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Third Construction Experience Synthesis Report

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NUCLEAR ENERGY AGENCY
COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES

Third Construction Experience Synthesis Report

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COMMITTEE ON NUCLEAR REGULATORY ACTIVITIES (CNRA)

The Committee on Nuclear Regulatory Activities (CNRA) addresses NEA programmes and activities concerning the regulation, licensing and inspection of nuclear installations with regard to both technical and human aspects of nuclear safety. The Committee constitutes a forum for the effective exchange of safety-relevant information and experience among regulatory organisations. To the extent appropriate, the Committee reviews developments which could affect regulatory requirements with the objective of providing members with an understanding of the motivation for new regulatory requirements under consideration and an opportunity to offer suggestions that might improve them and assist in the development of a common understanding among member countries. In particular it reviews regulatory aspects of current safety management strategies and safety management practices and operating experiences at nuclear facilities including, as appropriate, consideration of the interface between safety and security with a view to disseminating lessons learnt. In accordance with *The Strategic Plan of the Nuclear Energy Agency: 2017-2022*, the committee promotes co-operation among member countries to use the feedback from experience to develop measures to ensure high standards of safety, to further enhance efficiency and effectiveness in the regulatory process and to maintain adequate infrastructure and competence in the nuclear safety field.

The committee promotes transparency of nuclear safety work and open public communication. In accordance with the NEA Strategic Plan, the committee oversees work to promote the development of effective and efficient regulation.

The committee focuses on safety issues and corresponding regulatory aspects for existing and new power reactors and other nuclear installations, and the regulatory implications of new designs and new technologies of power reactors and other types of nuclear installations consistent with the interests of the members. Furthermore, it examines any other matters referred to it by the NEA Steering Committee for Nuclear Energy. The work of the committee is collaborative with and supportive of, as appropriate, that of other international organisations for co-operation among regulators and consider, upon request, issues raised by these organisations. The Committee organises its own activities. It may sponsor specialist meetings, senior-level task groups and working groups to further its objectives.

In implementing its programme, the committee establishes co-operative mechanisms with the Committee on the Safety of Nuclear Installations (CSNI) in order to work with that committee on matters of common interest, avoiding unnecessary duplications. The committee also co-operates with the Committee on Radiological Protection and Public Health (CRPPH), the Radioactive Waste Management Committee (RWMC), and other NEA committees and activities on matters of common interest.

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List of abbvreviations and acronyms

ANO	Arkansas Nuclear One
CAS	Consortium Areva Siemens
CEA	Concrete expansion anchors
CMTR	Certified Material Test Report Yield
CNRA	Committee on Nuclear Regulatory Activities (NEA)
CV	Containment vessel
EDG	Emergency diesel generator
GIB	Gas insulated bus
I&C	Instrumentation and control
IOZ	Inorganic zinc
IRS	Incident reporting system (IAEA)
MCR	Main control room
NCR	Non conformance report
NEA	Nuclear Energy Agency
OECD	Organisation for Economic Co-operation and Development
PCS	Plant control system
PHT	Primary heat transport
PROM	Programmable read only memory
PSRV	Pressuriser safety relief valve
RCP	Reactor coolant pumps
RPV	Reactor pressure vessel
SAT	Standby Auxiliary Transformer
SI	Safety injection
SICS	Safety Information and Control System
SPHSE	Self-priming high solids epoxy
STUK	Radiation and Nuclear Safety Authority (Finland)
WGRNR	Working Group on the Regulation of New Reactors (NEA)

Executive summary

This report analyses 36 events that regulators have observed during the construction of new nuclear power reactors, from siting to licensing and oversight. The database is part of the Contruction Experience (ConEx) programme, which was established in 2007 by the Working Group on the Regulation of New Reactors (WGRNR) of the Nuclear Energy Agency (NEA) Committee on Nuclear Regulatory Activities (CNRA). The aim is to find common themes among the events and to disseminate the identified lessons learnt. Based on the analysis, recommendations for regulatory oversight programmes and for the ConEx programme were formulated.

The events included all those submitted to the ConEx database but not included in any previous ConEx summary reports. The earliest described events occurred in 1996 and the latest in 2017.

There were events from nine participating countries. Most of the events were related to mechanical components. The most common causes of events were those related to human performance and direct causes. The lessons from the events that the regulators identified were varied and could have been more precise. However, the most common theme observed was inadqueate licensee oversight.

Based on the analysis, the following recommendations should be considered in regulatory oversight programmes:

1. New build regulators should consider paying more attention to mechanical components, as they might be more prone to construction events.
2. New build regulators should pay more attention to human factors in general, as they are a common cause in construction events.

The WGRNR should continue to develop construction event reporting. In particular:

1. The WGRNR should encourage more events to be reported in the event database and actively try to remove obstacles to reporting.
    a. The WGRNR should encourage all kinds of events to be reported and ensure that all kinds of events are reported.
    b. The WGRNR should ensure that all participating NEA member countries building new commercial nuclear power reactors report events.
2. The WGRNR should be aware of the possible biases present in the reporting system as a whole and try to mitigate them by providing clear guidance about what kind of events should be reported and how they should be reported.
3. The WGRNR should encourage participants to write more meaningful lessons and to provide a precise analysis of root causes.
4. Considering the number of events that find their cause in human performance and management (safety culture, risk analysis and associated control, procedures definition and training), the WGRNR, or the NEA more broadly, should be aware that working on these topics could be useful for regulatory bodies and new build stakeholders.

5. Considering the number of events that could have been avoided through better oversight and better project management, the WGRNR, or the NEA, should be aware that working on these topics could be useful for regulatory bodies and new build stakeholders.

1. Introduction

International co-operation and the sharing of experiences are of great value to the nuclear regulatory community. With that in mind, the Nuclear Energy Agency (NEA) Committee on Nuclear Regulatory Activities (CNRA) established in 2007 the Working Group on the Regulation of New Reactors (WGRNR) to facilitate collaboration and exchanges on the siting, licensing and oversight of the construction of new commercial nuclear power reactors.

To fulfil its purpose, the WGRNR created the Construction Experience (ConEx) programme. The ConEx programme includes a database of events that regulatory organisations have observed during the siting, licensing and oversight of the construction of new commercial nuclear power reactors. The lessons learnt through the programme can then be incorporated into the regulatory oversight programmes of the involved organisations.

According to the ConEx guidelines version 2 (NEA, 2016), the overall definition for ConEx events is as follows: "*Events that have causes and/or lessons learnt related to problems introduced before the commercial operation of nuclear power plants and detected at any stage of the plant life (during design, fabrication, testing, operation and inspection).*" Furthermore, the guidelines refer to the joint IAEA/NEA International Reporting System for Operating Experience (IRS) definition of an event.

The ConEx database comprises information on events that regulatory organisations have observed during the siting, licensing and oversight of the construction of new commercial nuclear power reactors. The database contains information characterising the event, an event narrative to describe what happened, a cause analysis, a safety assessment to evaluate the significance of the event, a description of actions taken because of the event, and a paragraph describing the lessons learnt from the event.

In 2019, the data from the ConEx database were transferred to the IAEA/IRS database. In the future, construction event reporting will be moved to the IRS database and the ConEx database will be phased out.

Earlier ConEx reports were published in 2012 and 2015 (NEA, 2012; NEA, 2015). These reports presented analyses of earlier events and made recommendations.

This third report is the last ConEx report, incorporating the analysis of 36 events. It was approved by the CNRA on 1st December 2020. The aim is to find common themes in the events part of the analysis and to share the identified lessons learnt. Based on the analysis, recommendations are formulated for regulatory oversight programmes and for the ConEx programme.

This report has five sections. This first section is an introduction, while the second describes the methods used in the analysis of the events. The third section describes the results of the analysis. In the fourth section, conclusions are drawn and the recommendations presented. The fifth section summarises the report.

2. Methods

As a first step, information about 36 events and relating appendices was collected from the ConEx database. This includes everything about these events stored in the database: event characteristics, event narrative, cause analysis, safety assessment, description of actions taken, and lessons learnt.

Second, all the events were read through by the task group to obtain an overall view of the events.

Third, event characteristics – such as the submitting country, cause of event, component affected, and organisations involved – were used to categorise the events.

Fourth, the lessons to be learnt from the events were aggregated into categories. The aggregation was based on similarities between the lessons.

Lastly, based on the results of this analysis, recommendations for regulatory oversight programmes and developing WGRNR work were formulated.

3. Results

3.1. General

Thirty-six events were included in the event analysis. Around half of the events were submitted and accepted after the second ConEx report (events numbered 119 to 141) (NEA, 2015). The rest are events submitted earlier but not included in previous ConEx reports (events 11-13, 28, 59, 66, 69, 75, 80, 85-88, 89, 102, 108 and 109).

The first event (11) was submitted to the ConEx database on 13 January 2011 and the last (141) on 21 January 2019. The event describing the oldest issue is event 13, which occurred on 22 February 1996. The event describing the newest issue is event 139, which occurred on 20 July 2017. The events are described in detail in Section 3.3.

Figure 3.1 shows the number of events submitted by each country. Altogether, there were events from nine countries. As shown in this figure, Korea submitted the most events included in this report, followed by Finland, France and the United States.

Figure 3.2 shows the number of events by cause of event. Most of the causes are related to human factors. Ten events show a deficiency in the risk or impact analysis process. This process is identified in many events because it is a large process with the objective of preventing events from happening. It can concern component failure, but also activities and processes. In addition, nine events highlight a potential lack of safety culture in the staff of stakeholders (e.g. licensee, vendors, subcontractors). Eight events highlight unsuitable procedures or requirements, and five events highlight competence issues. Finally, management and work organisation has been identified as a root cause for three events.

Figure 3.1. Number of events submitted by each participating country. Only countries that have submitted events that are included in this report are listed here.

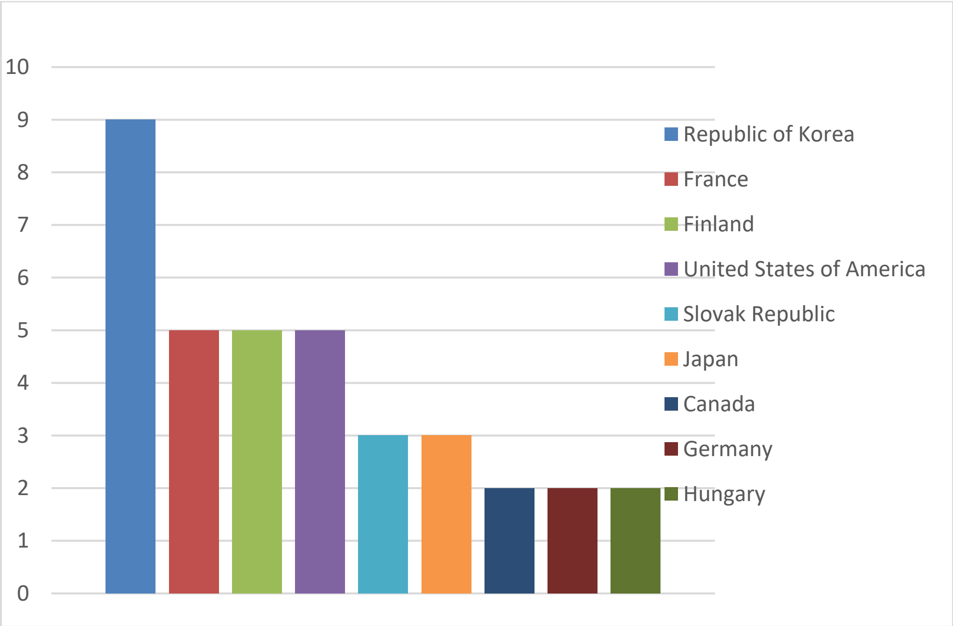
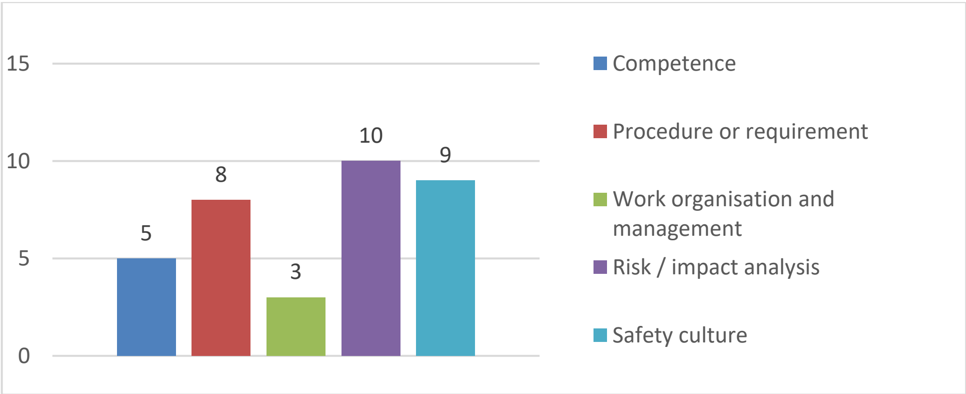


Figure 3.2. Number of events per each identified root cause of event.



The number of events that affected each component type is shown in Figure 3.3. Events affecting mechanical components are by far the most common: 22 events affected mechanical components. Five events have no specific component affected and in three events the participants did not specify the affected component. Electrical components, instrumentation and computers were affected by three, two and one event, respectively.

Figure 3.3. Number of events per each affected component identified.

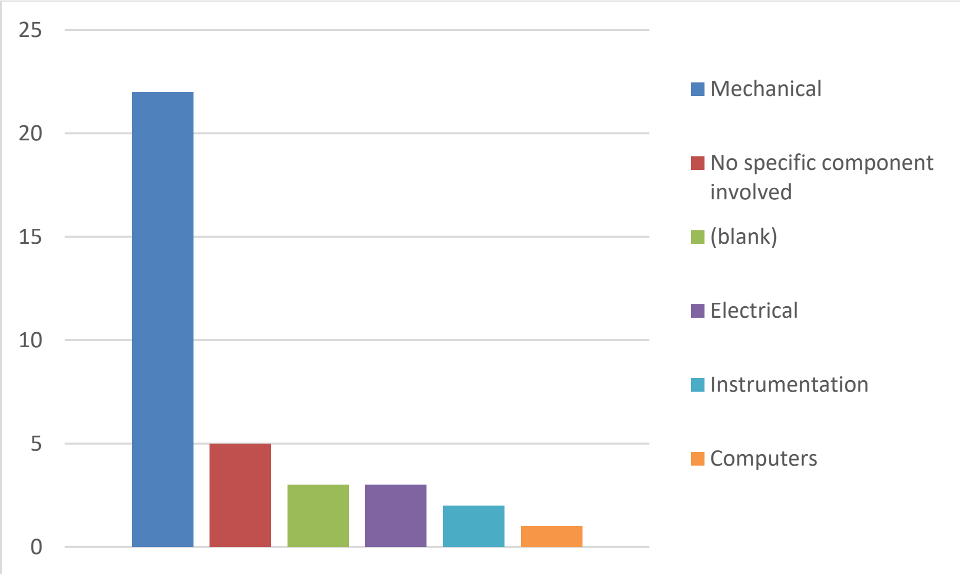


Figure 3.4. Number of events by each challenged safety function category.

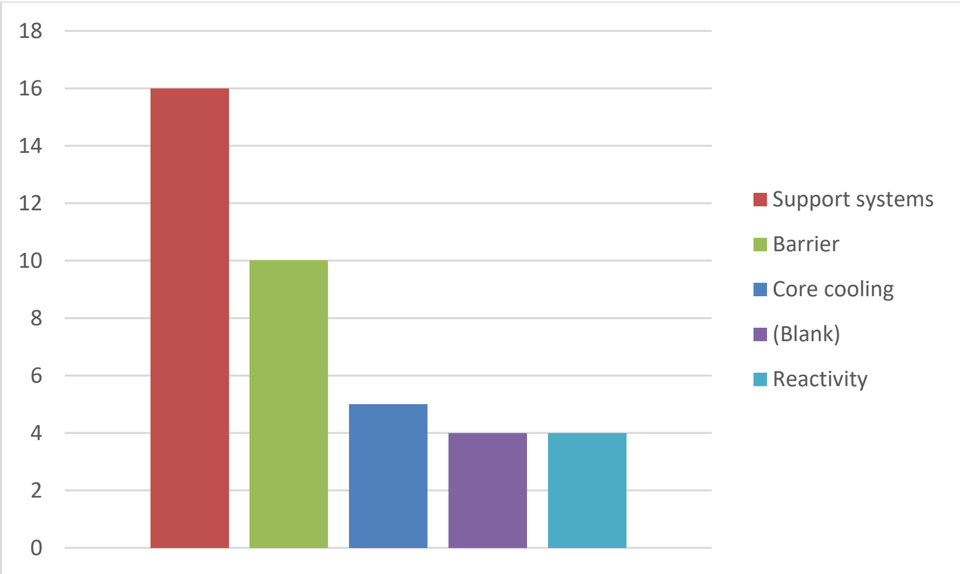
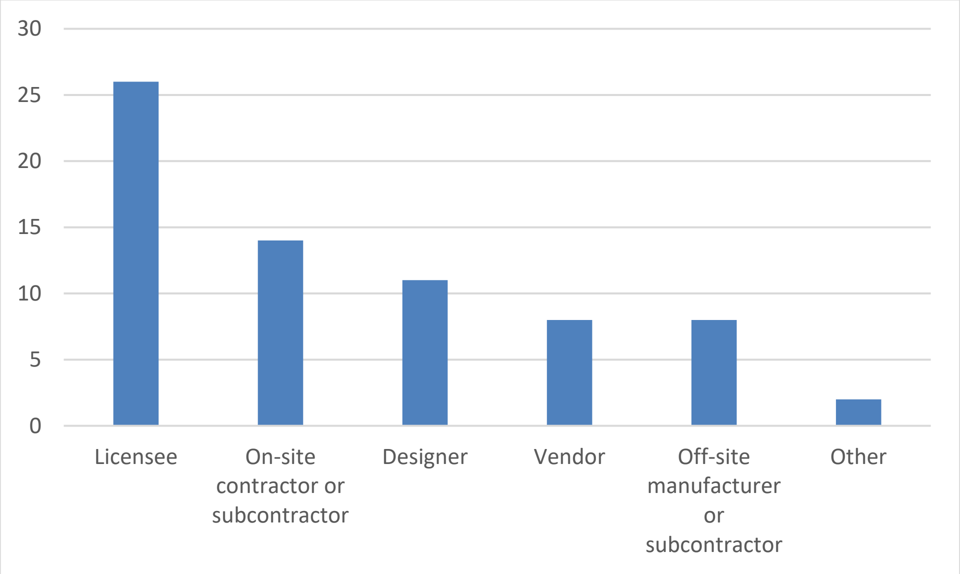


Figure 3.4 shows the number of events by challenged safety function category. The most common safety function to be challenged was support systems, with 16 events. The second most common was barrier, i.e. primary circuit and containment, with eight events. Five events challenged core cooling and four events challenged reactivity. Four events did not list the challenged safety function.

Figure 3.5. Number of events by each involved organisation



Note: Some events have multiple organisations involved.

Figure 3.5 shows the number of events by organisation involved. It should be noted that an event might involve several organisations. The licensee was involved in 26 events, the on-site contractor in 14 and the designer in 11. The vendor and off-site manufacturer were involved in 8 events each, while 2 events involved other organisations.

3.2. Lessons learnt

The lessons learnt listed from the events varied and were aggregated based on similarities. The share of events by aggregate category is shown in Figure 3.6.

These events provided many lessons about the oversight of activities (nine events). This category comes first, as expected, since it is likely that an event provides experience on what should be overseen and how. The oversight should be performed on safety-related activities that occur both onsite and offsite. The licensee should also be aware of how the safety culture is deployed among vendor and subcontractor staff.

Seven events provided a return of experience on requirement definition. For example, these events enabled the identification of specific activities related to safety and requirements. In addition, these events shed light on the necessity for the licensee to make sure they communicate the requirements to the staff involved and to check if these requirements have been well understood and respected.

Six events led regulators to identify lessons about installation management. Possible improvements were identified regarding the planning of activities and co-activity management.

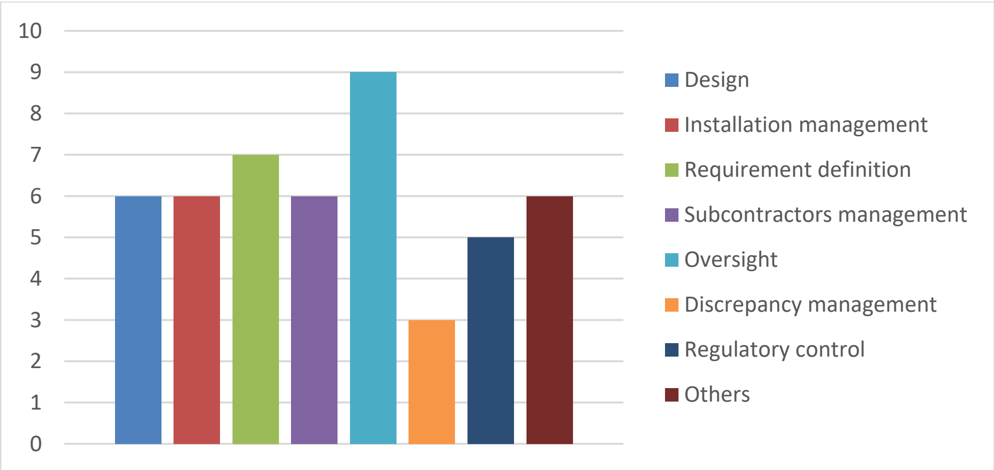
Six events also provided lessons about design. Among other things, these events are a reminder of the importance of defence-in-depth and of using components with strong operating experience.

This last lesson may concern subcontractors as well. Six events indicated possible improvements to subcontractor management. Communication of requirements, interface management and the definition of roles need improvement. These events also demonstrated the importance of choosing subcontractors with an adequate safety culture.

Three events provided lessons about discrepancy management. These events showed how important it is for licensees to identify deviations as soon as possible, to conduct a risk analysis as soon as a discrepancy analysis has been identified, and to consider the cumulative effects of the deviations.

Finally, five events led to regulatory bodies identifying inappropriate control points for inspections. However, 80% of the events in this specific category were reported by the United States. Many more events could provide control points for regulatory bodies. Hence, guidance about the database should be provided to identify, for every event, advice for regulatory bodies' control over new builds.

Figure 3.6. Share of events by each aggregate lesson learnt category.



3.3. Events

3.3.1. Design

Event 123 - Intrusion of fire gas into the control room during the generator transformer fire – Germany – All BWRs – 2 December 2009

Description

Due to an external transformer fire, fire gases intruded the switchgear building and control room. This fire gas intrusion had no safety consequences, however.

Cause(s)

The underlying cause was that an external fire or a fire in the ventilation system was not considered when designing the switchgear building ventilation system.

A contributing cause was that the automatic ventilation system mode could not be fully controlled from the control room.

Lesson(s) learnt

Automatically triggered ventilation systems should be controllable from the main control room.

Relevant fire scenarios (such as external fire) should be considered when designing fire protection systems and ventilation systems.

Event 109 - Lube oil purifier fire – Canada – All nuclear power plants – 1 January 2013

Description

A lube oil purifier unit caused a fire. The fire was caused by the unit heater remaining "ON" despite the switch indicating otherwise.

Cause(s)

The direct cause was a stuck electrical contact inside the purifier unit. The underlying cause was the system design, which allowed a single component failure to result in a fire. Indeed, there was no independence between the temperature control circuit and the high-temperature cut-off.

Lesson(s) learnt

Systems should be designed so that a single component failure does not lead to a hazard.

When a hazardous or anomalous condition has been identified, simply tagging and barricading the hazard might not be enough. An early risk analysis enables the identification of actions that can prevent the aggravation of the event.

When fire protection systems are taken out of service, consideration must be made for the activities that are performed in the affected area.

3.3.2. Civil construction

Events 130, 131 and 132 – Lack of subcontractor safety culture at Flamanville-3 site – France – Flamanville-3 – 2014 and 2015

Description

There were three events relating to Flamanville-3 containment concrete prestressing activities: Event 130 - Lack of grout during prestressing activities; Event 131 - Improper use of jacks during prestressing activities; and Event 132 - Lack of anchor wedges during prestressing issues.

All these events were related to the same subcontractor.

Cause(s)

All the events had a human mistake as direct cause. The underlying cause was the lack of a cautious and questioning approach by the subcontractor staff, a clear indication of a substandard safety culture.

Lesson(s) learnt

The main lesson in these events was the lack of safety culture shown by the contractor staff. The contractor had nuclear experience from the Olkiluoto-3 site, but the contractor staff had no prior nuclear experience.

Event 128 - Defect of the Hilti HSL-3 M24 concrete expansion anchors (CEAs) in Korean nuclear plants – Korea – All nuclear power plants – 13 January 2014

Description

The regulatory authority was informed by the manufacturer that certain concrete expansion anchors (CEAs) were defective. The defects could have had a substantial adverse effect on the performance of the anchorage.

Cause(s)

The direct cause of the event was that some of the CEAs had insufficient lubricant coating on the anchor cone. This caused an increase of frictional resistance between anchor cone and expansion sleeve, which in turn caused a decrease in frictional force between the sleeve and surface of the drilled hole. This could have resulted in the anchor being partially or completely pulled out of the hole.

Lesson(s) learnt

Before installation, every step of the manufacturing process must be documented and controlled by competent personnel.

Event 75 - Base concrete sink down after rain flow in the underground of standby auxiliary transformer (SAT) – Korea – Shin-Kori 3 – 27 July 2011

Description

During a field inspection an SF6 gas pressure decrease was found in the SAT and containment vessel (CV) cable connecting the gas insulated bus (GIB). After an inspection, the pressure decrease was found to be caused by a GIB connection point dislocation due to ground sinking in the SAT basement.

Cause(s)

The partial ground sinking was caused by a loss of fine particles in granular fill for the structure. This was caused by inflow of surface water during the rainy season.

The planned rainwater control and mitigation actions had not yet been completed because of the plant schedule. This might have contributed to the event.

Lesson(s) learnt

There should have been better temporary mitigation systems for rainwater control.

This event has some similarities to event 125. Both had a similar contributing cause: delayed plant schedule.

Event 66 - Inappropriate use of certified material test report yield stress and age-hardened concrete compressive strength in design calculations – All nuclear power plants – United States – 6 September 2012

Description

The report (information notice 2012-17) “Inappropriate Use of Certified Material Test Report Yield Stress and Age-Hardened Concrete Compressive Strength in Design Calculations” describes many instances where licensees have used non-conservative acceptance limits for steel and concrete designs that are based on CMTR actual strength values and higher hardened concrete compressive strength values obtained by extrapolation. See the information notice for details.

Cause(s)

The affected licensees and their contractors did not control the deviations from relevant quality standards as required. This resulted in reduced design margins in all cases.

Lesson(s) learnt

Use of non-conservative acceptance limits for steel and concrete design may inappropriately reduce safety margins inherent in associated specification and code requirements. Hence, the deviations from these requirements shall be controlled.

Event 59 - Defects in prestressing ducts – Flamanville 3 – France – 1 November 2009

Description

Several non-compliances relating to prestressing ducts of the inner wall of the reactor building occurred between November 2009 and June 2011.

Cause(s)

The main cause of these non-compliances was a lack of preparedness and training by the licensee and its subcontractors concerning the possible interactions between steelwork (and anchor plates) and prestressing ducts.

It was also noted that the licensee oversight function was not efficient enough.

Lesson(s) learnt

The licensee should anticipate possible non-compliances with the code requirements and should consider the cumulative impact of all non-conformances instead of considering them one by one. Also, the licensee should pay attention to the management of the safety margins.

3.3.3. Mechanical[1]

Event 141 – Issues with valve internals – Finland – Olkiluoto-3 – 1 January 2015

Description

During preparations for commissioning tests it was discovered that hundreds of valve internals had been mixed up during piping installation.

Cause(s)

Direct causes: OL3 nuclear island has around 12 000 valves of about 600 different design specifications. The high number of specifications is partly due to variations in valve actuator assemblies.

Underlying cause: Application-specific requirements for valves were inadequate at the start of the piping works. The handling of valve internals during disassembly was insufficient.

1. Please note that this categorisation of mechanical events is different from the categorisation presented in Figure 3.2. This paragraph contains events that have causes relating to mechanical components and phenomena. Figure 3.2, on the other hand, includes a wider set of events, including events affecting mechanical components, but not necessarily caused by mechanical components.

Lesson(s) learnt

There should be a detailed procedure for use of different types of valves. The procedure should ensure that specific requirements are applied. Valve disassembly and reassembly during piping works should be instructed.

Event 140 - Issues in OL3 PSRV design, qualification and commissioning – Finland – Olkiluoto-3 – 1 January 2010

Description

The pressuriser safety relief valve (PSRV) station consists of a main valve and four pilot valves.

The valve station has undergone extensive qualification testing. During the qualification, several issues with the design and technical solutions were discovered. The mechanical pilot valve had issues with vibration and fluctuations in the relief pressure.

Both mechanical and electrically operated pilot valves had issues with internal leakages. During the full-scale qualification tests, the position indicator rod (valve stem) of the main valve buckled. As a result, the design of the rod was changed.

During the qualification tests of the electrically operated pilot valve, the insulation resistance of the valve was too low compared to the requirements of the RCC-E standard.

Cause(s)

Underlying cause: The valve station has a new design, especially the mechanical pilot valve. There is not much operating experience with similar valves.

Lesson(s) learnt

In safety critical components, only designs with strong operating experience should be used.

Event 139 - Emergency diesel generator crankshaft damage during commissioning – Finland – Olkiluoto-3 – 20 July 2017

Description

During the commissioning functional tests of the OL3 emergency diesel generator (EDG) in 20 July 2017, abnormal noise and sparks occurred. The engine was stopped immediately. Damage was detected during the following disassembly of the engine, crankshaft, bearing and connecting rod. The crankshaft was damaged beyond repair. Some smaller parts (rocker arms and cylinder sleeves) were also damaged.

The crankshaft and other damaged parts were replaced with spare parts. The crankshaft was taken from a MAN diesel engine manufactured originally for the Angra-3 Nuclear Power Plant (Brazil). Other spare parts were readily available.

Cause(s)

The failure of the crankshaft was caused by bearing damage due to oil film thinning because of metal chips. This might be due to several root causes: 1) generator shaft run-out; 2) coupling misalignment; 3) pollution of lubrication oil with big particles. However, no definitive root cause was found. STUK and the licensee consider this failure as a single-failure and not a general (design) failure of the EDGs in question.

Lesson(s) learnt

Good spare part availability can help to avoid delays and improve safety by reducing equipment down time.

Event 126 - US AP 1 000 construction sites - Potential for substantial safety hazard caused by pipe support coating deviations – United States - V.C. Summer-3 – 14 March 2014

Description

The regulatory authority was informed that improper coatings had been applied that could negatively affect emergency core cooling.

The defect in question was caused by the inadvertent introduction of unqualified inorganic zinc (IOZ) coating (instead of the correct self-priming high solids epoxy [SPHSE] coating) applied to non-nuclear safety-related pipe supports intended for installation inside the containment. The amount of unqualified coating applied to these supports was significant enough to increase debris generation inside the containment to unacceptable levels. The resulting debris loading on the sump strainers would, in turn, reduce flow and impact long-term cooling for the AP 1 000 design during events that require that capability.

SPHSE can be applied as non-safety-related because it fails as chips and therefore would not transport to the sump strainers. IOZ, on the other hand, must be applied as safety-related because it fails as particles that would transport to the sump strainers.

Cause(s)

It appears that the manufacturer misinterpreted the coating requirements. The fact that the subject pipe supports do not perform a safety-related function may have contributed to the confusion.

Lesson(s) learnt

Latent manufacturing defects, if gone undetected, could result in a substantial safety hazard after the plant is commissioned.

Regulators may want to verify that their licensees and suppliers are using the correct qualified coatings inside the containment.

The licensee should have either identified the application of the coating as a safety-related activity or specified the correct qualified coating to apply.

Event 125 - Corrosion in cooling water and auxiliary cooling water systems – Finland – Olkiluoto-3 – 24 April 2014

Description

A corrosion problem was discovered in the plant’s cooling water systems. The systems had been put into service after testing and had then remained filled with water for a long period of time. The systems are part of the turbine plant and had been finished and tested well in advance of the plant itself. The contractor or subcontractor had elected to test the system after the installations were finished, well in advance of operation. It appeared that the system had not been drained, as at the time of the installation, it was thought that the plant and the system would be taken into operation sooner.

Cause(s)

The direct cause was improper corrosion protection.

The underlying cause was that while was a readiness for a cathodic protection system against corrosion, it was not in operation because it produces hydrogen and therefore creates an obvious risk without proper ventilation.

Lesson(s) learnt

When plant construction and commissioning is delayed, unexpected ageing-related issues might arise. The licensee should implement adequate oversight to notice any discrepancy regarding the equipment protection and conservation.

This event has some similarities to event 75. Both had a similar contributing cause: delayed plant schedule.

Event 119 - Inadequate seismic qualification testing of active valve assemblies – United States – All AP 1 000s – 28 June 2013

Description

During a vendor inspection, the regulatory authority found out that active valve assemblies for the pressuriser had been inadequately seismically tested.

Cause(s)

The vendor personnel failed to follow procedure.

The vendor failed to translate the customer's verification requirements into its procedures.

There was a lack of adequate oversight by the vendor, the customer and the licensee.

Lesson(s) learnt

The regulators may want to verify that their licensees require safety-relevant components to be adequately seismically tested and that licensees verify and oversee testing.

The licensee should verify that the vendor translates the requirements forward in the supply chain and that these requirements are followed by the staff.

Event 108 - Reactor shutdown due to gas locking of primary heat transport feed pumps – Canada – Darlington 1 – 5 September 2012

Description

A sudden failure in the bleed filter unit instrument air valve (V30) caused air to migrate through the primary heat transport (PHT) purification system and into the PHT feed pumps. This caused a gas lock in both pumps.

Cause(s)

The direct cause was the failure of the bleed filter unit instrument air valve (V30). The valve is of the Newman-Hattersley type, which has a known failure mechanism that could render the valve open.

The root cause was the licensee's inadequate assessment of the possibility that a valve failure might lead to gas intrusion from an interfacing system.

The contributing cause was the instrument air system's direct connection to the PHT purification system, which should not have been made, according to the design manual.

Lesson(s) learnt

The organisational and programmatic weakness that caused this event was that the earlier site reviews were inadequate and failed to identify the gas intrusion pathway.

A review for risk failure was performed for various Newman-Hattersley valves; however, V30 was not identified as needing any additional precautions. The result was that there was only a single physical barrier to instrument air entering the PHT purification system.

Event 102 - Polar crane brackets - welding defects – France – Flamanville-3 – 14 December 2011

Description

Manufacturing non-conformities were detected in welds of the polar crane brackets as they were being installed. The defects were generated during the welding process (MAG 136).

Cause(s)

The welding process was not adequately controlled by the manufacturer.

The contractor did not have adequate oversight of the manufacturer and the brackets.

No non-destructive surveillance (such as ultrasonic tests) were performed after thermal treatment of the brackets.

The bracket design did not allow weld control after manufacturing

Lesson(s) learnt

The licensee and the main building contractor oversight did not detect the defects until after installation.

Welding activities should be done by people with adequate qualifications, sometimes specific to the welding process, as a welding noncompliance can have a major impact on safety.

Event 88 - EDG malfunction due to damage to fuel system components – Korea – All nuclear power plants – 13 April 2012

Description

The emergency diesel generator (EDG) fuel system components were damaged at Shin-Kori unit 2 and Shin-Wolsong units 1&2. Shin-Kori unit 2 EDG train B experienced damage to the fuel injection nozzle and pump components. Shin-Kori unit 2 EDG train A had a damaged spring in the pump actuator. Later, similar damage was identified in Shin-Wolsong unit 1&2 EDGs. All the EDGs are of a similar design.

Cause(s)

The direct cause was deficiencies in the manufacturing process.

The underlying cause was a lack of quality assurance as the quality assurance process did not detect the quality defects in the components.

Lesson(s) learnt

Quality management and the quality assurance of components must be reinforced.

Event 85 - Unsatisfaction of minimum wall thickness due to excessive machining of counter-bore of valve to pipe connection point – Korea – Shin-Wolsung 2 – 13 January 2012

Description

The safety injection (SI) system piping to the containment spray isolation valve was found to have the wrong counter-bore. This resulted in the piping not meeting the minimum wall thickness.

Cause(s)

The excessive counter-bore was due to a drawing error in the piping fabrication drawing.

The error was not picked up by independent design verification.

Lesson(s) learnt

Regulators should verify that utilities and their contractors have in place a robust independent verification system for nuclear safety related work.

Event 28 - Heavy load lifting equipment problems – Browns Ferry 1 – United States – 4 October 2007

Description

The information notice (IN 2009-20) discusses three instances of heavy load lifting equipment problems caused by wire rope degradation mechanisms. See the information notice for details.

In addition to these three events, there was a heavy load lifting event at Arkansas Nuclear One (ANO) unit 1 in which a 600-ton main generator stator fell onto the turbine deck and caused some collateral damage. This caused the death of one worker and injured eight. Furthermore, the force imparted by this event caused the reactor coolant pump of the neighbouring unit 2 to trip. This led to reactor trip from full power.

Cause(s)

Fatigue of the wire strands.

Partial untwisting caused by uneven twist of wire ropes.

Inadequate supervisory and management oversight of the contractors.

For the ANO event the main cause was that the design did not ensure that the lift assembly could support the loads anticipated for the lift. Furthermore, the contractor failed to perform required load testing of the lift assembly.

Lesson(s) learnt

Heavy lifts have been historically problematic in the construction industry, including nuclear construction. Therefore, regulators should consider the relevance of the issue for nuclear new build, too.

Licensees should inspect, test and maintain heavy lift equipment adequately.

Event 12 - Abnormal noise - Low pressure turbine inlet pipe – Japan - Kashiwazaki Kariwa 7 – 21 May 1997

Description

During commissioning at full power, abnormal noise occurred around the low-pressure turbine inlet pipe. After shutdown, the cause of noise was identified to be a broken temporary pressure detection pipe installed for performance verification.

Cause(s)

The direct causes of the temporary pipe break were:

- thermal stress due to temperature difference;
- hydraulic stress due to steam flow;
- stress concentration and fatigue due to improper welding.

Lesson(s) learnt

Appropriate quality assurance shall be applied also to temporary equipment if its failure might adversely affect the normal plant operation.

3.3.4. Electrical

Event 134 – Fire blaze in battery 3BTA41 during acid filling – Slovak Republic – All VVERs – 16 August 2016

Description

During acid filling of the last of 216 cells of the battery 3BRA41, a blaze fire of the entire cell erupted, causing damage to the last cell, the next cells and the room in general.

Cause(s)

There was an evident lack of specific and specialty knowledge/experience about batteries by staff and workers involved in the design, installation and/or pre-test checking.

There was an evident lack of overall interface management. Many parties were involved in this system work. Every party made sure that its part was completed in accordance with the available documentation. However, there was no single entity responsible for the overall management of the task and the coherence of the interfaces.

There was not much independent verification. The whole purpose of independent verification was defeated in this case. Even though this system is classified as a BE3 “Hazardous area with danger of fire”, the inspector was unable to spot the discrepancy and issued the revision report endorsing the mistaken connection.

The direct event cause [crossed wiring] had been spotted over a year ago in another room, 1375, a non conformance report (NCR) was issued, and the wiring had been corrected. It is not clear why an overall check of the other rooms was not ordered.

Lesson(s) learnt

The licensee should oversee the contractors and ensure interfaces are managed.

Event 133 – Damaged I&C cables for SICS (safety information and control system) panels – Slovak Republic – All VVERs – 16 December 2015

Description

During individual testing activities by the consortium Areva Siemens (CAS) in unit 3, it was not possible to switch all fuses between the I&C cabinets and the main control room (MCR). This was due to short circuits on the connecting cables. After additional investigation, CAS found out that the insulation of the inner cores of the cables was damaged where the cables are fixed inside of the SICS cabinets by using PUK clamps.

Cause(s)

The direct cause was excessively high torque during tightening. The underlying cause was that the torque value of 2 Nm was not prescribed in CAS technological procedure for cable termination. The torque was only communicated internally.

The interaction of the proposed methods for fixation and earthing and the usage of torque for clamping were not known during the issuance of the used technological procedure. Thus, the root cause is missing knowledge about the combination of circumstances given by information.

Lesson(s) learnt

There should be work processes ensuring that requirements related to installation location (such as tightening torque specific to a certain location) are considered before installation.

Event 124 - Exchange of low-voltage relays in the Philippsburg-1 Nuclear Power Plant (KKP-1) – Germany – All BWRs – 29 June 1996

Description

A few control rods were interlocked because of an incorrect undervoltage relay change. Enough margin for subcriticality was maintained, however, and reactivity control was not jeopardised.

Cause(s)

The incorrect relay change happened because of unclear labelling on the relays. Furthermore, there were no comprehensive catalogues of different relay types used.

Lesson(s) learnt

A clear and comprehensive labelling and cataloguing system for relays and other I&C equipment should be implemented. Post-maintenance testing should be extended to also cover wiring and relay issues.

Event 11 - MOV supplying steam to the turbine-driven RCIC pump – Japan - Shika 2 – 26 January 2006

Description

During commissioning, a motor-operated isolation valve supplying steam to the turbine-driven reactor core isolation cooling pump failed to close sufficiently in a functional test.

Cause(s)

The direct cause was arc and deposits in the electromagnetic contactor of the valve.

The arc and deposits were caused by a high energy flux in the contactor. The flux was higher than planned because the contactor springs had been displaced, possibly during clean-up activities prior to reactor start-up testing.

Lesson(s) learnt

Maintenance on safety-relevant components is important for safety. Maintenance work should not leave any debris or loose parts that might endanger the safety function of the component.

3.3.5. Instrumentation and control

Event 87 - Reactor trip caused by PCS (plant control system) malfunction during commissioning test – Korea – Shin-Wolsung 1 – 27 March 2012

Description

A hardware failure in the I/O card of the plant control system (PCS) caused a reactor trip.

The event proceeded as follows:

The circuit breaker of the 13.8kV non-Class 1E power line (01M) was opened by a false signal generated from the I/O card (HFC-DC34) of the plant control system (PCS).

The opening of this circuit breaker caused the tripping of reactor coolant pumps (RCP) 01A/02A, which were powered from the power line.

Tripping of the RCPs caused a DNBR-Lo (departure from nucleate boiling ratio) - Low signal, which caused a reactor trip.

Cause(s)

The root cause was determined to be an electric short between data of the programmable read only memory (PROM), which is used in the I/O card, and the address lines the programme was using.

Lesson(s) learnt

Gathering operating experience from digital I&C systems is important for safety.

Event 13 - Reactor internal pumps (RIPs) C - Failure of control circuits – Japan - Kashiwazaki Kariwa 6 – 22 February 1996

Description

During commissioning, one of the reactor internal pumps tripped, resulting in a power decrease. After a second pump trip, the reactor was shut down for inspection.

Cause(s)

The cause was identified to be a malfunction of the pump controller C1 memory. Furthermore, the redundant C2 controller was closed due to over-current from smoothing condenser to inverter in the main circuit of power supply.

The second pump trip was caused by old input data in the controller.

Lesson(s) learnt

Operating experiences from digital I&C.

3.3.6. Site construction and installation

Event 137 – The slipping of the embankment of MVM Paksi Atomerőmű Ltd's cooling water inlet channel during site survey activities – Hungary – Paks 1 - 15 August 2015

Description

For the site investigation programme, two wells were created to examine the relationship of the water inlet channel beds. During the testing of the first well, uncontrolled water discharge caused damage to the embankment of the cooling water inlet channel of the operating nuclear power plant units.

Cause(s)

The uncontrolled release of this high volume of water on the embankment of the cooling water inlet channel caused the damage. This process was intensified by the high volume of precipitation during the days prior to the test.

Lesson(s) learnt

The lesson to be learnt from this incident is that production tests/examinations of ground/formation water wells should only be performed after the diversion of the discharged water is appropriately solved. Caution is essential near buildings or slanting reliefs.

Event 136 – Damage to an electric power cable of floodgate during environmental surface soil sampling – Hungary – Paks 1 – 25 March 2016

Description

Subcontractors of the new unit plant vendor were executing soil sampling at determined survey points for the purpose of environmental monitoring. These sampling activities were carried out on the site of the operating nuclear power plant. On 24 March 2016, at one of the survey points, continuous core sampling was completed at a depth of 0 - 3 metres. On 25 March 2016, the nuclear power plant's operating staff noticed an anomaly in the function of a floodgate situated between the cooling water inlet and outlet channel. A subsequent inspection revealed that the drilling activity of the previous day had damaged the electric power cable operating the floodgate.

Cause(s)

The following contributing factors have been identified:

During on-site activity the subcontractor was not following the steps described in the available Work Instruction issued by the operator of the existing nuclear power plant (MVM Paksi Atomerőmű Ltd.).

Work was performed without permission from the operator of the existing plant.

The new unit plant vendor and its subcontractors did not provide appropriate technological supervision during on-site activities.

The licensee of the new unit construction project (Paks II. Ltd.) did not submit all the basic regulations related to the Paks Nuclear Power Plant site works to the plant vendor.

MVM Paksi Atomerőmű Ltd. changed the procedure related to the approval of on-site activities, of which Paks II. Ltd. was not notified.

Paks II Ltd. was not adequately supervising on-site activities performed by subcontractors of the new unit plant vendor.

Lesson(s) learnt

Information flow and detailed requirements regulating on-site activities should be clearly established. When work is performed by another licensee at the site of an operating nuclear power plant, the roles and responsibilities of the employees should be timely and clearly regulated.

Event 138 – HVAC system leak tightness requirements not fully complied – Finland – Olkiluoto-3 – 31 December 2014

Description

During the preparation of periodical testing instructions, it was identified that the given criteria in leak tightness test procedure do not fully comply with the requirements given in the project specification.

Cause(s)

The wrong criteria were given in the leak tightness test procedure. This was not realised in due time.

Lesson(s) learnt

Good configuration management might prevent requirement specification mix-ups.

Event 129 - Fire at the reactor shaft on Unit 3 Mochovce project – Slovak Republic – Mochovce 3 - 21 January 2012

Description

During welding, hot particles were sprayed and fell through the fire protection canvas. The hot particles caused a fire in the reactor pressure vessel (RPV) pit. The plant Fire and Rescue corps put out the fire. No injuries or direct material damage to the equipment were observed.

Cause(s)

Fire protection was inadequate and work management was insufficient. The place of welding was insufficiently defined and incorrectly secured. The fire assistance patrol, together with the welder, did not secure the place of welding. As a result, flammable material was present nearby, which made the fire possible.

Lesson(s) learnt

Fire protection measures are especially important near high-risk activities such as welding.

Event 127 - V. C. Summer Unit 2-inadvertent damage to the containment vessel - V.C. Summer-2 – United States - 17 February 2015

Description

During concrete drilling required to repair earlier human errors, the containment steel vessel was damaged. In addition, structural safety-related rebar was damaged.

Cause(s)

The root causes were:

1) Failure by site management to develop and implement a clear and effective work process for concrete drilling; and

2) Single point vulnerabilities within the contractor's field engineering and an unclear division of roles and responsibilities between design engineering and field engineering in the non-conformance and disposition (corrective action) process.

Contributing causes included the bypassing of safety features such as cutting off the autostop feature on the drill in order to continue drilling.

Lesson(s) learnt

Regulators may want to verify that adequate quality controls are implemented when drilling concrete, especially the utilisation of clear and effective work processes for concrete drilling.

A somewhat similar event happened in Korea on 20 June 2012. See event 89.

Event 89 - Embedded pipes cut off mistakenly during wall drilling at the AAC D/G building – Korea – All nuclear power plants - 20 June 2012

Description

During drilling of the alternate AC diesel generator (AAC D/G) external wall at Shin-Kori unit 2 for design improvements as part of the Fukushima Daiichi accident response, two 3-inch pipes embedded in the external wall were damaged due to an inadequate review of the embedded (buried) piping drawings and the use of an inappropriate detection device.

Cause(s)

The review of the piping drawings was inadequate and there were limitations in the detection device used to detect possible pipes.

Lesson(s) learnt

Drilling of structural walls should be performed only after detailed reviews by an architectural engineer to prevent damage to embedded piping, etc.

A similar event happened in the United States in 2015. See Event 127.

3.3.7. Commissioning

Event 86 - Reactor trip caused by high level steam generator during commissioning – Korea – Shin-Wolsong 1 - 2 February 2012

Description

A reactor trip occured during power ascension at generator power 106 MWe and reactor power 18%. Specifically, the operator increased reactor power from 16% to 20%. The main feed water of the steam generator is automatically changed from down comer valve to the economiser valve when the reactor power is 18%. The economiser control valve controller malfunctioned.

Cause(s)

The trip was caused by a high water level in the steam generator. The high water level was due to a stuck pilot valve spool in the steam generator economiser valve position controller (E-MFCV). This caused the valve to be left open instead of following the reduced flow demand. The root cause of the stuck pilot valve is still to be determined.

Lesson(s) learnt

An event similar to the one that occurred at operating reactors has not been taken into consideration during the design process of new reactors.

Regulatory inspection of operating experience feedback should be strengthened.

Event 80 - Reactor trip due to the departure from nucleate boiling ratio low signal caused by rod mismatching during 50% load rejection test – Korea – Shin-Kori 1 - 31 October 2010

Description

During a load rejection test the reactor was tripped due to a departure from nucleate boiling ratio low signal caused by control rod mismatch.

Cause(s)

The inspection team investigated and determined that the rod position deviation resulted from the power transient during the load rejection test; the root cause was not found.

There is evidence of management pressure on operators that may have led them to cut corners.

Lesson(s) learnt

Operating experience from similar units should have been more thoroughly reviewed since there were multiple reactor trips during the load rejection and commissioning tests.

Event 69 - Inadvertent containment spray during the commissioning operation – Korea – Shin-Kori 1 - 17 September 2010

Description

During a power raising test to 50% of nominal power, the containment spray isolation valve was inadvertently opened, and reactor coolant was sprayed into the containment through the containment spray system. This caused a severe transient: coolant pressure and temperature were lowered rapidly.

The operators acted according to emergency operating procedures and no radioactive releases occurred. The plant entered a stable condition after the containment spray isolation valve was closed. Over 400 tonnes of borated water was sprayed into the containment during the event.

Cause(s)

The main cause was human error: the main control room operator mishandled the containment spray isolation valve hand-switch and a test engineer made a local equipment manipulation without approval from the main control room.

The plant had some design changes compared to the reference plant, but these were not reflected in the operating procedure. This might have been a contributing cause.

The shutdown heat exchanger outlet isolation valve, up-stream of the containment spray isolation valve, should have been closed during the heat-up operation but was open. This was a contributing cause.

Lesson(s) learnt

The commissioning organisation should have suitably experienced staff.

The staff should be familiarised with the plant before the commencement of commissioning operation.

Design changes should be reflected in operating procedures and training.

It should be acknowledged that commissioning a nuclear power plant is equivalent to operating a nuclear power plant in terms of safety culture.

4. Conclusions

As can be seen in Figure 3.3, most of the events are related to mechanical components. It is worth considering why so many construction events are related to mechanical components. It is possible that mechanical components are more prone to construction events and new build regulators should therefore pay greater attention to them. On the other hand, it may be that the relatively high number of events is simply due to the large number of mechanical components present in a nuclear power plant.

However, it might also be that event reporting favours events relating to mechanical components and the events are biased and thus do not provide a global view of construction activities. Therefore, the WGRNR should also encourage other types of events to be reported. Furthermore, the WGRNR should periodically assess if there are any biases in the reporting that should be noted.

Figure 3.6 shows lessons learnt from the events by aggregate category. The lessons learnt were often vague. Therefore, the WGRNR should encourage members to pay attention in examining and writing the lessons learnt with adequate precision. However, it should also be noted that many of these events could have been avoided with more effective oversight and better project management (installation management, subcontractors management, etc.).

Human performance and management-related causes are common, as can be seen from Figure 3.3. It might be that these are somewhat correlated and events that have human performance listed as a cause might also have management listed as a cause. However, it might be that human factors in general should receive greater attention from regulators. In addition, the WGRNR should encourage members to be more precise about the root causes of the events. A precise analysis of the root causes is necessary to fully benefit from the experience of the events. In addition, it can be observed that many events are caused by a deficiency in safety culture, competence or risk analysis process.

Support systems were challenged or might have been challenged in several events. This is most likely explained by the fact that there are a large number of support systems in a nuclear power plant and therefore events challenging support systems are more likely, relative to other systems (e.g. reactivity control). On the other hand, it is also possible that the reporting system favours events that challenge support systems and these events are overrepresented in the data.

Overall, there are only 36 events, with only 22 reported after the previous ConEx report in 2015. On average, only five events have been reported each year, which is lower than expected. Therefore, the WGRNR should encourage participating NEA member countries to report more events. This could be achieved by streamlining the reporting process. Furthermore, the WGRNR could place more emphasis on follow-up and learning from an event, perhaps by inviting participants to explain how they took the lessons learnted into account in their oversight.

The countries that submitted events (see Figure 3.1) do not comprise all the countries that are currently building nuclear power plants. Therefore, the WGRNR should encourage all new build countries to report events.

References

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