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Fukushima Dai-ichi status and prognosis

Posted by Euan Mearns on March 31, 2011 - 2:13am

The disjointed news flow from Tokyo Electric Power Company (TEPCO) continues to provide a confusing picture of the status of the 4 crippled nuclear power stations at Fukushima Dai-ichi on the East coast of Japan. This is leading to a very broad spectrum of opinion on the actual status and future consequences. The spectrum of opinion ranges from those who argue that Fukushima Dai-ichi is on course to become a Chernobyl scale incident or worse, to those who argue this is a storm in a teacup, pointing out that reactors have been hit by a large earthquake, gigantic tsunami and survived with minimal casualties so far. So where does the truth lie?

What do we think we know for sure?

1) The Japanese government have warned of a grave nuclear incident on a number of occasions.

2) The status of the reactors, fuel pools and dispersion of radioactive materials continues to get worse, not better.

3) There are perhaps 7 or 8 reactor loads of fuel in play compared with a single load at Chernobyl and 4 or 5 of those are outside of containment in badly damaged spent fuel pools.

4) **This report** suggests that daily release of radioactive ^{131}I and ^{137}Cs is running at around 73% and 60% of Chernobyl respectively.

5) The Chernobyl fire burned for 8 to 10 days whilst Fukushima Dai-ichi has been emitting radioactive material for around 15 days with no end in sight.

6) There is a 30 km exclusion zone in place and thousands of residents have become refugees with little prospect of returning home in the near future.

*Status of Fukushima Dai-ichi from **Japan Atomic Industrial Forum** on 30th March. Significance: Red = Severe (need immediate action); Yellow = High; Green = low. Click to enlarge.*

Weaknesses and leaks in containment

At **this press conference**, Dr. Masashi Goto, former Toshiba nuclear power plant designer, provides some explanation for how reactor vessels and primary containment may have developed leaks. Dr Goto explained that both containment and pressure vessels have access hatches for fueling and maintenance and these hatches have flanges, bolted in place and using organic seals. The design temperature is 138˚C and at temperatures over 300˚C the flanges buckle and can leak. The organic seals may have burned. There are also ducts for electric cables, pipes, and valves. etc., that are weak points.

Note that Dr. Masashi Goto also says that the cores of reactors 1, 2 and 3 had already melted, but

does not make clear if this was partial or total melt down.

Containment venting

The JAIF status report up top states that containment venting is temporarily stopped. It was this venting to release pressure that caused radiation to spike on a regular basis during the early days of the event. There have been a number of equivocal statements about pressure stabalisation in reactors 1 to 3 and I believe the simplest explanation is because they are now leaking. The JAIF status report says this:

> It is presumed that radioactive material inside the reactor vessel would have leaked outside the containment vessel at unit-1, 2 and unit-3, based on the investigation of the water sampled in the turbine building from Mar. 24th to 27th.

Noting that this seems to contradict JAIF saying that the containment vessel structural integrity is "not damaged" in units 1 and 3.

The fact that the reactor pressure vessels and containment seem to be leaking is not necessarily a bad thing since this lowers the risk of a pressure build explosion. But it does mean that these reactors will continue to leak radioactive material for so long as water is injected for cooling purposes. It also raises questions about the purpose of trying to restore the primary cooling loop that is dependent upon a pressure seal to drive steam toward the heat exchangers.

Understanding radiation dosage numbers

Different types of radiation (alpha, beta, gamma) have different effects on the human body and different types of radioactive materials also present different hazard levels depending upon how they are chemically ingested. For example, iodine concentrates in the thyroid gland posing risk of thyroid cancer. The REM (see below) is a measure that attempts to normalise this variability.

REM = roentgen-equivalent man
100 REM ~ 1 sievert

LD50 ~ 4.5 Sieverts or 450 REM

The LD50 is the level of exposure required to kill 50% of an affected group.

The spread of radioactive material

The following unofficial numbers for 24th March **posted** by commenter **schoff**, that I have reason to believe are accurate, show high levels of radiation in the dry well (D/W) which is the volume between the pressure vessel and primary containment. These numbers seem to confirm that the pressure vessels have leaked. At these levels workers would receive lethal dosage in 5 minutes and so it is clear that no one is going to be able to enter the dry well area to inspect damage or attempt repairs or remedial work.

The readings from secondary containment (the wrecked reactor buildings) are also high providing a lethal dose in 1 to 2 hours. Again, this is sufficiently high to prevent remedial work or repairs and explains why water has to be cannoned into the fuel pools from the exterior.

> Area Rad Monitors
>
> 1 "D/W: 4780 rem/hr S/C: 349 rem/hr"
> 2 "D/W: 5490 Rem/hr S/C: 193 Rem/hr"
> 3 "D/W: 6000 Rem/hr S/C: 158 Rem/hr"
>
> The S/C is believed to stand for Suppression Chamber Torus. D/W is the drywell.

Heavily contaminated water is now turning up at many locations within and without the reactor buildings and this is now beginning to hamper remedial works around the site.

This report in New Scientist also suggests that very large amounts of ^{131}I and ^{137}Cs are being dispersed vertically upwards from the site. Recall that radiation above the buildings was too high for helicopters to hover at the time spent fuel pools were exposed. ^{131}I has a half life of 8 days and ^{137}Cs has a half life of about 30 years. As a rule of thumb, after about 5 half lives have past, the abundance of the isotopes have decayed to virtually zero. ^{131}I will continue to be a problem for so long as it is leaking from the site but will decay to zero quite quickly once leakage stops. ^{137}Cs may be a problem for about 150 years.

Traces of ^{131}I from Fukushima Dai-ichi have shown up in Scotland and other sites in Europe.

The one thing in favor of the Tepco workers battling to contain the incident is that radiation levels throughout much of the site remain safe enough to enable periodic spraying of water into the spent fuel ponds. I fear this situation will not last for much longer.

Comparison of Fukushima Dai-ichi and Chernobyl

There are a number of key differences between Chernobyl and Fukushima Dai-ichi making comparisons of the incidents difficult:

1) The Chernobyl accident took place at fission power blowing the roof of the core and reactor building while Fukushima Dai-ichi was successfully shut down.

2) Chernobyl had a graphite core that burned, spreading radioactive material far and wide.

3) Chernobyl lacked a primary containment system.

4) Chernobyl involved a single reactor load of fuel while Fukushima Dai-ichi likely has 7 to 8 reactor loads spread between the cores of units 1, 2 and 3 and the spent fuel ponds of units 1 to 4.

5) Fukushima Dai-ichi unit 3 has MOX fuel loads containing plutonium in reactor and in spent fuel pool.

6) Fuel in pool of reactor 4 is not spent and is a 'hot' load outside of containment.

7) Fukushima Dai-ichi is located in the heart of Japan, the world's third largest economy whilst Chernobyl is located in Ukraine which has lower economic standing in the world.

In my estimation, the larger mass of fuel, much of it outside of containment, the geographic location and possible socio-economic impacts on Japan, longer duration and open-ended nature of this event and extant risk of explosion and fire will ultimately make Fukushima Dai-ichi the more serious incident.

Future course and consequences

Notwithstanding the successful filling of the spent fuel ponds with water, I do not believe Tepco has been able to take any action thus far that has halted the decline in condition of the Fukushima Dai-ichi reactor complex. Things are getting worse, not better, for every day that passes. The site is slowly but surely becoming too hazardous for operations, and if that happens, remedial work on cooling reactors and filling fuel ponds may have to stop raising the specter of further melt down and fires. All the while corrosion is eating away at the pressure vessels and associated pipes and valves and absent circulation cooling the heat dissipation problem builds (see **slow burning issues**).

Rational voices point to the fact that most modern reactors in operation as well as those being built and planned are much safer than the aging fleet at Fukushima Dai-ichi. This may be so, but populations around the world fear radiation and it is the public that will have the final say.

Earlier posts

Safety of nuclear power and death of the nuclear renaissance (March 15th)
http://www.theoildrum.com/node/7661

Fukushima Dai-ichi status and potential outcomes (March 17th)
http://www.theoildrum.com/node/7675

Fukushima Dai-ichi status and slow burning issues (March 25th)
http://www.theoildrum.com/node/7706

And open threads that contain archives of news links and commentary:

Drumbeat Special Edition: Fukushima Thread 13th March
http://www.theoildrum.com/node/7637

Fukushima Thread: March 14, 2011
http://www.theoildrum.com/node/7646

Fukushima Thread: March 15, 2011
http://www.theoildrum.com/node/7660

Fukushima Thread: March 16, 2011
http://www.theoildrum.com/node/7669

Fukushima Thread: March 17, 2011
http://www.theoildrum.com/node/7677

Fukushima Thread: March 18, 2011
http://www.theoildrum.com/node/7684

Fukushima Thread: March 19, 2011
http://www.theoildrum.com/node/7688

Fukushima Thread: March 20, 2011
http://www.theoildrum.com/node/7692

Fukushima Open Thread 28th March
http://www.theoildrum.com/node/7724

Fukushima Open Thread - 29th March
http://www.theoildrum.com/node/7641