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MISSION REPORT

THE GREAT EAST JAPAN EARTHQUAKE EXPERT MISSION

IAEA INTERNATIONAL FACT FINDING EXPERT MISSION OF THE FUKUSHIMA DAI-ICHI NPP ACCIDENT FOLLOWING THE GREAT EAST JAPAN EARTHQUAKE AND TSUNAMI

Tokyo, Fukushima Dai-ichi NPP, Fukushima Dai-ni NPP and Tokai Dai-ni NPP, Japan

24 May – 2 June 2011

IAEA MISSION REPORT

DIVISION OF NUCLEAR INSTALLATION SAFETY

DEPARTMENT OF NUCLEAR SAFETY AND SECURITY

SUMMARY

The Great East Japan Earthquake on 11 March 2011, a magnitude 9 earthquake, generated a series of large tsunami waves that struck the east coast of Japan, the highest being 38.9 m at Aneyoshi, Miyako.
The earthquake and tsunami waves caused widespread devastation across a large part of Japan, with 15 391 lives lost. In addition to this, 8 171 people remain missing, with many more being displaced from their homes as towns and villages were destroyed or swept away. Many aspects of Japan‘s infrastructure have been impaired by this devastation and loss.
As well as other enterprises, several nuclear power facilities were affected by the severe ground motions and large multiple tsunami waves: Tokai Dai-ni, Higashi Dori, Onagawa, and TEPCO`s Fukushima Dai-ichi and Dai-ni. The operational units at these facilities were successfully shutdown by the automatic systems installed as part of the design of the nuclear power plants to detect earthquakes. However, the large tsunami waves affected all these facilities to varying degrees, with the most serious consequences occurring at Fukushima Dai-ichi.
Although all off-site power was lost when the earthquake occurred, the automatic systems at Fukushima Dai-ichi successfully inserted all the control rods into its three operational reactors upon detection of the earthquake, and all available emergency diesel generator power systems were in operation, as designed. The first of a series of large tsunami waves reached the Fukushima Dai-ichi site about 46 minutes after the earthquake.
These tsunami waves overwhelmed the defences of the Fukushima Dai-ichi facility, which were only designed to withstand tsunami waves of a maximum of 5.7 m high. The larger waves that impacted this facility on that day were estimated to be over 14 m high. The tsunami waves reached areas deep within the units, causing the loss of all power sources except for one emergency diesel generator (6B), with no other significant power source available on or off the site, and little hope of outside assistance.
The station blackout at Fukushima Dai-ichi and the impact of the tsunami caused the loss of all instrumentation and control systems at reactors 1–4, with emergency diesel 6B providing emergency power to be shared between Units 5 and 6.

The tsunami and associated large debris caused widespread destruction of many buildings, doors, roads, tanks and other site infrastructure at Fukushima Dai-ichi, including loss of heat sinks. The operators were faced with a catastrophic, unprecedented emergency scenario with no power, reactor control or instrumentation,

and in addition, severely affected communications systems both within and external to the site. They had to work in darkness with almost no instrumentation and control systems to secure the safety of six reactors, six nuclear fuel pools, a common fuel pool and dry cask storage facilities.

With no means to confirm the parameters of the plant or cool the reactor units, the three reactor units at Fukushima Dai-ichi that were operational up to the time of the earthquake quickly heated up due to the usual reactor decay heating. Despite the brave and sometimes novel attempts of the operational staff to restore control and cool the reactors and spent fuel, there was severe damage to the fuel and a series of explosions occurred. These explosions caused further destruction at the site, making the scene faced by the operators even more demanding and dangerous. Moreover, radiological contamination spread into the environment. These events are provisionally determined to be of the highest rating on the International Nuclear Event Scale.

To date no confirmed long term health effects to any person have been reported as a result of radiation exposure from the nuclear accident.

By agreement with the Government of Japan, the International Atomic Energy Agency conducted a preliminary mission to find facts and identify initial lessons to be learned from the accident at Fukushima Dai-ichi and share this information across the world nuclear community. To this end, a team of experts undertook this Fact Finding Mission from 24 May to 2 June 2011. The results of the Mission will be reported to the IAEA Ministerial Conference on Nuclear Safety at IAEA headquarters in Vienna on 20 24 June 2011.

During the IAEA Mission, the team of nuclear experts received excellent cooperation from all parties, receiving information from many relevant Japanese ministries, nuclear regulators and operators. The Mission also visited three affected nuclear power plants (NPP) — Tokai Dai-ni, Fukushima Dai-ni and Dai-ichi — to gain an appreciation of the status of the plants and the scale of the damage. The facility visits allowed the experts to talk to the operator staff as well as to view the on-going restoration and remediation work.

The Mission gathered evidence and undertook a preliminary assessment and has developed

preliminary conclusions as well as lessons to be learned. These preliminary conclusions and lessons have been shared and discussed with Japanese experts and officials. They fall broadly under the three specialist areas of external hazards, severe accident management and emergency preparedness. They are of relevance to the Japanese nuclear community, the IAEA and the worldwide nuclear community to learn lessons to improve nuclear safety.

The IAEA Mission urges the international nuclear community to consider the following 15 conclusions and 16 lessons in order to take advantage of the unique opportunity created by the Fukushima accident to seek to learn and improve worldwide nuclear safety.

Conclusion 1: The IAEA Fundamental Safety Principles provide a robust basis in relation to the circumstances of the Fukushima accident and cover all the areas of lessons learned from the accident.

Conclusion 2: Given the extreme circumstances of this accident the local management of the accident has been conducted in the best way possible and following Fundamental Principle 3.

Conclusion 3: There were insufficient defence-in-depth provisions for tsunami hazards. In particular:

- although tsunami hazards were considered both in the site evaluation and the design of the Fukushima Dai-ichi NPP as described during the meetings and the expected tsunami height was increased to 5.7 m (without changing the licensing documents) after 2002, the tsunami hazard was underestimated;
- thus, considering that in reality a ‘dry site’ was not provided for these operating NPPs, the additional protective measures taken as result of the evaluation conducted after 2002 were not sufficient to cope with the high tsunami run up values and all associated hazardous phenomena (hydrodynamic forces and dynamic impact of large debris with high energy);
- moreover, those additional protective measures were not reviewed and approved by the regulatory authority;
- because failures of structures, systems and components (SSCs) when subjected to floods are generally not incremental, the plants were not able to withstand the
- consequences of tsunami heights greater than those estimated leading to cliff edge effects; and
- severe accident management provisions were not adequate to cope with multiple plant failures.

Conclusion 4: For the Tokai Dai-ni and Fukushima Dai-ni NPPs, in the short term, the safety of the plant should be evaluated and secured for the present state of the plant and site (caused by the earthquake and tsunami) and the changed hazard environment. In particular, if an external event Probabilistic Safety Assessment (PSA) model is already available, this would be an effective tool in performing the assessment.

Short term immediate measures at Fukushima Dai-ichi NPP need to be planned and implemented for the present state of the plant before a stable safe state of all the units is reached. Until that time the high priority measures against external hazards need to be identified using simple methods in order to have a timely plan. As preventive measures will be important but limited, both on-site and off-site mitigation measures need to be included in the plan. Once a stable safe state is achieved a long term plan needs to be prepared that may include physical improvements to SSCs as well as on-site and off-site emergency measures.

Conclusion 5: An updating of regulatory requirements and guidelines should be performed reflecting the experience and data obtained during the Great East Japan Earthquake and Tsunami, fulfilling the requirements and using also the criteria and methods recommended by the relevant IAEA Safety Standards for comprehensively coping with earthquakes and tsunamis and external flooding and, in general, all correlated external events. The national regulatory documents need to include database requirements compatible with those required by IAEA Safety Standards. The methods for hazard estimation and the protection of the plant need to be compatible with advances in research and development in related fields.

Conclusion 6: Japan has a well organized emergency preparedness and response system as demonstrated by the handling of the Fukushima accident. Nevertheless, complicated structures and organizations can result in delays in urgent decision making.

Conclusion 7: Dedicated and devoted officials and workers, and a well organized and flexible system made it possible to reach an effective response even in unexpected situations and prevented a larger impact of the accident on the health of the general public and facility workers.

Conclusion 8: A suitable follow up programme on public exposures and health monitoring would be beneficial.

Conclusion 9: There appears to have been effective control of radiation exposures on the affected sites despite the severe disruption by the events.

Conclusion 10: The IAEA Safety Requirements and Guides should be reviewed to ensure that the particular requirements in design and severe accident management for multi-plant sites are adequately covered.

Conclusion 11: There is a need to consider the periodic alignment of national regulations and guidance to internationally established standards and guidance for inclusion in particular of new lessons learned from global experiences of the impact of external hazards.

Conclusion 12: The Safety Review Services available with the IAEA's International Seismic Safety Centre (ISSC) would be useful in assisting Japan's development in the following areas:

- External event hazard assessment;
- Walkdowns for plants that will start up following a shutdown; and

- Pre-earthquake preparedness.

Conclusion 13: A follow-up mission including Emergency Preparedness Review (EPREV) should look in detail at lessons to be learned from the emergency response on and off the site.
Conclusion 14: A follow-up mission should be conducted to seek lessons from the effective approach used to provide large scale radiation protection in response to the Fukushima accident.
Conclusion 15: A follow-up mission to the 2007 Integrated Regulatory Review Service (IRRS) should be conducted in light of the lessons to be learned from the Fukushima accident and the above conclusions to assist in any further development of the Japanese nuclear regulatory system.

Lesson 1: There is a need to ensure that in considering external natural hazards:

- the siting and design of nuclear plants should include sufficient protection against infrequent and complex combinations of external events and these should be considered in the plant safety analysis － specifically those that can cause site flooding and which may have longer term impacts;
- plant layout should be based on maintaining a ‘dry site concept’, where practicable, as a defence-in-depth measure against site flooding as well as physical separation and diversity of critical safety systems;
- common cause failure should be particularly considered for multiple unit sites and multiple sites, and for independent unit recovery options, utilizing all on-site resources should be provided;
- any changes in external hazards or understanding of them should be periodically reviewed for their impact on the current plant configuration; and
- an active tsunami warning system should be established with the provision for immediate operator action.

Lesson 2: For severe situations, such as total loss of off-site power or loss of all heat sinks or the engineering safety systems, simple alternative sources for these functions including any necessary equipment (such as mobile power, compressed air and water supplies) should be provided for severe accident management.
Lesson 3: Such provisions as are identified in Lesson 2 should be located at a safe place and the plant operators should be trained to use them. This may involve centralized stores and means to rapidly transfer them to the affected site(s).
Lesson 4: Nuclear sites should have adequate on-site seismically robust, suitably

shielded, ventilated and well equipped buildings to house the Emergency Response Centres, with similar capabilities to those provided at Fukushima Dai-ni and Dai-ichi, which are also secure against other external hazards such as flooding. They will require sufficient provisions and must be sized to maintain the welfare and radiological protection of workers needed to manage the accident.

Lesson 5: Emergency Response Centres should have available as far as practicable essential safety related parameters based on hardened instrumentation and lines such as coolant levels, containment status, pressure, etc., and have sufficient secure communication lines to control rooms and other places on-site and off-site.

Lesson 6: Severe Accident Management Guidelines and associated procedures should take account of the potential unavailability of instruments, lighting, power and abnormal conditions including plant state and high radiation fields.

Lesson 7: External events have a potential of affecting several plants and several units at the plants at the same time. This requires a sufficiently large resource in terms of trained experienced people, equipment, supplies and external support. An adequate pool of experienced personnel who can deal with each type of unit and can be called upon to support the affected sites should be ensured.

Lesson 8: The risk and implications of hydrogen explosions should be revisited and necessary mitigating systems should be implemented.

Lesson 9: Particularly in relation to preventing loss of safety functionality, the robustness of defence-in-depth against common cause failure should be based on providing adequate diversity (as well as redundancy and physical separation) for essential safety functions.

Lesson 10: Greater consideration should be given to providing hardened systems, communications and sources of monitoring equipment for providing essential information for on-site and off-site responses, especially for severe accidents.

Lesson 11: The use of IAEA Safety Requirements (such as GS-R-2) and related guides on threat categorization, event classification and countermeasures, as well as Operational Intervention Levels, could make the off-site emergency preparedness and response even more effective in particular circumstances.

Lesson 12: The use of long term sheltering is not an effective approach and has been abandoned and concepts of ‘deliberate evacuation’ and ‘evacuation-prepared area’ were introduced for effective long term countermeasures using guidelines of the ICRP and IAEA.

Lessons 13: The international nuclear community should take advantage of the data and information generated from the Fukushima accident to improve and refine the existing methods and models to determine the source term involved in a nuclear accident and refine emergency planning arrangements.

Lesson 14: Large scale radiation protection for workers on sites under severe accident conditions can be effective if appropriately organized and with well led and suitable trained staff.

Lesson 15: Exercises and drills for on-site workers and external responders in order to establish effective on-site radiological protection in severe accident conditions would benefit from taking account of the experiences at Fukushima.

Lesson 16: Nuclear regulatory systems should ensure that regulatory independence and clarity of roles are preserved in all circumstances in line with IAEA Safety Standards