

Fukushima: The Crisis is Not Over

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Radioactive byproducts produce heat

During the normal operation of a nuclear reactor, there is an accumulation of many man-made radioactive materials such as iodine-131, cesium-137, strontium-90, plutonium-239, and many others.

These radioactive byproducts continue to produce a lot of heat, even after the reactor is shut down, because radioactivity cannot be stopped. This unstoppable heat is called “decay heat”.

Heat damages fuel, releasing hydrogen and radioactive gases

Unless the decay heat is removed as fast as it is produced, the temperature will continue to rise, eventually damaging the fuel and letting radioactive gases and vapors escape.

When you see hydrogen explosions, that means that the outside of the fuel has gone past 1000 degrees Celsius and the inside of the fuel is well over 2000 degrees Celsius. At that point the fuel gets brittle, and the zirconium coating burns, giving off hydrogen gas.

Inside the core, fuel starts melting

Inside the containment vessels of units 1, 2 and 3, the fuel gets soft and melts, then it falls to the bottom of the vessel in a molten blob of lava. So in each of those three reactors, there is essentially a blob of lava at the bottom of the reactor vessel.

Emergency workers used fire hoses connected to the ocean to pump seawater into the reactors, which had boiled dry either fully or partially.

Now, if the fuel had not melted, it would still be sitting there in a solid vertical configuration – individual fuel assemblies with channels between them, allowing the water to surround the fuel and completely cool it.

Water cannot fully cool a molten blob

But when the fuel is a blob at the bottom of the vessel, the water can only cool the top surface of the blob and that will not stop it from melting.

At this point the blob is around 2800 degrees Celsius at the centre. Even though the outside surface may be touching water, the inside of this molten mass remains at 2800 degrees.

And at the bottom of each of these boiling water reactor vessels, there are about 70 holes where the control rods can be inserted. I suspect that those holes were essentially the weak link that allowed the molten fuel to drip through to the bottom of the containment.

How far will the meltdown go?

So that's where we are, with molten fuel on the bottom of the containment. It spreads out at that point because the floor is flat.

I don't think it's going to melt through the concrete floor, although it could gradually do so over time. But the damage is already done because the containment has cracks in it and it's pretty clear that it is leaking.

So you pour water in at the top and it runs out at the bottom, carrying with it more and more radioactive byproducts that were created in the reactor fuel. Many of these materials escape into the environment as liquids and gases.

What about Unit 4, with no fuel in the core?

At the time of the accident there was no fuel in the reactor vessel of Unit 4. All the fuel had been taken out and placed in the spent fuel pool. But there was inadequate cooling there too, and the resulting overheating of the fuel led to a hydrogen gas explosion that blew the roof off.

But that means there is absolutely no containment for the nuclear fuel in that pool, unlike the molten fuel in the reactor cores of units 1, 2 and 3, which still have a containment, structure above them to limit radioactive releases directly into the air.

The entire spent fuel pool in Unit 4 is open to the sky, plainly visible from above. During the helicopter fly-overs you could look down into this blown-out shell of a building and see the fuel sitting there in the spent fuel pool.

That fuel is still producing a lot of heat, because the reactor was only shut down in November. So the temperature rise can easily damage the fuel and cause large radiation releases, as has been observed, from unit #4.

Fuel Pool Fires – Perhaps the Biggest Concern

Brookhaven National Labs did a study in 1997 that showed that if a fuel pool went dry and caught on fire, it could cause 187,000 fatalities among the surrounding population. So it's a big concern. In fact it is probably the biggest concern at the whole Fukushima complex.

I know the Chairman of the US Nuclear Regulatory Commission (NRC) stated that the reason he told Americans in Japan to stay 50 miles away from the Fukushima Dai-Ichi complex was his fear that the Unit 4 spent fuel would catch fire and volatilize large amounts of plutonium, uranium, cesium and strontium. If the Brookhaven study is to be believed, such an event could kill more than a hundred thousand people as a result.

What about earthquakes?

The Sumatra earthquake of December 2004 was a 9.1 magnitude quake, and the biggest aftershock occurred three months later, and that was an 8.6 magnitude quake. So even now, if the Sumatra event is any indication, large aftershocks are still possible.

One of the concerns about Units 1, 2 and 3, is that if you pour too much water into the structures surrounding the cores of those reactors, they get very heavy – and they are not designed to sway when they are so heavy. With tens of tons of extra water in them, the mass in the core area exceeds the seismic design. So they are unusually vulnerable to earthquake damage. They are in real jeopardy in case of a severe aftershock.

The same applies to the already weakened structure of the spent fuel pool in Unit #4. And as already mentioned, because the spent fuel pool is open to the sky, the radioactive releases from the damaged fuel in that pool could be exceptionally dangerous over a much larger area than previously envisaged.

What about entombment?

If all else fails, I think eventually TEPCO may get to the point of throwing up their hands and just pouring concrete on top of the reactor cores in Units 1, 2 and 3. They can't do that yet, because the cores are still too hot. But at a certain point there won't be anywhere near as much decay heat and you probably could consider just filling them with concrete, creating a giant mausoleum as they did at Chernobyl.

But Unit 4 is still a problem, because all the fuel is at the top – high up – and you can't pour concrete onto it because you will collapse the supporting structure. And the fuel in the pool is so radioactive, you can't lift it out either. I used to do this for a living, but Unit 4 has me stumped – I don't know what to do about it.