

# Nuclear Power Plant Operating Experience



from the IAEA/NEA  
International Reporting System for  
Operating Experience

2009–2011



**IAEA**  
International Atomic Energy Agency



**NEA**  
NUCLEAR ENERGY AGENCY



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## Foreword

Incident reporting is an important aspect of the operation and regulation of all public health and safety-related industries. Diverse industries such as aeronautics, chemicals, pharmaceuticals and explosives all depend on operating experience feedback to provide lessons learnt about safety.

The International Reporting System for Operating Experience (IRS) is an essential element of the international operating experience feedback system for nuclear power plants. IRS reports contain information on events of safety significance with important lessons learnt which assist in reducing recurrence of events at other plants. The IRS is jointly operated and managed by the Nuclear Energy Agency (NEA), a semi-autonomous body within the Organisation for Economic Co-operation and Development (OECD), and the International Atomic Energy Agency (IAEA), a specialised agency within the United Nations system. In order for the nuclear safety system to be fully effective, it is essential that national organisations allocate sufficient resources to enable timely reporting of events important to safety, and to share these events in the IRS database.

Editions of this report were published in 2000, 2003, 2006 and 2010 covering experience during 1996-1999, 1999-2002, 2002-2005 and 2005-2008 respectively.

This fifth report on nuclear power plant operating experience from the IAEA/NEA International Reporting System covering the 2009-2011 period follows on the success of the previous editions. This edition highlights important lessons learnt and is based on a review of the approximately 245 event reports received from the participating countries over this period.

This report is intended to provide senior safety managers in regulatory bodies and in industry with information related to the safety of nuclear power plants to help them in their decision-making role.



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## Executive summary

The most significant event during this reporting period occurred on 11 March 2011 when the Tohoku-Pacific Ocean earthquake resulted in the subsequent accident at the Japanese Fukushima Daiichi nuclear power plant (NPP). The massive earthquake of magnitude 9 and subsequent 14-metre tsunami hit the Fukushima Daiichi NPP and resulted in the loss of reactor core cooling functions, the prolonged simultaneous loss of all alternate current (AC) and direct current (DC) power, and ultimately, the release of radioactive materials into the atmosphere and ocean. Similar to the Three Mile Island and Chernobyl accidents, this accident had an effect worldwide. However, unique to this event, every country with operating nuclear power plants (NPP) was called upon to respond to their government and citizens on the safety of the nuclear reactors in their country in a manner never before experienced. Although the devastation that the Japanese people must cope with is tremendous due to the tsunami and nuclear accident, the frequently used phrase “any accident anywhere is an accident everywhere” became a global reality with the TEPCO Fukushima Daiichi accident.

The focus of this report is on events that have been reported to the International Reporting System for Operating Experience (IRS) database during the reporting period. At the time of this report, the Japanese remain focused on responding to their citizens and other local residents who were evacuated as a result of the accident at the Fukushima Daiichi NPP and tsunami and on the stabilisation of the Units 1-4. This event is not covered in this report but it will be reviewed in future IRS publications as definitive information and reports are made available. However, it is fundamental to operating experience feedback, not to lose focus on all of the other events that have occurred, and to have lessons to be learnt and applied. It is through the diligent attention to lessons learnt for many incidents that the nuclear community may avoid another major accident.

Interestingly, the causes of the majority of the events reported to the IRS within this period have been identified in previous events; although some events highlight new phenomena or unexpected aggravating conditions. It is a continuous challenge to close the operating experience feedback loop and apply lessons to prevent the recurrence of events.

Key lessons identified during the reporting period of 2009 to 2011 include the following issues:

(a) Design basis quality control in construction and modifications

Events have shown that design deficiencies can exist for long periods of time following the initial construction and commissioning of nuclear installations. These deficiencies may remain latent and then suddenly cause significant

challenges or problems. At times, initial construction deficiencies occur in areas that are subsequently inaccessible. The initial quality inspections during construction and installation are critical. However, routine inspection and preventive maintenance programmes are also important contributors in detecting defects before a defect causes a significant issue or jeopardises the design basis analysis.

Modifications are implemented in NPPs for many reasons including the required upgrading of safety systems or due to economic motivations, such as an increase in power rating. It is important therefore that any modification and the installation of modifications to plant systems and components is designed, implemented and tested in such a manner that the safety of the facility, workers and environment is not degraded. The original vendor or manufacturer's design basis should be reviewed to assist in avoiding such issues.

(b) Maintaining operating knowledge

Weaknesses in the knowledge of operating personnel contributed to several events. For example, on two occasions, indications that are generally known to be symptomatic of reactor coolant leaks were missed. On another occasion, positive reactivity was mistakenly inserted when conditions required that negative reactivity be inserted. The prevalence of weaknesses in operator knowledge as a direct causal factor or as a contributing factor in events merits organisational attention to this issue. Training organisations may consider emphasising fundamental aspects of operations and the significance of indications in describing integrated plant behaviour. Operators, at all levels of experience, should understand indications associated with normal operations to the extent that they can readily identify abnormal conditions. Additionally, operators should understand the expected outcomes of equipment manipulations so that abnormal system responses can be quickly diagnosed.

(c) Monitoring facility conditions and resolution of issues

Several events revealed inadequacies in plant monitoring and issue resolution programmes. Long-standing issues contributed to some events and in one instance resulted in a dual-unit trip. Other events revealed that the scope of equipment surveillance programmes should be periodically revisited to ensure the results are representative of actual conditions. For example, surveillance of electrical cables may need to be increased if the cables are exposed to environments for which they are not qualified. Similarly, portions of systems that are monitored for corrosion should be periodically verified to ensure that they adequately reflect the condition of system. The operating organisation should ensure their facility monitoring and issue resolution processes are structured to ensure identification of issues and potential problems and their resolution in a time commensurate with their significance.

(d) Oversight of vendors, contractors and subcontractors

In recent years, many facility modifications and modernisations have been implemented and commercial-grade equipment has been introduced into

safety applications because of the obsolescence of original equipment, necessitating an increase in the utilisation of vendors and contractors. The events reviewed for the period of this report demonstrate the need to improve quality assurance in the procurement phase, such as acceptance inspections. However, counterfeit, suspect and fraudulent items (CSFIs) have also been identified as a potential risk to safety. Therefore, the oversight of vendors and contractors (including subcontractors) should be enhanced to ensure that the services, items and parts supplied by the manufacturer meet their respective specifications and provide no adverse effect on their associates.

(e) Focusing on human performance and safety management

During this period a significant number of events have been reported related to human performance involving multiple human errors and root causes associated with safety management weaknesses.

Operating experience shows that errors often occur before, during, and immediately after refuelling outages, when evolutions are less familiar to the plant operators because they are infrequently performed. From a risk perspective, refuelling outages can constitute as much as one third of a facility's overall core damage frequency even though the average facility is only in refuelling outages about 5% of the time.

These events often involve either a failure to provide adequate procedures or a failure to properly follow procedures. In several instances, it appeared that the shutdown risk was either under-estimated or not considered. Overall, these events involved behaviours that are often associated with a loss of safety focus, such as taking actions when the consequences of those actions are uncertain, or taking actions outside the scope of the relevant procedure(s).

In all of the reported human performance events, the incorrect action was accompanied and enabled by other factors which, taken together, can have a significant impact on the likelihood of human errors. These events show that human errors can lead to significant transients, but that incidents can be significantly reduced when sufficient emphasis is placed on training, procedure development, resolving latent failures, awareness and understanding of risks and error likely situations, proper communication, and adherence to procedures.

The events related to the management of safety show that management oversight and timely communication of management expectations could have been instrumental in preventing the reported events. The impact of organisational factors on individual human performance merits additional attention. A need to enhance safety culture can be observed in quite a few of the events reviewed in this period. Oversight and management leadership did not always ensure that the necessary programmes and controls were in place.

(f) Radiological control

Protecting workers, the public and the environment from the harmful effects of radiation is a main goal to be achieved in the nuclear industry.

Lessons learnt from the events reviewed show the need to continuously focus on this issue. In one case, hundreds of workers received unnecessary dose during refurbishment activities.

Feedback from operating experience should be applied and incorporated in procedures. Plant conditions should be communicated to workers and monitored while activities in a potentially radioactive environment are being performed.

The need for training workers on changes in radiation hazards must be considered when evaluating risks associated with newly installed components. Radiation monitoring and protective measures have to be in place, as well as a programme of regular calibration of protective instruments. Changes in technologies may require a review of safety practices.

(g) Application of operating experience

A number of cases illustrate that events could be avoided if previously gained operating experience applicable to identical or similar components had been adequately considered. There were cases observed where the evaluation of operating experience was performed, and either did not lead to a proper understanding of the cause of the event, or in some cases the root cause analysis took too long to prevent the event from recurring. Ineffective use of operating experience continues to be an issue. It was noted that the analysis of the direct and root causes of an event, when solely based upon investigation of the individual event, without consideration of past operating experience may not always reveal the underlying cause of the problem and thus prevent recurrence. In some cases there was a lack of a questioning attitude about the frequent unavailability of safety-related equipment at NPPs with multiply units, despite this being a recognised industry-wide performance indicator.

(h) Assessment of, and preparedness for, external hazards

The Fukushima Daiichi accident emphasised the necessity to re-assess the severity of external hazards and combinations of hazards. External hazards create a common challenge to any NPP, especially when they have been operating for a significant number of years consistent with their design basis and licensing requirements at the time of commissioning. Changing environmental conditions can create unexpected natural external hazards. The reported events evidenced that conditions may change both over long periods of time and also during an event, thus aggravating the event consequences.

Effective management, close co-operation with local authorities and grid companies, as well as efficient application of operating experience could mitigate an event or minimise the consequences. The availability of additional support equipment can assist in managing the impact of external hazards.

## 1. The International Reporting System for Operating Experience

In 1978, the OECD Nuclear Energy Agency (NEA) took the initiative to establish an international system for exchanging information on safety-related NPP events. In 1981, the NEA countries formally approved the Incident Reporting System (IRS). In 1983, the IAEA extended the system to all United Nations member states with nuclear power programmes. Since 1983, the IAEA and NEA have jointly sponsored and overseen the operation of the IRS database; however, the IAEA houses and chiefly maintains the database.

In 2009, to reflect the evolution of the “Incident Reporting System” to one which includes an expanded view/use of operating experience feedback, the name of the system was revised to “International Reporting System for Operating Experience”. The system has retained the term “IRS”.

### 1.1 What is the IRS?

The IRS is a worldwide system designed to augment national operating experience feedback programmes. It is the only international NPP incident database accessible to, and shared by, government agencies. Reported information is shared among regulatory authorities and operating organisations such that all users can learn from others’ experiences and enhance the safety of NPPs worldwide.

The IRS is a systematic approach to provide access to nuclear installation events throughout the world and a means to provide lessons learnt from operating experience. Applying operating experience is a key factor in maintaining continuous improvement in nuclear safety and supports the defence-in-depth philosophy.

#### Participating countries

Argentina	Hungary	Slovak Republic
Armenia	India	Slovenia
Belgium	Italy	South Africa
Brazil	Japan	Spain
Bulgaria	Korea (Republic of)	Sweden
Canada	Lithuania	Switzerland
China	Mexico	Ukraine
Czech Republic	Netherlands	United Arab Emirates
Finland	Pakistan	United Kingdom
France	Romania	United States of America
Germany	Russian Federation	

The role of the IRS was reinforced by the obligation under Article 19 of the Convention on Nuclear Safety. Contracting Parties should take the appropriate steps to ensure that, "...programs to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organisations and regulatory bodies."

## **1.2 What are the benefits?**

The IRS increases the worldwide awareness of potential and actual challenges in NPP operations. The heightened awareness generated by feedback from operating experience has resulted in numerous improvements to equipment, procedures and training in many NPPs, thereby reducing the potential for subsequent failures that could result from events.

The participating countries use the IRS to also identify "precursors" and trends. Precursors are events of apparent low safety significance, which, if not properly monitored, have the potential to escalate into more serious incidents. Through the analysis of data reported to the IRS, the identification of precursors is facilitated thus enabling the implementation of measures to mitigate their consequences. For this reason, it is important for member countries to detect and report low-level events and near misses that could have resulted in significant consequences.

The analysis of IRS reports can also assist in determining whether a particular event is generic or recurring in nature. Recurring events may reveal several types of issues related to the safety of NPPs. A recurring event is defined as one with actual or potential safety significance that is the same as or similar to (a) previous nuclear industry event(s), and has the same or similar cause(s) as the previous event(s).

This report includes several examples of recurring events, including inadvertent control rod withdrawal while shutdown; unavailability of turbine-driven auxiliary feedwater pump; use of non-compliant lubrication grease mixture in qualified actuators; and fuel assemblies damaged during refuelling operations due to misalignment.

The IRS database contains event reports that provide detailed descriptions and preliminary analyses of causal factors that may be relevant to other facilities. The analysis may lead to corrective action by plant management or regulatory authorities.

Additional IRS resources include topical studies of events of particular interest. In the period of 2009-2011, these studies focused on the operating experience feedback from external flooding and the effect of non-safety system failures on systems important to safety. Additional operating experience assessments and topical reports were published by the NEA Working Group on Operating Experience and the European Clearinghouse on NPP Operational Experience.

Countries that participate in the IRS benefit from exchanging information related to the root cause analysis and lessons learnt from incidents at NPPs. Feedback on how to adequately remedy, or avoid, possible precursors is of paramount importance to operational safety. For example, cables not designed or

qualified for, but exposed to, wet or submerged environments have the potential to degrade. The potential for common-mode failure exists if electrical cables are used in environments for which they are not qualified. Additionally, countries can also share the actions taken in their country as a result of an event that occurred in another country.

Another use of IRS data is the application of operational feedback in the design of the next generation of NPPs. NPP operating experience has demonstrated that design modification issues documented in IRS reports can have a significant impact on safety.

### **1.3 How can the IRS benefit decision-makers?**

Decision-makers in the industry, regulatory authorities and nuclear organisations around the world face a challenging environment that includes privatisation, economic pressures, globalisation and fierce competition in the market place. This environment leads decision-makers to seek new strategies to manage operation and resources with the objective of a common goal – safe operation of the nuclear power plant. The IRS supports this goal by providing information on safety significant events from the global nuclear community.

To make informed judgements, decision-makers need credible and reliable information in order to prioritise their programmes and resources. They need to receive timely and accurate information on safety performance and any decrease in performance in order to maintain safe operation. They also need to share their experience and learn from others, thus making efficient use of resources.

Regulators also require timely and accurate information on hazards or the potential for hazards so that they can tailor effective requirements and inspections that address actual or potential hazards in a manner that assures that risks to the public and the environment are addressed.

The IRS is a global contact network and forum that enables safety experts around the world to share and review information on lessons learnt from reported events. It can provide world experts with information on individual and generic issues of safety significance and advanced notice on deteriorating safety performance. The IRS can also be used, together with other databases, to prioritise those issues of safety significance that have been reported and to assist in the identification of areas where further resources or research are appropriate.

### **1.4 How does the IRS work?**

#### **Event reports**

An event report is submitted to the IRS when the event is considered by the national co-ordinator to be of international interest. Each of the 32 member countries designates a National IRS Co-ordinator. Reporting to the IRS is based on the voluntary commitment of the participating countries. Events from which

safety significant lessons can be learnt are reported according to guidelines. Safety significance is defined as the following:

- the event itself is serious or important in terms of safety due to an actual or potential significant reduction in the plant's defence-in-depth;
- the event reveals important lessons learnt that would help the international nuclear community to prevent its recurrence as a safety significant event under aggravated conditions or to avoid the occurrence of a serious or important event;
- the event is similar to an event previously reported to the IRS, but highlights new important lessons learnt.

When information is considered time sensitive, a short preliminary report can be submitted about the known details of the event. Subsequently, a main report is produced and replaces the preliminary report. If additional information is identified after the main report, a follow-up report can be generated and submitted.

The main event report contains basic information including the title and date of the event, characteristics of the plant and an abstract. It also includes a narrative description of the event, a preliminary safety assessment (what were the direct causes, consequences and implications), root cause analysis and potential corrective actions, lessons learnt and guidewords containing the essential information that can be easily searched and retrieved. Often a written description of the event is supported by graphics (diagrams of affected parts of the facility, etc.). The National Co-ordinator also identifies the categorisation codes for the important aspects of the event to assist in future database searches.

When an event or series of events indicates a generic problem, the National Co-ordinator may produce what is known as a "generic report".

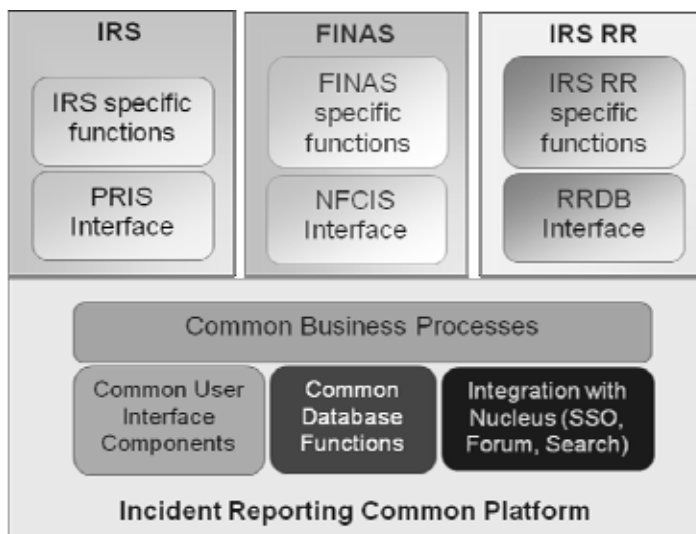
### **Sharing information**

Each IRS report becomes part of the web-based IRS, which was created to facilitate data input and report availability and speeds up access to information. The web-based IRS was launched in April 2006. The development of a common platform to support several databases followed in 2007. The new web-based IRS was launched in April 2008, followed by web-based FINAS in September 2008, and web-based Research Reactors IRS in November 2009. In October 2010, the software for web-based IRS and NUCLEUS Access was further upgraded.

Passwords are provided to users depending upon access level, thus ensuring a high level of security. Once a new report is posted on the web-based system the users will be informed by email. The routine receipt and distribution of reports on incidents form the basis for in-depth studies on implications and remedies, and assist in identifying safety issues common to NPPs. The event reports included in the IRS are selected because they are of particular interest for the international nuclear community – whether because of important lessons that can be learnt from them, the identification of new safety concerns or the interrelationship of events.



New IRS guidelines were issued in 2010 to provide updated guidance to users and add 20 new event codes applicable to construction events.



## 1.5 How is the IRS used?

### Topical studies

Topical studies constitute one of the major added-value products that result from the IRS database. Such studies provide in-depth evaluations on topical or generic issues by a team of nuclear experts. These issues begin with a national assessment by the reporting country that is then studied in-depth by experts at the international level, when warranted. At present, in addition to IRS topical studies, other topical studies based on IRS reports are produced by the NEA Working Group on Operating Experience and the European Clearinghouse on NPP Operational Experience (See Chapter 3).

### Annual meetings

A joint IAEA/NEA meeting of national co-ordinators is held annually to exchange information on events. These meetings serve to strengthen the mechanisms for the exchange of experience in the assessment of incidents and in improvements made to reduce the frequency of similar events. The national co-ordinators can select topics and event reports that are considered to be of particular safety interest to the international community for further analyses. Conclusions of the committee are distributed to participating countries. Additionally, the advisory committee of the IRS meets annually to review the information received and the operation of the system in general.

## **Restricted access**

Access to IRS reports is restricted. The system is designed to be of value mainly to technical experts working in the nuclear power field; therefore, information reported is written with technical detail not intended for distribution to the general public because of its proprietary nature. This restriction encourages openness within the nuclear community, including the disclosure of incident details and related plant actions.

## **Other systems**

The IAEA and NEA also jointly maintain the International Nuclear and Radiological Event Scale (INES). The INES was introduced in 1990. Its primary purpose is to facilitate communications and understanding among the nuclear community, the media and the public on the safety significance of events occurring at nuclear installations. The scale was modified in 1992 to include any event associated with radioactive materials and/or radiation, including the transport of those materials. The last version of the User's Manual is the 2008 edition. It is anticipated that events of safety significance reported to INES at level 2 and above would be included in the IRS.

## **Other activities**

Activities within the IRS extend beyond the exchange and feedback of event information. Both the NEA and the IAEA have assigned expert working groups which meet annually and discuss the safety relevance of such events, the regulatory perspective and the application of lessons learnt.

## **1.6 What has been achieved?**

Currently 32 countries with nuclear power programmes participate in the IRS. There are now over 3 750 event reports within the system. Events are added at the rate of about 80 per year. The reports are available in a user-friendly web-based system, with a full-text database and a powerful search engine allowing full-text searching. The capacity for data input, storage and access to written, numerical and graphical information is increasing the reporting and subsequent analytical capabilities and is making the IRS more effective in the enhancement of nuclear safety.

Over the years, the IRS has expanded from being primarily a vehicle for information exchange to becoming a source for analysis, in-depth discussions, generic studies and meetings for the exchange of information related to operating experience.

The Event Review Group (ERG) within the IAEA's Division of Nuclear Installation Safety reviews event reports for completeness, accuracy and consistency. The ERG meets regularly and works towards ensuring the quality of the reports posted on the web-based IRS.

## **2. Events and experience gained from the IRS during the reporting period**

### **2.1 Experience with design and installation**

The number of events caused by design and installation deficiencies or issues concerning plant systems, structures and components continues to be high. Many of these deficiencies may have existed for some time and in many cases since the facility was commissioned. Robust inspection and maintenance programmes play an important part in the identification of these latent design and installation deficiencies.

Two reports involved systems designed to mitigate the effects of leaks and flooding in essential systems. In one report, deficiencies were detected in the leak tightness of piping penetrations located in the emergency cooling system pump rooms. The utility inspected all of the penetrations and repaired over 40 of them. In another incident, several issues were identified involving inadequate flood protection features. It was discovered that a total of nine flow restrictor plates were missing in the drains of the interior steamline and feedline penetration rooms. These drains route water to the floor drain sumps in the auxiliary feedwater pump room of each unit. This deficiency was found to date back to the initial construction of the facility.

Several other event reports identified issues associated with hydraulic control systems, cables, connectors and junction boxes. In one instance, hydraulic oil leaked from a main steam valve which caused a fire when it ignited on hot steam pipework. The fire burnt for approximately five minutes before auto-extinguishing. The cause of the event was inadequate installation of the actuator hydraulic control system and failure of mounting arrangements due to over-tightening high tensile steel bolts into a soft aluminium plate.

In another case, an isolation fault was detected in the junction boxes of two containment isolation valves for the nuclear sampling system. Electrical cables in these junction boxes failed because of improper installation which resulted in exposed copper conductors that accessed external ground paths. Other similar events included a cable fire which occurred in a fire-resistant, electrical penetration. The primary cause of the cable fire was attributed to undersized cables for the circulating water pumps. In another event, cables in a cable tray sustained damage to their cable jackets from the radiant heat effects of an un-insulated hot pipe that was in proximity to the cable tray. These cables, which were rated for 194 degrees Fahrenheit (90 degrees Celsius), were close to the steam generator blowdown pipe, which had a surface temperature of 480 degrees Fahrenheit (248 degrees Celsius).

In another report, studies were performed on PWR operation during hot weather conditions particularly involving high head safety injection pump behaviour at ambient temperature. It was discovered that there was a difference of ten degrees between the maximum ambient service temperature set by the high head safety injection (HHSI) pump manufacturer (45°C) and the value specified by current safety analyses for rooms housing the pumps (55°C).

It was found that in one case a significant water leak in a pump's discharge piping occurred in a condenser circulating water system causing a pressure increase at the interface between the concrete foundation raft and the concrete floor in the turbine hall. The turbine hall floor partly lifted about 10 to 12 centimetres. The lifting of the turbine floor caused a misalignment of the manhole inlet and rupture of nearly all the floor-to-raft anchor rods distributed around the manhole inlet. Water flooded the turbine hall through the failed manhole which then flowed through a tunnel connecting the two units.

### **Safety significance**

One report describes how emergency cooling system pump rooms are designed to be watertight. Water from the containment condensation pool may leak into them during certain pipe rupture situations, the system is designed so that the flow will cease once the water level in the pump room reaches the same level as the condensation pool. Water escaping from the pump rooms would compromise this safety feature and reactor residual heat removal.

In another report, if all the flow restrictor plates were installed, the flow would be limited so as not to exceed the capacity of the auxiliary feedwater (AFW) system sump pumps following a postulated main feedwater line break.

The events involving the main steam valve hydraulic oil fire and cabling issues affected or damaged a number of safety-related systems such as the main steam valve, circulating water pumps, cooling water and service water systems. In many cases these events resulted in shutdown and extensive replacement of damaged cables, etc.

For the report regarding the review of HHSI pumps it was shown that in certain long-term accident scenarios, the charging (HHSI) pump room ventilation system (DVH) could potentially not keep ambient temperature below 45°C as required by the safety case. In this case, high temperatures could have caused the thermostatic valve that controls the pump lubrication system to fail resulting in a loss of this emergency core cooling system (ECCS) system.

### **Lessons learnt**

Two events demonstrate the importance of an understanding of the design bases and retaining accurate and complete documentation since the commissioning of the facility. Another incident demonstrated that deficiencies which are not identified and corrected, can lead to damaging flooding. In this case, water flooded the turbine hall which led to a reactor trip and forced outages of 3 and 5 weeks for each unit respectively.

As a result of the hydraulic oil fire, a number of corrective actions were identified including revising maintenance instructions for installation of the hydraulic control mounting, modifying hydraulic mounting arrangements to an approved design and performing a design review of the steam and feed valve hydraulic actuation systems.

As in the example of the HHSI pumps, events have shown that for certain specific accident scenarios previously not considered during the reactor design stage, there is an increased risk of equipment failure.

Plant design changes and maintenance practices that do not reflect the original equipment manufacturers recommendations can lead to failure of a component. Changes in material selection can also compromise the original design intent and specification.

Effective and robust surveillance and inspection programmes can identify design deficiencies which may affect the operation of safety systems. Design deficiencies which have existed since commissioning of the facility can result in unavailability or degradation of safety systems or have the potential for common cause failure.

## **2.2 Experience with the monitoring of plant condition and resolution of issues**

In the period considered with this report, several events were reported that demonstrated the potential results of lapses in programmes to monitor plant conditions and to resolve any identified issues. Events resulted from factors such as personnel error; an apparent absence of a sense of normal plant behaviour versus off-normal indications; and inadequate plant monitoring programmes which did not adequately reflect actual plant conditions.

During a periodic inspection, it was discovered that a pipe at the inlet of a heat exchanger in a high-pressure core injection diesel cooling system was degraded. The pipe was found to have less than the prescribed minimum wall thickness. Adherence of marine life on the inner lining of the pipe resulted in degradation of the lining and seawater coming into contact with the inner wall of the pipe. It was later discovered that the periodic inspection programme did not evaluate the material condition of the system at locations of worst case corrosion, and that the inspection frequency and process were not clearly defined.

Corrosion was discovered on the outer surface of an inlet pipe to an ECCS heat exchanger. The physical configuration of the system allowed standing water in a pipe trench to seep into the pipe penetration; that is, between the pipe and surrounding mortar. The corrosion went undiscovered and untreated because the affected area was difficult to access, and visual inspections were not performed on the affected pipe penetration.

Cable failures resulting from environmental factors have been reported in several plants. In most cases, the cables were exposed to submergence in water,

condensation, wetting and other environmental stresses. In one event, a transformer failure led to a loss of offsite power and a reactor trip. At another event, a transformer failure caused a safety-related bus to be de-energised. In both of these cases, the maintenance, surveillance and testing programmes were insufficient as no indication of impending cable failure was noted before the actual failures.

Inadequate electrical connections resulted in high resistance connections that led to bus faults, fires and loss of remote operation of equipment at multiple plants. During one event, the motor control centre provided only partial engagement of electrical stabs because it was not fully inserted. Two other events resulted from stab misalignment caused by poor maintenance practices or inadequate design. A final event resulted in loss of remote operation of a primary containment isolation valve because a control power cable for the valve was inadequately connected. In these cases, equipment that was recently manipulated for maintenance or recently (re)installed was ineffectively monitored for expected performance and indication.

Several events resulted from water intrusion into electrical equipment including one event that resulted in a dual-unit trip. In these events, the source of water was previously recognised; however, the adverse condition was never corrected primarily because of incorrect prioritisation of issues in the corrective action programme.

### **Safety significance**

Effective identification of issues and potential challenges and the resolution of adverse issues are critical to the safe operation of nuclear power plants. Deficiencies in this area affect all systems and factors that contribute to plant operation and safety, and while the consequences of individual events may be minor, programmatic weaknesses should be considered highly significant to safety.

Leakage can be caused by abnormal vibration, corrosion, ageing or improper maintenance. Leakage of reactor water can be readily identified with effective plant monitoring and trending of indications. Unresolved leakage can result in wetting of equipment, corrosion and in some cases degradation of safety-related systems.

Inadequate monitoring of electrical systems can lead to unseen weaknesses that can result in fires, plant trips and degradation of safety-related systems. Cabling that is exposed to environmental effects is used throughout NPPs and is commonly difficult to access. However, failure of such cables can lead to significant safety consequences including common-cause failures; therefore, their condition should be closely monitored. Unidentified high resistance connections typically result in equipment failures at the time of highest need and can complicate equipment operations from the spectrum of simple equipment unavailability to the most severe fire.

### **Lessons learnt**

Plant monitoring programmes often rely on formal equipment surveillance programmes or logging of indications as prescribed by regulations and/or technical guidance. However, good engineering and operating practices such as questioning attitudes, recognition of off-normal indications and thoughtful consideration of the impact of adverse equipment conditions on the overall facility should be part of

plant monitoring schemes as well. These practices contribute to a culture where operators retain an awareness of facility conditions to the extent that deviations from operational norms are readily identified and appropriately resolved.

The scope and frequency of inspection and monitoring programmes should be clearly defined and selected to provide results that are representative of the condition of equipment. It may be beneficial to periodically evaluate if the components being monitored adequately represent the system performance in the areas being inspected. If not, the inspection scope should be adjusted so that inspection results reflect the condition of the equipment and systems. Additionally, as a facility ages, condition monitoring programmes should be re-evaluated so that inspections of areas not readily accessible are accommodated as appropriate.

Inspection and condition monitoring programmes should be supported by effective issue resolution programmes. Once an adverse condition is identified it should be properly prioritised and resolved; with an urgency that is commensurate with potential safety significance of the condition. Longstanding issues should be periodically reviewed to ensure that they have been correctly prioritised with respect to their potential impact on the integrated plant.

Electrical cables are not typically designed or qualified for submergence in water unless they are specially procured as submarine cables. Therefore, cables should be adequately monitored, especially to verify conditions, especially to verify submersion. A facility may have to develop specific condition monitoring programmes for cables that are exposed to environments for which they are not qualified.

High resistance connections can result from oxidation or wear of stabs; design deficiencies, such as stab misalignment or insufficient stab contact surfaces; and inadequate maintenance practices and procedures. Plant condition assessment programmes should include evaluations of recently installed or overhauled electrical equipment to protect from inadequate connections.

### **2.3 Experience with human performance and safety management**

During the period a significant number of events have been reported related to human performance, several of which involved multiple human errors and root causes associated with safety management weaknesses.

At one station, while performing reactor cool-down and depressurisation activities for a refuelling outage, high vibrations were identified on all three operating reactor coolant pumps (RCPs). The licensee operated one RCP outside of its normal vibration tolerance to facilitate the cool-down and reactor depressurisation. This pump remained in operation for several hours after initiation of decay heat removal, leading to multiple seal failures resulting in the alarm of the reactor building iodine detector. This condition was not recognised and the alarm response procedure was not entered until several hours later and outage work, including the removal of the reactor building equipment hatch was allowed to continue. Management decided that one of the RCPs should be restarted to assist with RCS degasification and crud burst mitigation. Shortly after starting this pump,

two of its three seals failed. In response the operating crew did not properly monitor plant parameters as required by procedure.

At another station during a refuelling outage, there were several human performance-related issues. In one case, fuel handling operators failed to properly implement procedures while moving a control rod assembly (CRA) in the spent fuel pool. The refuelling bridge was moved to the next fuel assembly without first visually checking to ensure the CRA was not grappled. Further investigation revealed that the CRA fingers were still inserted in the previous fuel assembly and that the subsequent movement of the refuelling bridge severely bent them.

Another example describes an event when the personnel were conducting a flush of the boron thermal regeneration system (BTRS) chilled water piping. The procedure requires that components be manipulated both locally and in the control room. Despite a requirement, the procedure was not in hand. Due to misinterpretation of the procedure step, the valve was verified that it was closed but the handswitch was not placed in the “closed” position. When the subsequent steps in the procedure were performed, the valve automatically opened, and approximately 500 gallons (1 900 litres) of un-borated water were flushed from the BTRS to the volume control tank. This resulted in a positive reactivity transient. Control room operators also responded to the transient by continuing to insert control rods, borating and reducing main generator load; but not before the 1-minute average reactor power level increased to 100.73%.

In another case, one day after shutting down the unit for outage, control room operators began draining the pressuriser. In the process, it was not recognised that the reference leg was voiding resulting in an erroneously high pressuriser level reading. This resulted in the complete draining of the pressuriser allowing nitrogen from an on-going pressuriser relief tank purge to migrate into the top of the reactor vessel and into some of the steam generator u-tubes. The plant's investigation revealed several missed opportunities for mitigating this event, including: a) the proper response procedure was not implemented when the pressuriser heater “Off-level low” annunciator alarmed; and b) proper corrective actions were not implemented as a result of a similar industry event that had occurred in the past.

In another event, during outage work in a 6 kV power switchboard, a lead worker conducting voltage testing suffered burns on the face and hands, due to an arcing short, and required hospital treatment. The injury resulted from repeated violations of procedures by the involved personnel. This included: failure to perform the pre-job briefing, failure of installation supervisor to perform independent verification, inadequate labels and failure to apply standards for work conduct. Proper adherence to any of these work practices could have prevented the event.

In another event, while operating at full power, technicians performing a routine test of the reactor protection system caused a reactor scram by pressing the buttons for the wrong channels. In this instance, two consecutive failures to appropriately verify which channel was affected were involved. These errors resulted from a failure to follow the procedure and the failure to use human error prevention techniques both before selecting the button to press and afterwards when verifying



which channel had been affected by the action. Poor communications between the technician and the supervisor also contributed to the problem.

In a generic report, some examples describe painting or cleaning activities that adversely impacted various important equipment rendering them inoperable. At least three reactor trips were attributed, in part, to painting activities. The assessment found that those events often involved one or more of the following main causal factors: inadequate supervisory oversight, lack of self-verification, lack of adherence to procedures, lack of training, poor pre-job briefings and communication issues.

Other notable human performance events reported in the period related to incorrect valve position, lack of attention to detail when performing handling activities, work-arounds, response to excessive burden and stressful situations, and misinterpretation of procedures.

### **Safety significance**

The events related to human performance discussed above occurred, for the most part, during refuelling outages. They often involved either inadequate procedures or the failure to properly follow procedure. In several instances, it appeared that shutdown risk was either under-estimated or not considered. Overall, the events involved behaviours that are often associated with a loss of safety focus, such as taking actions when the consequences of those actions are uncertain, or taking actions outside the scope of the relevant procedure(s).

Operating experience shows that errors often occur before, during, and immediately after refuelling outages, when evolutions are less familiar because they are infrequently performed.

Overall, the reported events are safety significant because incorrect human actions and behaviours, initiated or escalated the event together with other contributors, or combined with one or more latent failures being present in the system, resulting in significant consequences such as: reactivity transients; unavailability of safety systems beyond the limits of the technical specification; inadvertent actuation of reactor protection systems; dropping and severely bending fuel elements; discharge of significant amount of slightly contaminated borated water into the containment; and injury of personnel. In one case, properly monitoring plant parameters and adherence to the procedure would have alerted the crew to the alarming reactor building iodine detector and to the severity of the on-going leaks.

However, some events that were initiated by a single equipment failure resulted in significant consequences due to additional undetected equipment failure or additional human error committed in the course of the event. In some events multiple human errors initiated the event and/or made the event more complex due to errors committed while responding to an initiating event.

### **Lessons learnt**

In all of these human performance events, an incorrect action was accompanied by other factors which together increased the likelihood of human

errors occurring. These included deficiencies in training, a lack of clear and complete communications among the operating staff and inadequate procedures. These events demonstrate that human errors can lead to significant transients, but that these incidents can be significantly reduced when sufficient emphasis is placed on training, procedure development, proper communication, and adherence to procedures. In at least one event, the deficiency occurred during commissioning activities; highlighting the need to approach operations and nuclear safety at a new facility in the same way they would on an operating facility.

Lessons learnt from events related to system misalignments and component mispositioning included the need to improve the following:

- component labelling, valve locking practices, use of valve checklists and post-maintenance testing;
- training in determination of valve position by individuals;
- independent verifications;
- awareness of unique valve designs or valve operating characteristics;
- awareness of burdens on a plant personnel that increase the likelihood of error; and
- effectively applying station and industry operating experience.

Also, lessons learnt show that in spite of careful design and continuous improvement of plant systems, there remains a possibility that a human performance mistake in the valve line-up of low safety class components can initiate a major transient and have significant consequences, especially if it is combined with one or more latent failures being present in the system.

In some of the reported events, the lessons learnt include a need to enhance pre-shift briefing by shift supervisors to the staff carrying out the switching actions, drawing attention to the specific types of work scheduled for the upcoming shift.

The events related to the management of safety demonstrate that management oversight and timely communication of management expectations are instrumental in preventing events. In the recent years, organisational factors are becoming more recognised for the impact on the individual human performance. Managing changes in the organisation can have impact on nuclear safety. The influence of human and organisational factors in the occurrence of events is getting higher attention. However, the need to enhance safety culture can be observed in quite a few events reviewed in this period. In some cases, more emphasis was placed on production reporting and less on independent verification of expected outcomes. Oversight leadership did not always ensure that the necessary programmes and controls were in place.

## **2.4 Experience with radiation protection**

During the reporting period, a number of events of radiological significance were reported. These events caused undue or unforeseen exposure to a large number of workers either due to working in an area with a high radiation field or high air-

borne contamination. Some of these events occurred due to improper planning or co-ordination during maintenance activities. In some cases, the plant operator, misguided by past experience, failed to recognise that the activities could have an impact on exposure and contamination levels. Poor oversight by the radiation protection group, weakness in management and non-conservative assumptions also contributed to these events.

In one event, radiation exposure occurred when two workers were carrying out a lamp installation task in the enclosed space beneath the reactor vessel in parallel with an activity involving removal of a guide tube (having an activated probe) from the reactor core. The event also brought out other weakness in radiation protection practices as the alarm set points of the dosimeters carried by the workers were lower than the prevailing area radiation field. As a result of this, these dosimeters were continuously alarming from the commencement of the lamp installation activity.

In another event, four temporary workers (involved in painting of a duct which contained spent fuel transfer lines) received radiation exposure during the transfer of spent fuel bundles. Prior to the incident, the utility had recognised the radiological risk associated with the job in the duct area and therefore, had made a special procedure. The procedure identified administrative requirements in terms of instructions to avoid simultaneous occurrence of two different activities. The incident revealed that the procedure was not adequate and a standard working permit system involving positive isolation of the spent fuel transfer system should have been used for the jobs involving the potential for high radiological risk.

Past experience at a pressurised heavy water reactor (PHWR) with primary system refurbishment activities revealed little occurrence of air-borne alpha contamination. The personnel in the radiological protection staff relied on this experience and allowed workers to carry out refurbishment activities in another PHWR at the same site without actually measuring the alpha contamination levels. However, the alpha contamination levels were later found to be considerably higher at the working site. Even though the exposures were below statutory limits, this resulted in radiation exposure to hundreds of workers. Poor oversight of the radiation protection staff, non-use of primary feeder source term information and the failure to integrate operating experience with alpha hazard in the radiation protection programme contributed to this event.

Another reported event highlighted significant weaknesses in the management and radiation protection programmes that allowed high air-borne activity levels in the containment to remain unaddressed for three days and resulted in uptake by over one hundred workers. The air-borne activity in the containment was introduced following the use of air for inserting the inspection probe in a steam generator. During earlier inspections, this activity had not caused any problems as seals around the nozzle dams had been made leak tight, preventing the air to escape into containment. The planned removal of one containment ventilation train at the same time that the primary system was open further aggravated the situation. Evaluation of the event revealed that the radiation protection staff did not have preparation or training to deal with an abnormal air-borne activity event.

One event report highlighted the lack of understanding of potential hazards and improper use of personal protective equipment which resulted in a tritium uptake to a worker involved in the replacement of a line in the heavy water supply system. The activities executed include cutting of the existing line, draining the heavy water and welding the new line. The event also identified weaknesses in the enforcement of the radiation protection programme.

### **Safety significance**

The reported events resulted in undue radiation exposure to workers. In a few events, radiation exposures occurred following air-borne contamination of the working areas. The review of the reported events revealed that in many cases, existing radiological hazards were not foreseen and hence had the potential for even higher exposure to workers.

### **Lessons learnt**

Protection of workers, public and environment is a common goal of the entire nuclear industry. To achieve this objective, the importance of radiation safety should be emphasised at all levels of the organisation. The reported events call for the following improvements in the radiation protection and management practices at NPPs:

- Administrative controls and instructions may not be sufficient for a job having the potential for high radiological risk. In such situations, positive isolations are needed. It is necessary that potential radiological risks associated with a job due to expected or envisaged failures (equipment or human) are examined in advance. The system/procedure followed for the job must be commensurate with the potential risk.
- In the work permit approval process, increased attention should be given to the potential interactions of systems to ensure that two different tasks, in which one task could impact on the other with regard to radiological considerations, are identified.
- Radiation protection programmes should be robust enough to deal with all kinds of hazards. Additionally, the programme should be conservatively implemented to avoid the possibility of undue exposures. Operating experience gained in this area should be widely disseminated and utilised.
- During activities that involve high radiological risk (such as, the opening of the primary boundary), it is essential that the process and mitigation systems required during these activities be maintained in the desirable configuration.

## **2.5 Experience with the procurement of spare parts**

During the reporting period, several events related to the procurement process and the use of spare parts were reported to the IRS. Some of the events involved deficiencies that went unnoticed as a latent problem for some time. In some cases, given the similarities of equipment in several NPPs, the deviations needed to be

promptly analysed, taking into account the extension-of-cause determination to identify the potential impact on other installations of the same or similar design.

At one facility, several incidents took place during a campaign to replace multiple electrical safety boards. The causes were linked mainly with the procurement phase including deficiencies or absence of requirements in the purchasing specifications, deficiencies in the factory and site acceptance testing documentation and incomplete requalification testing procedures. One of the problems related to an incomplete reloading sequence from the emergency diesel generators (EDG) due to an incorrect setting of protection relays and the presence of supplementary functions unknown by the utility. These malfunctions were not revealed during the factory and site acceptance testing.

In another event, it was identified that the membranes on bleed valves located in the control line for main steam isolation valves, replaced four months previously, aged prematurely. The affected membranes were made of a grade of elastomer that did not comply with the design drawing and were likely to degrade at a lower temperature. Given the similarity of this equipment, another NPP operating organisation checked the characteristics of membranes installed in other plants and revealed that all the membranes delivered by the supplier in the last 18 months also did not comply with the design requirements. At one unit, four membranes stuck to their seat and prevented the normal operation of the control valve.

In one incident, the high pressure emergency core cooling (HPECC) gas isolation valves failed to open during the periodic logic tests causing HPECC unavailability. The subsequent inspection and analysis revealed some discrepancies in the size and curvature of the recently installed valve seats compared with the original ones. The deformation of the valve seat had increased under the operating system pressure, causing friction between sealing rings and other parts being enhanced and the operating torque of valve being increased significantly.

One report involved the replacement of the isolation valves of the main steam relief valves in order to minimise their closure time and potential radiological release. Important welding problems occurred on one of these new valves and indications of flaws and metallurgical problems were shown on other ones. The pre-service tests and inspections by the manufacturer and by the authorised inspection agency had not reported these faults. In-depth examination revealed qualification deficiencies of the manufacturer and quality assurance deficiencies in the manufacturing and inspections of the valves.

A series of failures occurred in the diesel engines of EDGs at NPPs in three countries. These failures resulted from rapid degradation of a rod bearing that caused the engines to seize; it was later determined that the rod bearings were made by the same manufacturer. At one facility, a recently overhauled diesel switched off after 1.5 hours running time due to low oil pressure in a test run. In another plant, it was found that the damage was due to the anti-friction coat being slightly too thick, possibly causing localised melting and deterioration. The inspection of the diesel showed that one master piston rod bearing had been destroyed; the associated slave rod bushing was broken and bent. These “first

generation” bearings were replaced with “second generation” ones with the same geometry. The defective “first generation” bearings were supplied by the manufacturer without having prior qualification tests performed for use in NPPs.

### **Safety significance**

Problems in the procurement process and the use of spare parts could lead to common cause failures which can render safety-related systems unavailable for an extended period while remaining unnoticed. These problems have a tendency to be introduced when the plant equipment is modified, in particular, when replacing the original parts with new ones, and during the procurement phase. It is important to verify that the newly installed equipment is fit for purpose and has undergone all the necessary functional checks required during factory and onsite commissioning tests.

In order to limit the possibility of common cause failures stemming from procurement and spare parts issues, as well, maintenance should be conducted in a phased sequence to detect and to minimise the potential common cause element.

### **Lessons learnt**

Some events illustrate the need to take into account all requirements resulting from operation in normal and accident situations and to sustain them when manufacturing spare parts and maintaining the associated equipment. Therefore, defining and maintaining safety requirements, when procuring or replacing equipment, are important parameters to be sustained. Also, attention must be paid to any change in components and the impact of these changes regarding potential consequences on the plant safety must be analysed.

In some cases, the required examinations performed prior to onsite installation were not designed to reveal all of the potentially important problems. Some issues can only be discovered during fabrication by adequate methods and appropriate procedures applied by qualified people. As a result, adequate oversight of contractors (including sub-contractors) and manufacturing processes are essential.

The events related to deficiencies in purchasing specifications demonstrated the need for improvements in quality assurance programmes and for enhancements of acceptance inspections of spare parts. The factory and site acceptance tests should be carried out by suitably qualified and experienced personnel and should begin with a systematic review of all design specifications.

Lastly, these events highlight the fact that close attention must be paid to any change of manufacturer or production processes, especially when related to equipment used to ensure facility safety. As equipment continues ageing, new vendors may need to be identified for long service-life equipment, or equipment has to be redesigned because of the obsolescence of that originally installed. In these cases, particular attention must be given if commercial grade equipments are verified for use in safety applications so that the original design bases for the affected systems are maintained.

## 2.6 Experience with the control of modifications

Many events were reported during this reporting period involving deficiencies in the modification process. In some cases, modifications which were intended to improve plant safety resulted in degraded safety conditions because of unanticipated consequences. Such degraded conditions can remain undetected for long periods.

In one case, the replacement of the steam generators altered the hydraulic parameters involving the AFW system. A full-flow test of the AFW system, performed with somewhat different time delays than was usual in these tests, revealed that under some circumstances the AFW flow did not meet its design intent. The operator later concluded that this change had rendered the AFW system not fully available for 19 years. The event demonstrated that the standard full-flow test had not been capable of identifying inadequate flow within all possible operating conditions.

Four events involved degradations of plant seismic safety. In three of these cases, seismic restraints were temporarily removed and then later not replaced following modifications. In another case, new pipe supports which were intended to improve plant safety proved inadequate due to unforeseen hydro-acoustic phenomena.

In four other events, modifications to valves proved especially problematic. The replacement of a handle with a heavier one resulted in a change of the natural vibration frequency of a system and caused a crack in a weld joint. In another case, the replacement safety-relief valves from another company proved inconsistent with the original design and resulted in these valves sticking in the open position. In another event, fast-acting isolation valves had been replaced with new ones in an attempt to improve the environmental qualification of these valves. However, some of these replacement valves later proved inoperable due to common cause failures involving fixative screws with a larger diameter head and galling of the spring and the valve guiding head. In a final case, replacement pilot valves in the primary circuit overpressure protection system proved inadequate; specifically, during a periodic test, two valves failed to close while a third valve was found to be stuck in the closed position.

Another event repeated the theme of modifications causing unintended consequences. A new fire protection wall resulted in higher temperatures which caused degradation of electrical wire insulation.

### **Safety significance**

The above events demonstrate that modifications that are improperly executed can result in degradation of important safety systems. Seismic protection, containment, overpressure protection, and AFW systems were affected. In one case, the modification introduced a common cause failure. The risk of common cause failures increases if multiple components are replaced simultaneously, such as during upgrades for seismic or environmental qualifications, or during refurbishment. Modifications intended to improve safety, if not carried out with

adequate design checks and acceptance controls, can inadvertently result in a reduction of safety.

Several of the events discussed involved seemingly minor changes, such as replacing a handle or changing a valve with one from a different manufacturer. As even these minor changes can lead to significant events, sufficient design rigor needs to be maintained during all modifications.

### **Lessons learnt**

Several of the events concerning a decrease in seismic protection highlighted the loss of control of contractors, inadequate quality assurance and inadequate final inspection. However, these deficiencies can contribute to problems resulting from any modification. Thus the general measures needed to prevent events occurring subsequent to modifications remain much the same irrespective of the type of modification. Testing procedures should verify all possible operating configurations.

The four events involving valve modifications show that special care regarding design adequacy must be used when replacing valves using new materials or new design. Rigorous acceptance testing is required. In addition, since hydraulic disturbances are difficult to fully account for in design, detailed analysis of operating feedback is required.

When performing modifications intended to improve safety, design verifications and acceptance testing must look for possible unintended consequences. Such possible consequences can vary widely as seen in the listed events.

## **2.7 Experience with control rods and CRDMs**

There were a significant number of events related to control rods and control rod drive mechanisms (CRDM). These events either involved poor maintenance practices, or identified unexpected premature ageing of components.

One event was discovered while a boiling water reactor (BWR) was shut down for an annual refuelling outage. During this outage the personnel in charge of the refuelling operation noticed that a control rod was tilting somewhat. The day after, during the lifting of the control rod, it was observed that the control rod shaft extender was broken. The operator initially assumed that the broken extender represented a single exceptional failure. During the subsequent days, the plant operator examined other control rods, and cracks were identified in several control rod extenders. The examination of control rod shafts at another station of similar design also revealed cracks and a broken control rod extender.

Subsequent to extensive examinations, testing and analyses, it was concluded that thermal fatigue was the main contributing cause of the identified cracks and of the broken control rod extenders. The thermal fatigue occurred as a result of thermal oscillations caused by the mixing of the crud flow with relatively cold water and significantly warmer primary coolant in an area of the control rod extenders exhibiting stress concentrations and/or geometrical variations.



Three events of control rod over-insertion were reported from BWRs. The cause of these events was determined to be additional insertion pressure generated by drive water from a seat leak of the scram inlet valve. These seat leaks resulted from a variety of causes including: foreign material introduced in the system during filter replacement, improper adjustment of the stem stroke and partial loss of the Teflon valve seat. In two of these events, the seat was assembled with a mixture of different types of bolts which may have caused non-uniform protrusion of the valve seat.

At one facility a series of incomplete insertion of rod cluster assemblies had been observed. Analysis of these anomalies established that they originated from radiation induced swelling of the rods. The swelling behaviour was more significant than expected and led to the re-evaluation of existing maintenance strategies, especially for the rod cluster control assemblies subject to the highest neutron flux. This discovery may limit the operating life of these rod cluster control assemblies.

One control rod design has exhibited severe cracking of control rod blades near the end of their lifetime. These cracks were more numerous, and had more material distortion, than those observed in previous inspections of control rod blades. The cracking was attributed to irradiation-assisted stress-corrosion cracking. It was determined that a significant contributor to the excessive cracking was a rapid thermal transient that occurred when the automatic depressurisation system was actuated and injected cold water. The design life of certain control rod blades may be less than previously stated.

### **Safety significance**

Cracking of the control rod shaft extenders uncovered weaknesses in the reactor design related to the thermal mixing of the crud flow with the core circulation flow due to the geometrical arrangement of the circulation flow inlet into the control rod guide tubes, and geometrical and material properties of control rod extenders in the two reactors.

Maintenance strategies are designed to limit risks associated with three types of damage observed on absorber rods: wear, swelling and cracking. Excessive wear on an absorber rod can lead to its failure and the risk of it becoming jammed in the fuel assembly guide tube. As illustrated in the events described above, excessive swelling due to radiation may also cause incomplete insertion of the rod cluster control assemblies in the lower part of the fuel assembly. For this reason, control rods are replaced after a defined number of hours of use in a reactor. While it was determined not to be the case in the events discussed, incomplete insertion of rod cluster assemblies could have reduced the negative reactivity margin for shutdown.

The control rods in the final event consist of a series of absorber tubes, each containing capsules filled with boron carbide (a neutron absorber), welded together to form the control rod blades. Absorber tube cracks allow water to enter both the outer absorber tube and the boron-carbide capsules. When this occurs boron carbide may leach into the reactor coolant, resulting in a reduced control rod reactivity worth.

## **Lessons learnt**

These events illustrate the value of having an inspection plan for all parts and components located in the reactor pressure vessel; otherwise the consequences of complex phenomenon, like thermal fluctuations, may be difficult to fully demonstrate and assess.

Proper care must be taken during maintenance of control rod systems and components; this includes following foreign material exclusion processes when working on open systems, and the inspection of components prior to installation. The use of appropriate parts and complete procedures may have prevented the over-insertion events described in this section.

Specific monitoring of control rod components is essential near end of life. Monitoring and trending of age-related degradation may identify the need to re-adjust criteria for replacing control components.

## **2.8 Experience with unintentional or unexpected reactivity insertion**

During the reporting period, several reports involving unintentional or unexpected reactivity insertion were reported to the IRS. The events occurred at all types of reactors and in all modes of operation, including at power, during fuel handling, low-level power operations, and when testing or maintenance was being performed. Furthermore, the sources of reactivity inserted were different in most events. Human performance and safety management issues were involved in all these events.

In one incident, subsequent review of one PWR shutdown found that control room operators did not effectively control reactivity to maintain the reactor in the desired condition during low-power operations by properly anticipating, controlling and responding to changing plant parameters. The operators did not use control rods or boron concentration, two methods that operators can use to directly control the amount and timing of reactivity changes, to adjust for reactivity changes resulting from xenon build-up and reactor coolant temperature changes. In addition, after the reactor became subcritical through xenon build-up and a reactor coolant temperature increase, operators delayed inserting control rods for nearly two hours.

In another incident, fuel loading was carried out at a gas-cooled reactor using a combined fuel assembly made up of a plug unit and a stack of fuel elements. When a bump latch was carried out to join a new fuel stringer to a plug unit, it was noted through a viewing window that there was foreign material caught in the coupling. The fuel movement was stopped, leaving the fuel stringer suspended from the plug unit approximately 2.5 m above its original position. As the integrity of the coupling was not known, the decision was made to inject expanding polyurethane foam into the new fuel carrier to act as a shock absorber in case the coupling failed and the fuel assembly dropped. Because the foam had the potential to act as a moderator, this was in breach of local arrangements for the prevention of accidental criticality. In addition, the foam was a flammable material. Further event recovery action led to an unapproved modification to the facility to fit a temporary clamp to restrain the fuel to prevent it from falling. The root causes

were attributed to inadequate knowledge on the part of the individuals involved in the event regarding a potential criticality resulting from ex-reactor activities. The potential for criticality from injecting the foam was not recognised. There was a failure to set up an effective event recovery organisation to deal with the suspended fuel stringer.

During a forced outage, a PHWR unit was placed into an over-poisoned “guaranteed shutdown state”. Due to a longstanding deficiency in the reactor, namely a defective calandria tube, carbon dioxide gas (CO<sub>2</sub>) from the annulus gas system was allowed to enter into the moderator. The effects of the CO<sub>2</sub> in the moderator under radiolysis created conditions whereby gadolinium oxalate formation occurred. Some of the gadolinium oxalate subsequently plated out onto reactor internal components thus reducing the dissolved gadolinium concentration in the moderator, and allowing sub-critical reactor power to increase.

During moderator refill at another PHWR, a decreasing trend of the moderator gadolinium concentration was observed through routine sampling. This decrease in concentration was both unexpected and unexplained. The plant operator took the conservative decision to stop the moderator refill and return the reactor to the safe drained guaranteed shutdown state. Throughout this event, the reactor was always subcritical by a significant margin; however, the event did result in the normal margin being reduced. The direct cause was the introduction of oil into the moderator circuit. The root cause was the failure to identify the fact that non-gaseous hydrocarbons could generate oxalate anions in the moderator system. The contributing cause was determined to be an organisational insensitivity to contaminants in systems, structures and components, which affected equipment reliability. There have been three previous gadolinium oxalate events.

### **Safety significance**

All events were considered as events of potential safety significance. However, one event in particular was rated as INES level 2. In this event, the decision to re-enter the room once the criticality risk was understood created a foreseeable risk to the individuals involved. Despite the fact that reactivity control is essential for nuclear safety, events involving unintentional or unexpected reactivity insertion still do occur. This type of event should never be underestimated because of the potential for affecting the fuel integrity.

### **Lessons learnt**

To prevent recurrence of the above mentioned events, the following principles and recommendations are identified:

- a) One of the most important responsibilities of an on-duty licensed reactor operator and senior reactor operator is reactivity management in order to maintain the reactor in the desired condition, consistent with the technical specifications, by properly anticipating, monitoring controlling and responding to changing plant parameters.

- b) Operating organisations should review and consider revising procedures and training of operators so that, after the reactor becomes subcritical, the reactor operators will immediately proceed to insert control rods or add boron to ensure the reactor remains shut down.
- c) Reactivity management involves establishing and implementing procedures for operators to use in determining the effects on reactivity of plant changes, and to operate the controls associated with plant equipment that could affect reactivity. Before conducting planned evolutions involving reactivity changes, a reactivity management plan should exist that helps control room operators maintain the reactor in the desired condition by providing expected plant responses and expected alarms.
- d) Criticality control arrangements need to be visible at the point of work, and clearly understood by individuals.
- e) Required licensed operator training is expected to give an understanding of facility operating characteristics during steady-state and transient conditions, including causes and effects of temperature, pressure, coolant chemistry and load changes, as well as, operating limitations and their bases.
- f) Thorough operator post-transient (event) reviews are important for determining the cause of transients or any unexpected plant responses and for taking appropriate corrective actions to prevent recurrence.
- g) Maintaining rigorous control over the design basis and making conservative decisions when non-standard or unanalysed situations arise is important.
- h) Indirect methods of inspection or analysis of a failure (especially inside the reactor) must always be considered as potentially suspect.
- i) Individuals involved in the decision-making process should have sufficient depth of knowledge on criticality safety in ex-reactor areas.
- j) A narrow focus on delivering a technical solution to the problem may lead to poor decision-making, and the circumvention of company arrangements for managing events.
- k) The gadolinium oxalate phenomenon demonstrates that there may still be surprises in what appear to be more or less routine undertakings. Proper tracking and assessment of events which can impact system chemistry is necessary.

Despite the fact that reactivity control is essential for nuclear safety, events involving unintentional or unexpected reactivity insertion still do occur. This type of event should never be underestimated because of their potential for affecting fuel integrity. Human performance and safety management issues were involved in all events described above.

## 2.9 Experience with external hazards

Nuclear power plants are designed to withstand a variety of external hazards to the site like earthquakes, storms, tsunamis, floods, lightning, extensive fouling of water intakes, unusual weather conditions, as well as other external events such as loss of offsite power, without any harm to the public and the power plant itself. In general, NPP sites are chosen to minimise the impact of these hazards as much as possible.

An event associated with earthquake, tsunami and station blackout occurred at Fukushima Daiichi on 11 March 2011. Actual disastrous consequences were caused by the tsunami, which significantly exceeded the design. This event is not covered in this report but it will be reviewed in future IRS publications as definitive information and reports are made available.

Two events were reported that involved the loss of transmission lines. At one facility, an electrical transient was caused by a lightning-strike on a transmission line and resulted in the trip of one reactor coolant pump; which caused the reactor to trip. At another facility, a fire in the forest near the 500 kV outgoing transmission line caused actuation of the line's differential protection. Smoke from the fire reduced the air insulation of the line and allowed an electrical short from phase to ground; unit power was maintained on house load.

Several events involved the loss of heat sinks. One facility experienced a total loss of heat sink at one unit, and partial loss at two additional units, due to clogging of the trash rack, pre-filtration system and rotating screens by vegetable materials caused by the opening of a dam upriver.

At another facility, high winds resulted in ingress of slime, bottom sediments, and algae into the rotating drums of the unit pump station. Despite the emergency team's efforts to clean the drums and their screens, the cooling water flow in the condenser of one turbine driven feed water pump reduced, causing a pump trip and reactor power reduction to 50%.

In another incident, a facility experienced strong winds together with an incoming tide that led to massive seaweed ingress to the cooling water inlet. Operators manually shut down both reactors and there was a partial, temporary loss of reactor seawater cooling on one unit, including cooling of the concrete pressure vessel.

Another event was initiated at a facility when tributaries introduced debris near the water intake area after an unusually heavy rainfall. A mudslide downstream of the discharge channel introduced additional sediment and debris into the discharge channel. The combination of these two events caused the discharge channel to overflow, allowing additional debris to reach the lake near the intake of the pump house. In addition to the two sources of sediment and debris, a strong wind was also present that pushed debris towards the intake. The debris overloaded the rotating grids and caused the bypass gates to open. This led to a sudden fouling of the filters in the common water intake for service water and circulating water. This situation caused the unit to be brought to outage conditions.

Another loss of heat sink event included a period in which station operation was severely disrupted by frequent circulating water pump trips due to fouling of drum screens with plant debris and sediment. In a two-month period at one facility, three cases of ingress also led to reactor trips. In one case (on 12 February 2009), 8 circulating water pumps were lost with all four reactors trip. In the second case (on 24 February 2009) 4 circulating water pumps were lost with two units trip. In the third case (on 2 March 2009) 2 circulating water pumps were lost with one reactor trip. Banning of preventive dredging operations around the intakes in that period by new environmental regulations aimed at preserving certain animal species in the river estuary (i.e. allowing migration of eel hatchlings) contributed to these events. Such severe drum screen clogging, which had led to the reactor trips, could also have induced total loss of heat sink, with the concomitant aggravation of core meltdown risk in one or more of station's reactors.

Three facilities reported events associated with very low winter temperature. At one facility, low temperatures led to the formation of frazil ice and, for the first time at the site, icing of the protective grid located at the water intake, causing a difference of two metres between upstream and downstream water height. Blockage of this grid by ice lowered the water level at the entrance to the pumping station below the lowest safe water level, though it did not cause the essential service water pumps to malfunction.

At the second facility, the sea water temperature decreased rapidly. Frazil ice was formed at the screens and partially blocked the cooling water screening system. The water level at the main sea water pumps decreased and the pumps stopped, which then resulted in a reactor scram.

At the third facility, low temperatures resulted in freezing of stagnant water in the upper portion of the valves feeding the safeguard cooling tower wells from the make-up water supply, which led to the inoperability of both independent trains of the essential service water.

### **Safety significance**

From the reported events, difficulties were encountered in managing the situation of multiple heat sink losses due to the occurrence of an unexpected external hazard. The monitoring and protection measures currently in place at the pumping station were unable to detect the rapid clogging of the trash racks and filter screens that caused the event. As the fixed measures for cleaning this system were insufficient, additional mobile equipment had to be brought onsite.

Other problems were encountered due to loss of offsite power as well as low environmental temperatures, which may lead to reactor trips.

### **Lessons learnt**

External hazards may affect power plants in various ways. The lessons learnt from different events indicate a number of measures and proposals, which can be used to cope with such situations. In the following, some selected generic lessons are described:

- a) Carefully consider the robustness of current NPP design and emergency preparedness against beyond design basis events that could lead to common cause failures regardless of their assumed probability.
- b) Effective management of cooling system clogging events requires detection of the phenomena, diagnosis of the situation, and implementation of fast and reliable means of mitigation.
- c) Implement a seaweed risk indicator system, which demands proactive actions to be taken based on tidal, wind direction and wind speed indicators.
- d) The monitoring and protection measures are required to be in place at the pumping station to detect the rapid clogging of the trash racks and filter screens.
- e) The rotating drums of the unit pump station should be re-enforced, design changes to the protective structures in the cooling channel may be performed, and the depth of the cooling pond and intake channel should be monitored and sufficient.
- f) Additional mobile equipment had to be used onsite for simultaneous cleaning of the cooling systems at multiple units.
- g) Training should be provided to all operators, and procedures modified to emphasise the importance of maintaining the safety significant cooling in preference to other loads.
- h) A comprehensive process to review procedures and identify all systems, components or equipment whose operability could be impacted by severe weather conditions should be implemented. Design changes could also be performed, including canvas and heating provision to the valves and pipes of safety related systems. The minimum design temperature in the final safety report, which is not always the worst possible, should be reviewed to take into account extreme temperatures historically encountered at the plant location.
- i) The operating organisation should work in conjunction with the local government to establish a safety separation area along the outgoing lines and to perform regular pruning of vegetation in the area.

Continuously changing environmental conditions challenge power plant operation. Effective management, review of the robustness of current design and emergency preparedness against extended design basis events, close communication and co-operation with different authorities, availability of additional supporting equipment, and efficient use of operating experience can be helpful to prevent or mitigate the consequences of events resulting from external hazards.

## 2.10 Experience with foreign material intrusion

Events involving the intrusion of foreign material continue to occur at nuclear power plants. Experience has revealed that these events may impact on plant safety to varying degrees. It is also possible that the presence of foreign material in

a safety system may remain as a latent deficiency for a long period. This condition can adversely affect the functionality of a safety system during demand. In the past, significant foreign material intrusion (FMI) events have resulted in steam generator tube damage, failure of emergency diesel generators, service water system degradation and control rod failure.

In the review period, one IRS report identified an additional risk associated with the events of foreign material intrusion. In this event, foreign material prevented the closure of a check valve in the feed water line to a steam generator and thus allowed backflow of the steam. This introduced severe pressure transients in the system which led to a guillotine rupture of a fire water line to the steam generator as it was not designed for the pressure and temperature experienced.

This rupture also damaged nearby pipe anchors and supports. The foreign material (i.e. a welding electrode piece) was introduced in the affected system during construction of the facility. The event demonstrates that foreign material may represent a significant hazard to personnel and equipment.

In another event, the presence of loose materials was noticed during a visual inspection of the secondary side of the steam generator tube sheet. These were parts of a disintegrated feed water flow distributor, and had caused mechanical damage to several tubes of the steam generator during operation. The disintegration of the flow distributor parts was attributed to a non-compatibility of the materials with the working environment. The fact that similar events occurred at other nuclear power plants indicates deficiencies in the application of industry operating experience.

One reported event focused on the aspects related to human performance in the detection of foreign material using non-destructive testing. Eddy current testing of steam generator tubes found signals of mechanical wear and thus confirmed the presence of foreign material. Similar eddy current signals had been detected several times during previous inspections however these were rejected by the human analyst. This event highlights that human performance related causal factors like competency in analysing eddy current test signals can allow foreign material to remain in a system for long periods.

In another event, rags identified during an inspection inside the recirculation circuit were not removed fully and the reactor was brought to full power. The presence of the rags inside the recirculation circuit had the potential to render the safety injection pumps unavailable which means a degradation of cooling function for the reactor after a loss of coolant accident. The slow and inefficient communication towards the appropriate levels of management needed to make decisions and take actions was identified as the reason for this unsafe operation.

In another event, foreign material was introduced to a load limiter during periodic maintenance. This resulted in an unexpected increase in generator power. The cause for introduction of the foreign material was attributed to non-adherence of proper foreign material exclusion (FME) controls like establishment of a clean area and use of a FME plug while performing the maintenance.



## Safety significance

The potential threat presented by foreign material is two-fold. The first is the risk of pipe systems and fuel cooling paths being clogged, which can result in equipment or fuel assemblies becoming overheated. The second is the risk of mechanical damage to equipment, jamming of control rods, inoperability of valves or rotating machines, resulting in degradation of reactor protection and control capabilities. The reported events highlight that the presence of foreign material can also lead to severe pressure transients under certain process conditions and cause the guillotine rupture of system piping. Also, lost particles and foreign materials can move to other parts of the system affecting the satisfactory performance of plant critical functions.

In one case, the event had no real consequences to the safety of the unit as the system was not actuated. Nevertheless, the obstruction caused by the presence of foreign material could have led to the partial or total unavailability of the function under accident conditions.

## Lessons learnt

The reported events highlight that the lack of contractor oversight, non-adherence to FME control practices, poor safety culture, use of components incompatible with the working environment and deficiencies in maintenance and quality assurance practices are reasons for intrusion of foreign material into plant systems. The following measures are needed for managing foreign material related issues in nuclear power plants:

- Rigorous FME programmes should be instituted at all stages of a plant's life cycle. The programme should address aspects like awareness training of employees and contractors, safety culture, guidelines for favourable working conditions/practices and oversight during execution of jobs on reactor components and safety systems. A quality assurance programme should also be strictly implemented to achieve the objective of the FME programme.
- During the selection of materials for components/equipment, careful examination of their suitability for the respective environment should be done to prevent failures. For this purpose, the available industry operating experience should be fully utilised.
- Plant personnel should be competent enough to analyse the findings of inspections carried out routinely for the healthy monitoring of safety systems and equipment.

The reported events highlight that the intrusion of foreign material continues to occur, confirming that this issue is a recurring concern deserving more oversight both from management and regulatory authorities. Since in some cases, the system was not actuated, the events have no real safety consequences. However, the presence of foreign material could have led to the partial or total unavailability of the function in an accident situation.

## 2.11 Experience with cracks, corrosion and leaks

Twelve IRS reports of this nature were included in the current reporting period. Three of them refer to deficiencies in the ageing management programme. In particular, one IRS report gave examples at four different reactors of stress corrosion cracking (SCC) in stainless steel piping. This SCC was identified as being a problem in ageing PWR plants. However, solutions usually involved increasing the effectiveness of the inspection and surveillance programme and/or improving chemistry control. It is possible that ageing was a factor in some of the other events, but it is difficult to identify ageing *per se* when more specific causal factors were also identified. Of note, none of the events identified improvements to the ageing management programme as a corrective action.

Three of the events involved systems exposed to seawater. Corrective actions included measures to increase inspection and surveillance effectiveness. Ideally the need for improved inspection procedures should be identified before such problems become evident.

Corrective actions for several other events involved replacing defective components. An effective ageing management programme might be able to identify those defective components for replacement before a failure occurs. Additionally, this is related to the experience with the procurement of spare parts.

In one case involving non-isolable leakage from the primary system, several warning signs (increase in downstream temperature at the pressuriser safety valve, increased radiation inside containment) had been received starting three months before the final confirmation of the leak and plant shutdown for the repair. Organisational response to these warning signs proved inadequate. Small temperature variations were not taken into account. As a temporary measure, a radiation alarm threshold was reset because of an inconsistency between radiation monitoring and chemistry sample indications. There was tolerance for radiation monitoring issues by plant staff due to the unreliable status of radiation monitoring equipment. A contributory cause to the failure was eventually determined to be vibration.

Two events involved steam generator (SG) tubes. In one case, eddy current testing revealed cracks of more than 65% of the tube wall thickness. Root causes included the presence of components with copper-containing alloys in the secondary circuit and imperfect chemistry control. In another case, a primary-to-secondary leak was estimated to be 4.5 kg/h. The probable root cause of the SG tube leak was a manufacturing defect in the form of a metal burn (surface defect caused by local superheating), which in the course of operation resulted in metal damage under the impact of the working fluids with subsequent wall thinning. The rate of corrosion was found to depend on the extent of tube fouling and on the content of copper oxides in the deposits.

Other causal factors leading to corrosion and cracking included: rainwater seepage, operation under cavitation conditions, fretting and rubbing, impact load caused by a tool during maintenance, and repeated overheating during maintenance. The last two causal factors led to corrective actions involving improved maintenance procedures.

### **Safety significance**

Systems affected by the reported leaks, cracking and corrosion included emergency core cooling systems, the primary pressure boundary in both PHWRs and PWRs, the SG interface between the primary and secondary cooling systems, cooling for EDGs and residual heat removal. Other examples included less safety-related systems. However, corrosion and cracking mechanisms discovered in less obvious safety-related systems sometimes provide lessons for the possibility of such problems in more safety-related systems.

In all cases, the leaks discovered were small. None of the events were assigned an INES rating greater than zero (below scale, no safety significance).

### **Lessons learnt**

The corrective actions for most of the events involved improvements in preventive maintenance, inspection and surveillance. This is particularly true at ageing nuclear plants, as evidenced in the three reports which specifically mentioned ageing as a factor. Such improvements in preventive maintenance and inspections are especially important given the possibility that ageing may increase the possibility of common-cause failures.

Consideration of the implication of off-normal plant indications or adverse conditions upon the integrated plant is an essential component of an effective plant monitoring programme. It is common that seemingly innocuous indications, when considered alone, point towards more serious conditions when considered together and in the context of integrated plant operations.

Maintenance, inspection and surveillance programmes should emphasise structures, systems and components important for safety.

Stress corrosion cracking in stainless steel tubing may be an increasing problem as NPPs age.

The use of copper containing alloys on the secondary side of some PWR designs is a major factor in steam generator tube corrosion.

## **2.12 Experience with ineffective use of operating experience**

The events discussed below illustrate that events are reoccurring because previously gained operating experience applicable to the same or similar components was not adequately considered. The lessons learnt from these recurrent events show that the analysis of direct and root causes, based solely upon investigation of the individual event, without considering the past operating experience may not always reveal the underlying cause of the problem and thus prevent recurrence.

In one event, three control rods inadvertently, partially withdrew from their fully inserted positions at a BWR while it was shut down. The event was caused by the action of non-licensed operators using a deficient procedure to manually isolate hydraulic control units (HCU) in the field. This led to multiple control rods

moving out of the core without the prior knowledge or consent of the licensed control room operator. The operator had previously reviewed operating experience involving control rod withdrawal events at other BWRs and had implemented procedural changes to prevent this occurrence at the station. However, all of the affected procedures were not revised, including the one that was used during this event. It should be noted that the procedural deficiencies were only one of many failed barriers encountered in this event. Other issues include: inadequate pre-job briefing, operators not trusting their indications, a “shutdown” mindset that did not emphasise the potential impact on reactivity of maintenance activities, and non-licensed personnel performing activities that could affect plant reactivity without the knowledge or consent of a licensed operator.

A series of events related to the unavailability of turbine driven auxiliary feedwater (TDAFW) pumps were encountered at a PWR. The report involved recurring instances in which the TDAFW pump tripped on over-speed protection. The operator initially attributed the pump trips to excessive moisture accumulation in the turbine during the turbine start. It took three pump trips before a more thorough investigation was initiated. It was noted that the accumulation of water was heavily dependent on external temperature, and additional insulation was added. While this improved the situation, a number of additional pump trips still occurred. Then the packing on the steam inlet valve was replaced. Eventually, a failed spring in the pneumatic servomotor of the steam inlet valve was identified as the cause. Replacing the spring was effective in correcting the overspeed trip problem.

Although the operating organisation addressed the direct causes of the pump failure several times, it failed to identify the underlying causes of these failures. If the operating organisation implemented a recommendation that had been made after the first series of failures, the problem would likely to have been identified earlier. There were several similar events at other stations in which lack of root cause analysis led to recurring unavailability of TDAFW pumps.

Insufficient use of operating experience also contributed to a series of events in which electrical actuators were inappropriately lubricated. During scheduled preventive maintenance of electric actuators qualified for accident ambient conditions, the operators at three facilities of similar design detected a presence of a mixture of lubricating greases in the electrical actuators. One of the greases was injected into the actuators by mistake during lubrication procedures for the yoke nuts or electric actuators of residual heat removal (RHR) systems. The electrical actuators potentially impacted were those present in the systems important to safety, in particular ECCS, containment spray system, RHR system, and chemical and volume control system. This was not the first non-compliance of this type.

Another event was reported from a PWR in which an operator was unable to couple a control rod drive mechanism to its associated control rod assembly during reactor vessel reassembly. Upon subsequent disassembly of the reactor vessel head and upper internals, it was discovered that multiple fuel assemblies were damaged during reactor vessel reassembly and that these damaged fuel assemblies were interfering with proper control rod coupling. A post-event examination of the fuel alignment video revealed that the gap between the inner wall of the baffle and an adjacent fuel assembly was larger than that allowed by

the vendor specifications established by past industry events. The fuel alignment verification procedure was not in accordance with current vendor guidance; specifically, it did not include the maximum allowed gap value. Because the evolution proceeded with a larger than allowed gap, the fuel assembly upper end fitting and reactor vessel plenum grid pads could not properly align. The weight of the plenum rested on the upper end fitting tabs and deformed the fuel assemblies.

### **Safety significance**

The partial withdrawal of control rods event was associated with violating the sub-criticality margin of the core in shutdown conditions. The reactor remained subcritical by approximately 4.5%. However, an inadvertent criticality event could have occurred under different conditions given that the procedure did not place controls on RCS temperature or xenon concentration. Under a different set of initial conditions, this event could have resulted in an inadvertent criticality.

The safety significance of the TDAFW pump unavailability events is associated with a long-term unavailability of an important safety related pump. In case of actuation of the AFW system during a station blackout (the simultaneous loss of external grid sources and emergency diesel generators), the TDAFW pump is the only equipment remaining to feed the steam generators and to remove the residual heat from the reactor core.

Incorrect application of lubricants to the qualified electrical actuators could compromise their qualification status. Although each of the lubricating greases had been individually qualified for accident conditions, no studies had been conducted to determine the grease mixture's irradiation behaviour or to ensure the durability of its qualification for accident conditions. These lubrication deviations may therefore compromise the qualification and proper operation of safety-important valves under accident and/or post-accident conditions. This type of event has a great potential for common-mode failures that may remain unnoticed after several years of operation, thereby compromising safety.

The safety significance of the final event is associated with developing deformations in fuel assembly geometry that can undermine the integrity of the fuel cladding, which is one of the primary barriers to fission product release. Also, deformed fuel assemblies could affect reactivity control if they cause control rods to become stuck during reactor operations.

### **Lessons learnt**

One event illustrates the importance of understanding when field activities at BWRs and PWRs can significantly affect reactivity. The regulation in force required that the operation of apparatus and mechanisms that may affect the reactivity of a reactor shall be manipulated only with the knowledge and consent of a licensed operator present at the controls. In this case, the action of non-licensed operators (using a deficient procedure) to manually isolate the HCU's in the field led to multiple control rods moving out of the core without the prior knowledge or consent of the licensed control room operators. Moreover, the licensed operators'

failure to believe the control room indications unnecessarily delayed their diagnosis of, and response to, the event.

An overreliance on a computer-based keyword search programme system to identify applicable procedures when implementing a procedural change contributed to this event. It is important to update all applicable procedures to include the key recommendations provided in operating experience. The relevant information in this event included: specifying a minimum number of HCUs to be kept in service with a control rod drive (CRD) pump operating while shutdown; monitoring CRD drive pressures, rod positions and alarms during activities that could result in rod movement; and ensuring personnel who isolate HCUs are aware that they can effect control rod system drive pressure and cause inadvertent control rod movement.

The series of events related to the unavailability of TDAFW pumps identified a need for the reassessment of the maintenance plan of all equipment (e.g. mechanical, electrical, I&C) essential to ensure the availability and reliability of the AFW system, in order to detect possible weaknesses and gaps with the qualification requirements and the recommendation of the designer, as well as the reassessment of the periodic testing programme of AFW components in order to identify early degradations and to anticipate failures. Correct categorisation of the TDAFW unavailability origin, i.e. mechanical, electrical, or I&C in the frame of the working group, helped eventually identifying the main paths of improvement.

The traceability of lubrication operations should be properly implemented as well as the management of lubricating products stored in and released from the warehouse. Maintenance personnel awareness of risks associated with lubrication operations needs to be improved including application of more rigorous management of these operations. In cases where none of preventive maintenance document requires lubrication of the electric actuators and in order to eliminate the possibility of grease injection into the electric actuators, and thereby prevent the formation of grease mixtures, it may be prudent to replace existing lubricators with plugs.

The importance of using operating experience when verifying core alignment to avoid misalignment between fuel and reactor internals is highlighted by another event. Before verifying core alignment, operating organisations should consider reviewing and applying related operating experience and verifying that their procedures and methods are in agreement with the latest fuel vendor guidance.

Ineffective use of operating experience can contribute to the occurrence of significant events including those related to reactivity control, core cooling and the availability of safety related systems and equipment.

## 3. Insights from topical studies and conferences

### 3.1 Topical studies

Topical studies are carried out on topics of general interest where there may have been similar events in several of the participating countries. Topical studies are organised at the yearly meeting and developed by consensus. A study usually takes two or three years to complete. The studies listed below were completed during this reporting period.

#### ***External Flooding: Consequences, Corrective Actions, Good Practices (2011)***

NPPs by design require an ultimate heat sink which means they are sited close to the sea, a river or a lake. Thus there is always a risk of external flooding posing a hazard to the safe NPP operation. Although this risk is taken into account at the design stage, recent operating experience has shown that underestimating such risks combined with changes to environmental conditions such as global warming could leave many facilities vulnerable to external flooding, which therefore may significantly impact on plant safety, as the tsunami and subsequent accident at the Fukushima Daiichi nuclear power plant (NPP) adequately demonstrate.

In general the design basis for protection against natural phenomena requires that “structures, systems and components important to safety” shall be designed to withstand the effects of natural phenomena such as, earthquakes, tornadoes, hurricanes, floods and tsunami without loss of capability to perform their safety function.

This topical study has analysed external flooding events reported to the IRS database that have occurred in NPPs in the past, along with the relevant national safety standards of leading nuclear countries. This study also included a review of the preventative measures taken by the affected operators following the event, the root causes which led to the event and the identification of good practices in relation to improving defences against external flooding.

#### ***The Effect of Failure of Non-safety Systems on the Safety Systems/Primary Systems (2011)***

Analysis of some selected events revealed that the failure of non-safety systems have significant effects on the reliability of the safety systems because failure of the non-safety systems frequently challenge the safety systems either in the form of valid or spurious actuation. These actuations in some cases may result

in failure of safety systems to perform their intended functions. Therefore, due consideration has to be given to the reliability of non-safety systems in design, manufacturing, installation, commissioning, operation, maintenance, in-service inspection and surveillance during their operational life. Some recent events have also shown that there is need for review consideration of design modifications to evaluate harsh environmental effects such as extreme cold weather, floods, tsunamis, seismic events, etc. This analysis has identified systems which have considerable vulnerabilities to extreme environmental conditions, including circulating cooling water systems, service water systems, transformers, offsite power systems, etc.

### ***Operating Experience on Counterfeit, Suspect and Fraudulent Items (CSFI)***

Although operating experience reports in most countries have not flagged counterfeit items as a problem in operation, both industry and regulators have identified CSFI as a potential risk to NPP safety. Items found not to meet the standard are non-conforming items. However, the intent to deceive with counterfeit and fraudulent items is the critical element for CSFI. A successful CSFI prevention programme would identify non-conformance and CSFI in the warehouse during the receipt inspection. Although most regulatory bodies have reporting systems which cover CSFI, most do not have specific criteria to report events involving CSFI. A definitive identification of a counterfeit, versus a non-conformance from a known source, would help to identify, control and distribute information on this issue more easily. Likewise, developing explicit common terms and definitions would be an advantage when dealing with CSFI in both national and international contexts. Several countries are already working to define a standard language for CSFI. In 2012, a code for CSFI was added to the IRS database.

CSFI training of both industry and regulatory staff is a key element to preventing and detecting counterfeit and fraudulent components which could affect NPP safety. Sharing operating experience on CSFI has been identified as one of the best methods for decreasing the risk of counterfeit and fraudulent activity. Specific policies for the disposal of CSFI would help ensure that this material cannot be returned for potential re-use. Initiatives regarding this aspect are being carried out by industry in some countries. Likewise, using anti-counterfeiting methods or technologies in the purchased products could as well give industry an edge in detecting CSFI instances. [NEA/CNRA/R(2011)9]

### ***Status of Country Regulatory Response to the Forsmark-1 Event on 25 July 2006 and CSNI DiDELSYS Task Group Report Recommendations***

The event at Forsmark unit 1 on 25 July 2006, at which a short circuit in the offsite 400 kV switchyard caused inoperability of two emergency diesel generators (IRS report 7788), identified weaknesses in the electrical system design that could be generic for NPPs worldwide. Following the event, several studies were performed and many NPPs changes were made to address the weaknesses. The NEA member countries formed the Defence-in-depth of Electrical Systems (DiDELSYS) Task Group, which produced two reports. This report provides the country activities in response to the Forsmark-1 event and also recommendations of the DiDELSYS Task Group as of the summer of 2011. [NEA/CNRA/R(2011)8]



### **Operating Experience on Recent Failures of Large Oil-Filled Transformers**

Although transformers are not considered nuclear safety equipment, the failure of a large transformer at power can result in a reactor trip. The complications associated with a transformer failure, including fire, electrical distribution disruption, emergency declarations, and hazards to personnel, create distractions for operators and can complicate efforts to maintain the reactor in a safe, shutdown condition. Predictive and preventive maintenance is key to maintaining equipment, and to detecting any degrading conditions before they pose a challenge for normal operation. Poor oversight of contracted maintenance personnel and a lack of understanding by plant personnel of main transformers have been highlighted by industry groups as a possible contributor to transformer failures. Many NPPs do not retain the expertise onsite for anything more than routine sampling and maintenance. Contractors, required for more extensive maintenance and testing, must understand the quality control and procedural practices required for nuclear plant operations. [NEA/CNRA/R(2011)6]

### **Investigating Trending Utilising the International Database**

Trending provides a helpful tool in the framework of the regulatory national supervisory programmes. Negative trends may trigger systematically, or on a case-by-case basis, regulatory actions. On the international level meaningful trending can only be performed on safety significant events that are expected to be reported completely in the IRS database. Positive international trends can underline the excellent overall operating experience worldwide. Negative international trends, including the relative trending performed in this task, should be taken as a starting point for further investigation by dedicated international working groups. This report includes survey responses on trending performed within national OEF programmes and uses of the international database. [NEA/CNRA/R(2011)5]

### **Operating Experience Feedback Related to Fire Events and Fire Protection Programmes**

Fire can represent a serious nuclear safety risk. The review has identified positive findings associated with a consistent approach to inspecting fire protection provision and a good understanding by the operating organisation and regulators of the importance that adequate fire protection provision has on safety at NPPs. This evidence is reflected in the fact that there have been very few fire events at NPPs over a number of years across all NEA countries. This review has found that operating organisations and regulators do recognise the need to adequately address the provisions for fire protection and are appropriately managing them. [NEA/CNRA/R(2009)3]

### **Current Status of the National Operating Experience Feedback Programmes**

The report provides descriptions of the various regulatory operating experience feedback programmes in the OECD member countries and non-member countries as of 31 December 2008. To facilitate benchmarking of national OEF practices, the reporting was based on IAEA NS-G-2.11, *A System for the Feedback of Experience from*

*Events in Nuclear Installations*. The report provides insights into how data are collected, screened and used within these countries. [NEA/CNRA/R(2009)2]

### **Topical studies and quarterly reports performed by EU Clearinghouse**

In the European Union, in order to support the Community activities on evaluation of NPP operational events, a centralised regional “Clearinghouse” on NPP operational experience feedback (OEF) was established in 2008 at the JRC-IET, upon the request of nuclear safety authorities of several member states, in order to improve the communication and information sharing on OEF, and to promote regional collaboration on analyses of operational experience and dissemination of the lessons learnt.

One of the technical tasks of the European Clearinghouse consists of performing in-depth analysis of families of events (“topical studies”) in order to identify the main recurring causes, contributing factors, lessons learnt and to disseminate and promote recommendations aiming at reducing the reoccurrence of similar events in the future.

Topical studies developed by EU Clearinghouse are primarily based on operating experience reported to IRS, and the US Licensee event reports as well as on French and German event reports for some of the studies.

In the period 2008-2011, already ten topical studies have been completed. The studies involve Shika NPP criticality event of 18 June 1999, Forsmark NPP event of 25 July 2006, maintenance events, fuel related events, construction and commissioning events, report on the event of Olkiluoto-1 and Forsmark-2 of 2008, external events, events related to the supply of NPP components, events related to plant modifications, events related to ageing of NPPs.

The completed studies are available on the IRS website. In addition to developing topical studies, the EU Clearinghouse also issues quarterly reports on safety significant NPP events and organises workshops and technical meetings on operating experience.

## **3.2 Workshops and conferences**

### **International NEA Operating Experience Workshop (2011)**

The workshop included two discussion topics: the utilisation of operating experience in the regulatory inspection programme and inspection findings in the national OEF programme; and operating experience and inspection insights from the non-conformance of spare parts. The workshop brought together OEF personnel and regulatory inspectors to discuss commendable practices on the interactions and exchange of information between the two groups. For the first discussion topic commendable practices included: the conduct of routine meetings targeting OE among the inspectors and the OEF staff; the provision of a means to support routine transfer inspection findings to OEF staff; the clear definition of expectations for inspectors on operating experience information, in particular any feedback or documentation that is needed. Additionally, it was suggested that a

common database to capture both inspection results and operating experience could be utilised to: identify applicability to specific nuclear facilities; track status and completion of inspections; provide a regulatory basis for the inspector (if applicable); link the OE to specific inspection procedures; and provide a basis for generic applicability and trend OE.

The second topic was the regulatory bodies' oversight of licensee programmes on non-conforming items, including CSFI. A number of commendable practices were identified, including: direct inspection of the supply chain by the regulatory body (RB) as appropriate (2 methods); requirement for vendors to notify both the operating organisation and regulator when significant defects or non-conformances are identified; the early exchange of significant non-conformance information between RBs (including CSFI); direct inspection of licensee commercial grade dedication process; the report to RB of non-conforming parts discovered prior to installation; and regulatory inspections of activities related to the repair and replacement of parts (including requalification of the part or system). [NEA/CNRA/R(2012)1]

### ***NEA Special Topic Meeting on Maintaining and Transferring Knowledge on Operating Experience (2009)***

A knowledge management (KM) programme is the systematic approach to maintaining the corporate knowledge of an organisation. Many companies have integrated knowledge management into their company strategies. For a business, the loss of knowledge could lead to important financial losses or insolvency. For a regulatory body and the nuclear industry, the loss of knowledge could lead to a re-occurrence of a previous event. When considering an active KM approach there are three levels to consider: the corporate level, the group level and the individual level. These levels include both the sources of knowledge as well as the recipients of knowledge in the knowledge transfer process. Various knowledge management approaches use databases and networking tools as main entries. These databases must be well structured for retrieval to support newcomers in their search for wisdom. To be effective, an active knowledge management approach should be integrated into day-to-day work. Knowledge management can be divided into three different stages: knowledge gathering, knowledge transfer and knowledge storage. For all these stages various tools and procedures exist to facilitate knowledge maintenance. For operating experience, the "know what" is easier to transfer in training. However, it is the "know why" that is the tacit knowledge that is more difficult to transfer and is critical to prevent event re-occurrence. [NEA/CNRA/R(2012)1]



## 4. Conclusions

Of the 245 event reports that were submitted to the IRS database for the period 2009 to 2011, over half of these were selected as being very significant with specific learning points that should be included within this edition. It is important to note that only a very small number of events can be characterised by a single failure or error and there is a significant overlap among these categories with many events having common issues.

The IRS system in conjunction with other reporting systems continues to be an important tool in improving NPP operational safety through the effective application of operating experience which, if used appropriately, can help avoid repeated failures.

For example, prior to the accident at the Fukushima Daiichi NPP, there had been a similar event which occurred six years earlier when a tsunami caused by an earthquake off the coast of Sumatra, hit the east coast of India affecting a two-unit nuclear power plant. This event highlighted that external hazards may lead to multiple system failures in a plant, and that because these types of events cannot be prevented, plant design must take account of the challenges they pose. The vital functions of the plant (e.g. criticality control, removal of residual heat and containment) have to be ensured through all these hazards. Following this incident, the Indian regulatory body required that tsunami events of a significant magnitude be reviewed and considered in the design, operation and siting of existing and future nuclear facilities

The main conclusions that can be drawn from this edition are the following:

- During this review period, it was noted that the quality of IRS reports has improved substantially in recent years. Reports submitted are more detailed, identify the direct and root causes of events and the lessons learnt from them. Many of the reports now submitted to the IRS database include attachments, diagrams and pictures which assist the user to fully understand the issues and causes of the event and more importantly what actions need to be taken to avoid reoccurrence. Regulatory authorities and operating organisations of several member states are issuing more generic reports with comprehensive information assessment, giving perspective to the evolution of trends, as well as advice for corrective action programmes. This is a noteworthy good practice encompassing substantial added value. The submission of such generic reports is encouraged from all member states, as this is an important source of OE.

- Deficiencies in oversight and monitoring continue to contribute to events in many areas. Surveillance programmes should be reviewed to ensure that they are robust and effective so that safety-related systems and equipment are not compromised particularly with regard to the following areas:
  - i) Procurement of spare parts: Vendor and manufacturers recommendations must be reviewed and assessed with regard to the procurement of equipment and spares.
  - ii) Modifications, installation and design considerations: It is important that any modification or installation of a modification to plant systems or components are designed and implemented in such a manner that the safety of the plant as well as the safety of workers and environment is not degraded; they should also take into account the original design basis.
  - iii) Inspection processes: Surveillance programmes need to be periodically revisited to ensure that the results are representative of current plant conditions.
  - iv) Plant fundamentals: Plant personnel, at all levels of experience, should understand indications associated with normal plant operations to the extent that they can readily identify abnormal conditions.
- Radiological protection is important and personnel at all levels of the organisation should understand that even routine activities on non-safety related systems can impact reactor and radiation safety. Radiation monitoring and radiological protective measures should be reviewed. Additionally, instruments used to identify radiological conditions must be regularly calibrated.
- External hazards create a challenge to any plant, especially when the plant has been operating for a significant number of years. Effective management, close co-operation with local authorities and grid companies, as well as efficient use of operating experience could prevent these events or minimise their consequences.
- Ineffective use of operating experience, human performance issues and poor safety management has resulted in a significant number of events. Root cause analysis should be performed in a timely manner and should take account of previous operating experience to avoid reoccurrence of events. Human errors have been shown to lead to significant transients. Management should ensure that emphasis is given to training; procedural development and adherence; resolution of latent failures; and the awareness and understanding of risks and error likely situations to significantly reduce incidents. Operating organisations should ensure that management oversight is improved, safety culture is enhanced, and management expectations are clearly communicated in a timely manner to preventing events in this area.

## Abbreviations

AC	Alternate current
AFW	Auxiliary feedwater
BTRS	Boron thermal regeneration system
BWR	Boiling water reactor
CFSI	Counterfeit, suspect and fraudulent items
CRA	Control rod assembly
CRD	Control rod drive
CRDM	Control rod drive mechanisms
DC	Direct current
DIDELSYS	Defence-in-depth of Electrical Systems
ECCS	Emergency core cooling system
EDG	Emergency diesel generator
EU	European Union
FME	Foreign material exclusion
FMI	Foreign material intrusion
HCU	Hydraulic control units
HHSI	High head safety injection
HPECC	High pressure emergency core cooling
I&C	Instrumentation and control
IAEA	International Atomic Energy Agency
INES	International Nuclear and Radiological Event Scale
IRS	International Reporting System for Operating Experience
KM	Knowledge management
NEA	Nuclear Energy Agency
NPP	Nuclear power plant
OECD	Organisation for Economic Co-operation and Development
OEF	Operational experience feedback
PHWR	Pressurised heavy water reactor
PWR	Pressurised water reactor
RCP	Reactor coolant pump
RCS	Reactor cooling system
RHR	Residual heat removal
SCC	Stress corrosion cracking
SG	Steam generator
TDAFW	Turbine driven auxiliary feedwater
UN	United Nations





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The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information.

The NEA Data Bank provides nuclear data and computer program services for participating countries. In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

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## **INTERNATIONAL ATOMIC ENERGY AGENCY**

The International Atomic Energy Agency (IAEA) serves as the world's international governmental forum for scientific and technical co-operation in the peaceful use of nuclear technology. Established as an autonomous organization under the United Nations (UN) in 1957, the IAEA represents the culmination of international efforts to make a reality of US President Eisenhower's proposal in his "Atoms for Peace" speech to the UN General Assembly in 1953. He envisioned the creation of an international body to control and develop the use of atomic energy. Today, the Agency's broad spectrum of services, programmes, and activities is based on the needs of its 154 Member States.

### **Technology transfer**

The Agency works to foster the role of nuclear science and technology in support of sustainable human development. This involves both advancing knowledge and exploiting this knowledge to tackle pressing worldwide challenges – hunger, disease, natural resource management, environmental pollution, and climate change. A substantial part of the Agency's work relates to nuclear power, including its safety and waste management, and ensuring that nuclear technology is being used only for peaceful purposes.

Where appropriate, the IAEA facilitates transfer of nuclear technology to Member States for use in medical, agricultural, industrial, water management, and other applications. Many of these programmes contribute directly or indirectly to the goals of sustainable development and protection of the environment set out in "Agenda 21", of the 1992 UN Conference on Environment and Development. The Agency also has two scientific laboratories where training and research are performed in support of technical co-operation and assistance activities. Many of these activities are conducted in conjunction with the Food and Agriculture Organization (FAO). The Agency cooperates in a joint division with the FAO, promoting applications of isotopes and radiation in food and agriculture. This includes such areas as plant breeding and genetics, insect and pest control, soil fertility, irrigation and crop production, animal husbandry, and food preservation.

### **Nuclear safety**

The future role of nuclear energy depends on a consistent, demonstrated record of safety in all applications. Although the IAEA is not an international regulatory body, its nuclear safety efforts are directed towards creating multilateral, legally binding agreements, which are increasingly important mechanisms for improving nuclear safety, radiation safety, and waste safety around the world. IAEA safety recommendations are used by many countries as a basis for domestic standards and regulations. Codes of practice and safety guidelines have been developed for the siting, design, operation, and quality of nuclear power plants. To strengthen worldwide operational safety further, the Agency performs safety evaluations on request, including on-site review of nuclear power plants by international expert teams.

### **Non-proliferation of nuclear weapons**

As part of the global effort to prevent the proliferation of nuclear weapons, the IAEA verifies that nuclear materials are not diverted away from legitimate peaceful use for military purposes. Once a Member State becomes a party to a safeguards agreement, the Agency's inspectors monitor all declared nuclear material through on-site inspections, remote surveillance, and record verification. Without this systematic safeguards system, trade and technology transfer of nuclear applications would not be possible. To date, there are 223 safeguards agreements in force with 170 states. The IAEA safeguards role is being further strengthened to allow greater detection of any potential diversion of nuclear material.



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# Nuclear Power Plant Operating Experience

The application of lessons learnt from the International Reporting System for Operating Experience (IRS) is an essential element for enhancing the safe operation of nuclear power plants (NPPs) throughout the world. The IRS provides a mechanism for the exchange of information related to the incident, actions taken, root cause analysis and lessons learnt. This feedback on how to adequately remedy, or avoid, possible challenges and precursors is of paramount importance to operational safety. The IRS improves international awareness of potential challenges, actual incidents and "precursors" in NPP operations. The heightened awareness generated by feedback from operating experience has resulted in numerous improvements to equipment, procedures and training in many NPPs. The application of operational feedback also benefits the design of the next generation of NPPs. Operating experience has demonstrated that design modification issues documented in IRS reports can have a significant impact on safety. The IRS is jointly operated and managed by the OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA).

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