preparedness on the hard (equipment) side and the successful disaster response on the soft (people) side.

The staff at the Onagawa NPS were unanimous in stating that “It was the regular training that really mattered.”

In response to my question, “What was the key to success?” the first thing Managing Director Watanabe said at the Head Office was, “Because we were ready.”

“Of the five external power lines, only one could be used. People have said it’s like having your head attached to your body by only one piece of skin, but the next morning it had already been restored. That’s how strong we had built the transmission lines. Not only was the plant built on high ground, but the pumps were protected by a pit formation, the flood wall was reinforced and so on. It was these double and triple precautions that paid off.”

Training was also an essential aspect.

“They say, ‘Handle normal times with emergencies in mind so that you are able to handle emergencies like normal times.’’ You can draw up a basic scenario, but you have to adapt flexibly to a changing situation. Flipping through manuals does not build up the necessary skills. The most important training is that by operators for 'stopping.' On the simulator we create a variety of equipment malfunctions, earthquakes and other mishaps. Since an earthquake cannot be replicated on the simulator, a few years back we embedded speakers in the floor. They emit a roaring sound, raising the tension level. We conduct training to see if the operators can perform well under such conditions.”

This was the first time for a helicopter to land at the power station, but Mr. Watanabe noted that they had performed image training for such an event. If the plant were to become cut off from the outside world, it was decided that the Vice President would come from the Head Office, and a heliport was built.

“The image training was useful, but it would have been better to practice the real thing,” said Mr. Watanabe. In listing other areas needing improvement, he noted that this time there happened to be construction workers on hand to operate the heavy equipment, but it would be better to enable plant staff to do that.

“Our power station”

Making everyone aware of the importance of training, including plant staff and members of partner firms, is not an easy matter. To that end, what Managing Director Watanabe stresses is “my plant” awareness.

“As has been pointed out many times by many people, the most basic awareness is that ‘We are the ones who must maintain safety.’ It’s what has been impressed upon us by our seniors, and our role is to pass it along to others.”

Born in Minami-soma, Fukushima Prefecture, and having majored in electrical engineering at the graduate school of Waseda University, ever since entering Tohoku Electric Power, Mr. Watanabe has walked the consistent path of a “technology guy.” The Onagawa Nuclear Power Station was his first assignment on the front lines of power generation.

“I worked in the three-part shift in the main control room. I was also involved in building and test operation of Units 2 and 3. Since I lived with my family in Onagawa, for our son Onagawa is his home town. The awareness of ‘together with the local community’ came naturally.”

Before becoming Superintendent at Onagawa in 2009, he had headed the Higashidori Nuclear Power Station in Aomori. At that time he used “***Wa*** Plant” to refer to the “my plant” mentality. In the Tsugaru dialect of Aomori, ***Wa*** means “We.” Japanese ***Wa*** also refers to the “Ring” of the community and the “Harmony” of teamwork.

Then at Onagawa he would talk about building an “O-Ra-Ho power station.” ***Oraho*** in the local dialect means “ourselves.”

“O” stands also for ***otagai***, appreciating each other’s standpoint. “Ra” stands for ***rashisa***, living up to one’s own potential. And “Ho” stands for ***hokori***, the pride of a professional. He then turned these into the slogan, “Aim to build an O-Ra-Ho (our) power station.”

At first he would try to convey his messages to the staff at regular meetings, but when someone suggested communicating more widely by means of a “wall newspaper” or the like, he decided to post a “Message from the Superintendent.”

“Around twice a month, I would create these messages on the PC late at night. The messages were posted near the entrance, where they could be seen by the people who wore helmets and boots. The feeling I tried to convey was, ‘First of all, thank you all for your hard work. There is still much to be done, but I’m happy for the fact that we can make electricity here.”

Shun Tsubata, Superintendent
of the Onagawa Nuclear Power Station

The steadfast diligence for seeing things through to successful completion

Based on the knowledge and experience gained from the disaster, initiatives are being carried out currently at the nuclear power plants throughout Japan to raise their safety levels even further (Fig.10).

At the Onagawa Nuclear Power Station, the flood wall is being made higher, the emergency power supplies are being made more diverse, and work has begun on mounting seismic isolation fittings on transmission line support insulators. In addition, severe accident measures and training are being strengthened further.

What impressed me in particular is all the practical training being carried out so that workers will be able to cope with heavy snow, darkness of night, and other harsh conditions. This training is based on the principle of giving priority to the people on the front lines and geared to Onagawa's specific situation.

Current Superintendent Shun Tsubata, who transferred to Onagawa from Higashidori after the disaster, spoke proudly of the organization, noting that "The Onagawa members have a sense of solidarity from having overcome the disaster together. They have the strength to make it through."

Work has begun on raising the height of the flood wall. When it was built in April 2012, it was approximately 3 meters high (around 17 meters above sea level). This will be raised to approximately 15 meters, or around 29 meters above sea level. The total length will also be increased, from the current 600 meters to around 800 meters (Fig.11).

"I want us to build up even further our strength to make it through, drawing on our diverse experiences. The construction work will take another two years, but we will be taking this as a chance for human resource development, piling on the training."

The steps toward safety never come to an end. That's why the only thing we can do is to learn from failure and from success, continuing on with the unflagging efforts toward reduction of danger and greater safety. I see this as the wisdom of humankind.

Paying close attention to detail, never taking shortcuts, being honest and steadfast.

That is what the word ***madee*** is said to mean in the Fukushima dialect. It aptly describes the kind of approach that is the key to success, and that is a necessary part of all processes toward safety.

With Superintendent Tsubata
on high ground 60m above sea level overlooking
the entire Onagawa Nuclear Power Station

Fig. 10 Examples of Safety Assurance Measures implemented after the Fukushima Daiichi Accident

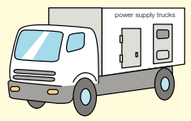
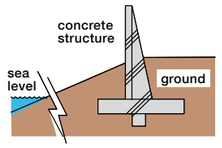
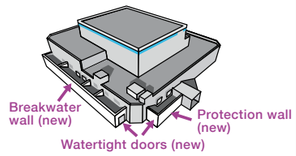
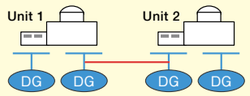
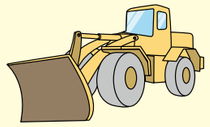
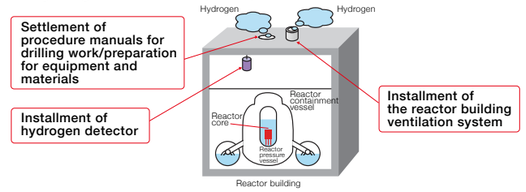
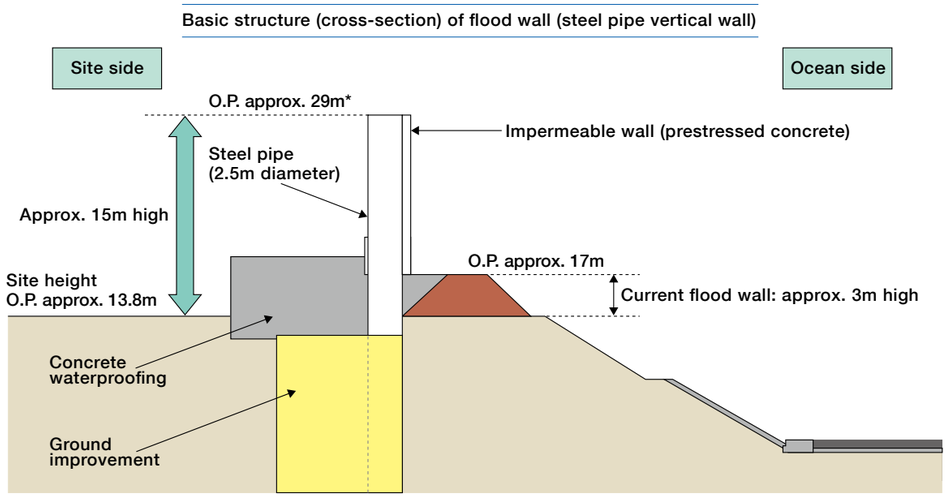
	Short Term Measures (completed)	Mid & Long Term Measures (to be implemented in a few years)
Emergency Safety Measures	Additional deployment of emergency power source vehicles 	Installation of coastal levee  Installation of protection walls 
Measures for securing power Source	Interconnection of emergency diesel generators between units 	Inspection of transmission line towers and measures against earthquake and tsunami 
Severe Accident Measures	Deployment of wheel loaders 	Installation of the reactor building ventilation and hydrogen detectors (BWR) 

Fig. 11 Initiatives for further enhancement of safety



*A height accounting for land subsidence (approx. 1m) of the power station site due to an offshore earthquake in the Tohoku region
O.P.: Onagawa Peil, the Onagawa NPS datum plane for construction, -0.74m below standard mean sea level of Tokyo Bay (T.P.)

High-voltage power panel in elevated power supply center.
Six power supply trucks, able to be connected by cable in an emergency, were also deployed at this elevated site.

Practice starting large-capacity power supply equipment, conducted as snow falls

Practice securing water source with backup water truck (portable pump). The water source (condensate storage tank) for supplying water from a tank to a nuclear reactor or spent fuel pool is replenished with coolant.

Practice hooking up power supply truck

Practice sending water with water truck (backup seawater pump). If the regular seawater pumps cannot be used, the truck pump is used to pump up seawater from the ocean and send it on to the cooling system.

Operation training on simulator premised on loss of all AC power supplies

Work proceeds on raising the flood wall height at the Onagawa Nuclear Power Station

Wako Tojima
Science Journalist

Visiting Lecturer, School of Social and International Studies, University of Tsukuba

Awards

Ministry of Foreign Affairs, Diplomacy Forum, Foreign Minister's Prize

The 7th Award for Excellent Endeavors from the Social and Environment Division of the Atomic Energy Society of Japan

Career

Graduated from the College of Comparative Culture, University of Tsukuba (Japan-U.S. relations) in 1985. While enrolled, studied American Politics at the University of Kansas as part of the International Exchange Program of the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

After working as a science reporter for The Yomiuri Shimbun, became a freelance writer primarily on scientific topics, seeking to identify relationships between science and society, with a focus on "life" in the areas of the environment, energy, medicine, life sciences, as well as science and technology.

Writings and Publications [in Japanese]

Jintai saisei ni idomu (Taking up the challenge of regenerating human body parts); *Meii ga kotaeru 55-sai karano kenkoryoku* (Famous doctors' advices on healthy living after 55; *Hoshasen riyo no kiso-chishiki* (Basics of radiation use); *Shiin jiten* (Encyclopedia of death causes); *Yomigaeru shinzo* (Regeneration of the heart); and many more books.

Long-running column on "*Shin Yojokun* (New precepts for the preservation of health)" in monthly *Bungeishunju*; numerous other articles.

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