IAEA Report on

Severe Accident Management in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant

International Experts Meeting
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IAEA REPORT ON SEVERE ACCIDENT MANAGEMENT IN THE LIGHT OF THE ACCIDENT AT THE FUKUSHIMA DAIICHI NUCLEAR POWER PLANT

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INTERNATIONAL EXPERTS MEETING
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Organized in connection with the implementation
of the IAEA Action Plan on Nuclear Safety

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FOREWORD

By Denis Flory
Deputy Director General
Department of Nuclear Safety and Security

In response to the accident at the Fukushima Daiichi nuclear power plant, IAEA Member States unanimously adopted the Action Plan on Nuclear Safety. Under this Action Plan, the IAEA Secretariat was asked to organize International Experts Meetings to analyse all relevant technical aspects and learn the lessons from the accident. The International Experts Meetings brought together leading experts from areas such as research, industry, regulatory control and safety assessment. These meetings have made it possible for experts to share the lessons learned from the accident and identify relevant best practices, and to ensure that both are widely disseminated.

This report on Severe Accident Management in the Light of the Fukushima Daiichi accident is part of a series of reports covering all the topics dealt with in the International Experts Meetings. The reports draw on information provided in the meetings as well as on insights from other relevant IAEA activities and missions. It is possible that additional information and analysis related to the accident may become available in the future.

I hope that this report will serve as a valuable reference for governments, technical experts, nuclear operators, the media and the general public, and that it will help strengthen nuclear safety.

EDITORIAL NOTE

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1. INTRODUCTION

Following the accident at the Fukushima Daiichi nuclear power plant (the Fukushima Daiichi accident), the IAEA Director General convened the IAEA Ministerial Conference on Nuclear Safety in June 2011 to direct the process of learning and acting upon lessons to strengthen nuclear safety, emergency preparedness and radiation protection of people and the environment worldwide. Subsequently, the Conference adopted a Ministerial Declaration on Nuclear Safety, which requested the Director General to prepare a draft Action Plan.[1] The draft Action Plan on Nuclear Safety (the Action Plan) was approved by the Board of Governors at its September 2011 meeting.[2] On 22 September 2011, the IAEA General Conference unanimously endorsed the Action Plan, the purpose of which is to define a programme of work to strengthen the global nuclear safety framework.

The Action Plan includes 12 main actions covering the key areas to be addressed for improved nuclear safety. One of the actions focuses on communication and information dissemination, and includes six sub-actions, one of which mandates the IAEA Secretariat to "organize international experts meetings to analyse all relevant technical aspects and learn the lessons from the Fukushima Daiichi nuclear power station accident".[3]

The IAEA Secretariat convened the International Experts Meeting (IEM) on Severe Accident Management in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, on 17–20 March 2014 at IAEA Headquarters, in Vienna. The overall objective of the IEM was to gather and share knowledge and experience gained in the light of the Fukushima Daiichi accident in this area, as well as to identify lessons learned and best practices.

The specific objectives of the IEM were:

— To share improvements made to severe accident management programmes following the Fukushima Daiichi accident;
— To discuss the appropriate regulatory oversight of severe accident management;
— To discuss how to train and equip operating personnel to effectively implement severe accident management guidelines (SAMGs);

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[1] Declaration by the IAEA Ministerial Conference on Nuclear Safety in Vienna on 20 June 2011, INFCIRC/821, IAEA, Vienna (2011), para. 23.

[2] Draft IAEA Action Plan on Nuclear Safety, Report by the Director General, GOV/2011/59-GC(55)/14, IAEA, Vienna (2011).

[3] Ibid., p. 6.

— To identify any gaps in knowledge related to the implementation of SAMGs and how these gaps may be addressed;
— To discuss linkages between on-site and off-site emergency response plans during a severe nuclear accident;
— To identify potential priority areas for research and development.

To meet these objectives, the IEM was organized into five thematic areas: SAMGs, equipment and training needs, regulatory oversight, on-site emergency response and the linkages with off-site emergency response. Each of these areas was summarized by the Session Chair and a Chairperson's Summary was produced (see Annex A).

The IEM was attended by approximately 170 experts from around 40 Member States and international organizations, including experts from utilities, research and development organizations, regulatory bodies, and manufacturing and service companies. It featured 43 expert presentations from keynote speakers and panellists, and provided several opportunities for open forum discussions, where the participants shared their experience and identified lessons learned.

1.1. BACKGROUND

The Great East Japan Earthquake occurred on 11 March 2011. It was caused by a sudden release of energy at the interface where the Pacific tectonic plate forces its way under the North American tectonic plate. A section of the Earth's crust, estimated to be about 500 km in length and 200 km wide, was ruptured, causing a massive earthquake with a magnitude of 9.0 and a tsunami which struck a wide area of coastal Japan, including the north-eastern coast, where several waves reached heights of more than ten metres. The flooding from the tsunami waves resulted in the failure of the power supplies necessary to maintain the fundamental safety functions, including the cooling of the reactors and the spent fuel. This failure led to severe core damage in three reactors and the release of radioactive material to the environment.

The response at the nuclear power plant to these events was severely hampered by the lack of reliable essential instrumentation for monitoring safety related parameters. The severe accident management arrangements were insufficient to alleviate consequences and to mitigate damage to the reactor cores.

The IEM on Reactor and Spent Fuel Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, held 19–22 March 2012, identified a number of lessons regarding severe accident management.[4] In particular, the need to strengthen severe accident management practices was highlighted, including the need to achieve a better balance between prevention and mitigation measures, the need to consider aspects of multi-unit sites for improved assessment of accident propagation, and the need to strengthen guidelines and regulations to be used by the nuclear power plant operating organizations and regulatory bodies.

The IEM on Severe Accident Management was guided by the discussions and observations of the March 2012 IEM on Reactor and Spent Fuel Safety, and focused on improvements made to severe accident management programmes. These improvements included regulatory oversight, the effective integration of on-site and off-site emergency response plans, and provision of the necessary training and equipment for personnel.

The scope of the meeting also included the relevant aspects of the off-site response to a nuclear emergency in order to highlight the importance of coordinating on-site and off-site activities.

1.2. OBJECTIVE

The objective of this report is to highlight the lessons learned on severe accident management in the light of the Fukushima Daiichi accident. The central components of the report are the insights gained from presentations by keynote speakers, from panellists, and from the discussions and contributions by participants during the IEM. These insights are supplemented by experience from other relevant IAEA activities, including the first IAEA fact finding mission to Japan, the compilation of good practices from recent Operational Safety Review Team (OSART) missions[5], and relevant activities carried out in the framework of the Action Plan.

The report summarizes the discussions and conclusions of the IEM and highlights the lessons learned to date in the following six key technical areas important for strengthening the management of severe accidents:

— Flexibility of severe accident management strategies.
— Training.

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Report on Reactor and Spent Fuel Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, IAEA, Vienna (2013), available at: http://www.iaea.org/sites/default/files/spentfuelsafety190312.pdf.

[5] Available at: http://www-ns.iaea.org/reviews/good-practices.asp.

— Strengthening of regulatory capabilities.
— Instrumentation and control.
— Emergency preparedness and response: interface between on-site and off-site response.
— Interface between SAMGs and on-site emergency preparedness and response.

2. HIGHLIGHTS OF THE IEM ON SEVERE ACCIDENT MANAGEMENT

2.1. INSIGHTS FROM THE EVENTS AT THE FUKUSHIMA DAIINI NUCLEAR POWER PLANT

While the situation faced by the operating personnel at the Fukushima Daiini nuclear power plant was different from that at the Fuksuhima Daiichi plant, there are many valuable lessons to be learned from the experience. An expert from Japan provided detailed information regarding the events at the Fukushima Daiini plant. Following the Great East Japan Earthquake, on 11 March 2011, the four reactors at the Fukushima Daini nuclear power plant were automatically shut down as designed and the emergency electrical power supply systems were activated as planned. There was no apparent damage to the Fukushima Daini nuclear power plant from the earthquake. Later that day, the first of several tsunami waves struck the Fukushima Daini plant, leading to widespread flooding of the site and damaging some of the important safety related equipment. Some on-site and off-site electrical power supplies remained functional, as did other vital equipment needed for the control of motors and pumps. While the situation at the Fukushima Daiini nuclear power plant was beyond what had been anticipated in the severe accident management arrangements, the damage was not as extensive as that experienced at the Fukushima Daiichi plant.

After the tsunami flood waters receded, plant personnel assembled at the Emergency Response Centre at the Fukushima Daiini nuclear power plant to assess the situation. Personnel were dispatched to the plant to conduct systems walk-downs to identify the status of equipment. These walk-downs were conducted in conditions of almost complete darkness, with the constant threat of debris from the flooding, and they were often interrupted by new tsunami alerts.

The high and low pressure water injection systems that were important to maintain cooling remained operable at each reactor unit. This allowed a recovery strategy to be developed that focused on achieving safe shutdown of the reactor units. The strategy was based on restoring the function of the residual heat removal system for each reactor unit and required coordination with off-site organizations to procure the necessary equipment. Starting on 11 March and for the next three and a half days, the plant operating personnel inspected and replaced failed pump motors. They also installed 9 km of temporary cables to provide electrical power to the residual heat removal and supporting systems from the functional power sources on the site. Through these efforts, the Fukushima Daiini nuclear power plant achieved safe shutdown of all reactor units at 07:15 on 15 March 2011.

The expert from Japan shared views on safety improvements that were developed based on the successful aspects of the response to events at the Fukushima Daiini nuclear power plant. These improvements included diversification of electrical power supplies, ensuring the availability of spare motors and cables, and installation of new terminals for connecting mobile power supplies. Issues associated with leadership and the accident's impact on operating personnel were also discussed.

The experience gained from the events at the Fukushima Daiini nuclear power plant highlighted that decision making needs to be based on centralized information management with a focus on achieving goals. It was noted that having a clear chain of command and sharing all relevant information helped motivate the response teams to achieve the objective of safe shutdown.

The operating personnel faced enormous challenges as they worked to control the situation. They encountered significant environmental hazards, and worked under great stress, as in some cases they did not know whether their families were alive or whether their homes had been destroyed by the tsunami. Working under these conditions for nearly two weeks led to over 100 operating personnel being diagnosed with post-traumatic stress disorder. This emphasized the need to consider both the physical and the emotional well-being of personnel during the response to a severe accident.

2.2. THE DIFFICULTIES ENCOUNTERED DURING THE RESPONSE TO THE FUKUSHIMA DAIICHI ACCIDENT

Another expert from Japan shared experiences from the response to the Fukushima Daiichi accident. He discussed the need to have a nationally coordinated emergency response plan in place and provided recommendations on how best to act on the lessons learned.

As conditions at the Fukushima Daiichi nuclear power plant continued to deteriorate following the hydrogen explosion at Unit 3 on 14 March, the Government of Japan called upon the Japanese Self-Defense Forces (JSDF) to assist with the response. They helped with activities including operating the large equipment needed to pour or spray water onto the spent fuel pools in Units 1, 3 and 4, and providing helicopter surveillance of the spent fuel pools. The JSDF had already provided vital logistics support to the Fukushima Daiini nuclear power plant, but the need to perform operations in the contaminated environment at the Fukushima Daiichi plant was far more challenging.

The expert pointed out that although the JSDF teams had been trained to operate in chemically contaminated environments, they had not been trained or equipped to work in an area contaminated with radioactive material. The water injection activities undertaken over the next several days from the ground and the air brought to light many issues for which solutions needed to be developed: for example, the decontamination of engines of vehicles and rotary aircraft, communication with other non-JSDF response teams and command and control. Proposals for dealing with these and other issues were developed and were summarized during the IEM.

The expert from Japan identified several important areas to be considered when making improvements to emergency response plans, including the need to prepare, and realistically assess, an integrated national emergency response plan. This plan should consider the need to use additional responders, such as the JSDF, who need to be adequately equipped and trained to deal with radiological hazards and decontamination. In addition, there is a need to consider and establish in advance the decontamination standards that may be used during an emergency.

SAMGs have been available at many nuclear power plants for some time. The SAMGs typically provide operators with guidance based on observable symptoms during an accident rather than requiring them to deduce the specific triggers or origins of the accident scenario being faced. This symptom based approach derives from the lessons learned from the accident at the Three Mile Island nuclear power plant in 1979. The nuclear power plant operator training at Three Mile Island prior to the accident was event based and led the operating personnel to discount certain instrument readings and to take actions that exacerbated the progression of the accident.

3. KEY AREAS IMPORTANT FOR STRENGTHENING SEVERE ACCIDENT MANAGEMENT ARRANGEMENTS

3.1. FLEXIBILITY OF SEVERE ACCIDENT MANAGEMENT STRATEGIES

Lessons Learned: Severe accident management procedures need to be designed so that operating personnel are able to respond to the symptoms of a severe accident without the need to diagnose the exact scenario that led to them.

SAMGs need to enable operators to successfully implement a knowledge based response strategy when needed. Such a response strategy relies on the operators using their understanding of the performance of the nuclear power plant and its systems to decide on an appropriate course of action. This approach is to be compared with a rule based response strategy which requires operators to follow prescriptive procedural guidance in response to an accident. The knowledge based strategy allows for flexibility and the application of response strategies that are adaptable to the events at hand.

The Fukushima Daiichi accident revealed that nuclear power plant operating personnel may be faced with an unexpected situation for which they have limited or no guidance. The international fact finding mission to the Fukushima Daiichi nuclear power plant[6] found that:

> "Severe Accident Management Guidelines (SAMG) and associated procedures generally assume that instruments, lighting and power are available. This may not be the case. In addition, these documents do not consider the possible state of the plant and the local environmental conditions such as the radiation field that may preclude manual actions from being taken."

The mission report concluded that at the Fukushima Daiichi plant:

> "Robustness of the instruments, lighting and power to countermeasure the accident elevation was not sufficiently considered in Severe Accident Management Guidelines (SAMG) or plant specific procedures."

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[6] INTERNATIONAL ATOMIC ENERGY AGENCY, 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, IAEA, Vienna (2011).

The mission report recommended that:

> "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."

At the International Experts Meeting:

At the IEM the view was re-affirmed that symptom based[7] procedures provide the best approach for severe accident management. While the experts agreed that current SAMGs are comprehensive, the unpredictable nature of accidents and their progression renders it impossible to foresee every possible situation that the operators may face. The experts considered that strategies for achieving successful outcomes in situations that are not specifically covered by the SAMGs are an important area for further study. The experts also discussed the need to establish a flexible strategy for the transition from a rule based response to a knowledge based response to a severe accident.

It was pointed out by some experts that an essential element of the knowledge based response is rooted in operator training. It is essential to enable operators to fully understand the minimum requirements to maintain the fundamental safety functions of control of reactivity, core cooling and confinement. Operators also need to have a sound knowledge of plant systems and the response of these systems to the loads that can be presented by a severe accident. In addition, experts highlighted the need for training to deal with the unexpected and to prepare leaders to be able to develop flexible and comprehensive strategies when responding to a severe accident.

The experts described some of the initiatives under way in Member States to address both the change in strategy and the training necessary to successfully implement a revised strategy. Some Member States have recognized in their guidance that design basis systems may not be available when needed by the plant operating personnel during a severe accident. For example, guidance prepared by some Member States recommends injecting water into the reactor pressure vessel when coolant temperatures reach a certain level, but because of the accident conditions, the high pressure injection systems may not function. In this event, core cooling cannot be achieved, and operating personnel need to resort

[7] An approach to accident management based on using directly measurable plant parameters.

to using other available means of achieving the same objective, such as steam generator crash cooling[8] and the use of low pressure water injection systems.

Some experts highlighted the importance of the concept of 'available time versus required time' and how this concept is being incorporated into SAMGs. The application of this concept will provide operators with vital information regarding the time available until fundamental safety functions are lost and the time required to mobilize equipment to complete the necessary tasks to maintain these functions. This approach will help the nuclear power plant operating personnel to prioritize their actions by indicating the activities that need immediate attention and those response strategies that may not be feasible given the time available to implement them.

The experts described other tools and guidance being developed to support the prioritization of operator actions when dealing with contradictory information or multiple system failures. Examples were provided of computer based tools designed to provide support in the early assessment of plant conditions, identification of safety function availability and optimization of available equipment line-ups to deal with severe emergency situations. These tools and guidance are primarily intended to assist the on-site technical support centre to provide the proper advice and guidance to the plant operators.

Several experts presented the enhancement of SAMGs to provide the means to cope with a wider range of events, including their application to spent fuel pools. In addition, the application of SAMGs to nuclear power plants during low power operations and in shutdown states was also described. In general, it was considered that the SAMGs for operating nuclear power plants are largely applicable to shutdown and low power operation states, with relatively minor changes.

3.2. TRAINING

Lessons Learned: Robust training programmes are needed for every organization involved in the management of a severe accident, including nuclear power plant operating organizations, regulators, decision makers and off-site emergency responders. These training programmes need to take a practical, learning-by-doing approach, using realistic training aids, and to allow for an evaluation of their effectiveness.

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[8] Steam generator crash cooling involves rapidly cooling down the steam generator by some combination of cooling water and depressurization.

It was noted at the IEM that since the beginning of nuclear power programmes, operator training has been recognized as one of the cornerstones of nuclear safety. Training has evolved to take into account new knowledge obtained from incidents and accidents at nuclear power plants as well as new developments in science and engineering. The Three Mile Island accident highlighted the need for improvements to operator training. One of the most significant impacts of this lesson was the creation of the Institute of Nuclear Power Operations, in the United States of America, and other similar organizations worldwide. These organizations function by providing peer review services to the nuclear industry in areas such as excellence in operations and the effectiveness of operator training programmes. They have proven to be very effective at achieving a high level of operator performance. The Chernobyl accident, in 1986, led many organizations to re-evaluate the effectiveness of their training programmes, and in some cases, organizations extended training to all operations staff, including management, so that all personnel are aware of how the plant should be operated. These events emphasize the need for effective training programmes and the need to continually evolve and update these programmes as operating experience becomes available.

The Fukushima Daiichi accident highlighted the need for training that enables all responders to effectively implement on-site mitigation strategies and the off-site emergency response. The training needs to take into account the nature of the challenges faced by responders to the Fukushima Daiichi accident, such as degraded environmental conditions, severe damage to infrastructure around the nuclear power plant and the loss of plant systems.

The Fukushima Daiichi nuclear power plant operating personnel were faced with unexpected and unprecedented challenges while working to mitigate the consequences of the accident. Even when faced with this situation, operators were able to apply effective, albeit delayed, mitigation strategies. However, the time taken to develop these strategies contributed to the propagation of the accident. There is a need to provide nuclear power plant operating personnel with the necessary knowledge and equipment to manage a severe accident. In addition, operating personnel need the opportunity to practise, through exercises, the development of accident management strategies to be deployed in a timely manner.

At the International Experts Meeting:

Many experts discussed the need to maintain effective training programmes as part of being a ‘learning organization’. The programmes need to be updated based on new operating experience and to take into account developments in science and engineering.

Some of the experts considered that such training programmes need to be based on best estimate analyses of accident scenarios so that training can be as realistic as possible. Realistic training exercises, including realistic considerations of the time needed to achieve a task, can be supported by accident analysis computer codes that incorporate an improved understanding of the phenomena associated with severe accidents. This information can be used as part of reactor simulator exercises or practical training programmes to ensure that nuclear power plant operating personnel understand both the expected evolution of a severe accident and the relevant physical phenomena involved.

The experts discussed the design of training programmes and the use of tools such as the systematic approach to training[9] to allow for the effectiveness of training to be assessed. The process of grading and evaluating drills and exercises was considered to be an essential part of the learning process. The process needs to involve all participants in providing feedback and identifying the strengths and weaknesses of the training programmes so that weaknesses can be corrected and programmes continually improved. The experts identified two main mechanisms to analyse the effectiveness of training, namely the use of industry peer reviews and regulatory inspections.

The experts highlighted the importance of training involving a combination of classroom instruction and practical, hands-on simulation including all organizations — both on-site and off-site — involved in the emergency response. The reference to 'all organizations' includes nuclear power plant operating organizations, management and off-site emergency responders who may be involved in emergency response decision making and implementation. Training needs to be designed to enable success for the individual based on his or her role in the emergency response organization. Cross-training between disciplines also needs to be included to ensure that the necessary expertise is available if critical personnel are not available during an emergency.

Some of the experts considered that regulatory bodies need to provide effective oversight of licensee training programmes for the management of severe accidents.

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[9] UNITED STATES DEPARTMENT OF ENERGY, Training Program Handbook: A Systematic Approach to Training, Rep. DOE-HDBK-1078-94, USDOE, Washington, DC (2014).

3.3. STRENGTHENING REGULATORY CAPABILITIES

Lessons Learned: There is a need for regulatory oversight of activities related to severe accident management. Regulatory bodies need to strengthen their inspection and oversight of licensees' severe accident management programmes and severe accident mitigation measures.

Effective regulatory oversight requires a strong and independent regulatory body empowered with technical expertise as well as inspection and enforcement authority. Furthermore, the regulatory body needs to have access to all aspects of a licensed activity and the enforcement authority to compel changes that are needed to correct any identified deficiencies.

The technical expertise of the regulatory body in the area of severe accident management can be developed in several ways. Some Member States rely on the assistance provided by technical support organizations, while others instil this technical expertise into the staff of the regulatory body[10]. Both of these practices allow the regulatory body to access the necessary technical expertise to assess and challenge actions taken by licensees. This technical expertise should also enable the regulatory body to identify emerging safety issues and, when needed, to require licensees to assess them and to take necessary actions. The identification of new safety issues does not necessarily imply having an independent research capability, but it should involve, at a minimum, effective cooperation with the international community to stay up to date with new information.

The IAEA Report on Strengthening Nuclear Regulatory Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant[11] also emphasized the need for regulatory bodies to require licensees to address the mitigation of severe accidents. The report highlighted the importance of taking into account prolonged emergencies associated with extreme site conditions, particularly those involving station blackout scenarios. The development of SAMGs and the availability of staff and associated training should be a regulatory requirement and be reviewed by the regulatory body. Severe accident management measures should be periodically re-evaluated to reflect state of the art knowledge.

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[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Use of External Experts by the Regulatory Body, IAEA Safety Standards Series No. GSG-4, IAEA, Vienna (2013).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Report on Strengthening Nuclear Regulatory Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, IAEA, Vienna (2013), available at:
https://www.iaea.org/sites/default/files/regeffectiveness0913.pdf.

The report also highlighted the actions already taken by regulatory bodies regarding severe accident management as described in the discussions held during the Integrated Regulatory Review Service missions. These actions included:

- Further developing the accident management programmes applicable under external hazard conditions;
- Securing additional protective equipment in preparation for a prolonged emergency;
- Establishing countermeasures for protecting maintenance workers;
- Reinforcing education and training for severe accidents;
- Reinforcing radiological emergency exercises;
- Introducing improvements to the SAMGs;
- Incorporating probabilistic safety assessment results into the safety analysis report;
- Establishing a backup control room.

At the International Experts Meeting:

The experts' discussions on the regulatory oversight of SAMGs showed considerable variation in the approaches taken. Experts indicated that some Member States consider the need for SAMGs as a regulatory requirement while other Member States consider SAMGs to be a voluntary initiative by the operating organizations and are considering making them a regulatory requirement. The detailed aspects of the regulatory oversight of SAMGs discussed by the experts included the technical basis for their development, training in their use, minimum staffing levels, issues involving multi-unit plants and the availability of equipment important for implementing mitigation measures.

The experts' discussions revealed a diversity of opinions regarding how regulatory oversight of SAMGs should be performed, including whether such regulatory requirements should be performance based or prescriptive. The experts recognized that the approach to regulatory oversight of severe accident management needs to be suited to the Member State's regulatory system.

The experts discussed in great depth the availability and types of equipment necessary to respond to a severe accident. The strategies in use or being considered by Member States relating to equipment requirements ranged from the use of hardened, permanently installed equipment to the use of portable, field deployable equipment.

The experts recognized that multi-unit sites pose specific challenges for regulatory oversight of severe accident management. These challenges arise from the nuclear power plant operating organizations considering the possibility of sharing equipment between the multiple units on a site and the potential for larger radiological consequences from accidents simultaneously involving multiple units on a site.

The experts emphasized the need for inspection and validation of arrangements for dealing with severe accidents. In particular, equipment needs to be inspected to ensure that it is properly installed and maintained. The assumptions regarding equipment performance need to be independently analysed to ensure that they are correct. The experts considered that a graded approach was appropriate for these regulatory oversight activities.

3.4. INSTRUMENTATION AND CONTROL SYSTEMS

Lessons Learned: For the purposes of severe accident management, the requirements for instrumentation and control systems need to take into account:

— The number of plant parameters to be monitored by the instrumentation;
— The environmental qualification requirements that best apply to this instrumentation to ensure that necessary and reliable information is available to the operators.

Instrumentation and control systems are designed to provide automated actuation of safety systems when needed and to provide operating personnel with sufficient information to allow them to respond properly to accident conditions. Instrumentation and control systems that provide for automated response to plant conditions are designated as safety systems because they are intended to respond to design basis accidents. Designation as a safety system means that these systems are designed to meet strict requirements for quality assurance, during manufacture, installation and maintenance. They are also designed to withstand the environmental conditions expected during a design basis accident. In contrast, non-safety related instrumentation and control systems are presumed to be less reliable because they do not need to meet the same set of strict requirements.

Accident management strategies may rely on both safety related and non-safety related instrumentation and control systems. Consequently, this distinction stimulated much discussion in different forums on the instrumentation and control systems to be used for the mitigation of severe accidents.

The loss of instrumentation and control during the accident at the Fukushima Daiichi nuclear power plant left operators with little indication of actual plant conditions. The loss of instrumentation and control systems had a serious impact on efforts to prevent a severe accident or to mitigate its consequences. The accident management guidelines did not cover contingencies for the loss of instrumentation necessary to display the key parameters which allow operators to determine the status of the nuclear power plant. Despite this, the operating staff performed their activities properly under the harsh conditions created by the accident. However, the inability to obtain fundamental information on the status of the plant and the need to improvise mitigation actions hampered the response. The IAEA Report on Reactor and Spent Fuel Safety[12] also highlighted issues associated with instrument and control systems. The report recognized that robust systems are needed to enable the necessary monitoring of safety parameters and plant conditions to support the implementation of SAMGs under severe accident conditions. The need to improve the robustness of the power supply under an accident environment was highlighted, together with the need for an appropriate operability time to allow continued instrument performance over the long term.

At the International Experts Meeting:

At the IEM, the discussions focused on how to deploy instrumentation that could survive the harsh conditions of a severe accident and the regulatory oversight needs for this instrumentation.

In presentations and discussions, the experts concluded that the electrical power supply to the instrumentation and control systems required for accident management purposes needs to be ensured under severe accident conditions. Several means of meeting this objective were considered and discussed, including the use of mobile or portable electrical power supplies and equipment, and locating the power supplies close to the instrumentation.

The experts considered that instrumentation and control systems need to be designed to cope with the worst expected environmental conditions, taking into account both design basis accidents as well as beyond design basis accidents. The environmental qualification of instrumentation and control systems has always been a requirement in most Member States. However, the unavailability of the instrumentation and control systems necessary for monitoring parameters such as the reactor pressure and reactor water level during the Fukushima Daiichi accident was the result of these systems being subject to conditions beyond their design basis. Most instrument qualification requirements are derived on the basis of analysing possible accident scenarios. The experts considered that the uncertainties associated with these analyses need to be properly taken into account in the design of instrumentation and control systems.

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[12] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Report on Reactor and Spent Fuel Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, IAEA, Vienna (2013), available at: https://www.iaea.org/sites/default/files/spentfuelsafety190312.pdf.

The location of instrumentation for use in severe accidents was also discussed by the experts. Vital instrumentation needs to be located in areas that are easily accessible to operating personnel during an accident. The experts considered that this was also a means of achieving the desired level of redundancy and diversity, as this local instrumentation is physically separated from that used during normal operations. The discussions during the meeting pointed to the importance of considering the installation of dedicated instrumentation and control systems for severe accident mitigation and of applying this principle both to new reactor construction and, to the extent practicable, to existing plants.

3.5. EMERGENCY PREPAREDNESS AND RESPONSE: INTERFACE BETWEEN ON-SITE AND OFF-SITE RESPONSE

Lessons Learned: The robustness of the interface between the on-site and off-site response organizations determines the resilience of emergency plans when faced with a severe accident in conjunction with an extreme external event. Further effort is needed to develop and implement appropriate guidance and tools to ensure that there is a common situational awareness[13] and a common understanding of response priorities in such extreme situations.

Effective communication between the operating organization and the off-site response authorities can be critically challenged in a nuclear emergency that occurs in conjunction with significant destruction of off-site infrastructure. Both the operating organization and the off-site response authorities depend on each other for the overall response. Without an effective means of achieving common operational understanding[14] and response prioritization, resources may not be optimally deployed and used.

This is particularly important when conditions impair the ability to mobilize and deploy required teams following an extreme external event such as an earthquake, a flood or even a snowstorm. This can be further complicated by the need for off-site response teams to manage large population movements out of potentially contaminated environments in the case of a severe accident that results in radioactive releases to the environment. Priorities for response may be difficult to establish in the face of a large scale destruction of the transport, medical and communication infrastructure.

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[13] Knowing what has occurred and is occurring and understanding the implications of these events and the potential outcomes associated with them.

[14] An overview of a situation that is created by assessing and fusing information from multiple sensors or sources to support timely and effective decision making.

In addition, the response could involve resources such as civil defence or the armed forces, which may not have specific plans or training for this type of situation. Without appropriate plans covering severe emergencies, efforts could be misdirected owing to an insufficient understanding of the situation and of the response priorities.

Emergency plans should contain provisions for the integration of response organizations that are not, or are seldom, involved in emergency exercises. Emergency preparedness programmes should also address the need for training of these organizations, whether as part of a regular training programme or within a just-in-time training approach.

In severe accidents, access to a nuclear power plant site, or access to different locations within a site may be rendered difficult or impossible. Emergency plans should include considerations for response in situations where the on-site and off-site infrastructure has been damaged by external events. The Fukushima Daiichi accident highlighted the additional challenges present during an emergency that affects several units at the same site. SAMGs and emergency plans need to address these potential challenges in a more comprehensive way.

At the International Experts Meeting:

The experts discussed the communication challenges that arose during the Fukushima Daiichi accident. Two experts from Japan described the involvement of JSDF personnel and emergency medical organizations supporting the operating organization and off-site response authorities. Limited training and guidance, the lack of clearly defined roles, and severe communication problems meant that decisions of the national and local governments on protective actions were not always coordinated. The concepts of single operational command and joint command and control are essential elements of a coordinated on-site and off-site response to a nuclear emergency. The experts considered that there is also a need for a strategy to ensure improved common situational awareness.

The contamination of equipment used to support the operating organization at the Fukushima Daiichi plant and its subsequent redeployment to off-site activities also presented major challenges. Decontamination of vehicles deployed to the site can be problematic and can delay their further use in off-site operations, particularly if water and electrical power supplies are disrupted. Applying removable surface covers proved an effective response to protect against the radioactive contamination arising during the Fukushima Daiichi accident. The experts identified the need for decontamination standards that are not so overly restrictive as to preclude the off-site use of vehicles and equipment that were used to support the operating organization at the site.

The experts also agreed that it is imperative for all response organizations to exercise in harsh conditions simulating those that would be found following an extreme external event. In some Member States, for example, severe snowstorms are common, and such conditions need to be part of the training and exercise programmes.

The importance of a proper human factors validation of SAMGs was highlighted during the IEM, particularly to gain a better understanding of staff performance under the stressful conditions of a severe accident. In some Member States, analyses of the human factor issues associated with the interface between the on-site operating organization and the technical support centre have been performed. The effectiveness of these interfaces is maximized when the individuals at each location have similar experience and expertise and undertake joint training and exercises.

The experts considered the need for those organizations not normally involved in detailed emergency planning for emergencies at nuclear power plants to have fully cross-trained personnel at the site. These individuals need to be able to operate the quickly deployable mobile equipment installed at many sites to deal with severe accidents, given the need for self-sufficiency of the operating organization in the presence of extreme external events.

Some experts also discussed the need for airlifting of people and equipment to be part of the plans to deliver critical assistance to the affected nuclear power plant. When facing severe damage to the road infrastructure, this is the most effective method for providing the operating organizations with the equipment and resources needed to deal with a severe accident.

3.6. INTERFACE BETWEEN SAMGs AND ON-SITE EMERGENCY PREPAREDNESS AND RESPONSE

Lessons Learned: The interface between SAMGs and the on-site emergency response arrangements needs to be strengthened to provide for continuous and well integrated coordination of reactor operation and emergency response. This needs to include consideration of a single and integrated command and control system capable of making decisions regarding on-site operations during a severe accident without the need for off-site approvals.

The on-site organization needs to be able to make critical decisions promptly. Decision making processes that require off-site approval can introduce delays that render severe accident mitigation measures ineffective or even counterproductive. On-site decision makers need to have the authority to make such decisions. If off-site technical support is required, it needs to be made available promptly and with a complete understanding of the situation at the nuclear power plant. Off-site decision making regarding mitigatory measures at a nuclear power plant is unlikely to be made with a complete understanding of the situation and can significantly impair the ability of the on-site decision makers to respond dynamically to a rapidly evolving situation.

SAMGs need to take into account that the progression of an accident may not be known at the outset and may vary significantly from previous analyses. Consequently, the emergency response organization and the emergency response strategy need to be flexible and adaptable. This calls for symptom based rather than event based mitigation strategies.

The ongoing availability of trained operating staff is also a critical factor to consider during a severe accident. Staff may be incapacitated or relief staff may not to be available for some time following an extreme external event. In such situations, cross-training of control room operators and emergency response staff prior to an accident — for example, in the operation of mobile emergency equipment — could be essential to plant survivability. The intent should be to make the deployment of mobile equipment so simple that several groups on the site, not just maintenance staff, can deploy the equipment.

Working under harsh conditions caused by an extreme external event and a severe accident requires the integrated coordination of all emergency workers, including control room operators, emergency response teams and security personnel. The robustness of the on-site command and control system and the versatility of all emergency workers are factors that can help in managing such complex emergencies.

Severe accident management and emergency response are not always planned and exercised together, which can result in discontinuities in the emergency response strategy. For example, in some cases, following combined exercises, some organizations found that their trigger points for emergency classification had to be re-evaluated. Operating and emergency response teams need to be managed in an integrated manner and be in constant communication with each other. A good practice identified at one nuclear power plant[15] highlighted by the IAEA OSART service was the parallel training of control room personnel and technical support centre staff. The purpose of such parallel training is to facilitate the communication and decision making processes during accident progression.

[15] See http://www-ns.iaea.org/downloads/ni/s-reviews/gp-2009/14.5.pdf.

At the International Experts Meeting:

The experts discussed the importance of having an integrated command and control system for severe accidents based on a sound understanding of the qualities required of emergency managers. Some of the experts considered that the decision making capability of emergency managers is as important as their technical expertise.

The experts agreed that exercises and drills need to be more all-encompassing and as realistic as possible in order to improve coordination at all levels. The approach to exercises and drills also needs to reflect a learning-by-doing attitude to identify and remove any obstacles to the successful management of an accident or emergency.

Several experts noted that the planning for severe accidents needs to include the possibility of losing key personnel. A good practice in some Member States highlighted by the experts was the cross-training of several teams in the deployment and connection of mobile emergency equipment. This cross-training included different groups of personnel such as nuclear power plant operators, emergency response staff and security personnel. Another good practice highlighted by the experts was the process of confirming that all key response actions can be performed by more than one role, thereby improving coverage.

The challenge of radiation protection of on-site personnel in a severe emergency was raised. Some nuclear power plants have re-assessed the radiation levels and environmental conditions that might occur following a severe accident to ensure that vital equipment can be accessed and that control rooms remain habitable. In the light of these re-assessments, changes have been made to on-site emergency response strategies, and radiation shielding and additional ventilation filters have been installed.

The experts reported that the SAMGs for some nuclear power plants do not require off-site approval for any on-site mitigation measures. This approach speeds up and streamlines the decision making process.

One expert explained that the most challenging exercise was one in which the technical support centre was supplied with incorrect data. While this had a negative impact on the response, it developed the understanding that having limited correct data may be better than having plentiful data if some are incorrect. It was suggested that SAMGs need to identify a limited set of data required, and that training on the SAMGs needs to include evaluating the accuracy of the data available and the ability of operators to work with limited data.

4. CONCLUSIONS

This report summarizes the technical issues discussed during the IEM on Severe Accident Management in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant and highlights the key lessons learned.

During the IEM several important themes emerged, including the need for a common operational understanding and improved training, and the need to develop flexible SAMGs to enable operating personnel to adjust or modify their response according to the situation.

The need for a common situational awareness between on-site and off-site emergency responders was highlighted. All organizations involved in the response to a severe accident need to have access to the same information to allow them to better coordinate their activities, in particular, the implementation of protective actions and transport of equipment and other resources to a nuclear power plant to be used during the response. Although training is one of the cornerstones of nuclear safety, the need for continued improvement of training programmes for severe accident management was reinforced during the IEM. Training needs to be provided to everyone involved in the response to a severe accident — from the nuclear power plant operating personnel to off-site decision makers. Cross-training between personnel is also essential to ensure that necessary actions can be completed even if key staff are unavailable during an accident.

Successful transition from a rule based to a knowledge based response to a severe accident was one of the important topics of discussion, in particular the need to take into account conditions not envisaged in the procedures and guidelines. The emergency responders need to be able to recognize the situation and to use their knowledge of the reactor and its systems to adapt or devise appropriate response strategies.

The meeting reinforced the conclusions of previous IEMs regarding the need for effective SAMGs. The experts discussed the many advances in SAMGs made since the IEM on Reactor and Spent Fuel Safety held in March 2012 and emphasized the importance of having effective regulatory oversight on SAMGs.

Finally, the experts made several suggestions for future activities, including: further developing guidance on severe accident management provisions and continuing to encourage the use of the IAEA services; sponsoring benchmarking activities on severe accident management and emergency response; developing guidance on damage control management at nuclear power plants; and assisting Member States to better coordinate severe accident management strategies with emergency response.

Annex A

CHAIRPERSON'S SUMMARY[1]

International Experts Meeting on Severe Accident Management in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant
17–20 March 2014, Vienna

INTRODUCTION

It is now just over three years since the Fukushima Daiichi accident and significant efforts and actions have been undertaken by Member States and other relevant organizations with the common goal of improving nuclear safety and ensuring the protection of people and the environment. The results of these efforts and actions are visible through, for example, the 'stress tests' that have been performed by Member States and discussed in forums such as these International Experts Meetings (IEMs) and conferences. Although there appear to be differences in the approaches taken to these assessments and the priorities for implementation of the results, the work performed by Member States appears to have converged to similar conclusions.

One aspect that has been raised in numerous forums is the need not only to strengthen the efforts to prevent nuclear accidents but also to enhance the mitigation capabilities for events that may lead to a severe accident. One of the lessons identified in the first in this series of IEMs on reactor and spent fuel safety was the need to strengthen severe accident management practices, guidelines and regulations to be used by the operating organizations and regulatory bodies. Accordingly, this IEM has been convened to exchange views and ideas on strengthening mitigation capabilities to deal with severe accidents and to consider the lessons learned and further actions to be taken to strengthen severe accident management arrangements.

This meeting was the seventh in the series of IEMs that have been organized by the IAEA in the framework of the Action Plan on Nuclear Safety in response to the action dealing with communication and information dissemination. This action requests that the IAEA organize IEMs to analyse all relevant technical

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[1] The opinions expressed in this Summary — and any recommendations made — are those of the Chairperson and do not necessarily represent the views of the IAEA, its Member States or other cooperating organizations.

aspects and learn the lessons from the Fukushima Daiichi accident. The previous IEMs were held on the topics of reactor and spent fuel safety, communication, severe natural hazards, decommissioning and remediation, human factors, and radiation protection.

The objectives of this meeting were:

- To share improvements made to severe accident management programmes following the Fukushima Daiichi accident;
- To discuss the appropriate regulatory treatment of severe accident management;
- To discuss how to effectively train and equip operators to effectively implement severe accident management guidelines (SAMGs);
- To identify any knowledge gaps related to the implementation of SAMGs and the ways to fill these gaps;
- To discuss linkages between on-site and off-site response plans during a severe nuclear accident;
- To identify potential priority areas for research and development.

Approximately 170 experts from around 40 Member States and international organizations gathered during IEM 7 to discuss their views regarding enhancements to severe accident response that are either planned or implemented in Member States. The meeting consisted of 13 keynote presentations, 31 invited presentations and 20 posters, which provided the framework for the constructive deliberations that took place during the 6 panel discussions.

The programme for the meeting contained five technical sessions dealing with the topics of:

- Improvements to SAMGs;
- Equipment and training needs for severe accident response;
- Appropriate regulatory treatment of severe accident management measures;
- The linkages between on-site and off-site response;
- Challenges in severe accidents and the link with SAMGs.

All the presentations delivered at the meeting are available on the IAEA web site and a report will be published in due course. This summary will form part of that report.

Training

The need for training arose during the discussions in all of the sessions of this meeting. One of the insights from these deliberations is that every organization involved in severe accident management, including operators, decision makers, regulators and off-site responders, needs to have robust training programmes in place. These training programmes should take a practical, learning-by-doing approach, using realistic training aids, and allow for an evaluation of their effectiveness. Several specific examples that were highlighted during the week were:

— The need to train operators and decision makers on the clear understanding of the phenomena involved in severe accidents;
— The need to train decision makers to evaluate both event and knowledge based situations;
— The need to ensure that on-site personnel are trained on the use of response equipment;
— The need to conduct exercises and drills, under varying extreme conditions and which should take into account human and organizational factors.

Flexibility and resourcefulness in accident management strategies

It was noted that accident management procedures should be designed in such a way that operators are able to respond to the symptoms of a severe accident without the need to diagnose the exact scenario that led to these symptoms. Given how these procedures are designed, the guidance needs to enable responders to successfully implement a knowledge based response strategy when needed.

Strengthening regulatory capabilities

The participants in the meeting made it clear that currently operating nuclear power plant operators have taken the necessary actions to continue safe operations while regulatory changes for severe accident management are being considered. In this context, regulatory actions that have been taken or that are under consideration include requirements related to command and control, minimum staffing needs, communication capabilities, equipment qualification and staff training. From these discussions, it is clear that there should be regulatory requirements related to severe accident management and that regulatory authorities should review severe accident management programmes developed by the licensee and strengthen inspection and oversight activities of severe accident mitigation measures.

Instrumentation and control

Two issues associated with accident monitoring instrumentation discussed were how many variables need to be monitored by this instrumentation during the course of a severe accident and what environmental qualification requirements should be applied to this instrumentation to ensure that necessary and credible information is available to the operators. From the presentations and discussions during the meeting, there appears to be good agreement as to the minimum number of variables that need to be monitored to effectively respond to a severe accident. However, there was some discussion on whether it is best to monitor these variables using the normal complement of plant instrumentation or to install special purpose instrumentation intended for use only under severe accident conditions. The decision on the approach is also strongly influenced by environmental qualification considerations. There was general agreement that environmental qualification of severe accident mitigation instruments is essential and that this qualification should consider factors such as elevated temperatures and pressures and the high radiation conditions under which these instruments may need to function. It was also emphasized that operators should be trained to evaluate information from multiple indications rather than relying solely on one measurement because of the inherent uncertainty in measurements under the extreme environmental conditions of a severe accident. It is recommended that the availability of information on essential safety parameters is sufficiently redundant so that the information can be accessed at different locations to ensure the effective management of severe accidents, taking into account the extreme environmental and radiological conditions that may prevail.

Response equipment

While it seems that most Member States have adopted response strategies using a combination of on-site and off-site equipment, there was considerable discussion surrounding how best to ensure that this equipment is available when called upon. Several important points were noted including the previously mentioned need to ensure that on-site operators are trained in the use of response equipment, the need to test the deployment of on-site and off-site equipment during extreme weather conditions and the need to ensure that for multi-unit stations there is sufficient response equipment for each unit. Guidance needs to be developed to establish the best approaches to the management and deployment of this equipment.

Common operational picture

The need for effective communication between the many diverse organizations involved in a response to a severe accident is essential, and some of the communications challenges presented during the response to the Fukushima Daiichi accident were discussed. It was clear from these discussions that emergency planning needs to allow for all organizations likely to be involved to effectively communicate with each other. This will ensure that a common operational picture emerges in which every organization has a good understanding of the accident progression. SAMGs and emergency plans need to ensure that all response teams including operators, technical support centres and emergency responders have a common situational awareness in order to respond effectively.

Expanded response to a severe accident

In an extreme accident situation many organizations may be called upon to respond that are not necessarily involved in the detailed emergency plans (e.g. defence forces). Member States should ensure that all such organizations are identified and have basic guidance on how to respond in such situations. Member States should also ensure that they have provisions to be able to extend the response arrangements, if required.

Emergency management organization

Many presentations identified the risk associated with the potential loss of key personnel. Emergency plans and severe accident management strategies should explicitly recognize this risk and make provisions to ensure the resilience of the response teams. This could be achieved in part through cross-training and the need for key actions to be confirmed by more than one position.

Concluding remarks

Throughout the many discussions this week, I was reassured by the commitment from the experts to the need for the ability to effectively mitigate severe accidents. This IEM brought together the on-site and off-site response experts, who took good advantage of this opportunity to share ideas on how best to further strengthen their ability to provide a coordinated response during a severe accident. It was noted that the IAEA plays a crucial role in assisting

Member States to prepare their capability to respond to a severe accident and several suggestions for future IAEA activities were noted as follow:

- The IAEA should work with Member States to continue to improve severe accident management provisions by further developing guidance and continuing to encourage the use of the IAEA services.
- The IAEA should sponsor benchmarking activities on severe accident management and emergency response.
- The IAEA should consider developing guidance on damage control management at nuclear power plants.
- The IAEA should assist Member States to better coordinate severe accident management strategies with emergency response.

In conclusion, I am very pleased with the outcome of this week's meeting. The experts openly shared their views and experience on these very important issues, and I am confident with the recommendations developed such as the need for robust training and the need to allow for flexibility in the response strategies. It was also reassuring to see that there was strong support for the need to strengthen the linkages between the on-site and the off-site response communities. I felt that the information that was shared will allow Member States to enhance the robustness of their plans for severe accident mitigation so that we can learn the lessons from the Fukushima Daiichi accident to further improve the safety of nuclear power plants and to increase public confidence in the safe use of nuclear energy for the common betterment.

Mohammad Anwar Habib
21 March 2014

Annex B

CONTENTS OF THE ATTACHED CD-ROM

The following papers and presentations from the International Experts Meeting on Severe Accident Management in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant are available on the attached CD-ROM.

RELATED DOCUMENTS

Programme of the International Experts Meeting on Severe Accident Management in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant

Chairperson's Summary
M.A. Habib
Pakistan Nuclear Regulatory Agency (PNRA), PAKISTAN

PRESENTATIONS

Opening Session (Monday)

(Keynote) Lessons Learned from the Fukushima Dai-ichi Accident and Responses in New Regulatory Requirements
T. Fuketa
Nuclear Regulation Authority (NRA), JAPAN

(Keynote) IAEA Activities under the Nuclear Safety Action Plan
G. Caruso
International Atomic Energy Agency (IAEA)

(Keynote) Severe Accident Management and Beyond Design Bases Event Response: An End-user Perspective
R. Harter
Duane Arnold Energy Center, UNITED STATES OF AMERICA

(Keynote) WANO Post-Fukushima Severe Accident Management Project
V. Galkin and A. Pidipryhora
World Association of Nuclear Operators (WANO)

(Keynote) On-site/Off-site Interface for an Effective Emergency Management
O. Isnard
Institute for Radiological Protection and Nuclear Safety (IRSN), FRANCE

(Keynote) East Japan Earthquake on March 11, 2011 and Emergency Response at Fukushima Daini Nuclear Power Plant
N. Masuda
Tokyo Electric Power Company (TEPCO), JAPAN

Session 1 (Tuesday): Improvements to Severe Accident Management Guides (SAMGs)

(Keynote) Improvement of Severe Accident Management for Indian NPPs
D. Mukhopadhyay
Bhabha Atomic Research Centre (BARC), INDIA

Enhancements to Severe Accident Management Guidelines to Address Fukushima Daiichi Lessons Learned
L. Gilbert
Bruce Power, CANADA

SAMGs for German NPPs: Main Features and Implementation
H. Plank, M. Braun and M. Loeffler
AREVA, GERMANY

Integrated Coping Strategies for Beyond Design Basis External Events
Jaewhan Kim and Kwang-Il Ahn
Korea Atomic Energy Research Institute (KAERI), REPUBLIC OF KOREA

Severe Accident Management: Lessons Still to Be Learned from Fukushima Daiichi
G. Vayssier
Nuclear Safety Consultancy (NSC) Netherlands, NETHERLANDS

Improving the Management of Severe Accidents: Initiatives Being Undertaken by the NEA following Fukushima
A. White
OECD Nuclear Energy Agency (OECD/NEA)

Euratom Research Activities on Severe Accident Management
M. Hugon
European Atomic Energy Community (Euratom)

EC-JRC-IET Activities to Support Enhancement of Severe Accident Management Guidelines (SAMGs)
M. Bieth and G. Pascal
Institute for Energy and Transport, Joint Research Centre (JRC-IET)

Session 2 (Tuesday): Equipment and Training Needs for Severe Accident Response

(Keynote) Progress, Challenges and Perspectives in the Field of Design Features, as regards SAMG
B. L'Epinois
AREVA, FRANCE

KNPP Achievements towards Mitigation of Severe Accidents
D. Popov
Kozloduy Nuclear Power Plant, BULGARIA

Groupe INTRA: Activities and Organization in France
P. Izydorczyk
Groupe INTRA, FRANCE

Accident Management Programme for Indian Pressurized Heavy Water Reactors
C.M. Bhatia
Nuclear Power Corporation of India Ltd, INDIA

Fukushima Effect on SAM Requirements and Regulatory Oversight in Hungary
G. Petőfi
Hungarian Atomic Energy Authority (HAEA), HUNGARY

CNSC Severe Accident Management Regulatory Activities
C. Cole, Q. Lei and C. French
Canadian Nuclear Safety Commission (CNSC), CANADA

Severe Accident Analyses to Support Filtering Strategies Rule Making
E. Fuller, M. Stutzke and S. Basu
Nuclear Regulatory Commission (NRC), UNITED STATES OF AMERICA

Application of Learning from Fukushima Daiichi to Severe Accident Management for a Major Fuel Cycle Facility
I. Gordon
Sellafield Ltd, UNITED KINGDOM

Session 3 (Wednesday): Appropriate Regulatory Treatment of Severe Accident Management Measures

(Keynote) Perspectives on Regulation of Severe Accident Mitigation
J.L. Uhle
Nuclear Regulatory Commission (NRC), UNITED STATES OF AMERICA

Strengthening National Regulatory Capabilities in Countries Embarking on New Commercial Nuclear Power Programmes Post-Fukushima Accident
A.A. Hamed, A.A. Gadalla and E. El-Sharkawy
Egyptian Nuclear and Radiological Regulatory Authority (ENRRA), EGYPT

Severe Accident Management: Regulatory Challenges and Fixing of Priorities
J. Arunan
Atomic Energy Regulatory Board (AERB), INDIA

Inspection and Validation Activities on Severe Accident Management in Korea after the Fukushima Accident
Han-Chul Kim, Jung-Jae Lee and Sung-Han Lee
Korea Institute of Nuclear Safety (KINS), REPUBLIC OF KOREA

Regulatory Model Development for the Validation of SAMGs
M.S. Khan
Pakistan Nuclear Regulatory Authority (PNRA), PAKISTAN

Updating WENRA Reference Levels for Existing Reactors in the Light of TEPCO Fukushima Daiichi Accident Lessons Learned
K. Couckuyt
Western European Nuclear Regulators Association (WENRA)

Regulator and TSO Activity in the Area of Severe Accident Management in the Light of Accident at Fukushima Daiichi NPP
N. Kozlova
Scientific and Engineering Centre for Nuclear and Radiation Safety (SEC NRS), RUSSIAN FEDERATION

Beyond Design Basis Analysis: Developments in UK's Approach and Perspective
A. Tehrani
Office for Nuclear Regulation (ONR), UNITED KINGDOM

Session 4 (Wednesday): Linkage between On-Site and Off-Site Response; Emergency Response Challenges in Severe Accidents in the Presence of Extreme Natural Events

(Keynote) Fukushima and JSDF: Difficult Communication between Off-Site and On-Site
M. Hamada
Shigematsu Works Co., Ltd, JAPAN

(Keynote) Organizational Interfaces in Off-Site Nuclear Responses
D. Nodwell
Ontario Ministry of Community Safety and Correctional Services, CANADA

OSART Results in the Area of Accident Management
M. Lipár
International Atomic Energy Agency (IAEA)

Post-Fukushima Development of Operating Severe Accident Management and ERO
M.I. Grolleau
Électricité de France (EDF), FRANCE

Severe Accident Management Guidelines and Emergency Preparedness Planning: Not One without the Other
S. Hennigor and F. Cadinu
Vattenfall, SWEDEN

Relief Activities Conducted by the Japanese Red Cross Society after the Fukushima Daiichi Nuclear Power Plant Accident and the Challenges for the Future
Y. Watanabe
Japanese Red Cross Society (JRCS), JAPAN

Activities on Enhancing Preparedness to BDBA and Severe Accident Management
A.P. Kolevatykh
Rosenergoatom, RUSSIAN FEDERATION

Session 5 (Thursday): On-Site Emergency Response: Challenges in Severe Accidents and Link with SAMGs

(Keynote) On-Site Emergency Response Planning and Severe Accident Management
D. Wilson
Point Lepreau Generating Station, CANADA

(Keynote) Koeberg NPP: Severe Accident Management Improvements
L. Perryman
Eskom, SOUTH AFRICA

Human and Organizational Considerations in Severe Accident Management
F. Dermarkar
Ontario Power Generation, CANADA

Development of SAMG and Its Implementation in China
Yang Zhiyi and Zhang Lin
Nuclear and Radiation Safety Center (NSC), CHINA

Karachi Nuclear Power Plant (KANUPP): Lessons from Fukushima
B. Ghias
Pakistan Atomic Energy Commission (PAEC), PAKISTAN

Implementation of the Severe Accident Management in Slovenské elektrárne
V. Reznik
Slovenské elektrárne, SLOVAKIA

Information System on Occupational Exposure Expert Group: Management of Worker Doses during Severe Accident Conditions
E.P. Anderson
Nuclear Energy Institute (NEI), UNITED STATES OF AMERICA