Nuclear Power Plant Operating Experience

from the IAEA/NEA International Reporting System for Operating Experience

2015–2017

IAEA
International Atomic Energy Agency

NEA
NUCLEAR ENERGY AGENCY

A Joint Report by the Nuclear Energy Agency
and the International Atomic Energy Agency

Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 2015-2017

NEA No. 7482

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Foreword

Incident reporting is a key aspect in the operation and regulation of all public health and safety-related industries. Diverse industries, such as aeronautics, chemicals, pharmaceuticals and the explosives industries, depend on operating experience feedback to provide lessons learnt, which can then be applied to improve operation, regulation and overall 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 and important lessons learnt that assist in reducing the 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). For the system to be fully effective, it is essential that national organisations allocate sufficient resources to enable the timely reporting of events important to safety and to share these events in the IRS database.

Six previous editions of this report (also called the “Blue Book”) were published in 2000, 2003, 2006, 2010, 2012 and 2018.[i,ii,iii,iv,v,vi] All of these editions have a similar structure and cover experience from 1996 to 1999, 1999 to 2002, 2002 to 2005, 2005 to 2008, 2009 to 2011 and 2012 to 2014, respectively.

Based on comments received on the 2018 edition, the NEA, the IAEA and representatives from IRS member countries undertook a review of the previously established report structure. The aim of this review was to better align the report with the objectives of the IRS and avoid repeating the same categories of events in every edition regardless of the nature of the information on operating experience provided in the IRS reports during the review period.[vii]

The objectives of the IRS are to exchange important lessons learned from operating experience gained in nuclear power plants; to promote feedback on events of safety significance; to help prevent occurrences or recurrences of serious incidents or accidents; and to inform the international nuclear community of potentially safety significant issues.[vii]

A consultants’ meeting was held in Vienna during the week of 2-6 July 2018 to develop a revised report structure – using the guidance provided by the IRS member states representatives who developed the 2018 edition – and a new approach. Using this new approach during the July meeting, the participants reviewed the information contained in the 246 IRS reports submitted by the member states during the 2015-2017 period. They then organised the event information of each report in three main categories using the basic criteria provided by IAEA staff. The three chosen categories were: human performance, equipment issues, and management and oversight.

The participants at the consultants' meeting were also instructed to identify subcategories based on the review of the information provided in the IRS reports. A subcategory entitled "installation and commissioning", for example, under the main category entitled "equipment issues", could be included based on the number and content of the IRS reports provided by member countries during the review period.

The new approach helped identify the most relevant event categories in terms of both the safety significance and the importance of the lessons learnt. The revised report structure was drafted after the review and categorisation of the 246 events. The most relevant event report categories and subcategories were also identified after this review.

At the conclusion of the consultants' meeting on 6 July, participants concurred that the revised structure allowed the report to focus on the most important and safety-significant IRS report information. The widening of the target audience beyond the nuclear power industry and the addition of a glossary were also acknowledged as potential benefits of this new approach.

The new report structure was thus presented and accepted during the annual Technical Meeting of the IRS National Coordinators held in Vienna during the week of 8-12 October 2018.

With the support of the IRS National Coordinators, the IAEA held a second consultants' meeting the following week, between 15-20 October 2018. The work completed during the 2-6 July 2018 consultants' meeting served as the main input to the 15-20 October 2018 consultants' meeting. At this latter meeting, participants were tasked with reviewing the event information within each main category, as well as potential subcategories, confirming any identified trends, verifying the safety significance, extracting the most important lessons learnt, and drafting the text and diagrams for the seventh edition of the Blue Book, which covers the 2015-2017 period.

This seventh edition represents the first application of the new structure, which highlights important lessons learnt from a review of the 246 IRS reports submitted by member countries during the 2015-2017 period.

Table of contents

List of figures

List of tables

Executive summary

In the 2015-2017 period, member states submitted 246 event reports to the International Reporting System for Operating Experience (IRS), which is jointly operated by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA). This section provides an overview of identified common categories with important lessons and information of interest to the broader nuclear community, grouped according to the reported events.

The lessons learnt outlined in this report have been divided into three main categories: human performance, equipment issues, and management and oversight.

Human performance continues to be a major contributor to the events being reported to the IRS. Information provided in the reports illustrates how improvements in operation and maintenance fundamentals, and in training, could reduce the number of human performance-related incidents.

Reports that evoke the conducting of routine/planned maintenance highlight the importance of both adequate maintenance procedure and procedural adherence by maintenance staff. The information provided in the event reports shows that more experienced maintenance personnel may be less reliant on procedures, while less experienced personnel are more reliant on procedures that may have been in use for a long time, without compensating for the presence of minor deficiencies as more experienced personnel may do.

Design issues involving emergency diesel generator (EDG) components and manufacturing issues for EDG replacement parts – with the latter being more common for older EDG models that have been in service for longer periods – continue to be reported to the IRS. One good practice relating to EDG replacement parts that may have prevented multiple EDG failures was highlighted in one of the reports.

Management and oversight improvements can make a significant contribution towards reducing the number of reported events. Oversight of contractors continues to be an area in need of improvement. Efforts to improve contractor training and ensure their compliance with procedures should be considered.

Issues related to the ageing of nuclear power plant components and equipment continue to emphasise the importance of licensees implementing robust ageing management programmes. The reports show that ageing issues are not limited to certain types of components but can affect all the components installed at construction. Ageing mechanisms must therefore be identified and supervised to prevent failures during the expected service lifetime. The ageing management programme should be periodically reviewed and updated when new ageing mechanisms are identified.

Although IRS reports are shared and reviewed by individual member countries, it was noted that repeat events – i.e. similar to those submitted in previous years – were reported during the current period, which would appear to imply that corrective actions taken to address past lessons learnt were not always effectively implemented.

Lessons learnt presented in Chapter 3 were extracted during the review of all of the event reports within a main category or subcategory and are thus general in nature. Six of the event reports were selected and summarised, and are presented in Chapter 4 because they provide specific information that is either new or of higher safety significance. These six event reports provide information relating to the management of external events and beyond-design-basis events, maintenance and ageing management programmes, as well as design and modification.

Chapter 1. The International Reporting System for Operating Experience

1.1. What is the International Reporting System for Operating Experience?

In 1978, the Nuclear Energy Agency (NEA), a semi-autonomous body within the Organisation for Economic Co-operation and Development (OECD), established an international system for exchanging information on safety-related events in nuclear power plants. In 1981, OECD member countries formally approved the operation of this system, called at the time the Incident Reporting System (IRS), and in 1983, the International Atomic Energy Agency (IAEA) extended the system to all its member states with a nuclear power programme. Since then, the IRS has been jointly operated by the IAEA and the NEA. After the creation of the first comprehensive IRS database, the "Advanced Incident Reporting System" in 1995, the responsibility for the handling information on events (including quality checking) was transferred to the IAEA.

In 2009, to reflect the evolution of the IRS to a system that included an expanded view and use of operating experience feedback, the name of the system was revised to the "International Reporting System for Operating Experience", with the system retaining the abbreviation IRS.

The IRS is a worldwide system designed to complement national programmes on operating experience. The information reported is assessed, analysed and fed back to all interested parties in the nuclear industry so as to help prevent similar event occurrences. The ultimate objective is to enhance the safety of nuclear power plants globally by reducing the frequency and severity of safety-significant events. Currently, 35 countries with nuclear power programmes participate in the IRS (see Table 1.1).

It should be emphasised that the IRS database contains high quality reports describing events with safety significance and lessons learnt relevant for the international community. The IAEA is currently reviewing its manual for IRS coding to provide member states with more guidance on the types of events that should be reported to the IRS.[viii] The main objective of the IRS is to encourage member states to share operating experience with other member states. It is important to identify and report on low-level events and near misses as well as recurrent events. The IRS can also be helpful in identifying significant event precursors. Precursors are conditions of apparently 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 these precursors can be facilitated and appropriate actions can be taken to mitigate their consequences.

Operating experience is therefore a key element of the "defence-in-depth" philosophy, which is a fundamental building block for safety throughout the nuclear power industry.

The role of the IRS was reinforced by the obligation under Article 19 of the Convention on Nuclear Safety of contracting parties to take the appropriate steps to ensure that programmes 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 organizations and regulatory bodies.

Table 1.1: **Countries participating in the IRS**

Argentina	Germany	Romania
Armenia	Hungary	Russia
Belarus	India	Slovak Republic
Belgium	Iran	Slovenia
Brazil	Italy	South Africa
Bulgaria	Japan	Spain
Canada	Korea	Sweden
China	Lithuania	Switzerland
Czech Republic	Mexico	Ukraine
Croatia	Netherlands	United Arab Emirates
Finland	Pakistan	United Kingdom
France	Poland	United States

1.2. What are the benefits of the IRS?

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

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 problems related to the safety of nuclear power plants. A recurring event is defined as one that has actual or potential safety significance that is the same as or similar to a previous nuclear industry event (or events) and that has the same or similar causes as the previous event (or events). It can also assist in determining how member states introduce measures to enhance nuclear safety as an answer to the Action Plan on Nuclear Safety, endorsed by IAEA member states in September 2011, to strengthen the global nuclear safety framework in response to the March 2011 accident at the Fukushima Daiichi nuclear power plant.

The IRS database contains event reports that provide detailed descriptions and analyses of the cause(s) of each event that may be relevant to other plants. These analyses may lead to the development and implementation of corrective action(s) by plant management or regulatory authorities.

Countries that participate in the IRS benefit from exchanging information related to the root cause analyses and lessons arising from incidents at nuclear power plants. Feedback on how to adequately remedy or avoid possible precursors is of paramount importance to operational safety.

Another potential use of IRS data is the application of operational feedback in the design of the next generation of nuclear power plants. Nuclear power plant operating experience has demonstrated that design modifications documented in IRS reports can have a significant and positive impact on the design and safety of future plants.

1.3. How can the IRS benefit decision makers?

Decision makers in nuclear operating organisations, regulatory bodies and technical support organisations around the world face a challenging environment that includes deregulation, privatisation and other economic pressures in electricity markets. This environment forces decision makers to seek new strategies and manage risks and resources, while still achieving and maintaining high standards of safety. The IRS contributes by providing information on safety-significant events from the global nuclear community.

In managing risks and resources, decision makers need access to reliable sources of operating experience. Typically, nuclear power plant operators have access to several sources of operating experience, including the IRS and those managed by the operators themselves, while regulatory bodies have access to a more limited number of sources. Decision makers also need credible and reliable system information on which to base the prioritisation of their programmes. To maintain an acceptable level of safety, decision makers need to receive early warning of deteriorating safety performance in the field. They also need to share their experiences and lessons learnt with others and thus make efficient use of their resources.

Regulators require that the industry report on actual or potential hazards so that they can develop effective regulations, requirements, guides or standards, which, when implemented, will limit the risk to the public.

The IRS is a global contact network and forum that enables safety experts around the world to share and review information on lessons arising from reported events. It can provide world experts with information on individual and generic issues of safety significance and advance information on deteriorating safety performance. The IRS can also be used, together with other databases, to prioritise issues of safety significance that have been reported and to identify areas in which further contributions in terms of resources or research would be appropriate.

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

1.4.1. Event reports

Each of the 35 member countries with a nuclear power plant under construction or in operation designates a national IRS co-ordinator. Reporting to the IRS is based on the voluntary commitment of the participating countries. An event report is submitted to the IRS when the event is considered by the national co-ordinator to be of international interest. Events of safety significance and events from which lessons can be learnt should be reported according to the IRS guidelines.

When information is considered time sensitive, a short preliminary report can be distributed within one month of the event. Subsequently, a main report is produced, and in some cases a follow-up report is generated and distributed when additional relevant information becomes available.

The main event report contains basic information, including the title and date of the event, the characteristics of the plant and an abstract. The main event report also includes a narrative description of the event, a safety assessment (the direct causes, consequences and implications), the results of a root cause analysis (if available), corrective actions, lessons learnt, and guide words containing essential information that can be easily searched and retrieved. Often, a written description of the event is supported by photographs and graphics (diagrams of affected parts of the plant, etc.).

When an event or series of events indicates a generic problem, the national co-ordinator may produce a “generic event report”.

1.4.2. Sharing information

Each IRS report becomes part of the web IRS database, which was created to facilitate data input and report availability and speed up access to information. Passwords are provided to users according to their need to know so as to ensure a high level of security. Users are informed by email when a new report is posted on the IRS system. The routine receipt and distribution of reports on events form the basis for in-depth studies on implications and remedies and assist in identifying safety issues common to nuclear power plants.

Given that information shared about the licensing process, construction experience and inspection practices is also helpful to all countries, the NEA has been operating the “Construction experience database” (“ConEx”) since 2008. The objective of the ConEx database is to identify major deficiencies that occurred during the design and construction of nuclear power plants. ConEx can be used to assess the adequacy and supplement, if necessary, current regulatory activities to detect and correct future events and prevent them from remaining undetected until the plant becomes operational. ConEx can also disseminate information to ensure appropriate regulatory attention is given to lessons learnt from past events. In 2019, the NEA Working Group on the Regulation of New Reactors (WGRNR) successfully completed the migration of the ConEx database to the IRS database hosted by the IAEA.

1.5. How is the IRS used?

1.5.1. *Annual meetings*

National co-ordinators meet once each year to review the information received and the operation of the system in general. The committee of national co-ordinators selects, for further analysis, topics and reports of those events that it considers to be of particular safety interest to the international community. The conclusions of the committee are distributed to participating countries. A joint IAEA/NEA meeting to exchange information on unusual events is also held annually with the NEA Working Group on Operating Experience (WGOE). 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.

1.5.2. *Restricted access*

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

1.5.3. *Other systems*

The IAEA and NEA also developed the International Nuclear and Radiological Event Scale in 1990. Its primary purpose is to facilitate communication and understanding among the nuclear community, the media and the public of the safety significance of events at nuclear installations. The scale was later modified to include any event associated with the transport, storage and use of radioactive material and radiation sources.

1.5.4. *Other activities*

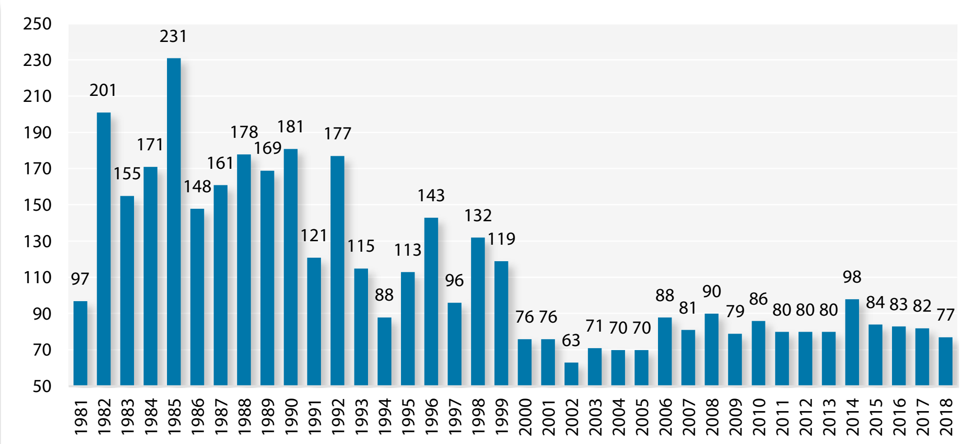
Activities within the IRS extend beyond the exchange and feedback of event information. Both the NEA and the IAEA have assigned experts that meet annually and discuss the safety relevance of IRS events, the regulatory perspective and the application of any lessons learnt. In addition, the European Union Clearinghouse[1] develops topical studies based on IRS reports.

1 The European Union Clearinghouse is a regional network that was established to enhance nuclear safety through improvement of the use of lessons learnt from operating experience. Membership is mainly composed of nuclear safety regulatory authorities and technical support organisations within the European Union. The clearinghouse is based in Petten, the Netherlands.

1.6. What has been achieved?

There are currently more than 4 300 event reports within the IRS system. Additional events are added at a rate of approximately 80 per year. The annual reporting rate since 1980 is shown in Figure 1.1.

Figure 1.1: **Annual reporting rate since 1981**



The reports are made available in a user-friendly, web-based system, with a full-text database and a powerful search engine to allow full-text searching. The enhanced capacity for data input, storage and access to written, numerical and graphical information has improved the reporting and subsequent analytical capabilities of the database 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.

Chapter 2. Description of the three main categories and of the related subcategories

All of the 246 reports submitted by member countries to the International Reporting System for Operating Experience (IRS) during the 2015-2017 period were first reviewed and grouped within three main categories: human performance, equipment issues, and management and oversight. The three main categories are defined as follows:

2.1. Human performance

Events either caused or aggravated by human error(s) and/or the behaviour(s) of nuclear power plant personnel, including licensed operators, maintenance and engineering personnel, and contractors.

Examples of events attributed to the human performance category include:

- events involving poor verbal communication (e.g. misunderstanding of instructions, poor radio communication);
- events involving the incorrect operation or positioning of plant equipment (e.g. valve not fully closed, incorrect switch selection, equipment not returned to service after maintenance);
- events involving a lack of procedural adherence (e.g. failure to follow approved operating, maintenance and safety procedures);
- events involving deficient work practices (e.g. complacency, lack of independent verification, incomplete shift turnover, use of improper tools);
- events involving a lack of training and qualification (e.g. lack of knowledge, deficient skills, lack of familiarity with a task).

2.2. Equipment issues

Events either caused or aggravated by the failure or loss of function of equipment within a plant system. The failure or loss of function may involve instrumentation, mechanical, electrical or computer equipment linked to a safety or safety-related function.

Examples of events attributed to the equipment issues category include:

- events involving the failure of a sensor, transmitter or controller;
- events involving the failure of a pump, compressor, valve, pipe, seal, fitting or hanger;
- events involving the failure of switchyard equipment, cables, circuit breakers, fuses, motors, generators, relays, connectors or hand switches;
- events involving the failure of safety or safety-related computer hardware or software.

2.3. Management and oversight

Events either caused or aggravated by organisational deficiencies, management direction and decision making or lack of supervisory oversight. Organisational policies, programmes, processes, procedures, roles, responsibilities, expectations, staffing, plans and priorities are all included in this category.

Examples of events attributed to the management and oversight category include:

- events involving procedural deficiencies or the absence of procedures (e.g. operating, maintenance and safety procedures);
- events involving deficiencies in the maintenance programme (e.g. maintenance plans and schedules, work package preparation, routine planned/preventive maintenance);
- events involving deficiencies in the qualification and training programme (e.g. training does not match the job requirements, personnel training and qualification records are not maintained);
- events involving the presence or perception of production or time pressure;
- events involving a lack of supervisory oversight.

Some of the 246 IRS reports submitted during the 2015-2017 review period may have been categorised within more than one category based on the information provided in the report. For example, an event caused by an equipment failure that resulted from a manufacturing defect would only be categorised within the category "equipment issues" provided there were no other contributing factors involved in the event. An event caused by a similar equipment failure may also be included within the category "management and oversight" if the IRS report attributed the equipment failure to the maintenance programme and procedure deficiencies. This was done to ensure none of the event information would be overlooked later during the development of this edition of the Blue Book.

During the review of the event reports, subcategories were identified based upon the number and frequency of certain types of events (e.g. procedural deficiencies, training issues, instrumentation failures), identified trends (e.g. common-mode events, fuel handling and storage issues, obsolescence issues), safety significance, and the importance of lessons learnt. The lessons learnt presented in Chapter 3 were extracted during the review of all of the event reports within a main category or subcategory and are thus general in nature.

Additionally, the data presented in the figures included in Chapter 3 have no statistical significance regarding the safety level of the nuclear power plants operated within the member countries. In particular, the number of reported events cannot be used as a quantifying measure of good operating practices, and increases or decreases in the number of reported events cannot be associated with a variation in safety level compared with the previous years. As the purpose of the IRS database is to share operating experience and lessons learnt to improve safety, no comparison is made between countries, types of reactors, operating practices, etc. Values and statistics mentioned in this report are only used to describe the events reported to the IRS during the 2015-2017 period in a macroscopic manner, according to predefined and recorded coding in the IRS database. The main purpose is to identify additional lessons from the trends and to give more sense to the lessons learnt from the IRS reports. It is also important to note that more than one IRS code from a single set may be applied to a single IRS report based on the complexity of the event information included in the report.

Finally, six specific event reports with information of special interest, such as new findings or issues of potentially higher safety significance, were identified, summarised and included in Chapter 4 of this report.

Chapter 3. Experience and lessons learnt from the IRS during the review period

The International Reporting System for Operating Experience (IRS) event reports involving deficiencies in human performance, equipment and management issues are denoted in the IRS database using a set of detailed codes that are listed in the International Atomic Energy Agency (IAEA) Manual for IRS Coding entitled *Services Series 19*.[viii] These codes form part of the IRS report and are used to facilitate searches and retrievals that may be required to support trend analyses or topical studies.

3.1. Human performance

As is often highlighted in various IAEA publications, including the IRS guidelines, safe plant operation and effective maintenance are the result of qualified and well trained plant staff, adequate procedures and tools, and good management.[viii] Deficiencies in human performance usually weaken defence in depth, which may in turn result in the degradation or loss of safety-related systems or in challenges to safety systems resulting from transients caused by component failure or loss of operational control.

A total of 153 events involving human performance issues were reported to the IRS during the 2015-2017 period. The number of IRS reports related to human performance has remained stable over the last ten years, with approximately 50 event reports per year (Figure 3.1). In the 2015-2017 period, 62% of the submitted reports were related to human performance issues.

Figure 3.1: **Number of IRS reports related to human performance issues (2008-2017)**

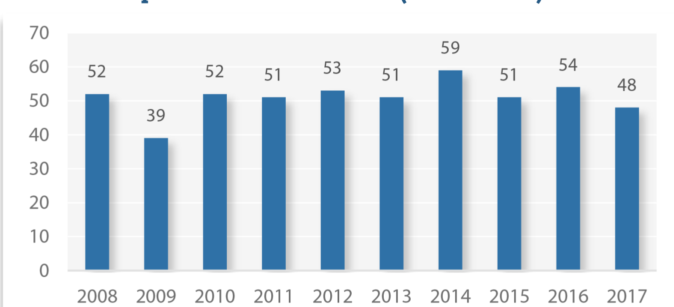


Figure 3.2 provides the breakdown of human performance events by predefined guide words (IRS codes) and shows the number of times each code was applied to the event reports submitted during the 2015-2017 review period.

Figure 3.2: **Human performance guide words (IRS codes) (2015-2017)**

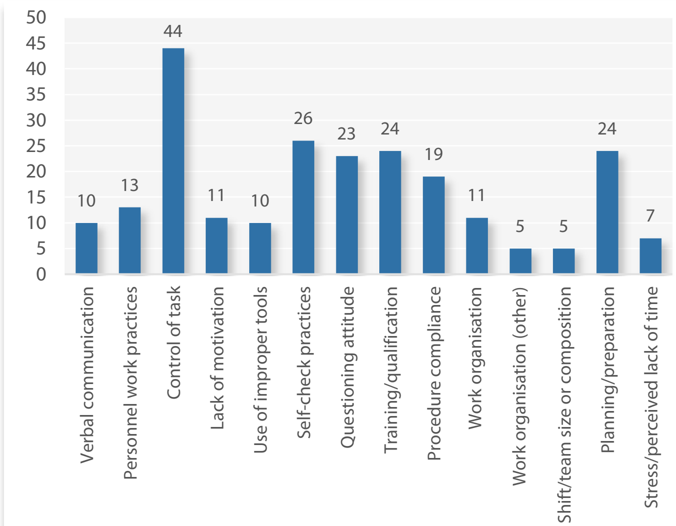
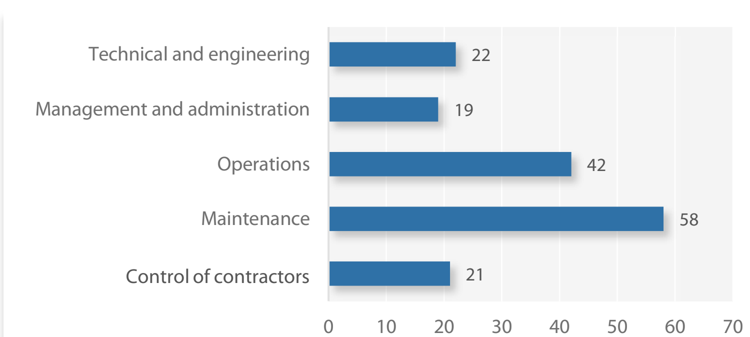


Figure 3.3 shows the number of times a specific work group was identified as being involved in a human performance event reported to the IRS.

Figure 3.3: **Specific work groups involved in human performance-related events (2015-2017)**



It is important to note that more than one human performance factor may be applied to a single IRS report, and that IAEA staff reviews the coding of each report to improve consistency.

The coding data shown in Figures 3.2 and 3.3, combined with the review of the report information, identified four human performance subcategories: operating practices, maintenance practices, procedural adherence, and training and qualification.

Each of the IRS reports linked to these four human performance subcategories was reviewed in more detail to identify any trends, and evaluate the safety significance and importance of lessons learnt.

3.1.1. *Operating practices*

Nuclear power plant personnel assigned to operations have a direct impact on the operation of the plant and its associated systems and components through the conduct of operational activities.[ix] These operational activities must therefore be conducted in a safe, effective and professional manner in accordance with established procedures, requirements and the fundamental safety principle of defence in depth.

Lapses or deficiencies in the conduct of operational activities may cause unnecessary plant transients or put the plant in a state that is outside the established operational limits and conditions. The IRS reports involving lapses or deficiencies in the conduct of operational activities are clearly identified by the set of detailed codes listed in the IAEA Manual for IRS Coding.[viii]

Based on the IRS coding and on the review of the reports, a total of 32 reports involving deficiencies with operating practices were identified for the 2015-2017 period. There is no statistically significant change in the number of reports involving deficiencies with operating practices over the last ten years (Figure 3.4).

Figure 3.4: **Number of IRS reports related to operating practices (2008-2017)**

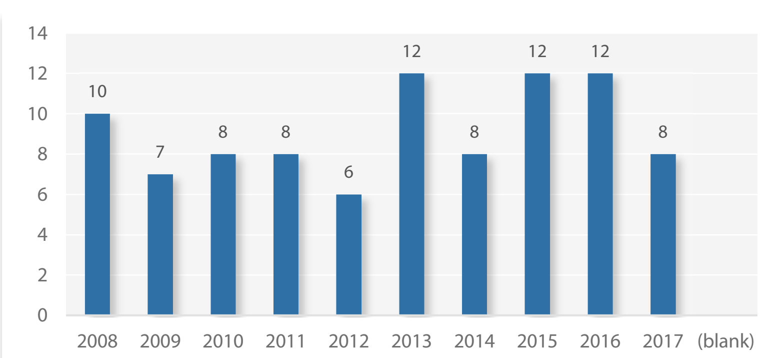


Figure 3.5 shows the number of operating practices events for the 2015-2017 period broken down by specific operating practice.

Figure 3.5: **Deficiencies in operating practices (2015-2017)**

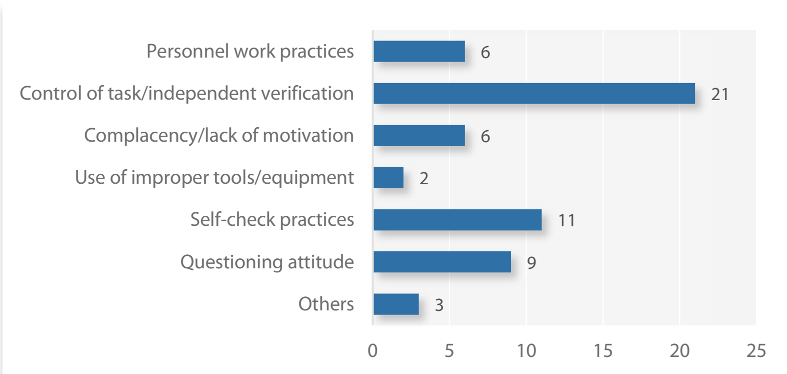


Figure 3.5 shows that the factors most frequently involved in operating practice deficiencies are control of task/independent verification, self-checking practices, a questioning attitude and personnel work practices. In addition, it appears that many operating practice deficiencies occur when isolating/de-isolating systems, and during routine testing.

The remainder of this section highlights the human performance lessons learnt that are related to operating practices and were extracted from the relevant IRS event reports.

Operating practices – lessons learnt

- It is important for the leadership of the operations department to reinforce the consistent application of operator fundamentals and to correct any identified performance gaps within the operating crews.
- It is important for all operating staff and contractors to remain focused on standards and expectations as they relate to attention to detail and configuration control.
- It is important for operators to develop and maintain a questioning attitude.
- It is important for operations personnel to perform double verification when conducting operational activities on systems involving risks to the plant's safety and stability.

- It is important for operations management to define unambiguously the responsibility for the control of the unit. Control room supervisors should maintain their supervisory role over the control room operators and not become actively involved "at the controls" where they could potentially lose sight of the overall status of the plant.
- It is important to develop operator's critical thinking and personal commitment to safety as a priority.
- It is important for plant management to promote the effective communication of operational information, both face to face and when using telecommunication equipment.
- It is important for the operations management and personnel to review operational diagrams prior to performing electrical switching operations. The results of the operational diagram review should be used when preparing for and performing electrical switching operations at nuclear power plants.
- It is important to take appropriate safety measures when either working on, or in the vicinity of, operating equipment. Both operations management and personnel should develop a solid understanding of potentially dangerous and/or high-risk plant situations, which may arise should errors be made during the conduct of the intended operational activity.

3.1.2. ***Maintenance practices***

The range of maintenance programmes, activities and practices includes servicing, overhaul, repair and replacement of parts, testing, calibration and inspection.[x] These programmes are crucial to the safe operation of nuclear power plants. These programmes ensure not only that the levels of reliability and availability of all plant structures, systems and components (SSCs) that have a bearing on safety remain in accordance with the assumptions and intent of the design, but also that the safety of the plant is not adversely affected after the commencement of operation.

Maintenance activities must therefore be conducted in a safe, effective and professional manner in accordance with established procedures, requirements and the fundamental safety principle of defence in depth. Lapses or deficiencies in the conduct of maintenance activities may cause unnecessary plant transients or put the plant in a state that is outside the established operational limits and conditions.

Based on the IRS coding and on the review of the reports, a total of 22 reports involving deficiencies with maintenance practices were identified for the 2015-2017 period. There is some statistical variation in the number of reports involving deficiencies with maintenance practices over the last ten years; however, it has not been significant for the last three years (Figure 3.6).

Figure 3.6: **Number of IRS reports related to maintenance practices (2008-2017)**

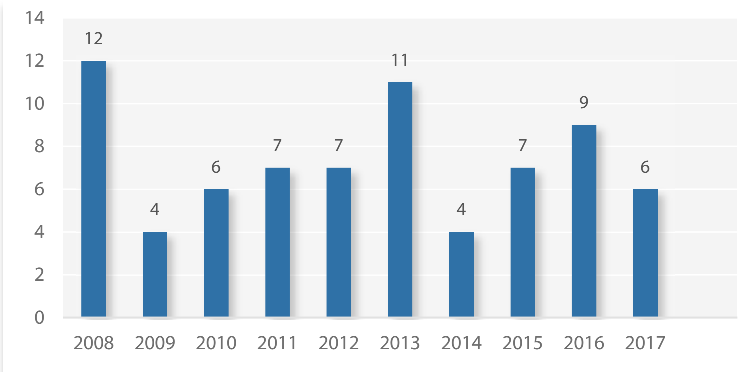
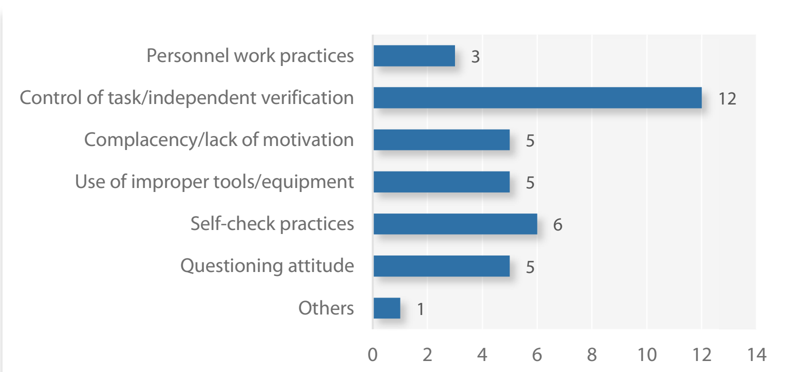


Figure 3.7 shows the number of maintenance practices events for the 2015-2017 period broken down by specific maintenance practice.

Figure 3.7: **Deficiencies in maintenance practices (2015-2017)**



The remainder of this section highlights the human performance lessons learnt that are related to maintenance practices and were extracted from the relevant IRS reports.

Maintenance practices – lessons learnt

- The importance of maintaining a questioning attitude and conservative decision making as tools for improving human performance should be emphasised.
- It is important to perform very careful planning before the beginning of any maintenance activity involving a barrier intended to prevent the release of fission products.
- Routine activities can cause unforeseen events when equipment is not properly restored to service after corrective maintenance. It is important to perform a safety and risk analysis before conducting online plant maintenance in order to ensure that all potential consequences on plant operations are identified and understood.
- It is important to analyse and capture all the risks involved with maintenance, from the preparatory phase to the return to service phase of the system concerned. In this respect, it is important to draft detailed procedures for the various phases of the work, in particular for the activities associated with restoring the system alignment during the return to service phase.
- Effective processing of lessons learnt from operating experience feedback associated with previous similar events is necessary and must not be limited to the recent past.
- When poor quality of maintenance is discovered on a piece of equipment, it is important to inspect all identical equipment as soon as possible, along with equipment with the same system configuration. Failing that, any deviation in work conditions must undergo appropriate examination of the potential impact of the new configuration.
- It is important to take precautionary measures during maintenance work in restrictive or confined spaces where inadvertent contact can be made with valves, switches and other important safety-related equipment. Maintenance supervisors and personnel should evaluate and understand past operating experience related to working in tight or confined spaces in order to avoid similar and repeat occurrences in the future.
- Training on safety culture principles and requirements should also be provided to contractor personnel performing maintenance activities in the plant.

Maintenance practices that impact radiological controls – lessons learnt

- It is important to consider the size of the work area when analysing the risk of an activity with implications for radiological protection. Work in a small area increases the likelihood that workers will become contaminated through contact. Small areas also complicate the drafting of precise radiological maps.
- It is important to consistently and thoroughly check for contamination when leaving a work site where there is a risk of contamination. Such checks provide precise contamination monitoring and, through prompt detection, can reduce the skin dose received by workers who may have been contaminated.

- Wearing a ventilated protective suit combined with the cramped conditions of some work sites may lead to worker fatigue. This may result in the worker exiting an area quickly without performing the necessary checks, such as contamination monitoring.

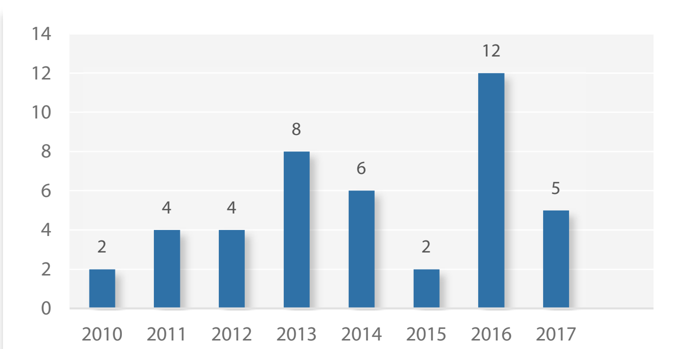
3.1.3. *Procedure adherence*

Operating procedures perform an important function because they are the nuclear power plant documents that provide plant staff with the instructions that they are required to follow in order to safely operate the plant during normal, abnormal and emergency conditions. The correct use of written operating procedures is therefore an important contribution to the safe operation of nuclear power plants since they can affect all aspects of nuclear plant operations.

When verbal and/or written instructions are used in operational practice at a nuclear power plant, administrative procedures should be in place to ensure that the verbal and/or written instructions do not diverge from the established operating procedures and do not compromise established operation limits and conditions.[xi]

Based on the IRS coding and on the review of the event reports, a total of 19 event reports involving procedural adherence were identified for the 2015-2017 review period. Figure 3.8 shows an apparent increase in the number of reported events relating to procedural adherence.

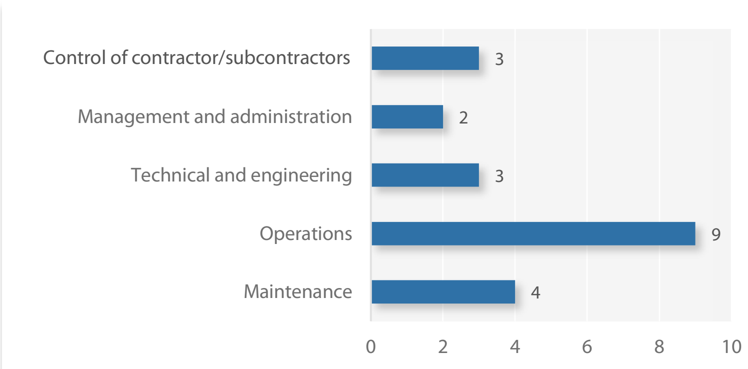
Figure 3.8: **Number of IRS reports related to procedural adherence (2010-2017)**



The reports considered in this group were caused by the failure of plant personnel to follow approved and correct procedures.

Figure 3.9 shows the number of times a specific work group was identified as being involved in the procedural adherence events reported to the IRS.

Figure 3.9: **Work groups involved in events relating to procedural adherence (2015-2017)**



The review of the reports grouped under this category shows staff did not follow plant procedures in many areas, including maintenance, system alignment, refuelling activities and spent fuel storage; however, an important number of them involved operations staff.

The reports also show that experienced plant personnel are susceptible to deviation from approved procedures. Several of the events resulted from a failure to understand the procedural requirements, while in other cases it appears that plant personnel purposefully took actions outside of procedures. In many of these events, the procedural guidance that could have led to the correct action was available to plant personnel, but a failure to understand the plant response led plant personnel to take non-conservative actions.

Several events involved procedures that were either misunderstood, misinterpreted or ignored by operators, even though the procedures had been correctly followed for years without incident. In other cases, operations personnel appear to have been working around the procedures without a complete understanding of the adverse impact that their actions and decisions could have on plant safety.

The review of the events grouped in this category highlights the need for a comprehensive, complete and accurate set of operating procedures, as well as the importance of procedural adherence to the safe operation of nuclear power plants.

The remainder of this section highlights the human performance lessons learnt that are related to procedure adherence, as extracted from the relevant IRS reports.

Procedure adherence – lessons learnt

- Operators at nuclear power plants should ensure documented and approved procedures are followed. Management may consider placing emphasis on procedural adherence in training, programmes (e.g. simulator training), planning meetings and pre-job briefings to ensure it forms part of the organisational culture.
- Once an operations procedure adherence issue is identified, it is important for plant personnel to perform a prompt human performance evaluation to determine why the procedure was not followed correctly.
- It is important to recognise that procedural adherence issues have resulted in errors involving safety-related equipment and system line-up, and these errors could have resulted in safety-significant events. Procedures that govern the conduct of operational activities should be sufficiently robust to minimise occurrences involving incorrect safety-related equipment and system alignments.
- Some event reports show staffing levels (either too few or too many) may have negatively impacted the ability of staff to follow operating procedures. It is important for operators to ensure that the implementation of procedures is performed with the appropriate number of duty operations personnel.
- It is important to avoid the development of a culture of "defect tolerance" or "defect acceptance" as it relates to both the plant equipment and procedures.

3.1.4. *Training and qualification*

In order to achieve and maintain high levels of safety, nuclear power plants are required to be staffed with an adequate number of highly qualified and experienced personnel who are duly aware of the technical and administrative requirements for safety. To establish and maintain a high level of competence, appropriate staff training and qualification programmes should be in place at the plant and kept under constant review to ensure their relevance.[xii]

The IRS reports involving procedures are clearly identified by the set of detailed codes.

Based on the IRS coding and on the review of the event reports, a total of 27 event reports involving deficiencies in training and qualification were identified for the 2015-2017 period. There is no statistically significant change in the number of event reports involving deficiencies with training and qualification over the last ten years (Figure 3.10).

Figure 3.10: **Number of IRS reports related to training and qualification (2008-2017)**

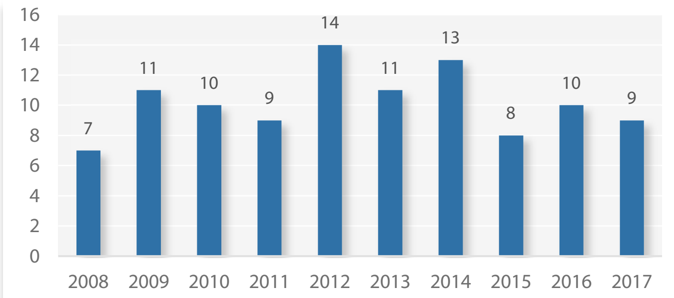
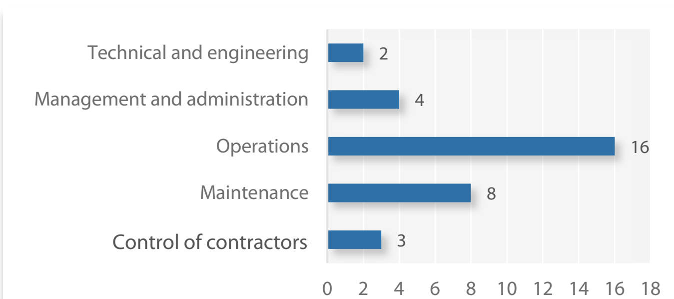


Figure 3.11 shows the number of times a specific work group was identified as being involved in the training and qualification events reported to the IRS.

Figure 3.11: **Work groups involved in training and qualification events (2015-2017)**



During the 2015-2017 time period, operating organisations identified situations where the operations crews were challenged by abnormal situations and simultaneous failures that revealed training deficiencies. Examples of the type of training used in response to abnormal situations include:

- Extensive use of the simulator, mainly focused on start-up and shutdown operations, with specific training on simultaneous and concurrent malfunctions.
- Training operations personnel to control the unit during anomalies in conjunction with equipment failures.
- Comprehensive operator training, including training on a full scope simulator with replica control room operating consoles, which are closely representative of the plant for which the operators are licensed.

- Training operations personnel on the actions required in response to loss-of-voltage events, not only on vital electrical buses but also on non-vital buses, which may have a significant impact on the operability of non-safety classified instrumentation and control systems. Loss of these systems may challenge the ability of operations personnel to implement the actions required to minimise the impact of such an event on plant operation.
- Training scenarios incorporating a sustained loss of instrument air provide a valuable opportunity to verify the accuracy and completeness of procedures, and prepare operations personnel, both in the control room and in the plant, to respond to this complex event.
- Training on weaknesses involving the response to the loss of the reactor protection system bus.
- Providing operations personnel with information on the potential consequences of plant parameters exceeding normal operating ranges in order to create sufficient awareness and ensure appropriate focus when monitoring plant parameters.
- Special training to improve the understanding of the core physics beginning/middle/end of cycle, and poisoning effects.
- Training of operations personnel and support staff (including firefighting intervention team members) on the execution of local actions required by event response and emergency operating procedures.

The remainder of this section highlights the human performance lessons learnt that are related to training and qualification, as extracted from the relevant IRS reports.

Training and qualification – lessons learnt

The review of event reports reveals training is often a reactive response to events involving human performance deficiencies. Several types of training have been developed and implemented as a corrective action intended to minimise event recurrence:

- Training focused on standards and expectations related to attention to detail and to configuration control.
- High intensity training programme during an extended shutdown to improve operations procedures and address perceived weaknesses in operator fundamentals, such as procedural use and adherence, communication, and appropriate understanding of the roles and responsibilities of the different positions.
- Refresher training programmes for field operators. Such a programme emphasises procedure adherence and conservative decision making.
- Initial and ongoing training programmes for mechanics on the following topics: “self-monitoring when working on safety and safety-relevant equipment and systems”, “developing personal attitudes of responsibility”, and “critical thinking”.

- Training on the principles of safety culture.
- Training personnel in plant departments who are to be responsible for acceptance of the work performed by the contracted companies.
- Training to improve knowledge of material essential to properly understand a defect.
- Reviews of reference manuals and handbooks provided by the manufacturers conducted when developing maintenance procedures and maintenance personnel training programmes.
- Plant personnel being provided with relevant design-basis information, including the specific environmental qualification requirements of the equipment they handle, operate and maintain. The intent of this training is to help plant personnel maintain compliance with the plant design basis when conducting maintenance activities.
- Maintenance personnel training focused on the identification of key equipment maintenance risks.
- Training to prevent the weakening or loss of overall team experience resulting from the personnel "generational change". This training includes mentoring during task performance, improving procedures using experience feedback from the older to younger generations of plant workers, and improving procedures for equipment control and post-maintenance acceptance.

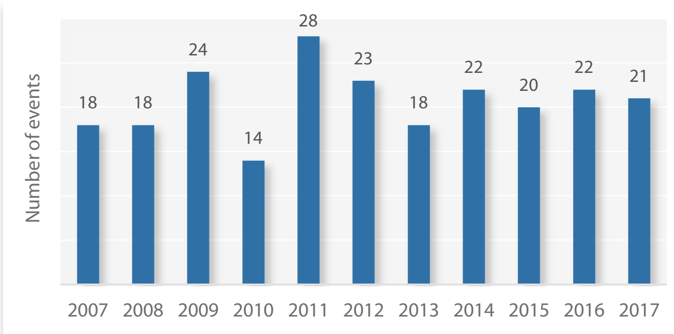
3.2. Equipment issues

The availability and reliability of all plant structures, systems and components (SSCs) that have a bearing on safety must be maintained in accordance to the assumptions and intent of the design to ensure the safety of the plant is not adversely affected by the commencement of operation. Therefore, each nuclear power plant's design organization should establish and implement a management system for ensuring that all safety requirements established for the design of the plant are considered and implemented in all phases of the design process and that they are met in the final design. This system will ensure continuing safety of the plant design throughout the lifetime of the nuclear power plant.[xiii]

Although nuclear power plants are designed and operated by considering all of the safety requirements documented in the national and international regulations, operational events caused by equipment issues may occur for several reasons, including design deficiencies, manufacturing defects, improper installation, operation outside of design parameters, improper surveillance and maintenance, premature ageing and degradation, and improper equipment alignment.

Figure 3.12 shows that the number of IRS reports related to deficiencies in design has remained stable over the last ten years, with approximately 21 event reports per year.

Figure 3.12: **Number of IRS reports related to deficiencies in design (2007-2017)**

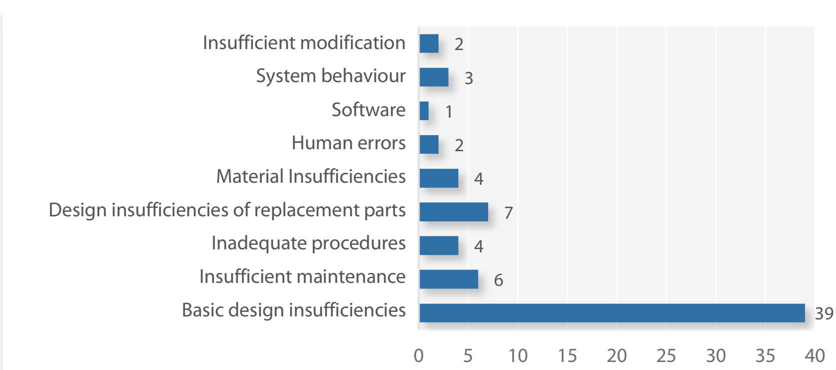


The review of the 246 event reports submitted during the 2015-2017 period identified 2 subcategories related to equipment issues: design and modification, including installation and commissioning, and emergency diesel generators. These subcategories were selected based on the number and nature of the events, as reported by member countries.

3.2.1. *Design and modifications*

A total of 63 event reports, involving equipment issues related to deficiencies in design and modification, were reported to the IRS during the 2015-2017 period. Figure 3.13 shows the breakdown of the types of events reported to the IRS during the 2015-2017 review period.

Figure 3.13: **Types of design and modification deficiencies identified in the event reports submitted to the IRS during the 2015-2017 period**



Many of the equipment design and modification issues relate to real or potential external factors such as seismic events, marine life impeding water intake or severe cold conditions. One report relates to inaccurate calculations used in the design of cooling water trains, which were unable to detect the erosion of safety margins. Other reports describe deficiencies in the design requirements of an electronic control mechanism, or improper maintenance, testing and installation, and the design of circuit breakers.

There were also reports of modifications of previous designs using similar components without a complete understanding of the original design requirements, as was the case for steam generator tube replacements and steam generator hot collector vent pipes.

There was also a report suggesting that the hazards from a high energy arcing fault may pose substantially greater risks for electrical equipment containing aluminium components than for equipment containing only copper components.

The remainder of this section highlights the equipment issues relating to design and modifications, and installation and commissioning lessons learnt that were extracted from the relevant IRS reports.

Design and modification – lessons learnt

- It is important to conduct periodical technical reviews of the design basis in light of the latest geological data, and to implement improvements as required to ensure all structures of a nuclear power plant have the required seismic resistance.
- It is important to design nuclear power plants' water intake systems by fully considering the potential changes in the marine environment and potentially increasing the capacity of the water intake filtration systems to be able to safely deal with such external events.
- With regards to operating inside the technical specification limits, it is important to review the surveillance test methodology in order to ensure that diminished safety margins and their potential impact on safety are promptly detected.
- It is important to conduct a technical review of the design and installation of instrumentation cabinets located outdoors and to confirm their operability in severely cold conditions by ensuring the cabinets are properly sealed and heated.
- It is important to conduct a technical review of the design of high voltage electrical equipment to determine whether a greater than expected high energy arcing fault could occur and whether surrounding electrical equipment could be jeopardised by such an event.
- Given the occurrences of several fires that impacted safety systems because of improper maintenance, testing and installation, and design of circuit breakers, it is important to improve the design and oversight of circuit breakers in the design analysis as they are an integral part of the power supplies.

- It is important to perform proper design reviews, installations and maintenance of electrical switches and electronic cards.
- In cases where reverse engineering techniques are used to manufacture obsolete components, it is important that full compliance with the design requirements and quality assurance criteria is ensured for the quality and reliability of safety-related components.
- It is important to select the proper material for heat exchanger tubes during the design phase, as well as control the water chemistry during plant operation.
- It is important that the tube sheet joint welds be designed and manufactured with a full understanding of the design codes (e.g. ASME Code) and rules.
- It is important to improve industry guidance in order to prevent design control issues, such as the thermal-hydraulic modelling of the steam generators that cause steam generator tube degradation and ultimately lead to tube leaks.
- It is important to perform in-depth analysis for design modifications. A deviation from the original design specifications and improper monitoring of a steam generator hot collector vent pipe resulted in corrosion, leakage and the release of radioactivity to the atmosphere. It is important that the field location ambient temperature characteristics are taken into account when steam generator safety valve pressure switches are set. In one report, the original setting was done at an ambient temperature of 20°C while the field location's ambient temperature ranged from 45°C to 56°C.
- Deficiencies in the design requirements following a design modification of an electronic control mechanism impacted the safe operation of pilot operated pressuriser relief valves in several separate instances a few years apart. This underlines that particular attention should be paid when preparing and implementing modifications even when they are supposed to improve the safety of a facility. It also highlights the importance of the proper integration of operating experience feedback in the analysis of the potential impact of plant design modifications.

Design and modification issues related to installation and commissioning – lessons learnt

- It is important that distances between decoupled structures that are intended to cope with the impacts of design extension conditions (e.g. plane crash) should be considered in the design and arrangement of systems and components fitted to the structures. Broken and damaged threaded bolts were reported to have come off the mount of a ventilation duct that was flanged to a fire damper in a bunkered emergency feed building. The building hosted electrical cabinets for the reactor safety system, which could be damaged in the case of aircraft crashes and further beyond-design-basis hazards.

- It is important that reference manuals and handbooks be reviewed when developing maintenance procedures and designing training programmes for components (e.g. electronic components) to ensure plant personnel are aware of relevant design basis information, including environmental qualification requirements.
- It is important that cable trench penetrations into buildings be sealed after installation of cables at the construction stage to prevent external flooding.
- It is important to maintain the separation of control cables for safety-related divisions, as well as between safety-related and process systems at all times.

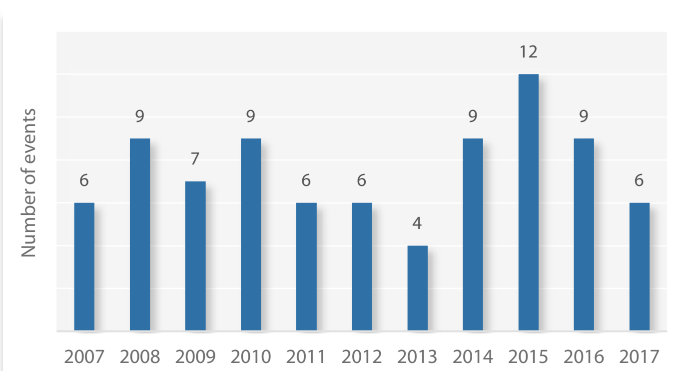
3.2.2. *Emergency diesel generators*

To ensure safety, the design of a nuclear power plant includes an emergency power supply capable of supplying the necessary power in anticipated operational occurrences and design basis accidents, in the event of a loss of off-site power. In some cases, the design includes an alternate power source to supply the necessary power in design extension conditions.[xiii]

Emergency diesel generators (EDGs) are frequently used to meet this requirement. EDGs must be robust, reliable and operable when needed. Despite all the measures applied during the design stage, there are reported instances when EDGs were found to be unavailable because of malfunctions, incorrect system configuration, lack of maintenance, deviations from proven practices and non-adherence to operating procedures. EDG deficiencies are often identified during periodic testing.

Figure 3.14 shows that the number of IRS reports related to EDG deficiencies has remained stable over the last ten years, with an increase in 2015. After the Fukushima Daiichi accident, the emergency power supply equipment became a focal point, and plant operators started to report more on issues related to EDGs.

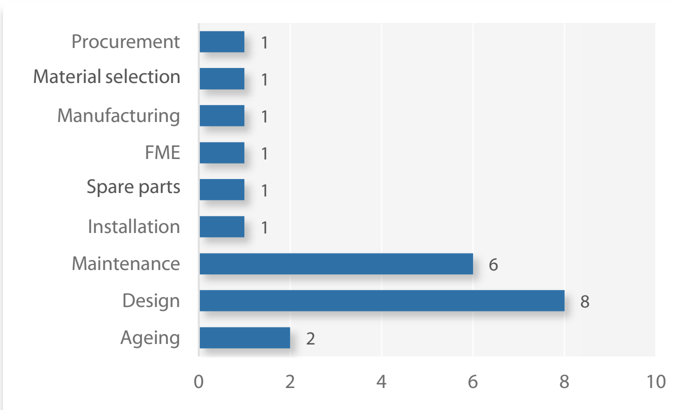
Figure 3.14: **Number of IRS reports related to emergency diesel generator deficiencies (2007-2017)**



A total of 16 reports involving EDG issues linked to deficiencies in design and modification were reported to the IRS during the 2015-2017 period.

It was noted that the IRS reports related to EDGs mainly involved component design issues and replacement part manufacturing issues, with the latter being more common for older EDG models that have been in service for long periods. As a good practice relating to EDG replacement parts, it was noted that the installation of lower quality replacement bearings, which could have resulted in several EDG failures, was prevented through the effective use of operating experience. Figure 3.15 shows a breakdown of the main types of EDG issues identified in the 16 IRS event reports involving deficiencies in design and modification.

Figure 3.15: **Main types of EDG design and modification issues identified in the event reports submitted during the 2015-2017 review period**



The remainder of this section highlights lessons learnt from equipment issues that are related to EDGs and were extracted from the relevant IRS reports.

Emergency diesel generators – lessons learnt

- The use of operating experience can improve EDG availability and have a positive impact on nuclear safety. Operating experience should be used as a source for continuous improvement of safety and the availability of equipment.
- Periodic reviews of the surveillance and maintenance programmes, taking into consideration the ageing of EDG components, are necessary to maintain their reliability.

- The quality control of the manufacturing of a few older EDGs was not as robust as required for critical safety equipment. It is recommended that the quality assurance programmes of vendor and operating organisations be sufficiently developed to ensure that the replacement of ageing components is carried out in a timely manner and using quality controlled replacement parts.
- It is suggested to ensure proper control of the quality of the EDG fuel and other operating fluids to maintain EDG reliability. The procurement process should be periodically reviewed to determine whether improvements are needed.

3.3. Management and oversight

Nuclear safety is the result of work performed by qualified and well-trained plant staff using good quality tools and procedures provided by the plant management organisation. In many countries, the operating organization retains the prime responsibility for safety throughout the lifetime of facilities and activities, and this responsibility cannot be delegated.[xiv]

Leadership in safety matters has to be demonstrated at the highest levels in an organization. Safety has to be achieved and maintained by means of an effective management system. This system has to integrate all elements of management so that requirements for safety are established and applied coherently with other requirements, including those for human performance, quality and security, and so that safety is not compromised by other requirements or demands.

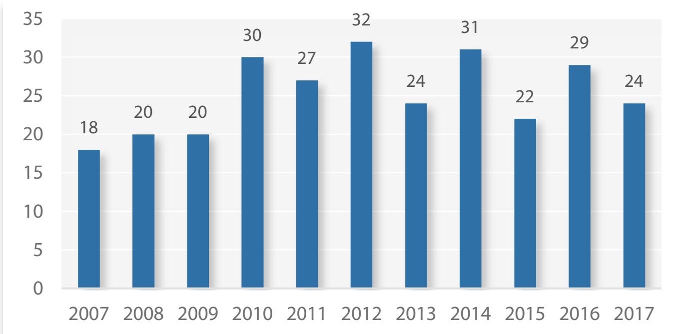
The operating organisation's responsibilities thus include:

- establishing and maintaining the necessary competences;
- providing adequate training and information;
- establishing policies, programmes and procedures to maintain safety under all conditions;
- verifying the appropriate design and quality of facilities, equipment and activities;
- ensuring the safe control of all radioactive material that is used, produced, stored or transported;
- ensuring the application of lessons learnt from experience.

Although nuclear power plants have robust safety management/quality assurance policies, programmes, systems and procedures, operational events caused by deficiencies in management and oversight do occur.

Figure 3.16 shows the total number of IRS reports involving management and oversight issues for the last ten years. The figure reveals that the number of IRS reports related to deficiencies in management and oversight has remained stable over the last ten years, with approximately 26 event reports per year.

Figure 3.16: **Number of IRS reports related to deficiencies in management and oversight (2007-2017)**



A total of 75 events involving management and oversight issues were reported to the IRS during the 2015-2017 period. The number of IRS reports related to deficiencies in management and oversight for the 2015-2017 period represents 30% of the total number of the reports submitted to the IRS.

A review of the 246 event reports submitted identified 5 subcategories relating to deficiencies in management and oversight. These include: maintenance programme, ageing management programme, procedure adequacy, use of operating experience and implementation of corrective actions, and management of external events. These subcategories were selected based on the frequency and significance of the events reported by member countries during the 2015-2017 review period.

3.3.1. *Maintenance programme*

Effective maintenance, surveillance and in-service inspection (MS&I) are essential for the safe operation of a nuclear power plant. They ensure not only that the levels of reliability and availability of all plant structures, systems and components (SSCs) that have a bearing on safety remain in accordance with the assumptions and intent of the design, but also that the safety of the plant is not adversely affected after the commencement of operation.

The range of maintenance activities includes servicing, overhaul, repair and replacement of parts, and often, as appropriate, testing, calibration and inspection.[x]

A total of 43 reports involving issues with planned and preventive maintenance programmes were reported to the IRS during the 2015-2017 period. A review of the reports and associated IRS coding determined the reports involving issues with planned and preventive maintenance were often indicative of either human performance issues such as the ones described in Sections 3.1.2 to 3.1.4 of this report, or of management programme issues not limited to the maintenance programme. Figure 3.17 shows the main causes of the event reports involving deficiencies with the application of the maintenance programmes.

Figure 3.17: **Relative proportion of the main causes of the event reports involving deficiencies with the application of the maintenance programmes submitted to the IRS during the 2015-2017 review period**

Figure 3.17 emphasises the importance of procedures in conducting maintenance programme activities. Section 3.3.3 of this report provides more information on the general topic of procedural adequacy. Figure 3.17 also notes the importance of ensuring that maintenance programme activities conducted by contractors are managed and supervised using rigorous processes.

Six of the IRS reports described deficiencies with the application of foreign material exclusion (FME) programmes. The information from one of these reports is presented in Section 4.2 and provides new insights that should be taken into account when establishing the scope of FME programmes.

The remainder of this section highlights the management and oversight lessons learnt related to maintenance programmes, as extracted from the relevant IRS reports.

Maintenance programme – lessons learnt

- It is important to recognise that routine and planned maintenance activities can result in unforeseen events. Deficiencies in the processes associated with the oversight of maintenance activities and the verification and acceptance of equipment following maintenance can result in serious and unforeseen events.
- It is important that the knowledge, skills and abilities of personnel responsible for the planning, co-ordination and conduct of maintenance programme activities be developed and maintained through a continuous development and training programme.
- Foreign material exclusion (FME) practices should not be strictly limited to activities involving open systems because FME can also affect equipment that is closed, especially in electrical rooms and cabinets when working with conductive and potentially airborne materials. Failure to take appropriate precautionary measures may lead to short circuits and the loss of power to safety system equipment.

3.3.2. *Ageing management programme*

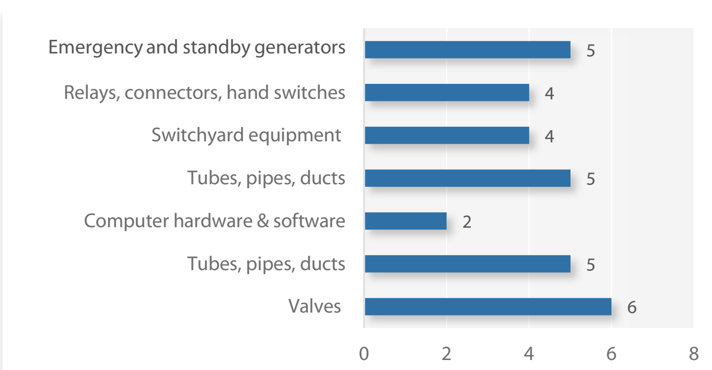
The primary objective of an ageing management programme is to ensure that the effects of ageing will not prevent structures, systems and components (SSCs) from being able to accomplish their required safety functions throughout the lifetime of the nuclear power plant (including its decommissioning). Ageing management is most effective when it is properly carried out at all stages of the lifetime of a nuclear power plant.[xv]

The importance of ageing management to nuclear safety is increasing in light of the growing number of operating organisations giving high priority to continuing the operation of nuclear power plants beyond the time frame originally anticipated for their operation.

In order to be effective, ageing management programmes must address both the effects of physical ageing of SSCs, any resultant degradation of their performance characteristics, and the non-physical ageing (obsolescence) of SSCs (i.e. becoming out of date in comparison with current knowledge, codes, standards, regulations and technology).

A total of 30 reports involving deficiencies in some elements of the ageing management programme were submitted to the IRS during the 2015-2017 period. Figure 3.18 shows the number of reports involving ageing issues for different types of SSCs submitted to the IRS. To provide information on generic problems of safety interest, 11 reports were selected for further review. It became evident that the reports are related to different equipment and did not point to any specific type of equipment.

Figure 3.18: **Number of event reports submitted to the IRS involving ageing issues for different types of SSCs during the 2015-2017 review period**



The following examples should help better illustrate the deficiencies in ageing management programmes and the types of SSCs that were identified in the event reports involving ageing management issues:

- Appropriate ageing management programmes for elastomeric elements within the safety-related systems were not always implemented in the installation phase, or revised according to changes in environmental conditions or modes of operation. Thermal degradation and ageing of elastomeric elements led to the failure of safety-related equipment.
- Circuit breakers installed in the 1970s did not function as designed because of ageing and inappropriate testing. These breakers impacted other safety significant components, preventing their actuation.
- An internal ground fault in one phase of a step-up transformer resulted in an electrical arc within the transformer. This led to an explosion and a transformer fire. The explosion resulted in the loss of off-site power and significant damage to the transformer.
- A degraded 24 V battery resulted in an EDG failure. The battery was later found to have exceeded the service life recommended by the manufacturer.
- A reactor trip occurred following a loss of off-site power during a storm. A failed relay prevented a fault in the local electrical grid from being immediately isolated in the plant switchyard. The failed relay, one of several originally installed in 1988, had been in service for approximately 29 years.

The remainder of this section highlights the management and oversight lessons learnt that are related to ageing management programmes and were extracted from the relevant IRS reports.

Ageing management programme – lessons learnt

- It is important to realise that ageing issues are not limited to certain types of SSCs. All SSCs installed during the construction of a plant can be susceptible to ageing problems.
- An effective ageing management programme is more important than individual component ageing programmes.
- Ageing mechanisms must be identified and controlled to prevent system failure during the expected lifetime.
- An adequate control of the number of spare parts must be established during the lifetime of the nuclear power plant. The list of components that are included in the ageing management programme should be periodically reviewed as new ageing mechanisms are identified.
- More frequent monitoring of a transformer's condition (online gas monitoring data and periodic dissolved gas analysis of the transformer oil) does not indicate the real condition of the transformer (especially for older transformers).

- Ageing of voltage surge arrestors in front of large power transformers when combined with transformer ageing phenomena may result in non-critical winding isolation faults. These initial faults may degrade rapidly when under the influence of switching transients and lead to sudden transformer failure.
- When an unloaded transformer is connected to an AC voltage source, the inrush current may be up to ten times higher, or more than the rated current of the transformer. This may impart dynamic forces on the transformer windings. The windings of older transformers are losing their ability to withstand these forces. Directly energising old transformers from high voltage sources (such as the electrical power grid) should thus be avoided.
- Ageing of large power transformers should be considered when dealing with long-term operation or life time extension of nuclear power plants (e.g. life time extension beyond 40 years).
- Personnel safety precautions should be put in place pending the replacement of an ageing power transformer.

3.3.3. *Procedure adequacy*

The category of procedure adequacy covers events where issues relating to incorrect or missing procedures were identified as a cause or contributing factor to an event. Unlike the events considered under Section 3.1.3 (procedure adherence), which relate to events involving instances where procedures were not followed as written, the events considered in this section focus on events where operating procedures for normal, abnormal, or emergency conditions were either simply not available or were incorrect.[xi]

Figure 3.19: **Issues with written procedures and documents (2015-2017)**

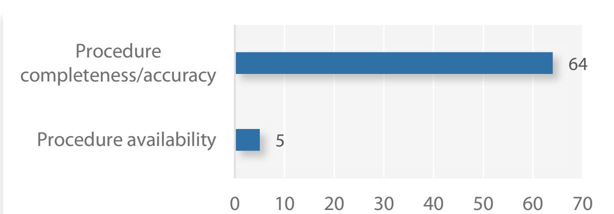


Figure 3.19 shows that a total of 69 event reports involving the absence of procedures or incorrect procedures were reported to the IRS during the 2015-2017 period. Five of these event reports involved the absence of procedures, while the remaining 64 event reports involved procedural deficiencies. Event reports involving procedure adequacy issues represent approximately 30% of the reports submitted to the IRS during the 2015-2017 period.

Procedures perform an important function because they are the nuclear power plant documents that provide plant staff with the instructions they need to safely operate the plant during normal, abnormal and emergency conditions. The availability and adequacy of procedures is therefore an important contribution to the safe operation of a nuclear power plant since these procedures can affect all aspects of nuclear plant operations.

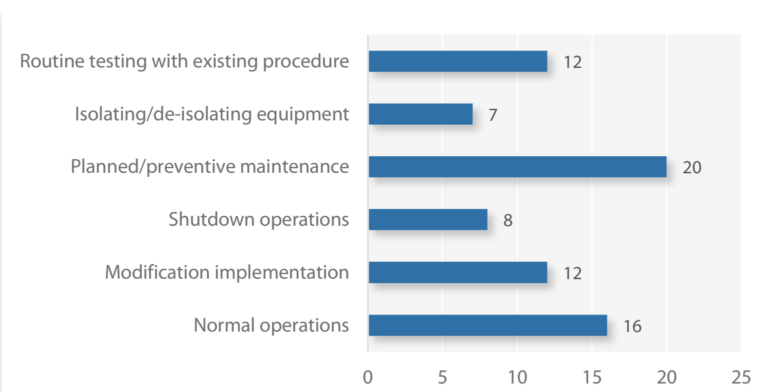
Types of procedural adequacy reports include:

- maintenance and calibration procedures;
- operating procedures, including, abnormal plant operating procedures;
- testing procedures;
- work plans and instructions for unique tasks;
- generic documentation for plant policies and programmes.

Events relating to maintenance and calibration procedures were the most frequently reported during the 2015-2017 review period.

Figure 3.20 shows the relative proportion of procedure-related reports when grouped by type.

Figure 3.20: **Relative proportion of the main types of procedural event reports involving the absence of procedures and incorrect procedures submitted to the IRS during the 2015-2017 review period**



The remainder of this section highlights the management and oversight lessons learnt that are related to procedure adequacy and were extracted from the relevant IRS reports.

Procedure adequacy – lessons learnt

- The development and revision of operating procedures should be validated by multidisciplinary teams from operations and engineering. Validation of a procedure using only the plant simulator may be insufficient because the simulator model may not exactly replicate plant equipment performance.
- The plant processes intended to control non-safety-relevant work activities should include a safety assessment step to confirm that the non-safety-relevant work will not have an impact on plant safety.
- Several of the event reports show that the operating crew response was complicated by a lack of complete procedures. Operators of nuclear power plants should ensure that operating procedures are complete and minimise the use of personnel knowledge and skill alone in the operation of nuclear power plants.
- Operating procedures should be comprehensive and cover all of the anticipated conditions of the plant during normal, abnormal and emergency conditions. Operating procedures should also be developed such that staff can follow the procedures regardless of experience level (e.g. novice and experienced employees).
- Infrequently used procedures should be reviewed for adequacy before use (e.g. more than six months of an interval since the last use).
- Test procedures should highlight the importance of non-return steps in the procedure whenever they have the potential to affect plant safety systems and components. Also, post-maintenance testing/operational checks should be included in test procedures, when appropriate, to facilitate the detection of any latent deficiency that may have been introduced during testing.
- It is important to recognise the impact of procedural design (e.g. ergonomically designed and user-friendly versus unclear and difficult to follow) on adherence to procedures. Procedures that are written using acknowledged industry best-practices are easier to follow and more effective in minimising the potential risk to safety.

3.3.4. *Use of operating experience and implementation of corrective actions*

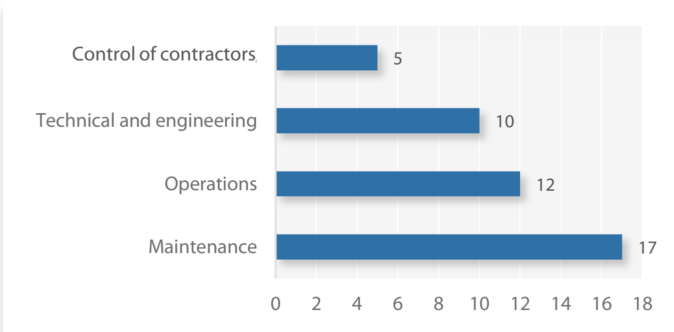
Article 19 of the 1994 Convention on Nuclear Safety states that:

> "Each Contracting Party shall take the appropriate steps to ensure that:
>
> vi. Incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;
>
> vii. Programmes 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 organizations and regulatory bodies."

A total of 38 event reports involving issues with the use of operating experience and implementation of corrective actions were reported to the IRS during the 2015-2017 period. A review of these reports did not identify any adverse trends associated with the use of operating experience. The operating experience and corrective action issues described in the reports varied greatly. The effective use of operating experience can be a valuable tool; using lessons from past mistakes can also help to prevent recurrence. The repetition of events demonstrates weakness not just in the affected programme but also in other organisational factors that can lead to long delays between the receipt of operating experience and the implementation of the identified recommendations. The main lessons learnt underline the need for timely review, assessment of external operating experience and follow-through on identified recommendations and commitments. An organisation dedicated to safety takes advantage of any information available to prevent the occurrence or reoccurrence of potentially significant issues that can affect safety.

Figure 3.21 shows the number of times a specific work group was identified as being involved in the operating experience events reported to the IRS.

Figure 3.21: **Work groups involved in operating experience events (2015-2017)**



The following examples illustrate the wide variety of reviewed reports involving issues with the use of operating experience and implementation of corrective actions:

- Two pressuriser relief valves failed to close during the periodic testing of the remote electrical control of the valves because some copper tracks on the printed circuit board (PCB) were cut off as a result of localised overheating. The observed overheating was attributed to a lack of design requirement on the thermal behaviour of the PCBs. Similar overheating problems reported a few years earlier were not successfully taken into account because the problems had occurred at a different type of plant.

- A brass alloy valve was installed in a non-safety-related steam system, which could include some impurities such as ammonia. An existing industry operating experience notification described the ability of ammonia in steam carry-over to chemically react with copper and copper alloys. This notification appears to not have been considered because the steam system was not safety related.
- Low steam generator levels caused a reactor trip during start-up when the steam generator level was being manually controlled. The supervisor of the operating crew did not question the long-term use of the steam generator manual level controls despite known operating experience, which has shown that manual control should not normally be used for long periods of time.
- A plant configuration control issue resulted in a plant transient when operators failed to secure a long-cycle clean-up alignment of the condensate and feedwater system prior to opening a main feedwater isolation valve. This resulted in a rapid and unexpected increase in the reactor vessel level. An opportunity to add a precaution to the procedures so as to avoid improper operation of the valve was missed eight years earlier when a similar event occurred.
- A plant experienced an automatic reactor scram due to a loss of forced circulation, which was the result of a loss of off-site power to the safety and non-safety electrical buses. A similar event had occurred two years earlier; however, a complete root-cause analysis was not conducted at the time. The less rigorous apparent cause analysis conducted following the first occurrence was not conclusive and attributed the event to an "unknown equipment cause". The corrective actions taken following the earlier event did not correct the cause of the event, and did not prevent recurrence because the nature of the failure was not determined conclusively. Corrective actions were assigned from the apparent cause analysis without a full understanding of the causes.

The remainder of this section highlights the management and oversight lessons learnt that are related to use of operating experience and implementation of corrective actions, all of which are extracted from the relevant IRS reports.

Use of operating experience and implementation of corrective actions – lessons learnt

- It is important for a root cause assessment to be performed for each event, and not just a perceived or apparent cause evaluation of an event. This requires having a clear and accurate problem description when establishing the scope of an investigation. For example, a root cause assessment that is strictly focused on the organisational and programmatic issues of a nuclear power plant may not be able to identify a root cause that originated from within an outside organisation such as a vendor.
- It is important that the effectiveness of an organisation's operating experience programme be periodically evaluated and improved as appropriate. This is particularly applicable when there is evidence that lessons learnt from previous events have not been effective in preventing event recurrence.

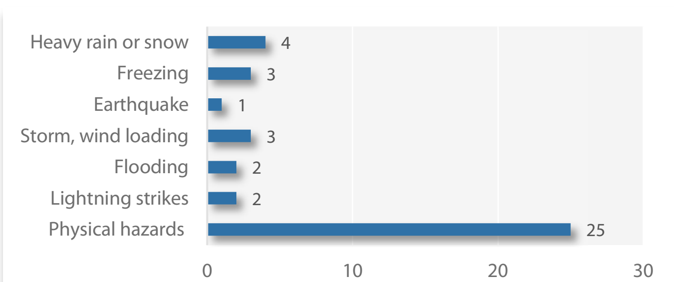
- It is important for lessons learnt from operating experience to be communicated to other nuclear industry organisations and peers so that these lessons may be reviewed for applicability at other nuclear facilities, and when appropriate, facilitate the implementation of safety improvements across the industry.
- Before work is carried out on a system, it is important to conduct a review of the lessons learnt from prior operating experience during the preparatory phase. This review should not be limited to the recent past.
- When a deficiency related to conducting maintenance on a piece of equipment is identified, it is important to inspect all similar equipment as soon as possible to confirm their availability.

3.3.5. *Management of external events*

The category that consists of the management of external events covers events with causes relating to either the occurrence of an unusual external condition or the discovery of a situation in the nuclear power plant that would invalidate the design assumptions or the results of the safety analysis.

A total of 40 reports involving issues with the management of external events were reported to the IRS during the 2015-2017 review period. Figure 3.22 shows the relative proportion of the main types of external events reported to the IRS during the 2015-2017 review period.

Figure 3.22: **Relative proportion of the main types of external events reported to the IRS during the 2015-2017 review period**



The types of external events covered in this section include:

- severe precipitation (e.g. rain or snow);
- unusually high winds;
- seismic events;
- unusually high quantity of marine animals or plants in the nuclear power plant cooling water inlet channel.

The remainder of this section highlights the management and oversight lessons learnt that are related to the management of external events, as extracted from the relevant IRS reports.

Management of external events – lessons learnt

- It is important that periodic safety reviews re-examine all the safety hypotheses, in particular, those relevant to seismic and flooding protection. Standard geotechnical screening methods may not be sufficient to detect weaknesses in some instances, such as the presence of a canal or dyke near the site.
- It is important that a safety analysis of cranes includes an evaluation of the ability of the cranes to withstand seismic events when the crane is in use and carrying a load.
- It is important to maintain the water tight connections between the various buildings of a facility to prevent water flowing from one room to another where safety-related equipment may be located. These watertight barriers between the rooms should be sufficiently robust to withstand the stresses of design-based external hazards.
- EDG high crankcase pressure can trip during a low barometric condition that could result in an EDG lockout condition. The EDG lockout condition prevents subsequent EDG starts (normal or emergency) until operators manually reset the lockout condition locally at the EDG.
- Potential degradation of equipment subject to deposits accumulated over time and combined with difficult weather conditions, particularly in the case of reactor units exposed to saline conditions (seaside nuclear power plant sites) or dust.

Half of the events occurred as a result of errors made by regular operating personnel while the other half was attributed to errors made by maintenance personnel. The descriptions of these events indicate that external events mostly affected electrical equipment, in particular the switchyard and intake of essential service water.

3.3.6. Control of contractors

It is important to recognise that licensees often rely on contractors and supplemental personnel to perform work. This is especially the case during scheduled outages. The work may include specialised, low-frequency tasks involving one-time modifications or the overhaul of major equipment.

Figure 3.23 shows that most of the events submitted to the IRS were caused by maintenance activities. The descriptions of these events indicate that contract workers are not consistently informed of the potential consequences of their work on plant operation. These consequences should be carefully explained during the preparation phase of the work that is to be performed.

Figure 3.23: **Relative proportion of the main types of activities involving the external events submitted to the IRS during the 2015-2017 review period**

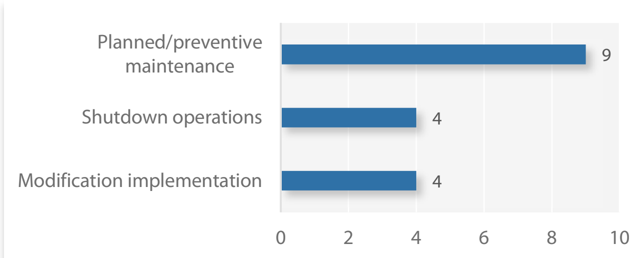
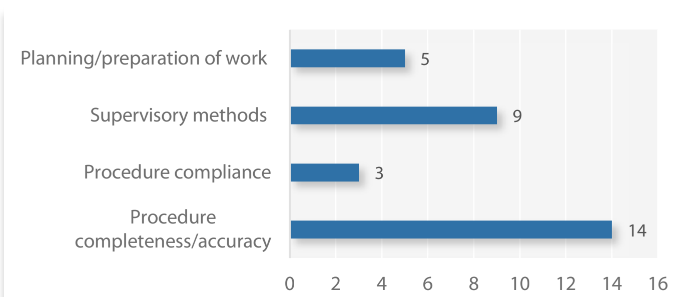


Figure 3.24 shows that the majority of events submitted to the IRS point to issues with procedure adequacy and contractor supervision. Before work is started by a contractor, the licensee should do a thorough review of all relevant documentation that will be used to ensure it is appropriate. The work procedure to be used by the contractor should also be verified, and the work should be closely monitored for quality and appropriate execution.

Figure 3.24: **Relative proportion of the main causes of the event reports involving deficiencies with the application of the maintenance programmes submitted to the IRS during the 2015-2017 review period**



The remainder of this section highlights the management and oversight lessons learnt that are related to licensee control of contractors as extracted from the relevant IRS reports.

Licensee control of contractors – lessons learnt

- It is important for plants to maintain the oversight of work carried out by contractors and to have documented processes for verification and acceptance of the work after it is completed.

- Although the performance of particular tasks, including the development and execution of work instructions and procedures, may be delegated to outside organisations, the licensee retains the overall responsibility for ensuring procedures and their application meet the quality assurance expectations of plant process controls and the quality assurance programme. This is important for safety-related equipment and systems.
- Industry operating experience has shown the importance of licensee programmes designed to ensure effective station oversight of contractor activities. It is also essential to establish clear lines of accountability within the licensee organisation that maintain sufficient knowledge and technical expertise so as to exercise an appropriate level of oversight over the design, maintenance, modification or refurbishment activities performed by contracted personnel. This includes verification that procedures and work instructions contain sufficient detail, and that supplemental personnel are familiar with site work control processes and expectations in relation to the adherence to procedures.

Chapter 4. **Other safety issues**

The review of the 246 reports submitted to the International Reporting System for Operating Experience (IRS) during the 2015-2017 period identified 6 reports that contained operating experience information that is either new or of special safety interest. These reports provide operating experience information relating to the following areas:

- management of external events and beyond-design-basis events;
- maintenance and ageing management programmes;
- design and modification.

The information presented in this section is based on the detailed event reports submitted to the IRS; however, it has been summarised to remove some of the technical details and facilitate the reader's understanding. The complete event reports are available to all registered IRS users from the member states.

4.1. Reports related to management of external events and beyond-design-basis events

Report #1

After the Fukushima Daiichi nuclear power plant (NPP) accident, NPP operators reviewed the design safety margins related to external and beyond-design-basis events.

During a review of seismic safety margins, an NPP operator discovered an insufficient seismic resistance of part of a canal embankment upstream of the NPP site. The condition was identified upon completion of a new seismic resistance calculation, which used more accurate geotechnical data. The results identified that a part of the embankment would not withstand the consequences of a safe shutdown earthquake. The potential consequence of a breach of the embankment after an earthquake would be the flooding of the site. The site was not designed to withstand such flooding at that time. A breach in the embankment would potentially lead to a severe accident and would also hinder the implementation of the on-site and off-site emergency response measures. This report highlights the need for periodic safety reviews for the re-examination of plant safety. Particular attention should be given to use the most up-to-date seismic and flooding data. Figures 4.1 and 4.2 are aerial views that show the site and the geographical area surrounding the site.

Figure 4.1: **Aerial view of the nuclear power plant**

Figure 4.2: **Geographical situation at the nuclear power plant**

Report #2

During a post-Fukushima review of a postulated beyond-design-basis accident at a heavy water reactor, it was anticipated that the conditions inside of the reactor building would significantly exceed design limits during a specific beyond-design-basis event. In particular, the water level in the reactor building may exceed the height anticipated for design-basis accidents in the following scenarios:

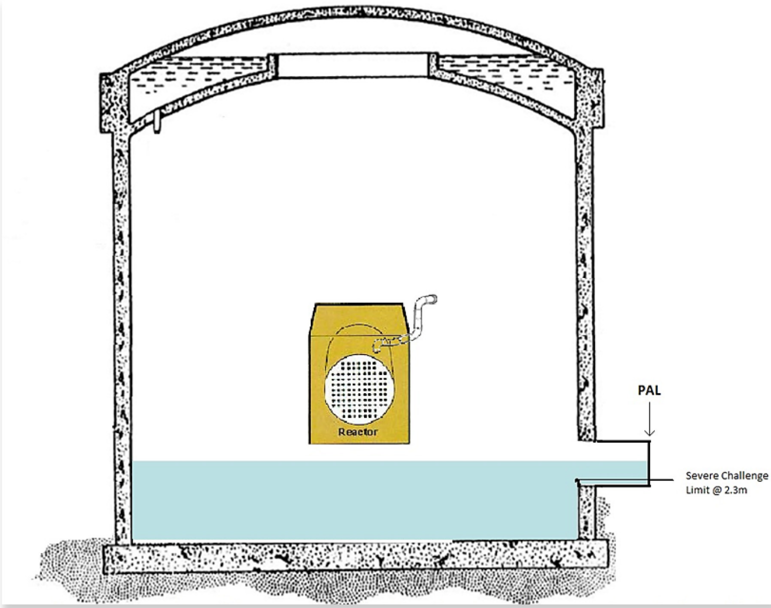
- severe accident sequences where available inventories of water in existing systems are collectively displaced to the reactor building basement;
- severe accident sequences where prolonged emergency injection of water in various systems is required in order to maintain the core cooling safety function.

The water level in the reactor building could reach the personnel airlock elevation, challenging the integrity of the soft inflatable seals on the airlock door when they become submerged. The airlock seals are not qualified for beyond-design-basis conditions (temperature, pressure, radiation). These conditions would have potentially led to a containment breach.

Figure 4.3 is a simplified cross-sectional view of the reactor building, which shows the location of the personnel airlock (PAL) and how a higher than anticipated water level in the reactor building may result in flooding of the PAL.

To address this issue, a third manually operated watertight airlock door was installed on the reactor building side of the airlock penetration. This third door is designed with hard rubber seals to withstand the conditions described. The reactor building water level instrumentation was improved to measure the new expected water level while withstanding the containment environmental conditions. The lesson to be learnt from this event is that the higher containment flooding level to be expected under certain severe accident conditions may challenge some safety systems. More specifically, plants should verify that the increased water level does not compromise the sealing of the containment access hatches and that the instrumentation should fully cover the range of the expected flooding.

Figure 4.3: **Simplified cross-sectional view of the reactor building**



Note: The figure shows how a higher than anticipated water level caused by the addition of water from an outside source during a beyond-design-basis accident may result in flooding of the PAL.

Figures 4.4 and 4.5 show the interior (service building side) and exterior (reactor building side) of the installed third airlock door.

Figure 4.4: **Exterior of the third PAL door in the reactor building**

Figure 4.5: **Interior of the third PAL door in the reactor building**

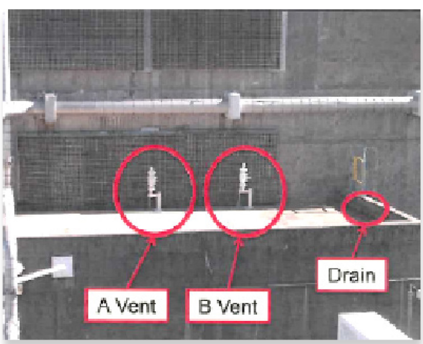
4.2. Reports related to maintenance and ageing management programmes

The following three event reports relate to the lack of maintenance of non-safety systems, which could challenge safety-related equipment, and one event report relating to foreign material exclusion practices.

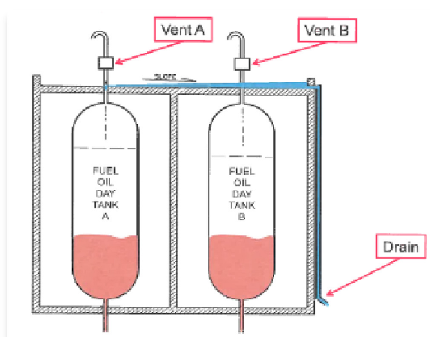
Report #1

Through-wall corrosion of the vent lines on the emergency diesel generator (EDG) fuel tanks allowed rain water to leak into the EDG fuel tanks and challenge the EDG safety function. During a review of EDG and its support systems for compliance to the maintenance rule, the safety to non-safety-related interface associated with the EDG feed tank vent lines did not identify this potential challenge to the performance of the EDG safety functions. A better maintenance strategy could have been developed had this potential challenge been identified. Figure 4.6 shows the feed vent line configuration and the nature of the corrosion damage.

Figure 4.6: **EDG fuel feed tank vent line configuration and photographs of the corrosion damage to the feed tank vent lines**



View of EDG feed roof with "A" (left) and "B" (right) EDG feed tank vent lines.



Potential flow-path for rain water into EDG fuel oil feed tanks.

As-found condition of "A" (left) and "B" (right) EDG feed tank vent lines.

Report #2

A make-up operation on the intermediate demineralised water system (SNO) caused it to overflow. The end of the SNO overflow drainage pipe was clogged with corrosion residue preventing it from draining and causing water to back up through the drainage line, into the ventilation area in the control room, and into the electrical building. The water then propagated down into the lower levels of these areas through openings that did not meet the specified leak tightness requirements.

The spillage of water in the various levels of the electrical building rendered equipment unavailable, including electrical blockage of the control rod clusters and the unavailability of one of the two reactor protection system trains. This caused a forced reactor outage that lasted approximately 50 days. This report highlights the sensitivity of safety-related electrical equipment to internal flooding. The report also illustrates the potential hazard to equipment important to safety from systems considered to have a minor safety impact, and which are consequently not the subject of detailed preventive maintenance. Figure 4.7 shows the nature of the corrosion damage and clogging of the SNO overflow drainage pipe.

Figure 4.7: **Photograph of the corrosion damage and clogging of the SNO overflow drainage pipe**

The lesson learnt is that systems with only a minor safety impact should still be covered by a preventive maintenance programme if their failure can potentially impact the integrity of the safety-related systems.

Report #3

A highly unique event was reported in 2017. The event involved safety system actuations and the loss of safety injection function, which were caused by an electrical fault in a closed electrical cabinet. The electrical fault was the result of a nearby work activity involving the application of a fire-retardant but conductive material on power cables. Dust or small particles produced by the application process infiltrated the closed electrical cabinet nearby, which over time caused an electrical fault.

This event showed that foreign material exclusion (FME) practices should not be strictly limited to activities involving open systems. FME can also affect equipment that is closed and in service. This is especially relevant when working with conducive and potentially airborne materials in the vicinity of electrical rooms and cabinets; however, there may be other types of work activities and in-plant situations that could pose similar risks.

The scope of FME programmes and practices should be reviewed to ensure operating equipment is protected from the infiltration of foreign material during work activities that generate airborne materials.

4.3. Report related to design and modification

Older digital control equipment used in NPPs is maintained and upgraded through back-fitting with more modern digital equipment.

For safety-related or reactivity control systems in older NPPs, it is becoming more difficult to procure matching spare or replacement parts. Back-fitting of these systems with newer digital equipment remains an option for long-term operation. This situation currently applies to new plants being built, which include digital control systems from the beginning of operation.

In one of the reports submitted during the 2015-2017 period, the installation of an additional data acquisition system caused errors due to synchronisation issues. After the addition of this system, the amount of data needed to be synchronised was too large for the hardware to handle, causing it to shut down. An additional hardware upgrade was required to restore the system to normal operation.

In a separate report, while the plant was in the hot shutdown state, the digital control equipment, which provides both information displays to and digital control inputs from the main control room, became unavailable. A failure of the historical data storage system caused a large amount of data to be transferred after placing the storage system back into operation. The data transfer process used nearly all the resources of the digital control equipment for the plant. Normal digital system operation was unavailable for approximately 30 minutes. Software and hardware design modifications were implemented to increase computing power and to limit the use of computing resources for non-critical or non-essential tasks so as to minimise the risk of recurrence.

The lessons learnt from these reports are that the design of digital control equipment should prevent non-essential tasks from removing computer processing power required for essential tasks. The hardware design of digital control equipment should provide enough computer processing power and data storage for all of the required tasks. The design of hardware and software should prevent overloading of the digital control equipment.

Chapter 5. Conclusions

The importance of operating experience feedback in enhancing nuclear safety has been well recognised throughout the nuclear energy community. A general goal of national and international operating experience feedback processes is to help prevent the recurrence of events involving serious potential hazards. National operating experience feedback is the basis for international operating experience feedback, and so without this high-quality, national operating experience feedback, it is impossible to have effective international operating experience feedback.

By signing the Convention on Nuclear Safety, each contracting party has committed, under Article 19, to taking the appropriate steps to ensure that:

> "incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body… and that …programmes 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 organizations and regulatory bodies."

All of the contracting parties have indicated in review meetings that they have such programmes in place, and these programmes have indeed been valuable in sharing experiences.

In developing the operating experience feedback programme, and the network for its implementation, it is important to keep in mind the main idea behind the programme: writing reports and collecting data is meaningful only when there is a direct link to the reduction of risk and the enhancement of operational safety. Event reporting needs therefore to be coupled with programmes that transform the lessons learnt into risk reducing measures, such as improvements in design, operator training, operating procedures and enhanced safety culture. To achieve this goal, the operating experience feedback process would need to provide greater focus on corrective actions, good practices and their implementation, as well as information sharing among all parties that contribute to the safe operation of nuclear facilities.

The national organisations that need to be involved in the operating experience process are the operators of facilities and regulatory bodies. No operating experience feedback network can function effectively without the active participation of the nuclear operators and national organisations that work in a co-operative spirit, which has been demonstrated by their signing of the Convention on Nuclear Safety. It is expected that the main responsibility of collecting and using relevant national operating experience, and reporting it to the international network, will be clearly assigned to the appropriate organisations in each country. The other duty of national organisations is to assess the information received on operating experience from the international network and initiate proper measures to reduce risks at nuclear facilities.

Activities within the International Reporting System for Operating Experience (IRS) of the Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA) extend beyond the exchange and feedback of event information. Both the NEA and IAEA have specifically assigned expert working groups to meet on a regular basis in order to discuss the safety relevance of selected IRS events. The conclusions and recommendations from these working group discussions are extremely valuable to the nuclear community in that they help to enhance the safety of plants in terms of design, commissioning, operation and decommissioning.

In order to strengthen the national operating experience programmes within each member state:

- All countries operating nuclear facilities need to act as part of an international network for mutual learning, as indicated in the Convention on Nuclear Safety, and freely share information of importance to operational nuclear safety, as well as allocate the needed resources to make the international operating experience feedback effective and efficient.
- The operating experience feedback process needs to contain all of the components that close the feedback loop: collection, review and quality control, analysis, conclusions, dissemination, follow-up and feedback.
- A knowledge management component needs to be built into the system with efficient search functions – for example, semantic searches – to ensure the maintenance of relevant nuclear safety information and its transfer to future generations of experts.

In support of these objectives, the 246 IRS reports submitted by member states during the 2015-2017 period were reviewed. The goal of this review was to identify key lessons learnt that could be shared among member states. The following list highlights the key lessons learnt, which have been extracted from the IRS reports:

- Human performance issues continue to be a major contributor to events that have been reported. Human performance issues appeared in 62% of the total number of events reported during the 2015-2017 review period. Improvements in operation and maintenance fundamentals, as well as training, could reduce the number of human performance-related reports and improve safety.
- The majority of procedure-related issues were identified to have been caused by the inadequacy and incompleteness of procedures. The impact of deficient procedures is greater on less experienced personnel, who are more reliant on these procedures than more experienced personnel.

- Management and oversight issues were identified in 30% of the IRS reports submitted during the 2015-2017 period. Improvements to management, as well as to oversight processes and practices could make a significant contribution towards reducing the number of reported events and towards improving safety.
- Equipment issues, especially those related to design and modification, continue to be reported in considerable numbers. The number of emergency diesel generator events is of concern because of the importance of this equipment during a loss of off-site power.
- Several reports relating to the management of external events were generated as a result of post-Fukushima reviews. Significant safety improvements were also made as a result of the review of safety margins in light of updated seismic and environmental data.
- Oversight of contractors continues to be highlighted as an area for improvement. Efforts to improve contractor training and ensure their compliance with procedures should be considered.
- Foreign material exclusion programmes and practices should extend beyond open systems. The scope of these programmes and practices should be reviewed to ensure that closed equipment is protected from the infiltration of foreign material during work activities that generate airborne materials. This form of protection is especially relevant when working with conducive and potentially airborne materials in the vicinity of electrical rooms and equipment.
- Lack of preventive maintenance on non-safety significant systems can challenge the safety function of safety significant systems.

Although IRS reports are shared and reviewed by individual member state, it was noted that repeat events, similar to those submitted in previous years, were also reported during the 2015-2017 period. These repeat events would appear to indicate that the corrective actions taken to address past lessons learnt were not always effectively implemented. Ongoing efforts to improve the effectiveness of national operating experience programmes should thus be maintained.

Glossary[1]

Barrier

Anything that is used to protect a system or person from a hazard and includes physical barriers, natural barriers, administrative controls and human actions.

Also, administrative or physical controls designed to promote consistent performance that should inhibit an inappropriate action.

Barriers can be either administrative or physical in nature.

Causal factors

Causes that, if corrected, would not of themselves have prevented the event but are important enough to be recognised as needing corrective action to improve the quality of the process or product.

Also, a factor that influences the outcome of a situation. The reasons for an action that was taken or an event that occurred in the sequence of events that led to the grounds for an investigation.

Also, a condition that shapes the outcome of a situation.

Also, causes that, if corrected, would not of themselves have prevented the event, but are important enough to be recognized as needing corrective action to improve the quality of the process or product.

Common cause failure

The failure of two or more structures, systems and components (SSCs) to perform their functions as a result of a shared cause or specific occurrence. (Note: a common-mode failure, in which two or more SSCs fail in the same manner or mode because of a shared cause or specific occurrence, is a type of common cause failure).

1. The definitions contained in this glossary are based on the following documents listed in the Endnotes: IAEA/NEA, 2010a; IAEA, 2002c; IAEA, 1996.

Multiple unavailability of an identical component is of particular importance in this case, since the probability of several components being simultaneously and independently unavailable is small.

Defence in depth

The application of more than a single protective measure for a given safety objective such that the objective is achieved even if one of the protective measures fails.

This basic safety principle is used to compensate for potential human and mechanical failures.

The defence-in-depth concept is implemented based on several levels of protection, including successive barriers and preventing the release of radioactive material to the environment. The concept includes protection of the barriers by averting damage to the plant and to the barriers themselves. It also includes further measures to protect the public and the environment from harm in case these barriers are not fully effective.

Direct/observed cause

The failure, action, omission or condition that immediately produced the event (i.e. the direct initiator of an effect or event).

Event

Any unintended (unusual) occurrence or a sequence of related occurrences, including human errors, equipment failures or other mishaps, the consequences or potential consequences of which are not negligible from the point of view of nuclear safety. An event may also be cited by other terms, such as a deviation, an incident or an accident.

An action or happening that occurred during some activity.

Also, an unwanted, undesirable consequence for the safe operation of a plant (generally in terms of reduced safety margin).

Also, an undesirable consequence that challenges the safety of the reactor core.

Also, an undesirable occurrence.

Also, in the context of the reporting and analysis of events, an event is any unintended occurrence, including operating error, equipment failure or other mishap, the consequences or potential consequences of which are not negligible from the point of view of radiological protection or nuclear safety.

Failure

Inability of a structure, system or component to function within acceptance criteria.

Note that the structure, system or component is considered to fail when it becomes incapable of functioning, whether or not this is needed at that time. A failure in, for example, a backup system may not be manifest until the system is called upon to function, either during testing or upon failure of the system it is backing up.

Human errors

Groups/families of attributes to characterise wrong human behaviour (understanding, intention and action).

Examples of such groups are: violation (the person has a good understanding; he or she develops an intention that is not in compliance with his or her understanding); mistake (the intention of the person is wrong because his or her understanding is not in compliance with the prescribed task); slip (the intention was good, but the action was wrong).

Human factors

A general term summarising the various aspects of human behaviours in working conditions, including the behaviour itself and the factors important to understand the behaviour. This includes cognitive, ergonomic, technical and organisational factors.

Human performance

The capabilities and characteristic behaviours of human beings in complex or stressful task environments such as nuclear power plant (NPP) engineering, operation and maintenance.

Deficiencies in human performance (including licensed operators, other plant personnel and contractor personnel) may degrade the defence in depth.

Normal operation

Operation of an NPP within specified operational limits and conditions, including shutdown, power operation, shutting down, starting up, maintenance, testing and refuelling.

Nuclear safety (or simply safety)

The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of site personnel, the public and the environment from undue radiation hazards.

Operation

All activities performed to achieve the purpose for which the plant was constructed, including maintenance, testing, refuelling, in-service inspection and other associated activities.

Operational limits and conditions

A set of rules that set forth parameter limits, the functional capability and the performance levels of equipment and personnel approved by the regulatory body for safe operation of the NPP.

Operating experience

A valuable source of information to learn about and improve the safety and reliability of nuclear installations. It is essential to collect such information in a systematic way that conforms with agreed reporting thresholds for events occurring at nuclear installations during commissioning, operation, surveillance and maintenance activities, as well as decommissioning, and for events concerning deviations from normal performance, by systems and by personnel, which could be precursors of events.

Precursor

An event that has the potential, under other circumstances, to lead to a core damage event.

Prescribed limits (also called authorised limits)

Limits established or accepted by the regulatory body.

Protection system

A system that monitors the operation of a NPP, and which, on sensing an abnormal condition, automatically initiates actions to prevent an unsafe or potentially unsafe condition.

Such a system would include all monitoring and control instrumentation, electrical and mechanical devices and circuitry, from sensors to actuation devices involved in the protective function.

Quality assurance

All those planned and systematic actions necessary to provide adequate confidence that an item or service will satisfy given requirements for quality.

Recovery actions

Activities to terminate the event and to bring the plant to a safe state.

Regulatory body

A national authority or a system of authorities designated by a member state, assisted by technical and other advisory bodies, and having the legal authority for conducting the licensing process, for issuing licences and thereby for regulating NPPs.

Siting, design, construction, commissioning, operation and decommissioning or specified aspects thereof.

This national authority could be either the government itself, or one or more departments of the government, or a body or bodies especially vested with appropriate legal authority.

Residual heat

The sum of the heat originating from radioactive decay and shutdown fission, and the heat stored in reactor-related structures and in heat transport media.

Root cause

The fundamental cause(s) that if corrected will prevent recurrence of an event or adverse condition.

Also, the most basic reason(s) for an event that can be reasonably identified and that over which management has control to remedy.

The fundamental cause of an initiating event, which, if corrected, will prevent its recurrence, namely, the failure to detect and correct the relevant-latent weakness(es) and the reasons for that failure.

Safety culture

The assembly of characteristics and attitudes in organisations and individuals, which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance.

Safety functions

Safe operation of NPPs is maintained by the following fundamental safety functions:

- controlling reactivity;
- cooling of the radioactive material;
- confinement of the radioactive material.

Safety management system

A system to achieve and enhance safety by bringing together requirements for managing the organisation, including planned and systematic actions providing confidence that the requirements are satisfied.

The safety management system ensures that health, environmental, security, quality and economic requirements are integrated in safety requirements.

Safety systems

Systems important to safety, provided to ensure the safe shutdown of the reactor or the residual heat removal from the core, or to limit the consequences of anticipated operational occurrences or accident conditions.

Safety systems consist of the protection system, the safety actuation systems, and the safety system support features. Components of safety systems may be provided solely to perform safety functions, or they may perform safety functions in some plant operational states and non-safety functions in other plant operational states.

Screening

Reviewing operating experience information to determine what information is valuable for and applicable to a particular plant or more generically applicable to a number of plants of similar type or that use the same equipment.

Endnotes

This report references a number of IAEA and NEA documents pertaining to operating experience and nuclear safety. The following list of those documents is provided so that readers seeking more detail can locate them.

i IAEA/NEA (2000), *Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 1996-1999*, OECD Publishing, Paris.

ii IAEA/NEA (2003), *Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 1999-2002*, IAEA, Vienna.

iii IAEA/NEA (2006), *Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 2002-2005*, OECD Publishing, Paris.

iv IAEA/NEA (2010b), *Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 2005-2008*, IAEA, Vienna.

v IAEA/NEA (2012), *Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 2009-2011*, OECD Publishing, Paris.

vi IAEA/NEA (2018), *Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 2012-2014*, IAEA, Vienna.

vii IAEA (2018a), *Operating Experience Feedback for Nuclear Installations*, IAEA Safety Standard Series No. SSG-50, IAEA, Vienna.

viii IAEA/NEA (2010a), *IRS Guidelines: Joint IAEA/NEA International Reporting System for Operating Experience*, IAEA Services Series No. 19, IAEA, Vienna.

ix IAEA (2008), *Conduct of Operations at Nuclear Power Plants: Safety Guide*, IAEA Safety Standard Series No. NS-G-2.14, IAEA, Vienna.

x IAEA (2002a), *Maintenance, Surveillance and In-Service Inspection at Nuclear Power Plants*, IAEA Safety Standard Series No. NS-G-2.6, IAEA, Vienna.

xi IAEA (2000), *Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants*, IAEA Safety Standard Series No. NS-G-2.2, IAEA, Vienna.

xii IAEA (2002b), *Recruitment, Qualification and Training of Personnel for Nuclear Power Plants*, IAEA Safety Standard Series No. NS-G-2.8, IAEA, Vienna.

xiii IAEA (2016), *Safety of Nuclear Power Plants: Design*, IAEA Safety Standard Series No. SSR-2/1 (Rev. 1), IAEA, Vienna.

xiv IAEA (2006), *Fundamental Safety Principles,* IAEA Safety Standard Series No. SF-1, IAEA, Vienna.

xv IAEA (2018b), *Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants*, IAEA Safety Standard Series No. SSG-48, IAEA, Vienna.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 36 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Korea, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission takes part in the work of the OECD.

OECD Publishing disseminates widely the results of the Organisation's statistics gathering and research on economic, social and environmental issues, as well as the conventions, guidelines and standards agreed by its members.

This work is published under the responsibility of the Secretary-General of the OECD. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the Organisation or of the governments of its member countries.

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 33 countries: Argentina, Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Korea, Romania, Russia, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission and the International Atomic Energy Agency also take part in the work of the Agency.

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 sound and economical use of nuclear energy for peaceful purposes;
- 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 analyses in areas such as energy and the sustainable development of low-carbon economies.

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management and decommissioning, 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.

Corrigenda to OECD publications may be found online at: *www.oecd.org/about/publishing/corrigenda.htm*.

INTERNATIONAL ATOMIC ENERGY AGENCY

The International Atomic Energy Agency (IAEA) is the world's central intergovernmental forum for scientific and technical co-operation in the nuclear field. The IAEA works with its Member States (171 Member States at time of publication) and multiple partners worldwide to promote the safe, secure and peaceful use of nuclear technologies.

The mission of the IAEA is:

- as an independent intergovernmental, science and technology-based organization, in the United Nations family, that serves as the global focal point for nuclear co-operation;
- assists its Member States, in the context of social and economic goals, in planning for and using nuclear science and technology for various peaceful purposes, including the generation of electricity, and facilitates the transfer of such technology and knowledge in a sustainable manner to developing Member States;
- develops nuclear safety standards and, based on these standards, promotes the achievement and maintenance of high levels of safety in applications of nuclear energy, as well as the protection of human health and the environment against ionizing radiation;
- verifies through its inspection system that States comply with their commitments, under the Non-Proliferation Treaty and other non-proliferation agreements, to use nuclear material and facilities only for peaceful purposes.

NEA PUBLICATIONS AND INFORMATION

The full **catalogue of publications** is available online at www.oecd-nea.org/pub.

In addition to basic information on the Agency and its work programme, the NEA website offers free downloads of hundreds of technical and policy-oriented reports. The professional journal of the Agency, **NEA News** – featuring articles on the latest nuclear energy issues – is available online at www.oecd-nea.org/nea-news.

An **NEA monthly electronic bulletin** is also distributed free of charge to subscribers, providing updates of new results, events and publications. Sign up at www.oecd-nea.org/bulletin.

Visit us on **Facebook** at www.facebook.com/OECDNEA or follow us on **Twitter** @OECD_NEA.

OECD/NEA PUBLISHING, 2 rue André-Pascal, 75775 PARIS CEDEX 16

Nuclear Power Plant Operating Experience

The International Reporting System for Operating Experience (IRS) is an essential system for the international exchange of information on safety related events at nuclear power plants worldwide. The fundamental objective of the IRS is to enhance the safety of nuclear power plants through the sharing of timely and detailed information on such events, and the lessons that can be learnt from them, to reduce the chance of recurrence at other plants. The first edition of this publication covered safety related events reported between 1996 and 1999. This seventh edition covers the 2015-2017 period and highlights important lessons learnt from a review of the 246 event reports received from participating states during those years. The IRS is jointly operated and managed by the OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA).

Nuclear Energy Agency (NEA)
46, quai Alphonse Le Gallo
92100 Boulogne-Billancourt, France
Tel.: +33 (0)1 73 21 28 19
nea@oecd-nea.org **www.oecd-nea.org**

ISBN 9789264697201