

KEYNOTE SEMINAR

FUKUSHIMA: ‘LESSONS LEARNED’ FOR UK NEW NUCLEAR BUILD

**IMPLICATIONS FOR THE WORLD-WIDE NUCLEAR REGULATORY REGIMES – SPECIFIC
APPLICATION TO EUROPE & UK**

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FUKUSHIMA DAI-ICHI IMPLICATIONS FOR THE WORLD WIDE NUCLEAR REGULATORY REGIMES

Just over three months ago an earthquake and tsunami struck the Japanese nuclear complex at Fukushima. The events that followed suggested to some of us that things at Fukushima were seriously amiss, but the Japanese authorities presented a different picture.

Indeed, the Japanese government has been confused and taciturn in its management and release of factual information, its nuclear regulator NISA being overly dependent upon and trusting of the plant operator TEPCO, and the International Atomic Energy Agency has seemed to be reluctant to challenge the often misleading account of what has developed into a seriously unstable radiological situation – its recent Fact Finding Mission glossed over the facts, turning an all knowing blind eye on some very odd anomalies at Fukushima.

As for the public: over 200,000 individuals, some of them forcibly, have had to be evacuated from the Fukushima Prefecture to the north-east of the plant, about 3,200km² of urban and arable land has been heavily contaminated, schoolchildren are now expected to tolerate a dose exposure of up to 20mSv. Confronted with all of this, the IAEA mission, headed by the UK's Chief Nuclear Safety Inspector Mike Weightman, concluded, amongst other things, that the people evacuated will shortly be able to resume their normal lives.

Nothing could be further from the truth.

The facts of the matter are brutally straightforward: At 14:46 Standard Japanese Time on 11 March 2011 the *Japanese Great Easter* earthquake struck the east coast of Japan with this seismic event triggering the automatic and abrupt shut down of at least 10 operating nuclear power plants. The sudden cessation of electricity input at key nodal points befuddled the national electricity distribution grid which, itself suffering from seismic damage, collapsed denying the individual nuclear power plants electricity with which to maintain essential reactor fuel cooling and crucial instrumentation and control systems operational.

At the Fukushima Dai-ichi (N^o 1) plant, site emergency diesel generating sets fired up providing on-site power to the reactor cooling pumps and other essential services of the three operating nuclear plants, as well as cooling for the six-reactor unit spent fuel ponds and also for the central spent fuel store. On-site supplies continued in operation for just over one hour until the entire site was swamped by a 10m plus tsunami with a total wave height amplified by the backwash as the tsunami wave was contained and reflected by the heavily terraced of western section of the site – this part of the site was occupied by four reactors, three of which had been fully operational at the time of the earthquake.

Thereafter, the Tokyo Electric Power Company, TEPCO, was unable to restore either on or off-site power and the entire Fukushima Dai-ichi nuclear complex went into and remained in a station blackout.

What we do know is that during this station blackout a series of worsening radiological situations have developed and persist at the Fukushima Dai-ichi nuclear power complex.

Each of the three operational reactors on the site, although each had shut down automatically at the time of the earthquake, underwent and were severely damaged by violent explosion. A fourth nuclear unit, even though defueled at the time, was also severely damaged by explosion.

Within a few hours it became apparent to those following events that the reactor cores of the three operating units had melted down, that the molten fuel or corium had slumped to the bottom of the reactor pressure vessels, that these reactor pressure vessels themselves had failed and that, in various degrees, the so-called primary containments of the pressure suppression system had each also failed.

But that was not the end of it.

What remained of the reactor instrumentation clearly indicated an ongoing and deteriorating situation – thermal activity within the reactor buildings increased, there occurred sharp perturbations in containment pressure and radiation levels, particularly within what remained of the primary containments, doubts about the effectiveness of the jury-rigged water injection arose, and increasing concerns about the volumes of highly contaminated water were linked to TEPCO's seemingly ad hoc seawater cooling strategy.

Possibly the most intriguing aspect of TEPCO's reporting was its continuing assertion that both the reactor pressure vessels and primary containments remained intact – it states quite clearly that only the top 1m or so of the fuel cores were uncovered, and that water injection was maintaining the fuel cool and largely undamaged, and both reactor and primary containments continued in effectiveness.

Whereas, to the contrary, it seems that TEPCO must have known within two or three hours of the tsunami strike that the reactor cores were doomed to a full melt down, with the 65 to 95 tonne fuel cores fully melting to slump into the bottom of the reactor pressure vessels within 16 hours.

All of this was known to TEPCO because the instrumentation readouts show the reactor pressure vessels to be empty of water with the fuel cores completely uncovered within 3 hours and, alongside this, the actual fuel core temperatures to be soaring to 2,800°C within 3 to 4 hours of loss of cooling power and station blackout.

TEPCO managed to maintain the increasingly absurd line that the fuel cores had not melted and that the reactor containments were holding for two months into the accident. During that time, the 10,000 or so tonnes of highly contaminated water on the site increased to 100,000 tonnes presenting almost insurmountable storage capacity difficulties against which thousands of tonnes of so-called lightly radioactive water was sacrificially dumped into the marine environment.

Those in the public sector organising the sheltering and evacuation zones, by then stretching 60 or more kilometres from the Fukushima plant knew nothing of the additional risks that accompanied the full fuel melt downs and breaches of the reactor pressure vessels.

Even now, well after the course of real events having been established, the Japanese government omits to publish crucial reactor data prior to 20 March. So not only a station blackout since 11 March, but an effective information blackout that was condoned, if not accepted not only by the regulator NISA but also by the IAEA in its regular Fukushima updates.

What we do know for certain is that the earthquake and tsunami were just the start of it – in the ensuing station blackout the fuel cores melted, during which the zircaloy fuel cladding violently and exothermically reacted with the remaining high temperature steam, adding to the heat and liberating hydrogen. In turn, this hydrogen was a ticking time bomb, biding its time to deflagrate in each of the three reactors in turn when the opportunity arose.

Thus we have it: the weakness of the Fukushima nuclear reactors was

- First, the inability to maintain cooling during a station blackout
- Second, the failure to recover from a station blackout
- Third, being unable to curtail the hydrogen generation and its deflagration

and

- Fourth, not providing sufficient surety of primary and secondary containments for these circumstances.

So just what are the implications of this?

The underlying weakness is, obviously, with the Zircaloy clad fuel system – all light water reactors, both PWR and BWRs worldwide about 400 or so in total, share this Zircaloy fuel system – it follows that all light water reactors, including both the existing and those Generation III reactors, such as the European Pressurised Reactor or EPR and the Westinghouse AP1000, both destined for Britain’s new nuclear build programme, will have to be re-evaluated and the necessary mitigation measures put in place.

Mitigation applies to both reactor in-core fuel and, the mounting volumes of spent fuel held in what are often lightly protected and contained spent fuel ponds, not just at the nuclear power plants but also at the reprocessing works, such as BNFL Sellafield and COGEMA la Hague.

But there is something about the ways in which we define and demonstrate nuclear safety that is fundamentally flawed. This is that we should not have relied so heavily on probability – that is as chance would have it.

Just what was the chance of the combination of earthquake and tsunami, what was the chance of a swamping tsunami wave height, what was the chance of the electricity grid collapse, and so on and so forth?

The Japanese regulator would have judged the product or cascade of all of these chances to have been so low as to have been incredible, so low that it was so unlikely to happen so, it follows, it could be ignored so no plans for its eventuality had to be made or practised.

That is like assuming that a tiny speck of ice floating in the enormous geographical space of the North Atlantic would never – and you all know where I am going with this – collide with a pencil thin transatlantic liner – no need, therefore, to make the Titanic unsinkable, nor equip it with life boats.

So what can we learn from Fukushima?

First, that it is beyond our wit to foresee all possible circumstances and events and, moreover, to predict their severity.

Second, the very severe radiological consequences of Fukushima, like Chernobyl before it, demonstrate that we have simply got it wrong – accidents are accidental by their very nature, so much so that the cost of us ignoring this commonsense axiom has, yet again, been radiologically catastrophic.

Thank you