Response to a CRPA Member's Questions

Dan Meneley, April 16, 2011

(1) Whether it was possible for the Japanese nuclear plant operators to purge out some of the hydrogen produced in a controlled manner to prevent or minimize the severity of the hydrogen explosions that were predictable and caused so much damage.
(2) Whether in a CANDU-6 reactor system, if it were hit by a similar earthquake-tsunami, the safety system could stand better with less severe consequences of radioactivity release to the outside environment.

I will try to throw some light on a very uncertain situation. As I am sure you understand, everyone is just now trying to sort out the complex mixture of data, information, and misinformation.

(1) So far as we know, all safety systems worked as designed, and the plants withstood the direct effects of the earthquake. I think (but am not certain) that the Daiichi units tripped on an earthquake signal or from related vibration. Unfortunately, a number of fossil-fired power plans in the area also tripped and the local power grid collapsed. The overall effect was a total loss of offsite power. The turbine main steam shutoff valve closed following the reactor trip signal. At least some of the emergency diesels on the site started correctly and ran for approximately one hour. Up to the end of this hour we might assume that essential plant services were available, so that there was no excess hydrogen generated -- but this is not a very important assumption, one way or the other.

When the tsunami struck, everything changed. Fuel tanks for the emergency diesels were carried away. Diesels shut down, of course. Water, for a short time several metres deep, flooded much of the station, including the turbine hall, where tow operators were drowned at this time. A narrow range of instruments and essential valves and so on were powered by storage batteries for about a further eight hours, until they were discharged. (Each unit was now in BLACKOUT, with no electrical power of any kind. The Residual Heat Removal System must have stopped working at some time during this time interval, along with the Reactor Circulation Pumps. After this, steam would be discharged to the primary containment, and then to the pressure suppression torus. Pressure would rise in the torus until its own pressure relief valves opened. Uncertain situation - these relief valves presumably discharged to the secondary containment -- the reactor building. (In US Mark I designs, discharge should have gone directly to the stack -- but there was no forced circulation in this case, of course.

As time went on, the temperature in the pressure suppression torus reached saturation. From this time on, steam was discharged directly into the reactor building. We do not know for certain, but it is very likely that the pressure, temperature, pH, and oxidation potential of the steam being discharged from the reactor pressure relief valves were all disrupted and could have led to evolution of large quantities of hydrogen due to radiolysis taking place in the reactor core. Fuel overheating could have, in the later stages, produced more hydrogen from zirconium-water reaction.

In any case, you have seen the result -- hydrogen explosions.

What could/should the operators have done to prevent these explosions? Very little, I expect, given the chaotic conditions inside the plant. If they had time and resources they could have knocked huge holes into the walls and ceiling of the reactor building, I suppose. But, apart from making a terrible mess of these buildings, the explosions seems to have done little serious harm or any good to the immediate crisis -- except perhaps to remove the roof and walls so that further explosions were precluded. I suppose that you could count a negative effect in that radioactive materials could more easily spread around the site.

The real crisis, of course, was the inability to circulate clean water through the cores to remove decay heat. I desperation, they drew ocean water up with portable pumps and pumped it into two pre-positioned inlets - I don't know the name of the first one, but it conducts water directly into the core. The second inlet was intended to receive a fire hose. I need to know more about these systems.

The most recent good news I've heard is that fuel may not be as badly damaged as was once feared -- that evidence comes from the Unit 4 spent fuel pool.

Sorry about the long answer.

(2) I find it easiest to start from the assumption that there were four CANDU 6 units located on the Daiichi site on April 11th, 2011. My first assumption is that the designers and regulators had earlier insisted that the units be designed for a Richter 8.2 earthquake. This is, of course, possible. If we further assume that the grid collapsed due to the earthquake, and that the project designers had insisted that there should NOT be a seismic trip on the unit, at least one of the four units would very likely have undergone a step-back to 60% power. Class IV interunit ties (seismically qualified) would enable all four unit service transformers to

continue operation.

When the Tsunami hit, the station would be totally flooded for a few minutes (assuming that the sea wall was badly designed, at a height of about 7 metres.) With due consideration of station flooding scenarios at the design stage, there is no particular reason that any of the units operating before the tsunami should be shut down. The emergency diesels would not be needed so long as at least one unit continued to operate at 60% power, with an intact turbine-generator set.

If, however, all of these CANDU 6 units DID trip following the tsunami, they would then rely on emergency diesel generators to maintain minimal fuel cooling. Allowing that their designer had been sufficiently intelligent to locate diesels and fuel supply at a reasonable elevation above sea level, fuel cooling would continue if there was a continuing supply of seawater via the raw service water system. If even that supply were interrupted, at least 24 hours' of cooling would be available via the moderator water and the vault shield water.

THIS SCENARIO REQUIRES ONLY MINIMALLY OPTIMISTIC ASSUMPTIONS -- MOSTLY, THAT THE DESIGNERS SHOULD HAVE TAKEN DUE PRECAUTIONS AGAINST THE COINCIDENCE OF TWO EXTERNAL EVENTS -- EARTHQUAKE AND LARGE TSUNAMI.

Given the site on which the hypothetical CANDU 6 plant is located, these assumptions are not very much to expect of a sensible plant designer.