Fukushima Daiichi Nuclear Disaster

By

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On march 11 2011 the Tōhoku earthquake and subsequent tsunami hit the Fukushima Daiichi nuclear power plant. The damage and subsequent equipment failures resulted in the largest nuclear disaster since Chernobyl. After Chernobyl it is only the second incident to register a 7 on the international nuclear event scale. It is estimated that the Fukushima disaster released about 10% to 30% of the radiation of Chernobyl. The plant was not prepared for an earthquake of that magnitude but if a few safety measures had been put in place the complete meltdown could have been averted.

The plant was comprised of 6 separate reactors. At the time of the earthquake reactors 4,5 and 6 were shut off for maintenance. The earthquake triggered an automatic procedure called SCRAM that shutdown the active fission reaction in reactors 1,2 and 3. After the nuclear reactors were shut down emergency generators were started to provide power to the cooling systems. When the Tsunami hit it flooded the generators which were housed in the basement of the facility. Without electricity to power the cooling systems the reactors began to overheat. As the reactors overheated the zirconium fuel cladding reacted with the water to release hydrogen gas. The hydrogen gas was vented from the reactor pressure vessel into the upper secondary containment buildings. The gas mixed with air in the containment buildings and exploded in reactor 1 on March 12, reactor 3 on March 14th, and reactor 2 on March 15th.

After the meltdown a 20 km exclusion zone was set up around the plant. The plant has also been found to be leaking radioactive water into the ocean. While a timeline for decommissioning the plant has not been established it is estimated it will take 30 to 40 years.

The Fukushima power plant seemed to have been set up for failure from the very beginning. Final construction plans were changed to reduce running costs of the sea water pumps, despite warnings from mid-level engineers along with final station heights above sea level were changed to unsafe elevations. Outdated response measures and poor decisions made by the Plant Operator all but guaranteed an unrecoverable nuclear meltdown in the case of a power earthquake and tsunami.

Designs for the Fukushima were largely based on data gathered from the 1960 tsunami that decimated the Chilean coastline. Originally designed to be built 10 m above sea level, the Fukushima Daiichi reactors 1-3 were placed on the Japanese coastline with very little tsunami prevention measures. As stated in the Fukushima Accident 2011 Report [1], the original plans for the Fukushima Daiichi (“number one”) power station was originally designed to be built 10 m above sea level with sea pumps placed 4 m above sea level, well above the maximum predicted tsunami height of 3.1 m. In 2002 the maximum predicted height the power plant could safely handle was elevated to 5.7m, sealing off the sea pumps from being effective in the occurrence of a large tsunami.

According to the WNA report, the tsunami countermeasures that were used at the Fukushima nuclear plant were unchanged since their implementation in the 1960s. In a report published and delivered in 1990 by the U.S. Nuclear Regulatory Commission (NRC) [2] stated that the largest threat to the nuclear facilities built on the coastline was from a large seismic events. The NRC, among other nuclear safety groups, set regulations and safety protocol for nuclear facilities worldwide.

Reactors Daiichi 1-3 were shut down due to the earthquake, of which Reactor 1 was the worst. Drastic measures were taken so the turbines were bypassed to bring the flow straight the condensers commencing cool down. Forty-one minutes after the earthquake, the tsunami hit and destroyed the seawater pumps for the condensers along with auxiliary cooling alternatives, which included the RHR(Residual Heat Removal System. After the shutdown of the fission reactions, the reactors were still producing 1.5% of their thermal energy and without the proper cooling from the destroyed condenser and cooling systems, a large amount of steam accumulated and pressure began to build in the reactors. The hot steam accompanied by hydrogen later created a hydrogen explosion in reactor 1. Reactor 1 reached the worst meltdown of all and Reactors 2 and 3 also reached meltdown but not as worse. The hydrogen explosions of Reactor 1 released radioactive materials into the air and caused many people to have to evacuate the area.

On March 25, 2011 the government requested voluntary evacuation in the Fukushima area of 20-30 km. Thereafter, the government sets 20 km from Fukushima as a no go area. Six on site workers had received doses of radiation in the 250 milliSieverts range. As for beyond the site of Fukushima there were some places that reached 0.84 milliSieverts per day 24km from the site such as the town of Namie. However, the safety standard set by the government was 0.09 milliSieverts per day. The radiation in the air has not caused any devastating effects to the locals but it did cause 160,000 of them to have to leave their homes and they could only return temporarily a year after in 2012. Due to the heavy radiation in some areas evacuees will not be able to fully return to their homes until the decontamination of the areas have been taken care of.

The only environmental aspect other the than the air that has been affected is the water that was used at the nuclear plant that has been contaminated. Some radioactively contaminated water had been already released to the sea with lower amounts of radioactive contamination. The remaining water has been decontaminated and treated before it was released to sea.

Years before the Fukushima nuclear reactor incident statistical data was provided by numerous agencies surrounding the possibility of a tsunami, relative to the geological location of the Fukushima reactor. For example, on January of 2011 the Headquarters for Earthquake Research Promotion had reported that there was a 99% probability that an earthquake of magnitude 7.5 would occur offshore of the Miyagi region. Such information was extremely valuable to officials given that the March 11 earthquake's epicenter was offshore of the Miyagi region. In addition, the responsible parties (mainly TEPCO and NISA) should have collected historical data of their geographical location in order to see how frequent tsunamis and catastrophic tsunamis occur. For example, for the last decade Japanese researchers found layers of sediment that appeared to have been deposited due to massive tsunamis. Furthermore, these Japanese researchers concluded that such massive tsunamis occur once every one thousand years. Information like this and others, like knowing that since 1498 there have been several tsunamis that had a maximum amplitudes of 20 meters, could have been incorporated into prevention plans.

On top of having relevant statistical data, it is in the Tokyo Electric Power Company's (TEPCO) best interest to form strong relations with engineering related communities and with their local government. This would allow "outside" organizations to provide relevant data to TEPCO and design accordingly. In addition to forming strong relationships, stricter regulations would allow TEPCO to more easily implement precautionary measure into their design. One example where this preventive measure was not followed is in 2002 when the Japan Society of Civil Engineers (JSCE) proposed an updated methodology on tsunami safety. This being said, TEPCO voluntarily decided to implement JSCE's guidelines for tsunami safety by raising their design-basis tsunami height from 3.1 meters to 5.7 meters. This revision would have lowered the damage caused by the March 11, 2011 tsunami but NISA never updated the licensing documents or reviewed TEPCO's analysis.

The most important preventative measure TEPCO could of done in order to avoid such an event is focus on their back-up equipment. First of all, TEPCO should have placed their diesel generators at a higher level or on an upper level in the building. This would have prevented the generators from becoming flooded. Secondly, by raising the height of the seawater pumps TEPCO would of been able to continue cooling the reactors even after the “scram” shut down. These two preventative measures would have allowed the reactors to continue to cool down and provide AC power to the pumps in order to allow the cooling process. Finally, by insuring that these systems had watertight connections, operation of the plant would continue with minimal flooding.

In this document we began by stating the March 11, 2011 event that occurred at the Fukushima nuclear reactor. We then went onto explaining the steps that lead to the meltdown of reactors 1, 2, and 3. Furthermore we explained what went wrong in the nuclear reactors and why there was a hydrogen explosion. Then we went over the radiation leaks and radioactive matter expelled into the atmosphere. Finally, we ended by providing several preventative measures TEPCO should have implemented in order to prevent such a catastrophic event.

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[1] World Nuclear Association, “Fukushima Accident 2011,” World Nuclear Association, London, United Kingdom, 20013.

[2] U.S. Nuclear Regulatory Commission, “NUREG1150, Severe Accident Risks: An Assessment of Five U.S. Nuclear Power Plants,” Vol. 1, December 1990