

# REVIEW OF THE INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA) PRELIMINARY SUMMARY OF ITS FACT FINDING EXPERT MISSION TO JAPAN OF 24 MAY TO 1 JUNE 2011

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## REVIEW OF PRELIMINARY SUMMARY OF THE IAEA EXPERT MISSION TO JAPAN 1 JUNE 2011

During the period 24 May through to 1 June the International Atomic Energy Authority (IAEA) sent a team of about 20 nuclear experts, drawn from a dozen countries, to Japan to investigate the causes, damage and radiological consequences at the nuclear facilities affected by the *Tohoku-Taiheiyou-Oki* earthquake-tsunami. The IAEA published a [Preliminary Summary](#) of its fact-finding mission on 1 June 2011 – this Review considers those aspects of the IAEA summary relating specifically to the severely damaged nuclear power plants (NPPs) at the Fukushima Dai-ichi complex.

The IAEA Summary makes and draws a number, albeit preliminary, observations and conclusions:

### 1) Loss of Instrumentation

In para 6 page 1 [¶6, p1] the IAEA implies that all instrumentation was lost at the arrival of the tsunami (~15:30 SJT). However, this is contradicted by the [15 May statement](#) of TEPCO (Tokyo Electric Power Company) acknowledging that key reactor instrumentation, for Unit 1 at least, functioned for several hours following the tsunami strike. This instrumentation transmitted and recorded for at least 13 hours the fuel core temperature and continued unabated to record the reactor pressure vessel (RPV) water level, RPV shell temperatures and, mostly, the thermal, pressure and radiation environmental parameters within the primary containment (both wet and dry wells).<sup>1</sup>

The information conveyed from the functioning instruments provides a clear insight into the conditions inside the RPV crucial to TEPCO's immediate post-incident management of what is now known to have been a rapidly deteriorating situation. Moreover, importantly for the IAEA team, knowledge of TEPCO's reaction to this real time information is fundamental to understanding how and to what extent the post-incident management response failed in the immediate and interim terms.

It is not clear why the IAEA team chose not to comment on the continuing availability of instrumentation output during the period immediately following the earthquake and tsunami strikes.

### 2) Loss of RPV Fuel Core Cooling

Contrary to the IAEA statement [¶2, p3] that there were '*no means to . . . cool the reactor units*', it is quite clear from the fuel core [temperature records](#) that effective cooling was underway (in at least Unit 1) for about 2.5 hours following the tsunami strike at 15:30h SJT.<sup>2</sup> This cooling, sufficient to reduce and maintain the fuel core at about 300°C, was (most probably) rendered by a combination of the *isolation condenser* (Unit 1) and *core isolation cooling*<sup>3</sup> via the residual steam driven turbine-pump designed to be independent of electricity power supplies.<sup>4</sup>

<sup>1</sup> a) In-RPV reactor measurements are shown by '[Reactor Core Status of Fukushima Daiichi Nuclear Power Station Unit 1](#)', TEPCO, 15 May 2011 – see also '[Plant Data of Fukushima Daiichi Nuclear Power Station](#)', TEPCO, 11 March 2011

b) The Nuclear and Industrial Safety Agency (NISA) published regular daily updates for Units 1, 2, 3 and 4 from a few days following the incident providing detailed accounts of the surviving instrumentation for the individual unit RPV, primary containment and spent fuel pond - see [NISA Conditions](#) for example of 6 April.

c) TEPCO also published regular updates of the plant status - see [TEPCO Plant Status](#) data sheets.

<sup>2</sup> SJT – Japanese Standard Time used throughout this review.

<sup>3</sup> See Figure 2A of '[TEPCO Plan to Flood the Primary Circuit Containment of Unit 1, Fukushima Dai-ichi](#)', Large & Associates, R3197-A1, 10 May 2011

<sup>4</sup> TEPCO operatives valved off the isolation condenser at 15:03h into the incident<sup>4</sup> ([Figure 2B](#)), that is before the tsunami strike of 15:37h when the Fukushima Dai-ichi site lost all power, but it was then reactivated at 18:18h [\[p5\]](#). The second coolant system (the residual steam turbine driven pump) that was also independent of electricity supplies, may have ceased operation shortly thereafter, with the loss of RPV water level suggesting that venting of the RPV commenced at the latest by about 19:30h, either by containment failure of the RPV (or the unisolable legs of the steam/feedwater pipework) or by intentional venting of the RPV to the wet well of the primary containment (recorded to be underway by 04:00h).

The combination of the RPV fuel core condition and its containment, particularly the RPV shell enclosure and, secondly, the primary containment, effectively sets the risk of a significant radioactive release occurring. This risk, in itself, is crucial for the resourcing and timely implementation of off-site emergency actions and countermeasures to safeguard the public in the region of the NPPs.

In the days and weeks following the earthquake, TEPCO insisted that the greater part of the reactor fuel cores remained immersed under water and that the RPV containments were sound – this ‘controllable’ situation was not at all challenged by the Japanese nuclear safety regulator NISA. This strongly implied that the risk of further radiological release had been curtailed by the end of the first week and, as a result, the emergency procedures and actions in the public sector overseeing the welfare of tens, if not hundreds of thousands of individual members of public were appropriate and entirely adequate. This was obviously not so because TEPCO admitted on 15 May<sup>1a</sup> (2 months later) that the fuel core of Unit 1 had in fact completely melted and slumped into the bottom of the RPV within 16 hours of the tsunami strike and, in doing so, had burnt through the RPV shell containment.

The prolonged absence of this crucial information on the state of the reactor fuel and its containment (Units 2 and 3 were confirmed to be in a similar condition 2 days later) is completely overlooked in the IAEA summary report.

Moreover, when dealing with the off-site emergency response the IAEA only refers to the to the ‘*longer term response*’ to protect the public to have been ‘*impressive and extremely well organized*’ [Bullet 1, p4]. This pointed reference to the ‘*longer term response*’ seemingly enables the IAEA mission to avoid commenting upon the confused, and sometimes bizarre immediate and interim-term situations that arose and continue to persist in the public sector in and around the Fukushima Prefecture – the IAEA Summary Report omits to consider the confusion over the dose limits applied to both workers engaged in emergency remedial actions at the NPP and for the public in the increasingly radiological contaminated areas; the holding back of the results of the nationally installed and proven SPEEDI radiation monitoring, modelling and radiological analysis system; and, particularly, the application of the 20mSv dose limit applied to children required to continue school attendance in the contaminated areas that stretched towards and into Fukushima City.

### 3) Delay in Declaration of INES Level 7 Incident

The IAEA makes a passing reference to the declaration of the International [Nuclear Event Scale](#) (INES) Level 7 [¶2, p3], noting that this level at Fukushima has only been ‘*provisionally*’ determined.

Surprisingly, the IAEA chooses not to comment on i) the delays in the Japanese Government’s declaration of the most severe incident category, taking one month from the initiating earthquake date even though it (or at least TEPCO) must have had full knowledge of the very serious fuel core melt situation and RPV containment failure within hours of the tsunami strike. Also, the IAEA fails to note that ii) this delayed INES declaration would set back the notification of the normally confidential *Event Rating Form* (ERF) to adjacent states (particularly South Korea, Russian and China), as required by signatory parties to the IAEA convention itself.

### 4) Combination of External Events

Although the IAEA identifies the need to adequately cover combinations of external events [B5, p4], the Summary skirts over the possible contribution of the seismic loading and damage deriving from the earthquake event, as distinct from the damage being caused solely by following tsunami.

There have emerged a number of claims that essential pipework and equipment sustained seismic loading damage prior to the tsunami strike. On 13 April [NISA required](#) TEPCO to undertake an assessment of the seismic resilience of the built structures of the Fukushima Dai-ichi and other NPP

sites and, in response to this, TEPCO published its analysis<sup>5</sup> on 28 May. However, this work considers only the building structures and excludes assessment of the nuclear plant, equipment and safety systems housed within the reactor and turbine hall units, even though an earlier TEPCO report of 23 May<sup>6</sup> refers to an alert relating a possible main steam piping fracture [item 5, p4].<sup>7</sup>

These doubts from a number of usually well-informed sources<sup>8</sup> about possible (pre-tsunami) seismic damage to the reactor coolant circuit, services and containments should warrant further and detailed investigation. This is because the Fukushima Dai-ichi NPPs were designed and (supposedly) maintained to the highest international seismic standards – seismic failure at Fukushima Dai-ichi has obvious implications for NPPs, not just elsewhere in Japan but for all plants located in seismic sensitive regions globally – surprising, therefore, that the IAEA have not expressed interest in this potential weakness of the nuclear safety regulatory standard.

## 5) Planned Road-Map to Recovery

The IAEA states [B3, p4] that the road-map, *'with modification as new circumstances are uncovered'* (acknowledgment in itself that the Fukushima Dai-ichi incident is still unfurling), *'could result in remediation of areas off site affected by radioactive releases to allow people evacuated to resume their normal lives'*.

This is a remarkably up-beat and optimistic statement by the IAEA mission team that has little if not no substantiation whatsoever.

Upwards of 200,000 members of public have been removed, many of them forcibly, from evacuation and controlled zones that are broadly equivalent in area to the zones imposed around Chernobyl in 1986; and little as been mapped out about the health impact of the ongoing radiological discharge to the marine environment and its effect on coastal communities to the north and south of the Fukushima Dai-ichi nuclear complex. To date, the radiological dose to very large numbers of public has been significant and, in addition, those continuing to occupy contaminated zones run the risk of accumulating dose levels that would be unacceptable in Western Europe under an equivalent emergency situation - it is, surely, very unlikely that these individuals, along with those previously evacuated, will ever, as the IAEA mission team puts it, be able *'to resume their normal lives'*.

## 6) Fundamentally Flawed Approach in the Nuclear Regulatory Framework

The IAEA indirectly identifies fundamental flaws in the nuclear regulatory approach [B3, 4, 5, 6 & 8, p4], specifically:

- i) natural hazards (tsunami etc) were underestimated;
- ii) NPP design, safety systems and operational protocols should apply to extreme (low frequency) events, including physical separation, diversity and redundancy measures;
- iii) nuclear safety regulator independence and clarity of roles should be preserved;
- iv) the approach to combinations of external events (eg earthquake+tsunami, aircraft crash+fuel fire, etc) should be included in all aspects of the design, operation and emergency response of NPPs; and

<sup>5</sup> Summary *'Reports About the Study Regarding Current Seismic Safety and Reinforcement of Reactor Buildings at Fukushima Daiichi'*. TEPCO, 28 may 2011

<sup>6</sup> *'Analysis and Evaluation of the Operation Record and Accident Record of Fukushima Daiichi Nuclear Power Station at the time of the Tohoku-Chihou-Taiheiyou-Oki-Earthquake (Summary)'*, TEPCO, 23 May 2011

<sup>7</sup> This potential fault was also noted for Units 2 and 3 - since was no noted increase in steam flow TEPCO assumed that it was a common instrument malfunction across all three Units.

<sup>8</sup> *'Fukushima May Have Leaked radiation Before Tsunami'*, Bloomberg, 19 May 2011

- v) the hazard of hydrogen generation from the RPV in-core fuel and storage pond spent fuel should be reviewed in detail and the necessary mitigation systems provided.

Although somewhat masked by the IAEA's overly cautious approach, these preliminary findings are significant - reading between the lines:

In effect, the nuclear safety case for Fukushima Dai-ichi underestimated i) the risk of a natural hazard (here the earthquake-tsunami combination) that could potentially challenge the NPP. It considered that the frequency of such a large and overwhelming tsunami to be so low as to be considered an '*incredible*' event for which no pre-planning and countermeasures were required. It follows ii) and iv) that all such external events (not just an earthquake-tsunami combination) should now be included in credible hazards that NPPs are required to counter. Importantly, the sense of this IAEA finding seems to (and should) apply to existing NPPs worldwide.

The IAEA mission team seem to be concerned with the independence of the role of the iii) nuclear safety regulator NISA during the aftermath of this ongoing incident at Fukushima Dai-ichi. TEPCO appear to have been allowed to assume the lead role from the onset with NISA and the other Japanese authorities seemingly satisfied just to reiterate (and endorse) the information and data provided by TEPCO. Moreover, there has been and continues to be little sense of any meaningful peer reviewing of both the information provided by and, importantly, the remedial actions undertaken by TEPCO. Indeed, this charge of subservience might also be levied against the IAEA itself because in its reporting it remained taciturn over a number of increasingly obvious shortcomings of the TEPCO and Japanese authorities' management as the incident aftermath developed – eg knowledge of the melt downs of the fuel cores, delay in declaration of INES Level 7, holding back of the SPEEDI in-field monitoring, etc., confusion over both worker and public dose exposure limits, and so on

On the matter of v) hydrogen risks, which played such a decisive role in the damage severity and radiological outcome at Fukushima Dai-ichi, the IAEA mission team calls for '*detailed evaluation*' and that '*necessary mitigation systems*' be provided. The source of the hydrogen was the vigorous and exothermic reaction with the zirconium-alloy fuel cladding (and fuel assembly bracing, etc) with the steam that filled the depleted water spaces in the RPVs of Units 1, 2 and 3<sup>9</sup> - this zirconium clad fuel system is common to all light water moderated reactors (essentially BWR and PWR)<sup>10</sup> worldwide. So, according to the IAEA preliminary findings, all light water NPPs worldwide sharing this Zircaloy fuel system should be subject to detailed evaluation (reactor fuel cores and spent fuel ponds) and back-fitted with the necessary mitigation measures.

## CONCLUDING COMMENTS

The IAEA Preliminary Summary is disappointing, being an overly cautious and not at all informative review of the reasons and responsibility for, and radiological outcome of the very severe and ongoing nuclear incident at Fukushima Dai-ichi.

The IAEA Mission Team fail to shed any further light whatsoever on the events and circumstances that culminated in the catastrophic failure and radiation release from three operational nuclear power plants, and for the explosion and radioactive release from the spent fuel pond of a fourth but defueled nuclear reactor. It provides no explanation or reason for the substantial and confusing delays that occurred in the aftermath management of the incident – for example, why the INES Level 7 declaration was

<sup>9</sup> The Zircaloy-steam reaction is also likely to have occurred in the spent fuel pond of Unit 4 if, as it is assumed, the pond drained down leaving the racked fuel exposed. On this issue, the boil-down time for the pond water would have been longer than the 4 day period between the tsunami loss of cooling event and the 15 May explosion, so it might have been that the pond itself or its connection the adjacent flooded RPV cavity, or indeed, the RPV itself was damaged by the pre-tsunami earthquake seismic loading – the TEPCO suggestion that the hydrogen fuelling the explosion somehow migrated from Unit 3 (which had exploded earlier) is not particularly convincing.

<sup>10</sup> BWR (Boiling Water Reactor) as at Fukushima Dai-ichi and PWR (Pressurised Water Reactor) which is the dominant type of NPP worldwide, ie in France as at Flamanville.

delayed for one month when it was so obvious from the onset that this was a very serious radiological incident indeed; why TEPCO, with the knowledge of NISA, delayed the release of data showing a complete fuel melt and breach of the RPV containment for two months; why the SPEEDI monitoring results were not published in full from the onset; on the confusion and delays over the radiation dose limitation system applied in the off-site public domain; and so on and so forth. Holding back and/or the incomplete publication of this information and data could have particular relevance to the effectiveness of the countermeasures being applied over the off site areas involving tens if not hundreds of thousands of members of public.

In its Preliminary Findings the IAEA recognises but skirts around how the incident at Fukushima Dai-ichi has revealed and highlighted fundamental flaws in the Japanese and international regulatory approaches. In effect, the IAEA Summary states unambiguously that the external hazard to Fukushima Dai-ichi was underestimated in frequency of occurrence (ie chance) and severity (ie damage potential); that the NPP had no effective defence against this natural hazard and that, in these respects, the Japanese nuclear regulatory system failed and permitted an ill-prepared NPP to operate in an unsafe way.

Also, the IAEA points towards but fails to identify specifically the international dimension of nuclear safety issues raised by Fukushima Dai-ichi. It somewhat vaguely recommends that combinations of external events should be covered in the design and operation of NPPs, which implies that all externally sourced events (flooding, aircraft crash, terrorist attack, etc) should be reviewed for all NPPs worldwide. Quite specifically, the IAEA identifies the hydrogen hazard of the zirconium alloy fuel systems used universally in light water reactors although, that said, it not only fails to quantify this risk but, crucially, it does not recommend how the international nuclear safety regulatory community might set about, and with what urgency, practicably implementing remedial measures on a worldwide basis.

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